Agriculture and Allied Science

# Restructured and Revised Syllabi of Post-graduate Programmes

## Volume 11- Agricultureal Engineering and Technology

- Farm Machinery and Power Engineering
- Processing and Food Engineering
- Irrigation and Drainage Engineering
- Renewable Energy Engineering
- Soil and Water Conservation Engineering
- Agriculture Structure and Environment Management
- Irrigation and Water Management


- DR . BALASAHEB SAWANT KONKAN KRISHI VIDYAPEETH, DAPOLI, RATNAGIRI.
- VASANTRAO NAIK MARATHWADA KRISHI VIDYAPEETH PARBHANI
- DR. PANJABRAO DESHMUKH KRISHI VIDYAPEETH, AKOLA
- MAHATMA PHULE KRISHI VIDYAPEETH, RAHURI

Compiled By

Dean & Director of Instruction Co-Ordination Committee of SAU's 2022-23

# Restructured and Revised Syllabi of
# Post Graduate Programmes

# M. Tech. and Ph. D. (Agriculture Engineering)
# in
# Farm Machinery and Power Engineering

**Compiled**
**by**

**Broad Subject Co-ordinator**
**Associate Dean,**
**Dr. Annasaheb Shinde College of Agricultural Engineering and Technology, MPKV, Rahuri**

**Discipline Coordinator**
**Professor and Head (FMPE)**
**College of Agricultural Engineering and Technology,**
**Dr. BSKKV, Dapoli**

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## Preamble

Three major points were kept in mind while preparing course curricula related to Farm Machinery and Power Engineering (1) the syllabus and courses taught at UG level as recommended by 6th Dean committee (2) preparing students to keep pace with future requirement of the human resource in institutions and industry (3) to align the syllabus with ARS/NET examination.

Course curricula and course outlines in Farm Machinery and Power Engineering have been designed keeping in view the courses offered by the faculties from associated/ closely related disciplines, viz. Mechanical Engineering, Mathematics, Renewable Energy Engineering, Electrical, Electronics and Computer Engineering, Processing and Food Engineering, Civil Engineering, etc.

It becomes more important for the post graduate students to not only learn the recent advances but have also to be trained/ hands on experience in the modern and latest techniques in their major disciplines so that they can participate and contribute in the development and advancement in their related fields. Further, the present education aims at development of skills amongst the degree holders for development of entrepreneurship and to prepare students in tune with the demands of the corporate sector.

All courses are designed to cover all basic topics and by taking into consideration demands of corporate sector harnessing commercial aspects, modern research tools and their applications, supplementary skills required and enhancing the global competitiveness and employability of students. To meet these objectives new courses were added which covers areas: Machinery for Precision Agriculture, Automation and Control, Machinery for Horticulture and Protected Agriculture, Advance Manufacturing Technologies, Principles of Hydraulic and Pneumatic Systems, Ergonomics in Working Environment, Machinery for Special Farm Operations, Mechanics of Traction and its Application.

Further, existing courses were suitably modified and restructured by deleting topics already covered in UG, removing overlapping topics in different courses, adding topics/ courses to cover ARS/NET exam syllabus and topic important to the farm machinery industry and emerging trends in Farm Machinery & Power Engineering. The modified/revised courses cover the areas: Advances in farm machinery, Computer aided Design of Machinery, Design

of Farm Machinery, Ergonomics in Working Environment, Machinery for Special Farm Operations, Mechanics of Traction and its Application.

The course content and syllabus upgraded make it more of practical oriented and as per ARS/NET Syllabus. The ICAR recommendations of National Core Group and BSMA committee on Agricultural Engineering for PG courses have been taken into consideration in framing these courses to be implemented in the SAUs of Maharashtra State. It is hoped that these will prove very useful to the future students.

**Committee on Agricultural Engineering**

**(Farm Machinery and Power Engineering)**

| **ICAR-BSMA Broad Subject** | **ICAR-BSMA Approved Disciplines** | **Degree Programmes** | | **Broad Subject Coordinator (Chairman of all Disciplines' Sub Committees** | **Discipline Coordinator (Secretary of respective Discipline Sub-Committee)** |
|---|---|---|---|---|---|
| Agriculture Engineering and Technology | Farm Machinery and Power Engineering | M.Tech. | Ph.D | Dr. D.D. Pawar, CoAE, MPKV, Rahuri | Dr. P U Shahare<br>Professor and Head (FMPE)<br>College of Agricultural Engineering and Technology,<br>Dr. BSKKV, Dapoli |
| | | | | | Dr. S M Nalawade<br>Professor and Head (FMPE) CoAE, MPKV, Rahuri |

**Organization of Course Contents and Credit Requirements:**

**Minimum Residential Requirement:**

**M. Tech.: 4 Semesters**
**Ph.D.: 6 Semesters**

**Name of the Departments / Divisions**

Farm Machinery and Power Engineering

**Nomenclature of Degree Programme**

**(a) M. Tech. Programme**

M. Tech. (Agricultural Engineering) in Farm Machinery and Power Engineering

**(b) Ph. D. Programme**

Ph.D. (Agricultural Engineering) in Farm Machinery and Power Engineering

**Code Numbers**

- All courses are divided into two series: 500-series courses pertain to Master's level, and 600- series to Doctoral level.
- Credit Seminar for Master's level is designated by code no. 591, and the Two Seminars for Doctoral level are coded as 691 and 692, respectively
- Master's research: 599 and Doctoral research: 699

**Course Contents**

The contents of each course have been organized into:

- Objective – to elucidate the basic purpose.
- Theory units – to facilitate uniform coverage of syllabus for paper setting.
- Suggested Readings – to recommend some standard books as reference material. This does not obviously exclude such a reference material that may be recommended according to the advancement and local requirement.
- A list of international and national reputed journals pertaining to the discipline is provided at the end which may be useful as study material for 600/700 series courses as well as research topics.
- Teaching schedule and practical schedule has also be given at the end of each course to facilitate the teacher to complete the course in an effective manner.

## Eligibility for Admission

### M. Tech. Agricultural Engineering (Farm Machinery and Power Engineering):

Bachelor degree in Agricultural Engineering (4 year programme) and passing the Common Entrance Test in Agricultural Engineering conducted by competent authority.

### Ph.D. Agricultural Engineering (Farm Machinery and Power Engineering)

Master degree in Agricultural Engineering with specialization in Farm Machinery and Power Engineering/ Farm Machinery and Power/ Farm Power and Machinery/ Farm Power and Machinery Engineering/ Renewable Energy Engineering

**OR**

Master degree in Mechanical Engineering with specialization in Machine Design/ Machine Design and Development /Design Engineering/ Mechanical System and Design from Govt. recognized /accredited University or institute.

The students of Mechanical Engineering and Renewable Energy Engineering must have Bachelor degree in Agricultural Engineering (4 year programme) and passing Common Entrance Test in Farm Machinery and Power conducted by competent authority.

Students from Mechanical Engineering and Renewable Energy Engineering will be required to complete Non credit deficiency courses of 6 to 10 credits as per student’s advisory committee advice.

## Course and Credit Requirements

| Course Details | Masters Degree | Doctoral Degree |
|---|---|---|
| Major Courses | 20 | 12 |
| Minor Courses | 08 | 06 |
| Supporting / Optional | 06 | 05 |
| Common PGS Courses | 05 | 05* |
| Seminar | 01 | 02 |
| Research | 30 | 75 |
| **Total** | **70** | **100** |

*****if not completed at Master’s level

## Course Layout and Structure of Masters Degree

### Master's Degree Programme [Requirement: 70 Credits]

### MAJOR COURSES (Requirement: 20 Credits)

| S. No. | Course Title | Course Code | Credits |
|---|---|---|---|
| 1 | Soil Dynamics in Tillage and Traction | FMPE 501* | 2+1 |
| 2 | Testing and Evaluation of Agricultural Equipment | FMPE 502* | 2+1 |
| 3 | Ergonomics and Safety in Farm Operations | FMPE 503* | 2+1 |
| 4 | Design of Tractor systems | FMPE 504 | 2+1 |
| 5 | Design of Farm Machinery-I | FMPE 505 | 2+1 |
| 6 | Design of Farm Machinery-II | FMPE 506 | 2+1 |
| 7 | Management of Farm Power and Machinery System | FMPE 507* | 2+1 |
| 8 | Principles of Automation and Control | FMPE 511 | 2+1 |
| 9 | Principles of Hydraulic and Pneumatic Systems | FMPE 512 | 2+1 |
| 10 | Applied Instrumentation in Farm Machinery | FMPE 513 | 2+1 |
| 11 | Systems Simulation and Computer Aided ProblemSolving in Engineering | FMPE 514 | 1+1 |
| 12 | Computer Aided Design of Machinery | FMPE 515 | 0+2 |
| 13 | Advance Manufacturing Technologies | FMPE 516 | 2+0 |
| 14 | Machinery for Precision Agriculture | FMPE 517 | 2+1 |
| 15 | Machinery for Horticulture and Protected Agriculture | FMPE 518 | 2+0 |
| 16 | Fundamentals of Agricultural Drone | FMPE 519 | 2+1 |
| 17 | Pesticides Application Techniques | FMPE 520 | 1+1 |
| 18 | Special Problem | FMPE 521 | 0+1 |
| 19 | Internship | **FMPE 522 | 0+1 |

*Compulsory Course
** Minimum of three weeks

## MINOR COURSES (Requirement: 08 Credits)

**Disciplines for Minor Courses:**

1. Renewable Energy Engineering
2. Process and Food Engineering
3. Irrigation and Drainage Engineering
4. Soil and Water Conservation Engineering
5. Agronomy
6. Entomology
7. Basic Sciences

**Suggestive Minor courses**

| S. No. | Course Title | Course Code | Credits |
|---|---|---|---|
| 1 | Engineering Properties of Biological Materials | PFE 511 | 2+1 |
| 2 | Mechatronics and Robotics in Agriculture | ME 501 | 2+0 |
| 3 | Vibrations | ME-504 | 2+1 |
| 4 | Fatigue Design | ME-507 | 2+1 |
| 5 | Computer Aided Design | ME-515 | 2+1 |
| 6 | Biomass Energy Conversion Technologies | REE 503 | 2+1 |
| 7 | Agro Energy Audit and Management | REE 516 | 2+1 |
| 8 | Dimensional Analysis and Similitude | CE 501 | 1+1 |
| 9 | Experimental Stress Analysis | CE 510 | 2+1 |
| 10 | Finite Element Methods | MATHS 501 | 1+1 |
| 11 | Numerical Methods for Engineers | MATHS 502 | 2+0 |
| 12 | Big Data Analytics | CSE 501 | 2+1 |
| 13 | Artificial Intelligence | CSE 502 | 2+1 |
| | Any other course (s) of other department other than course(s) from major can be taken as per recommendations of the Student's Advisory Committee. | | |

## SUPPORTING COURSES (Requirement: 06 Credits)

**Disciplines for Supporting Courses:**

1. Renewable Energy Engineering
2. Process and Food Engineering
3. Irrigation and Drainage Engineering
4. Soil and Water Conservation Engineering
5. Agronomy
6. Entomology
7. Basic Sciences

**Suggestive Supporting Courses**

| S. No. | Course Title | Course Code | Credits |
|---|---|---|---|
| 1 | Statistical Methods for Research Works | *STAT 501 | 2+1 |
| | Courses from subject matter fields (other than Major and Minor) relating to area of special interest and research problem can be taken as per recommendations of thestudent's advisory committee. | | |

*Compulsory Supporting Course

**COMMON COMPULSORY PGS COURSES (Requirement: 05 Credits)**

| S. No. | Course Title | Course Code | Credits |
|---|---|---|---|
| 1 | Library and Information Services | *PGS 501 | 0+1 |
| 2 | Technical Writing and Communications Skills | *PGS 502 | 0+1 |
| 3 | Intellectual Property and its management in Agriculture | *PGS 503 | 1+0 |
| 4 | Basic Concepts in Laboratory Techniques | *PGS 504 | 0+1 |
| 5 | Agricultural Research, Research Ethics and Rural Development Programs | *PGS 505 | 1+0 |

*Compulsory Course

**LIST OF OTHER ESSENTIAL REQUIREMENTS**

| S. No. | Course Title | Course Code | Credits |
|---|---|---|---|
| 1 | Masters' Seminar | FMPE 591 | 0+1 |
| 2 | Masters' Research | FMPE 599 | 0+30 |

## Course Layout and Structure of Doctoral Degree

**Doctoral Programme [Requirement: 100 Credits]**

**MAJOR COURSES (Requirement: 12 Credits)**

| Sr. No. | Course Title | Course Code | Credits |
|---|---|---|---|
| 1 | Advances in Farm Machinery and Power Engineering | FMPE 601* | 2+1 |
| 2 | Advances in Machinery for Precision Agriculture | FMPE 602 | 2+1 |
| 3 | Energy Conservation and Management in Production Agriculture | FMPE 603 | 3+0 |
| 4 | Mechanics of Tillage in Relation to Soil and Crop | FMPE 604 | 2+1 |
| 5 | Mechanics of Traction and its Application | FMPE 611 | 2+1 |
| 6 | Farm Machinery Management and Systems Engineering | FMPE 612* | 2+1 |
| 7 | Machinery for Special Farm Operations | FMPE 613 | 2+1 |
| 8 | Ergonomics in Working Environment | FMPE 614 | 2+1 |
| 9 | Machinery for Crop Residue Management and Conservation in Agriculture for Field and Horticultural crops | FMPE 615 | 2+1 |
| | | **Total** | **17+7** |

***** Compulsory courses

**MINOR COURSES (Requirement: 06 Credits)**

**Disciplines for Minor Courses :**

1. Renewable Energy Engineering
2. Process and Food Engineering
3. Irrigation and Drainage Engineering
4. Soil and Water Conservation Engineering
5. Agronomy
6. Entomology
7. Basic Sciences

**Suggestive Minor courses**

| S. No. | Course Title | Course Code | Credits |
|---|---|---|---|
| 1 | Energy Planning Management and Economics | REE 615 | 3+0 |
| 2 | Thermo-Chemical Conversion of Biomass | REE 602 | 2+1 |
| 3 | Fatigue Design | ME-507 | 2+1 |
| 4 | Computer Aided Design | ME-515 | 2+1 |
| 5 | Digital Image Processing | CSE 506 | 2+1 |
| | Any other course (s) of other department other than course(s) from major can be taken as per recommendations of the student's advisory committee. | | |

**SUPPORTING COURSES (Requirement: 05 Credits)**

**Disciplines for Supporting Courses :**

1. Renewable Energy Engineering
2. Process and Food Engineering
3. Irrigation and Drainage Engineering
4. Soil and Water Conservation Engineering
5. Agronomy
6. Entomology
7. Basic Sciences

**Suggestive Supporting courses**

| S. No. | Course Title | Course Code | Credits |
|---|---|---|---|
| 1 | Research and Publication Ethics | *CPE-RPE 601 | 1+1 |
| | Courses from subject matter fields (other than Major and Minor) relating to area of special interest and research problem can be taken as per recommendations of the student's advisory committee. | | |

*Course has been made compulsory by UGC for PhD students. Course code and its detailed course outline to be adopted in toto as recommended by UGC.

**LIST OF OTHER ESSENTIAL REQUIREMENTS**

| **S. No.** | **Course title** | **Course Code** | **Credits** |
|---|---|---|---|
| 1 | Doctoral Seminar-I | FMPE 691 | 0+1 |
| 2 | Doctoral Seminar-II | FMPE 692 | 0+1 |
| 3 | Doctoral Research | FMPE 699 | 0+75 |

**COMMON COMPULSORY PGS COURSES (Requirement: 05 Credits)**

| S. No. | Course Title | Course Code | Credits |
|---|---|---|---|
| 1 | Library and Information Services | *PGS 501 | 0+1 |
| 2 | Technical Writing and Communications Skills | *PGS 502 | 0+1 |
| 3 | Intellectual Property and its management in Agriculture | *PGS 503 | 1+0 |
| 4 | Basic Concepts in Laboratory Techniques | *PGS 504 | 0+1 |
| 5 | Agricultural Research, Research Ethics and Rural Development Programs | *PGS 505 | 1+0 |

*Compulsory Course if not completed at Master's level

# Course Syllabus and Content for Masters Degree

## FMPE 501: Soil Dynamics in Tillage and Traction 2+1

### Objectives:

To have an understanding of the principles of soil mechanics as applied to interaction of tillage tools and traction devices with soil in terms of soil forces and deformation during for soil cutting and generation of traction.

### Unit-I

Characterization of state of stress in a point: Derivation, representation by Mohr's Circle. Coulomb's law of friction and cohesion. Measurement of soil resistance properties: Direct shear box, torsion shear apparatus, tri-axial apparatus. Soil behaviour considerations: Soil water pressure and movement. Critical state soil mechanics: Soil stress-strain behaviour, shear rate effects.

### Unit-II

Mechanics of tillage too and geometry of soil tool system , design parameters and performance of tillage tools, Soil cutting forces: The universal earthmoving equation, two dimensional cases, smooth vertical blade, smooth and rough raked blades in cohesive soil, unconstrained tool to soil adhesion. The shape of failure surfaces. Hettiaratchi's calculations, effect of soil weight. Soil cutting force by method of trial wedges.

### Unit-III

Extension of theory to three dimension: Hettiaratchi, Reece-Godwin and Spoor. Three dimensional wedges: McKyes and Ali, Grisso models. Dynamic effect: Inertial forces, change in soil strength. Concept of critical depth. Complex tool shapes: Curved tools-shank and foot tools-mould board plough. Soil Loosening and manipulation: Measurement of soil loosening and its efficiency. Draft force efficiency: Loosening and pulverization efficiency. Soil mixing and inversion: Soil properties, tool shape, tool speed and tool spacing.

### Unit-IV

Traction devices: Tyres, type, size, selection mechanics of traction devices. Maximum traction force: Soil deformation and slip, estimation of contact areas. Sinkage in soil: Rolling resistance, Bekker's formulae, McKyes formulae. Soil compaction by agricultural vehiclesand machines.

### Practical:

Measurements of soil shear strength by in-situ shear box apparatus and soil friction by friction plate. Measuring cone penetrometer resistance and working out tractive coefficientsfor tyres. Measurement of in-situ shear strength of soil by torsional vane shear apparatus. Solving problems on stress in soil. Solving problems on soil properties. Solving problems of tool forces. Problems on tillage tool forces, wheel slippage, tyre deflection, design and performance of traction devices.

### Course Outcome:

The student will be able to understand the principles that govern manipulation of soil bytillage tools. The student will be able to apply the principles of soil mechanics to theoretically calculate the forces on tillage tools during soil cutting and forces generated by tractor wheels.

### Teaching Schedule

| S. No. | Topic | No of Lectures |
|---|---|---|
| 1. | Characterization of state of representation by Mohr's Circle. Stress in A point: Derivation, | 2 |

| | | |
|---|---|---|
| **2.** | Coulomb's law of friction and cohesion. | 1 |
| 3 | Measurement of soil resistance properties: Direct shear box, torsionshear apparatus, tri-axial apparatus. | 2 |
| 4 | Soil behaviour considerations: Soil water pressure and movement. | 1 |
| 5 | Critical state soil mechanics: Soil stress-strain behaviour, shear rateeffects | 2 |
| 6 | Mechanics of tillage too and geometry of soil tool system , design parameters and performance of tillage tools. Soil cutting forces: The universal earthmoving equation, two dimensional cases, smooth vertical blade, smooth and rough raked blades in cohesive soil, unconstrained tool to soil adhesion. | 3 |
| 7 | The shape of failure surfaces. | 2 |
| 8 | Hettiaratchi's calculations, effect of soil weight. | 2 |
| 9 | Soil cutting force by method of trial wedges. | 2 |
| 10 | Extension of theory to three dimensions: Hettiaratchi, Reece-Godwin and Spoor. | 2 |
| 11 | Three dimensional wedges: McKyes and Ali, Grisso models. Dynamic effect: Inertial forces, change in soil strength. | 2 |
| 12 | Concept of critical depth. | 1 |
| 13 | Complex tool shapes: Curved tools-shank and foot tools-mould board plough. | 1 |
| 14 | Soil Loosening and manipulation: Measurement of soil looseningand its efficiency. | 1 |
| 15 | Draft force efficiency: Loosening and pulverization efficiency. | 1 |
| 16 | Soil mixing and inversion: Soil properties, tool shape, tool speedand tool spacing. | 2 |
| 17 | Traction devices: Tyres, type, size, selection mechanics of tractiondevices. | 1 |
| 18 | Maximum traction force: Soil deformation and slip, estimation ofcontact areas. | 1 |
| 19 | Sinkage in soil: Rolling resistance, Bekker's formulae, McKyes formulae. | 2 |
| 20 | Soil compaction by agricultural vehicles and machines. | 1 |
| | **Total** | **32** |

**List of Practicals**

| Sr. No. | Topic | No of practicals |
|---|---|---|
| 1. | Measurements of soil shear strength by in-situ shear box apparatus and soil friction by friction plate. | 3 |

| | | |
|---|---|---|
| 2. | Measuring cone penetrometer resistance and working out tractive coefficients for tyres. | 2 |
| 3. | Measurement of in-situ shear strength of soil by torsional vane shear apparatus. | 1 |
| 4. | Solving problems on stress in soil. | 2 |
| 5. | Solving problems on soil properties. | 2 |
| 6. | Solving problems of tillage tool forces. | 1 |
| 7. | Problems on wheel slippage and tyre deflection. | 3 |
| 8. | Problems on design and performance of traction devices. | 1 |
| 9. | Practical examination | 1 |
| | **Total** | **16** |

**Suggested Reading:**

1. McKyes E 2016. Soil Cutting and Tillage: Vol 7. *Developments in Agricultural Engineering* Elsevier R Science Publisher SBV.
2. Koolen, A J and Kuipers H 1983. *Agricultural Soil Mechanics. Springer-Verlag* ISBN 13:978-3-642-69012-9.
3. Gill W R and Van den Berg G E 1968. *Soil Dynamics in Tillage and Traction*. Handbook 316, Agricultural Research Service, US Department of Agriculture, Washington DC, 1968
4. John B L, Paul K T, David W S and Makoto H 2012. *Tractors and their Power Units*. 4$^{th}$ Edition. Springer Science & Business Media, ISBN: 81-239-0501-7, ASAE ISBN: 0-929355-72-5.
5. McKYES E 1989, *Agricultural Engineering Soil Mechanics*, Elsevier science publishers B. V., P.O. Box 211, 1000 AE Amsterdam, the Netherlands.
6. Willium J Chancellor.1995. *Advances in Soil Dynamics*. Vol. 1.ASAE, First Ed
7. Sinekov G.N. 1965. *Design of Soil Tillage Machines*. INSDOC, New Delhi

**FMPE 502 : Testing and Evaluation of Agriculture Equipment 2+1Objectives:**

To enable the student to learn the procedure for testing of different farm machinery and the concept behind evaluation of different performance parameters of farm machinery and the standards adopted therein.

## Unit-I

Importance and significance of testing and types of testing. Test equipment, usage and limitations. Test procedures and various test codes: National and International. testing terminology, standardise testing procedures to be adopted, protocol for testing of agricultural machinery

**Unit-II**

Lab testing of stationary diesel engine for full load, variable load and governor test. Tractor Test Codes and Data Interpretation Estimation of error. Laboratory and field testing of tillage and sowing machinery: Sub-soiler, laser land leveler, mould board Plough, disc plough, rotavator, cultivator, disc harrow, seed cum fertilizer drill and planter.

## Unit-III

Laboratory and field testing of manual and power operated intercultural machinery and plant protection machine.

## Unit-IV

Laboratory and field testing of reaper, thresher and chaff cutter.

## Unit-V

Laboratory and field testing of straw combine and combine harvester. Review and interpretation of test reports. Importance and need of standardization of components of agricultural equipment.

## Practical:

Lab testing of stationary diesel engine for full load, variable load and governor test. Laboratory and field testing of selected farm equipment: Tillage, sowing and planting, chaff cutter, threshers and plant protection equipment. Material testing of critical components. Accelerated testing of fast wearing components.

## Course Outcome:

The student will be able to test farm machinery, prepare performance reports and also analyze the performance reports to find the suitability of a machinery for a given farm operation.

## Teaching Schedule

| Sr. No | Topic | No. of lectures |
|---|---|---|
| 1. | Introduction, standardization efforts, Testing programme and procedures, testing terminology, type of testing systems, Various test codes, standardise testing procedures to be adopted, protocol for testing of agricultural machinery | 2 |
| 2. | Study of different types of dynamometers and function and working procedure of load cell for determination of draft | 2 |

| | | |
|---|---|---|
| 3. | Stationary diesel engine performance testing | 2 |
| 4. | Tractor Test Codes and Data Interpretation Estimation of error | 2 |
| 5. | Testing and evaluation of tillage machinery | 2 |
| 6. | Testing and evaluation of seed-cum-fertilizers drills/planters | 3 |
| 7. | Testing and evaluation of manually and power operated Sprayers | 3 |
| 8. | Testing and evaluation of reapers and straw combines | 1 |
| 9. | Testing and evaluation of combine harvester and threshers | 3 |
| 10. | Testing and evaluation of manually and power operated chaff cutters | 2 |
| 11. | Testing and evaluation of advanced machinery | 2 |
| 12. | Reliability in Engineering with emphasis on agricultural machinery | 2 |
| 3. | Discussion on Farm machinery codes | 2 |
| 14. | Interpretations of the information given in different codes on farm machinery | 1 |
| 15. | Formulation of test-code for machines that do not have any code. | 2 |
| 16. | Current topics/discussion | 1 |
| | **Total** | **32** |

**List of Practicals**

| Sr. No | Topic | No. of lectures |
|---|---|---|
| 1. | Lab testing of Stationary diesel engine for full load, variable loadand governor test | 2 |
| 2. | Lab Testing and evaluation of seed-cum-fertilizers drills | 1 |
| 3. | Lab Testing and evaluation of seed-cum-fertilizers planters | 1 |
| 4. | Lab Testing and evaluation of knapsack Sprayers | 1 |
| 5. | Lab Testing and evaluation of nozzles | 1 |
| 6. | Field testing of rotavators | 1 |
| 7. | Lab testing of rotavators for soil sample analysis | 1 |
| 8. | Testing and evaluation of reapers | 1 |

| | | |
|---|---|---|
| 9. | Testing and evaluation of combine harvester and threshers | 1 |
| 10. | Testing and evaluation of chaff cutters | 1 |
| 11. | Testing and evaluation of laser land leveler | 1 |
| 12. | Case study of test reports of different agricultural implements | 3 |
| | **Total** | **15** |

**Suggested Reading:**

1. Barger E L, Liljedahl J B and McKibben E C 1967. Tractors and their Power Units. Eastern Wiley 4th Edition.
2. Indian Standard Codes for Agricultural Implements. Published by BIS, New Delhi.
3. Inns F M 1986. Selection, Testing and Evaluation of Agricultural Machines and Equipment. FAO Service Bull. No.115.
4. Mehta M L, Verma S R, Rajan P and Singh S K 2019. Testing and Evaluation of Agricultural Machinery. Daya Publishing House, Delhi.
5. Nebraska Tractor Test Code for Testing Tractor, Nebraska, USA.
6. Smith D W, Sims B G and O'Neill D H 2001. Testing and Evaluation of Agricultural Machinery and Equipment -Principle and Practice. FAO Agricultural Services Bull. 110.
7. Training Manual on Testing of Agricultural Machinery for testing centers of Department of Agriculture & Co-operation, Ministry of Agriculture, Govt. of India. Compiled by Dr. Surendra Singh, CIAE, Bhopal.

**FMPE 503 : Ergonomics and Safety in Farm Operations 2+1**

**Objectives:**

To understand the principles of the science of Ergonomics and its application to farm machinery in order to reduce drudgery in the use of tools and equipment and also make them safe and comfortable to operate.

**Unit-I**

Description of human-machine systems. Ergonomics and its areas of application in the work system. History of ergonomics. Modern ergonomics.

**Unit-II**

Anthropometry: Its role in daily life, principles in workspace and equipment design, design of manual handling tasks and application in equipment design. Human postures: Postural stress and its role in design of farm machinery.

**Unit-III**

Human factors in tractor seat design: Entry system, controls, shape, colour coding, dial and indicators. Modern technology for comfort in driving places.

**Unit-IV**

Physiological parameters: Psychological and mental stresses and their measurement techniques. Human energy expenditure: Calibration of subjects, human workload and its assessment.

**Unit-V**

Safety considerations and operators protective gadgets in farm operations. Standards/codes for tractors and agricultural machinery safety.

**Practical:**

Identifying role of ergonomics in our daily life. Measurement of anthropometric dimensions of agricultural workers and establishing relationship between them. Determination of human requirements for field operation with manually operated equipment. Assessment of psychological/general load for specific agricultural operations. Calibration of human subject on bicycle ergometer and/ or treadmill for its energy output and physiological parameters like heart rate, oxygen consumption rate under laboratory conditions. Case studies of agricultural accidents and safety measure.

**Course Outcome:**

The student will be able to apply the concepts of ergonomics in the design of agriculturaltools and equipment and also evaluate the ergonomic suitability of such equipment.

**Teaching Schedule**

| S. No | Topic | No. of lectures |
|---|---|---|
| 1 | Introduction to ergonomics, definition of ergonomics | 1 |
| 2 | Operator- machine-environment system approach | 1 |
| 3 | Relative advantages of man and machine, ergonomics in daily life | 1 |
| 4 | Importance of ergonomics in agriculture and farm machinery | 1 |
| 5 | History of ergonomics, modern ergonomics | 1 |

| | | |
|---|---|---|
| 6 | Man machine environment components, broad objectives of ergonomics | 1 |
| 7 | Basic issues and processes under ergonomics for design and developmentof machine | 1 |
| 8 | Anthropometry and its uses in daily life | 1 |
| 9 | First hourly examination | 1 |
| 10 | Principles of applied anthropometry in ergonomics | 1 |
| 11 | Availability of anthropometric database for Indian agricultural workers | 1 |
| 12 | Definitions and possible applications of anthropometric dimensions | 2 |
| 13 | Workspace and equipment design | 1 |
| 14 | Different modes of force application | 1 |
| 15 | Design of manual handling tasks | 1 |
| 16 | Biomechanics aspects in machine design | 1 |
| 17 | Mid-semester examination | 1 |
| 18 | Human posture, posture stresses and its role in design of agricultural machinery | 1 |
| 19 | Work place design for standing and seated workers | 2 |
| 20 | Human factors in tractor seat design | 1 |
| 21 | Entry system, controls, shape, colour coding, dial and indicators | 1 |
| 22 | Modern technology for safety and comfort in driving place | 1 |
| 23 | Physiological and psychological parameters for ergonomic evaluation | 1 |
| 24 | Physiological and psychological stresses and measurements techniques | 1 |
| 25 | Human work load assessment, human energy expenditure | 1 |
| 26 | Calibration of subjects – concept, importance and techniques | 1 |
| 27 | Accidents and safety in agriculture operations, general safety guidelines | 1 |
| 28 | Safety feeding systems for threshers and chaff cutters | 1 |
| 29 | Safety gadgets for tractors and trailers | 1 |
| 30 | Standard/ codes for agricultural machinery safety | 1 |
| | **Total** | **32** |

**List of Practicals**

| Sr. No | Topic | No. of lectures |
|---|---|---|
| 1 | Identify role of ergonomics in our daily life | 1 |
| 2 | Measurement of anthropometric dimensions of agriculture workers andestablishing relation between them | 2 |
| 3 | Measurement of strength parameters | 1 |
| 4 | Determination of human requirements of field operation with manual operated equipment | 2 |
| 5 | Assessment of psychological/ general load for agricultural operations | 1 |

| | | |
|---|---|---|
| 6 | Assessment of stress on eyes by specific agricultural operation | 1 |
| 7 | Noise measurement in tractors | 1 |
| 8 | Calibration of human subject on bicycle ergometer | 1 |
| 9 | Calibration of human subject on treadmill | 1 |
| 10 | Measurement of physiological parameter viz. heart/ pulse rate | 1 |
| 11 | Measurement of oxygen consumption under laboratory conditions | 1 |
| 12 | Case study of accidents and safety on tractors and trailers | 1 |
| 13 | Case study of accidents and safety on chaff cutters and threshers | 1 |
| 14 | Practical examination | 1 |
| | **Total** | **16** |

**Suggested Reading :**


1. Bridger R S 2009. Introduction to Ergonomics. CRC Press, Boca Rotan, USA Sanders
2. M S and McCormick E J 2000. Human Factors in Engineering and Design. McGraw Hill. 7th edition
3. Astrand P, Rodahl K, Dahl H A and Stromme S B 2003. Textbook of Work Physiology - hysiological Basis of Exercise. McGraw Hill.
4. Gite L P 2009. Anthropometric and Strength Data of Indian Agricultural Workers for Farm Equipment Design. Central Institute of Agricultural Engineering, Bhopal.
5. Gite L P, Agrawal K N, Mehta C R, Potdar R R and Narwariya B S. 2019. Handbook of Ergonomical Design of Agricultural Tools, Equipment and work Places. Jain Brothers, New Delhi.
6. Ernest J. McCromick 1976 Human Factors in Engineering and Design. McGraw hill. 4th Edition.
7. Grandiean E. 1980. Fitting the Task to the Man. Taylor and Francis Ltd, London.
8. Kroemer K H E 2008. Fitting the human: Introduction to Ergonomics. Taylor and Francis, London, 6th edition.
9. Murrel K. F. H. 1965. Ergonomics: man in his Working environment. Chapman and Hall, London.

**FMPE 504 : Design of Tractor Systems 2+1**

**Objectives:**
To introduce the student to the principles that direct the design of a tractor and its subsystems and enable the student to apply the concept of machine design in designing the subsystems and critical components.

**Unit-I**
Design and types, research, development, design procedure, technical specifications of tractors, modern trends in tractor design and development, special design features of tractors in relation to Indian agriculture.

**Unit-II**
Engine related terminology. Selection of stroke-bore ratio. Design of engine components: Piston, connecting rod, cylinder, cylinder head, crank shaft etc.

**Unit-III**
Design of tractor systems like clutch, gearbox, steering, steering geometry, turning force, hydraulic system & hitching, chassis, operator's seat, work-place area and controls. Tire selection, aspect ratio etc.

**Unit-IV**
Mechanics of tractor stability. Computer aided design and its application in farm tractors. **Practical:** Engine design calculations, transmission component design calculations. Extensive practices on the computer aided design packages.

**Course Outcome:**
The student will have an overview of the philosophy guiding the design of a tractor and also design tractor systems and components.

**Teaching Schedule**

| Sr. No. | Topic | No. of Lectures |
|---|---|---|
| 1 | Design and types, research, development, design procedure, technical specifications of tractors, modern trends in tractor design and development, special design features of tractors in relation to Indian agriculture. | 2 |
| 2 | Instrumentation and digital control for precise and ease of operation | 1 |
| 3 | Engine related terminology. Selection of stroke-bore ratio. | 1 |
| 4 | Design of engine components: Piston, connecting rod, cylinder, cylinder head, crank shaft etc. | 3 |
| 5 | Design of tractor clutch | 2 |
| 6 | Design of tractor gearbox | 3 |

| | | |
|---|---|---|
| 7 | Tractor steering system, functional requirements, steering geometry, turning force | 2 |
| 8 | Steering system design parameters and design procedure | 2 |
| 9 | Hydraulic system & hitching — principles of operation | 1 |
| 10 | Hydraulic system - Design parameters and design procedures including design of pump, cylinder etc. | 2 |
| 11 | Design of chassis | 2 |
| 12 | Electric tractor and its construction with power supply system, | 1 |
| 12 | Human factors in tractor design. Design of operator's seat | 2 |
| 12 | Work-place area and controls | 1 |
| | Electronics and guidance system of tractor | 1 |
| 13 | Tire selection, aspect ratio etc. | 1 |
| 14 | Mechanics of tractor stability. Dynamic and static analysis of forces acting on farm tractor, case studies. | 3 |
| 15. | Computer aided design and its application in farm tractors | 2 |
| | **Total** | **32** |

**List of Practical**

| **Sr. No.** | **Practical** | **No. of Practical** |
|---|---|---|
| 1. | Engine design calculations, Stroke-bore ratio determination, Design of radiator, Balancing of crankshaft | 2 |
| 2. | Engine design calculations, Calculation of volumetric /thermal efficiencies | 1 |
| 3. | Transmission component design calculations -Design of clutch | 1 |
| 4. | Transmission component design calculations<br>-Design of gear box and calculation of speed ratios | 2 |
| 5. | Design of Ackerman steering. Calculation of turning radius. | 1 |
| 6. | Design of brakes (mechanical and hydraulic) | 2 |
| 7. | Design of hydraulic system | 2 |
| 8. | Calculation for determination of centre of gravity of tractor, moment of inertia and stability | 3 |
| 9. | Practice on the Computer Aided Design (CAD) packages for design of various components | 2 |
| | **Total** | **16** |

**Suggested Readings :**

1. Sharma P C and Agarwal D K 2000. *Machine Design*. S K Kataria and Sons, Delhi
2. Barger E L Liljedahl J B and McKibben E C 1967. *Tractors and their Power Units*. Wiley Eastern Pvt. Ltd.
3. Macmilan R.H. 2002. *The mechanics of Tractor- Implement Performance and Worked Examples.* University of Melborne, Australia
4. .D. N. Sharma and S. Mukesh. 2016. *Design of Agril. Tractor-Principles and Problems,* Third Ed. Jain Brothers, New Delhi.
5. R. K. Khurmi and J.K. Gupta. 2005. *A text book of Machine Design*. Eurasia Publishing House Pvt Ltd. New Delhi

**FMPE 505 : Design of Farm Machinery–I 2+1**

## Objectives:

To understand the interaction of tillage tools with soil and design the components of the tillage tools based on their requirement and also to learn how the systems of planting machinery are designed.

## Unit-I

Farm machinery design: Modern trends, tasks and requirements, economic considerations of durability, reliability and rigidity. Physico-mechanical properties of soils. Technological process of ploughing. Wedge. Working process of mould board plough, determination ofbasic parameters. Design of coulters, shares, mould boards.

## Unit-II

Constructing of mould board working surface. Design of landside, frog, jointer. Forces acting on plough bottom and their effect on plough balance: Trailed, semi mounted and mounted plough. Draft on ploughs, resistance during ploughing. Design disk ploughs: Concave disk working tools, forces acting.

## Unit-III

Machines and implements for surface and inter row tillage: Peg toothed harrow, disk harrows, rotary hoes, graders, rollers, cultivators. Design of V shaped sweeps. Rigidity of working tools. Rotary machines: Trajectory of motion of rotary tiller tynes, forces acting, power requirement. Machines with working tools executing an oscillatory motion.

## Unit-IV

Methods of sowing and planting: Machines, agronomic specifications. Sowing inter-tilled crop. Grain hoppers: Seed metering mechanism, furrow openers and seed tubes. Machines for fertilizer application: Discs type broadcasters. Organic fertilizer application: Properties of organic manure, spreading machines. Liquid fertilizer distributors. Planting and transplanting: Paddy transplanters, potato planters.

## Practical:

Design of mould board working surface: Coulter, frog, share, jointer, mould board plough. Trailed, semi mounted and mounted ploughs. Design of disc plough, disc harrow, peg tooth harrow, cultivators, sweeps. Design of rotary tiller. Design of traction and transport devices. Design of seed drills: Metering mechanism, hopper, furrow opener. Fertilizer spreader, liquid fertilizer applicators and design of its sub systems. Design of paddy transplanters and potato planters.

## Course Outcome:

The student will be able to appreciate the principles behind the design of tillage tools and planting machinery. He will be able to arrive at design configurations for such machines.

## Teaching Schedule

| S.No. | Topic | No of Lectures |
|---|---|---|
| 1. | Farm machinery design: Modern trends, tasks and requirements, economic considerations of durability, reliability and rigidity. | 3 |
| 2. | Farm machinery design: economic considerations of durability, reliability and rigidity. | 2 |
| 3. | Physio-mechanical properties of soils. | 1 |

| | | |
|---|---|---|
| 4. | Technological process of ploughing. Wedge.<br>Working process of mould board plough, determination of basic parameters. | 2 |
| 5. | Design of coulters, shares, mould boards. | 2 |
| 6. | Constructing of mould board working surface. | 1 |
| 7. | Design of landside, frog, jointer. | 1 |
| 8. | Forces acting on plough bottom and their effect on plough balance: Trailed, semi mounted and mounted plough.<br>Draft on ploughs, resistance during ploughing. | 2 |
| 9. | Design disk ploughs: Concave disk working tools, forces acting. | 2 |
| 10. | Machines and implements for surface and inter row tillage: Peg toothed harrow, disk harrows, rotary hoes, graders, rollers, cultivators. | 2 |
| 11. | Design of V shaped sweeps. Rigidity of working tools. | 1 |
| 12. | Rotary machines: Trajectory of motion of rotary tiller tynes, forces acting, power requirement. | 2 |
| 13. | Machines with working tools executing an oscillatory motion. | 2 |
| 14. | Methods of sowing and planting: Machines' agronomic specifications. Sowing inter-tilled crop, Grain hoppers Seed metering mechanism, Furrow openers and seed tubes. | 2 |
| 15. | Machines for fertilizer application: Discs type broadcasters. | 1 |
| 16. | Organic fertilizer application: Properties of organic manure spreading machines. Liquid fertilizer distributors. | 2 |
| 17. | Planting and transplanting: Paddy transplanters, potato planters. | 2 |
| 18. | Case studies | 2 |
| | **Total** | **32** |

**List of Practicals**

| **S.No.** | **Topic** | **No of practicals** |
|---|---|---|
| 1. | Design of mould board: Coulter, frog, share | 1 |
| 2. | Design of mould board: mould board plough working surface, jointer. | 1 |

| | | |
|---|---|---|
| 3. | Trailed, semi mounted and mounted ploughs. | 1 |
| 4. | Design of disc plough | 2 |
| 5. | Design of disc harrow | 1 |
| 6. | Design of peg tooth harrow | 1 |
| 7. | Design of cultivators and sweep. | 1 |
| 8. | Design of rotary tiller. | 1 |
| 9. | Design of traction and transport devices. | 1 |
| 10. | Design of seed drills: Metering mechanisms | 1 |
| 11. | Design of seed drills: hopper and furrow opener. | 1 |
| 12. | Design of Fertilizer application equipment: fertilizer spreaders | 1 |
| 13. | Design of Fertilizer application equipment: Liquid fertilizer applicators and design of its sub systems | 1 |
| 14. | Design of paddy transplanters | 1 |
| 15. | Design of potato planters. | 1 |
| | **Total** | **16** |

**Suggested Reading :**


1. Bosoi, E S, Verniaev O V, Smirnov II and Sultan-Shakh E G 1990. *Theory, Construction and Calculations of Agricultural Machinery* - Vol. I. Oxonian Press Pvt. Ltd. No.56, Connaught Circle, New Delhi.
2. Gill R and Vanden Berg G E 2013. *Soil Dynamics in Tillage and Traction*. Scientific Publishers(India) ISBN-10: 8172338031
3. Bernacki C, Haman J. and Kanafajski Cz.1972. *Agricultural Machines Theory and Construction. Vol.I.* U.S. Dept. of Commerce, National Technical Information Service, Springfield, Virginia 22151.
4. Yatsuk E P 198.1 *Rotary Soil Working Machines Construction, Calculation and Design*. American Publishing Co. Pvt. Ltd, New Delhi.

**FMPE 506 : Design of Farm Machinery–II 2+1**

## Objectives:

To learn the engineering principles behind application of pesticides and the systems that implements the same. To learn the concepts behind design of crop harvesting and threshing equipment.

## Unit-I

Pesticide calculation examples. Multidisciplinary nature of pesticide application. Overview of chemical control integrated pest management. Targets for pesticide deposition. Formulation of pesticides.

## Unit-II

Spray droplets. Hydraulic nozzles. Power operated hydraulic sprayer design principles. Air assisted hydraulic sprayer design principles. Controlled droplet application. Electrostatically charged sprayers. Spray drift and its mitigation. Aerial spraying systems. Use of drones for spraying: Design of spray generation and application issues.

## Unit-III

Introduction to combine harvesters: Construction, equipment subsystems, power sub systems. Crop harvesting: Plant properties, physical and mechanical properties of plant stem, plant bending modelling. Properties of plant grain: Physical, mechanical, grain damage. Propertiesof MOG: Mechanical and aerodynamic.

## Unit-IV

Design of grain header: Orienting and supporting reel. Plant cutting cutter bar: Working process, cutter bar drive. Knife cutting speed pattern area. Design of auger for plant collection. Corn header: Working elements, snapping roll design, stalk grasping and drawing process. Corn ear detachment: Stalk cutting and chopping.

## Unit-V

Cereal threshing and separation: Design of tangential and axial threshing units. Performance indices of threshing units. Modelling material kinematics in different threshing units. Factors influencing the threshing process and power requirement. Separation process and design of straw walker. Cleaning Unit process and operation. Grain pan: Chaffer and bottom sieve. Blower design and flow orientation. Design of conveying system for grain. Straw choppersand shredders.

## Practical:

Measurement of spray characters for different nozzles. Problems on sizing of sprayer components. Design of sprayer for special purpose: Orchard and tall trees. Harvesting machine. Problems on design of cutterbars, reels, platform auger, conveyors. Design of threshing drum: Radial and axial flow type. Design of cleaning and grading systems. Designof blowers.

## Course Outcome:

The student will know the principles behind the design of crop spraying equipments and harvesting and threshing machinery.

## Teaching Schedule

| Sr No. | Topic | No of Lectures |
|---|---|---|
| 1. | Overview of chemical control integrated pest management. | 1 |
| 2. | Targets for pesticide deposition. Formulation of pesticides. | 1 |
| 3. | Multidisciplinary nature of pesticide application. | 1 |

| | | |
|---|---|---|
| 4. | Pesticide calculation examples. | 2 |
| 5. | Spray droplets. Hydraulic nozzles. Power operated hydraulic sprayer design principles. | 2 |
| 6. | Controlled droplet application. Spray drift and its mitigation. | 1 |
| 7. | Air assisted hydraulic sprayer design principles. Electrostatically charged sprayers. | 2 |
| 8. | Aerial spraying systems. Use of drones for spraying: | 1 |
| 9. | Design of spray generation and application issues. | 1 |
| 10. | Introduction to combine harvesters: Construction, equipment subsystems, power sub systems. | 1 |
| 11. | Crop harvesting: Plant properties, physical and mechanical propertiesof plant stem, plant bending modelling. | 1 |
| 12. | Properties of plant grain: Physical, mechanical, grain damage. | 2 |
| 13. | Properties of MOG: Mechanical and aerodynamic. | 2 |
| 14. | Design of grain header: Orienting and supporting reel. Plant cutting cutter bar | 2 |
| 15. | Working process, cutter bar drive. Knife cutting speed pattern area. | 1 |
| 16. | Design of auger for plant collection. | 1 |
| 17. | Corn header: Working elements, snapping roll design, stalk grasping and drawing process. Corn ear detachment: Stalk cutting and chopping. | 2 |
| 18. | Cereal threshing and separation: Design of tangential and axialthreshing units. Performance indices of threshing units. | 2 |
| 19. | Modelling material kinematics in different threshing units. Factors influencing the threshing process and power requirement. | 1 |
| 20. | Separation process and design of straw walker. | 1 |
| 21. | Cleaning Unit process and operation. Grain pan: Chaffer and bottom sieve. Blower design and flow orientation. | 2 |
| 22. | Design of conveying system for grain. Straw choppers and shredders. | 2 |
| | **Total** | **32** |

**List of Practicals**

| **S. No.** | **Practical** | **No. of practicals** |
|---|---|---|
| 1. | Measurement of spray characters for different nozzles. | 1 |

| | | |
|---|---|---|
| 2. | Problems on sizing of sprayer components. | 1 |
| 3. | Design of spraying units – manual | 1 |
| 4. | Design of spraying units – powered | 1 |
| 5. | Design of sprayer for special purpose: Orchard and tall trees. | 1 |
| 6. | Design of agitation units – mechanical and hydraulic | 1 |
| 7. | Harvesting machines: Problems on design of shear type cuttingmechanism | 1 |
| 8. | Harvesting machines: Problems on design of impact typeharvesting mechanism | 1 |
| 9. | Harvesting machines: Problems on design of platform auger and conveyors. | 1 |
| 10. | Harvesting machines: Problems on design of reels | 2 |
| 11. | Design of threshing drum: Radial flow type. | 1 |
| 12. | Design of threshing drum: Axial flow type. | 1 |
| 13. | Design of cleaning systems. | 1 |
| 14. | Design of grading systems. | 1 |
| 15. | Design of blowers. | 1 |
| | **Total** | **16** |

**Suggested Reading:**

1. Thornhill E W and Matthews G A 1995. *Pesticide Application Equipment for Use in Agriculture* Vol II. Mechanically powered equipment FAO Rome.
2. Miu P 2016. *Combine Harvesters Modeling and Design*. CRC Press, Boca Raton, USA ISBN 13:978-1-4822-8237-5
3. Bosoi E S, Verniaev O V, Smirnov II and Sultan-Shakh E G 1987. *Construction and Calculations of Agricultural Machinery - Vol.II.* Oxonian Press Pvt. Ltd. New Delhi.
4. Bernacki C, Haman J and Kanafajski Cz 1972. *Agricultural Machines Theory and Construction. Vol-I.* U.S. Department of Commerce, National Technical Information Service, Springfield, Virginia22151.
5. Bindra, O S and Singh H 1971. *Pesticides Application Equipments.* Oxford & IBH Publishing Co., New Delhi.

## FMPE 507 : Management of Farm Power and Machinery System 2+1

### Objectives:

To understand how principles of management are applied to farm machinery systems to makethem more effective and profitable.

### Unit-I

Importance and objectives of farm mechanization in Indian agriculture, its impact, strategies, myths and future needs. Estimation of operating cost of tractors and farm machinery. Management and performance of power, operator, labour. Economic performance ofmachinery, field capacity, field efficiency and factors affecting field efficiency.

### Unit-II

Tractor power performance in terms of PTO, drawbar and fuel consumption. Power requirement problems to PTO, DBHP.

### Unit-III

Selection of farm machinery, size selection, timeliness of operation, optimum width and problem related to its power selection. Reliability of agricultural machinery. Replacement of farm machinery and inventory control of spare parts.

### Unit-IV

Systems approach to farm machinery management and application of programming techniques to farm machinery selection and scheduling. Network Analysis: Transportation, CPM and PERT, dynamic programming, Markov chain.

**Practicals**

Study of latest development of different agricultural equipment and implements in India and other developing countries. Size selection of agricultural machinery. Experimental determination of field capacity of different farm machines. Study of farm mechanization in relation to crop yield. Determination of optimum machinery system for field crop and machine constraints. To develop computer program for the selection of power and machinery.

### Course Outcome:

The student will be able to understand how farm machinery is selected and operated to make them economically viable.

### Teaching Schedule

| Sr N | Topic | No of lectures |
|---|---|---|
| 1. | Importance and scope of farm mechanization in Indian Agriculture | 1 |
| 2. | Cost analysis of Farm Machinery and tractor, Breakdown analysis, Inflation. | 2 |
| 3. | Measurement of power performance (PTO power, drawbar power and fuel consumption) of tractor and power tiller | 3 |
| 4. | Study of field capacity and field efficiency of different farm machinery and factor affecting them | 1 |
| 5. | Selection of Farm Machinery size wrto power source and timeliness of operation | 4 |

| | | |
|---|---|---|
| 6. | Application of programming technique to problem of farm power and machinery selection. | 4 |
| 7. | Replacement models, spare parts and inventory control | 2 |
| 8. | Maintenance and scheduling of operations. | 2 |
| 9. | Network analysis – transportation | 2 |
| 10. | Network analysis – critical path method, PERT | 2 |
| 11. | Network analysis – dynamic programming | 3 |
| 12. | Network analysis – markov chain | 3 |
| 13. | Linear programming, multivariable system, simplex algorithm. Theoryof network. | 3 |
| | **Total** | **32** |

**List of Practicals**

| **Sr. No** | **Topic** | **No of practicals** |
|---|---|---|
| 1. | Introduction to latest development of advanced agricultural equipment's in India | 3 |
| 2. | Experimental determination of field capacity of different farm machines | 3 |
| 3. | Case studies on optimum size selection of agricultural machinery | 3 |
| 4. | Determination of inventory of different farm machines for a farm of size 50 ha as per regional crop rotations | 3 |
| 5. | To develop computer program regarding selection of farm machinery size and power requirement for a 10, 50 and 100 ha farm size | 4 |
| | **Total** | **16** |

**Suggested Reading:**

1. Hunt D 1979. *Farm Power and Machinery Management*. Iowa State University Press,USA
2. Kapoor V K 2012. *Operation Research: Concepts, Problems and Solutions*. Sultan Chandand Sons, India.
3. Culpin C 1996. *Profitable Farm Mechanization*. Lock Wood and Sons, London.
4. Singh, S and Verma, S R. *Farm Machinery Maintenance and Management*. DIPA, ICAR,KAB-I, New Delhi.

5. Carveille, L A 1980. *Selecting Farm Machinery*. Louisiana Cooperative Extn. ServicesPublication.

6. FAO 1990. *Agricultural Engineering in Development: Selection of Mechanization Inputs*. FAO, Agri service Bulletin

7. S.C. Jain and Grace Philip. 2003. *Farm Machinery- An Approach*. Standard Publishers. Delhi-6

8. Surendra Singh. *Farm Machinery: Principles and Applications*. DIPA-ICAR, New Delhi.

**FMPE 511 : Principles of Automation and Control 2+1**

**Objectives:**

To learn the principles behind systems for industrial automation and control especially with respect to electronically implemented systems.

**Unit-I**

Introduction to industrial automation and control: Architecture of industrial automation systems, review of sensors and measurement systems. Introduction to process control: PID control, controller tuning, implementation of PID controllers, special control structures, feed forward and ratio control, predictive control, control of systems with inverse response, cascade control, overriding control, selective control and split range control.

**Unit-II**

Introduction to sequence control: PLCs and relay ladder logic, sequence control, scan cycle, RLL syntax, sequence control structured design approach, advanced RLL programming, the hardware environment, Introduction to CNC machines.

**Unit-III**

Control of machine tools: Analysis of a control loop, introduction to actuators. Flow control valves, hydraulic actuator systems, principles, components and symbols, pumps and motors. Proportional and servo valves. Pneumatic control systems, system components, controllers and integrated control.

**Unit-IV**

Control systems: Electric drives, introduction, energy saving with adjustable speed drives stepper motors, principles, construction and drives. DC motor drives: Introduction to DC-DC converters, adjustable speed drives. Induction motor drives: Introduction, characteristics, adjustable speed drives. Synchronous motor drive-motor principles, adjustable speed and servo drives.

**Unit-V**

Networking of sensors, actuators and controllers, the fieldbus, the fieldbus communication protocol, introduction to production control systems.

**Practical:**

Control system practical: Characteristics of DC servomotor, AC/DC position control system. ON/OFF temperature control system. Step response of second order system, temperature control system using PID level control system. Automation: Introduction to ladder logic, writing logic and implementation in ladder. PLC programming, water level controller using programmable logic controller. Batch process reactor using programmable logic controller. Speed control of AC servo motor using programmable logic controller.

**Course Outcome:**

Understanding of the principles behind implementation of systems for automation and control.

**Teaching Schedule**

| S. No. | Topic | No of Lectures |
|---|---|---|
| 1 | Introduction to industrial automation and control | 1 |
| 2 | Architecture of industrial automation systems | 1 |
| 3 | Review of sensors and measurement systems-I | 1 |
| 4 | Review of sensors and measurement systems-II | 1 |
| 5 | Introduction to process control | 1 |
| 6 | PID control, controller tuning and implementation of PID | 1 |
| 7 | Special control structures, feed forward and ratio control | 1 |
| 8 | Predictive control and control of systems with inverse response | 1 |
| 9 | Cascade control, overriding control | 1 |
| 10 | Selective control and split range control. | 1 |
| 11 | Introduction to sequence control | 1 |
| 12 | PLCs and relay ladder logic, sequence control and scan cycle, | 1 |
| 13 | RLL syntax, sequence control structured design approach, | 1 |
| 14 | Advanced RLL programming and the hardware environment, | 1 |
| 15 | Introduction to CNC machines. | 1 |
| 16 | Control of machine tools | 1 |
| 17 | Analysis of a control loop | 1 |
| 18 | Introduction to actuators. | 1 |
| 19 | Introduction to flow control valves, | 1 |
| 20 | Hydraulic actuator systems, principles, components and symbols | 1 |
| 21 | Introduction to hydraulic pumps and motors | 1 |
| 22 | Introduction about proportional and servo valves. | 1 |
| 23 | Pneumatic control systems, system components and controllers and integrated control. | 1 |
| 24 | Introduction about electric control systems | 1 |
| 25 | Electric drives, energy saving with adjustable speed drives | 1 |
| 26 | Stepper motors, principles, construction and drives. | 1 |
| 27 | DC motor drives: Introduction to DC-DC converters, adjustable speed drives. | 1 |

| | | |
|---|---|---|
| 28 | Induction motor drives: Introduction, characteristics, adjustable speed drives | 1 |
| 29 | Synchronous motor drive-motor principles, adjustable speed and | 1 |
| 30 | Networking of sensors, actuators and controllers, | 1 |
| 31 | The field bus, the field bus communication protocol, | 1 |
| 32 | Introduction to production control systems. | 1 |
| | **Total** | **32** |

**List of Practical**

| **Sr.No.** | **Topic** | **No of Practicals** |
|---|---|---|
| 1. | Control system including characteristics of DC servomotor. | 2 |
| 2 | AC/DC position control system | 1 |
| 3 | Temperature control system | 1 |
| 4 | Step response of second order system | 2 |
| 5 | Temperature control system using PID level control system | 1 |
| 6 | Introduction to ladder logic, writing logic and implementation in ladder. | 2 |
| 7 | PLC programming | 2 |
| 8 | Water level controller using programmable logic controller | 1 |
| 9 | Batch process reactor using programmable logic controller | 2 |
| 10 | Speed control of AC servo motor using programmable logic controller | 2 |
| **Total** | | **16** |

**Suggested Reading:**

1. https://nptel. ac. in/downloads/108105063/
2. Manesis S and Nikolakopoulos G 2018. *Introduction to Industrial Automation.* 1st Edition, CRC Press. Textbook - ISBN 9781498705400 - CAT# K24766

**FMPE 512 : Principles of Hydraulic and Pneumatic Systems 2+1**

**Objectives:**

To understand the principles behind operation of hydraulic and pneumatic systems and their components and design simple hydraulic and pneumatic circuits and select components for the same.

**Unit-I**

Hydraulic power, its advantages, applications, properties of hydraulic fluids, viscosity, bulk modulus, density. Concepts of energy of hydraulic systems, laws of fluid flow.

**Unit-II**

Hydraulic pump and motors, principle, capacity, classifications, working, performance. Design of various types of pumps and motors.

**Unit –III**

Actuators, types, design of linear actuator and rotary actuators. Hydraulic rams, gear motors, piston motors and their performance characteristics. Hose, filters, reservoirs, types of circuits, intensifier, accumulator, valves. Valve types: Direction control, deceleration, flow, pressure control, check valve and their working etc. Unit-IV Hydraulic circuit design. Applications in farm power and machinery: Tractor, combine, farm machinery systems, hydrostatic system etc.

**Unit-V**

Power pack, pneumatic circuits, properties of air. Compressors, types. Design of pneumatic circuits.

**Practical:**

Study of various hydraulic pumps, motors, valves, directional control valves, cylinder piston arrangements, engineering properties of hydraulic fluids, hydraulic system of tractor, power steering system.

**Course Outcome:**

Ability to design simple hydraulic and pneumatic circuits and to select the components for the same. To design hydraulic and pneumatic systems of farm Machinery.

**Teaching Schedule**

| SN | Topic | No. of lectures |
|---|---|---|
| 1 | Introduction to hydraulic power, its advantages, applications. | 1 |
| 2 | Properties of hydraulic fluids, viscosity, bulk modulus, density. | 2 |
| 3 | Concepts of energy of hydraulic systems, laws of fluid flow. | 1 |
| 4 | Introduction to hydraulic pump and motor. | 1 |
| 4 | Principle of hydraulic pump and motor, capacity, classifications, working, | 1 |

| | | |
|---|---|---|
| | performance. | |
| 5 | Design of various types of hydraulic pumps. | 1 |
| 7 | Design of various types of hydraulic motors. | 1 |
| 8 | Actuators, types, design of linear actuator and rotary actuators. | 3 |
| 9 | Hydraulic rams, gear motors, piston, motors and their performance characteristics. | 3 |
| 10 | Hose, filters, reservoirs, types of circuits, intensifier, accumulator, valves. | 3 |
| 11 | Valve types: Direction control, deceleration, flow, pressure control, check valve and their working etc. | 4 |
| 12 | Valve types: Direction control, deceleration, flow, pressure control, check valve and their working etc. | 2 |
| 14 | Applications in farm power and machinery: Tractor, combine, farm machinery systems, hydrostatic system etc. | 3 |
| 15 | Power pack, pneumatic circuits, components of pneumatic systems, properties of air. | 3 |
| 16 | Compressors, types. Design of pneumatic circuits., Study of hydraulic and pneumatic drives in agricultural systems with basic robotics | 3 |
| | **Total** | **32** |

**List of Practicals**

| SN | Topic | No. of Practical's |
|---|---|---|
| 1 | Study of various hydraulic pumps | 1 |
| | Study of hydraulic actuators | 1 |
| 2 | Study of various hydraulic motors | 1 |
| 3 | Study of various hydraulic valves | 1 |
| 4 | Study of various hydraulic directional control valves | 2 |
| 5 | Study of various hydraulic cylinder piston arrangements | 1 |
| 6 | Engineering properties of hydraulic fluids | 2 |
| 7 | Study of hydraulic system and circuits of tractor | 2 |
| 8 | Study of power steering system | 1 |
| 9 | Study of power pack, pneumatic circuits, components of pneumatic systems | 2 |
| 10 | Study of hydraulic and pneumatic drives in agricultural systems with robotics | 2 |
| | **Total** | **16** |

**Suggested Reading:**


1. Majumdar S R 2003. *Oil Hydraulics Systems: Principles and Maintenance*. Tata McGraw Hill Co, New York.
2. Anthony E 2003. *Fluid Power with Applications*. Tata McGraw Hill Co. 2 Pearsons Education (Singapore) Pvt. Ltd.
3. Krutz G 1984. *Design of Agricultural Machines*. John Wiley and Sons.
4. Merritt H E 1991. *Hydraulic Control System*. John Wiley and Sons Inc.
5. Anthony Esposito 1997. *Fluid Power with Applications* $4^{th}$ Ed. Prentice-Hall Inc. New Jersey.
6. Mobley R. K. 2000. *Fluid Power Dynamics*. Newnes Publication.
7. Chapple Peter 2003. *Principal of Hydraulic System Design*. Fist Edition Coxmoor Publishing Company.

**FMPE 513 : Applied Instrumentation in Farm Machinery 2+1**

## Objectives:

To understand the operation of instruments that is used in design and evaluation of farmmachinery and their application.

**Unit-I**

Characteristics of Instruments (Static and Dynamic), Basic Instrumentation system Introduction to transducers (sensors). Active and passive transducers, analog and digital modes, primary and secondary, null and deflection methods etc, Need for instrumentation in agriculture..

## Unit-II

Strain gauges, types and applications in two and three dimensional force measurement infarm machinery. Various methods of determining strain/stresses experimentally. Design, selection and analysis of strain gauges.

## Unit-III

Load cells, torque meters, flow meters types and principles of working. Devices for measurement of temperature, relative humidity, pressure, sound, vibration, displacement (LVDT), velocity, acceleration etc. Measuring instruments for calorific value of solid, liquid, and gaseous fuels.

## Unit-IV

Basic signal conditioning devices, data acquisition system. Recording devices and their types. Micro computers for measurement and data acquisition. Data storage and their application including wireless communication. Application of sensors in farm machinery and power: Tractor and selected farm machinery.

## Practical:

Calibration of load cells, torque meters, flow meters etc. Experiment on LVDT, strain gauge transducer, speed measurement using optical devices, vibration measurement, making of thermocouples etc, application of sensors in farm machinery like wheel hand hoe, etc.

## Course Outcome:

The student will be able to select and implement suitable systems for measurement of different parameters like force, torque, speed and pressure etc, that are used in design and evaluation of Farm machinery.

## Teaching schedule

| Sr. No. | Topic | No. of Lectures |
|---|---|---|
| 1. | Characteristics of Instruments (Static and Dynamic), | 2 |
| 2 | Basic Instrumentation system Introduction to transducers (sensors). | 1 |
| 3 | Classification of Transducers, Need for instrumentation in agriculture | 3 |
| 4 | Basic Strain gauges and its types; | 1 |
| 5 | Construction of strain gauges, Bridge structure, Quarter bridge, half bridge, full bridge | 2 |
| 6 | Various methods of determining strain/stresses experimentally. | 1 |
| 7 | Applications of strain gauges in two and three dimensional force measurement in farm machinery | 2 |

| | | |
|---|---|---|
| 8 | Design, selection and analysis of strain gauges. | 1 |
| 8. | Principles of working of transducers alongwith application a)Load Cell b)Torque meter c)Flow meters | 2 |
| 9 | Devices for measurement of temperature and relative humidity | 2 |
| 10 | Devices for measurement of pressure | 2 |
| 11 | Devices for measurement of, displacement, velocity and acceleration | 2 |
| 12 | Devices for measurement of vibration sound | 1 |
| 13 | Devices for measurement of level | 1 |
| 14 | Measuring instruments for calorific value of solid, liquid, andgaseous fuels | 2 |
| 15 | Basic signal conditioning devices and data acquisition | 1 |
| 16 | Micro computers for measurement and data acquisition; general purpose microcontrollers and microprocessors | 1 |
| 17 | Recording devices and their types | 1 |
| 18 | Data storage and their application including wireless communication | 1 |
| 19 | Application of sensors in farm machinery and power: Tractor and selected farm machinery | 1 |
| | **Total** | **32** |

**List of Practicals**

| **Sr.No** | **Topic** | **No of Practicals** |
|---|---|---|
| 1. | Calibration of Load Cells | 2 |
| 2. | Calibration of Torque Meters | 1 |
| 3. | Calibration of Flow Meters | 1 |
| 4. | Experiment on LVDT. | 2 |
| 5. | Experiment on Strain Gauge | 1 |
| 6. | Speed measurement using optical devices | 2 |
| 7. | Vibration Measurement | 2 |
| 8. | Making of Thermocouples | 2 |

| | | |
|---|---|---|
| 9. | Application of Sensors in Farm Machinery like wheel hand hoe etc. | 3 |
| | **Total** | **16** |

**Suggested Reading:**


1. Doeblin E O 2004. *Measurement System- Application and Design*. Tata McGrawHill
2. Nakra B C and Choudhary K K 1985. *Instrumentation, Measurement and Analysis.* 2nd Edition Tata McGraw Hill.
3. Nachtigal C L (Editor) 1990. *Instrumentation and Control. Fundamentals and Application.* Wiley Series in Mechanical Engineering
4. Ambrosius E E 1966. *Mechanical Measurement and Instruments*. The Ronald Press Company.
5. Oliver F J 1971. *Practical Instrumentation Transducers*. Hayden book company Inc
6. Sawhney A.K. *Electrical and Electronic Measurements and Instrumentation*, Dhanpatrai and Sons, New Delhi
7. Patronabis, O. *Instrumentation and Control*, PHI Learning Pvt Ltd, New Delhi

## FMPE 514 Systems Simulation and Computer Aided Problem Solving in Engineering 2+1

### Objectives:

To give the student orientation in simulation of continuous and discrete systems especiallyusing computer programme and software.

### Unit-I

Mathematical modeling and engineering problem solving: Conservation laws and engineering. Computers and software: Software development, structured programming, logical representation. Modular programming. Approximation: Round off errors, truncation errors, significant figures, accuracy and precision.

### Unit-II

Nature of simulation: Systems models and simulation, discreet event simulation, time advance mechanisms, components of discrete event simulation model, simulation of single server queuing system. Program organization and logic, development of algorithm. Simulation of an inventory system.

### Unit-III

Solving roots of equation using computers. Application in: Ideal and non-ideal gas laws, open channel flows, design of an electric circuit, vibration analysis. Solving linear algebraic equation on computers: Naïve Gauss Elimination, techniques for improving solutions, LUdecomposition and matrix inversion. Application in: Steady state analysis of chemical reactors, statically determinate truss, current and voltage in circuits, spring mass systems.

### Unit-IV

Optimization techniques. Search techniques: Golden Sections, quadratic interpolation. Application: Optimum design of tank, least cost treatment of waste water, power transfer for circuits. Solving ordinary differential equation on computers: Modeling engineering systems with ordinary differential equation, solution techniques using computers.

### Practical:

Comparison of analytical and numerical solutions using Spread sheet. Generation of random variables. Generation of discreet and continuous random variate-coding. Implementation of single server queue on computer. Exercises with software packages for roots of equation: Solving linear algebraic equation, curve fitting and optimization. Solving simultaneous equation through Gauss elimination, solving steady state analysis of chemical reactors, statically determinate truss, current and voltage in circuits, spring mass systems on computers. Application of ordinary differential equation to solve mixed reactor problems,predator prey models and chaos.

### Course Outcome:

Ability to analyze problems from a systems perspective and apply the principles to simulation of continuous and discrete engineering systems.

### Teaching Schedule

| Sr.No | Topic | No. of Lectures |
|---|---|---|
| 1 | Introduction to mathematical modeling in engineering problem solving, comparison of analytical and numerical approaches. | 1 |
| 2 | Conservation laws applied to engineering, modeling simple | 1 |

| | | |
|---|---|---|
| | system | |
| 3 | Computer modeling, computing environments software development process. | 1 |
| 4 | Modular design, top down design, structured programming, – algorithm design. | 1 |
| 5 | Program composition, quality control- testing and documentation software strategy. | 1 |
| 6 | Approximation- round off errors- accuracy and precision – definitions, number system in the computer- truncation errors. | 1 |
| 7 | Nature of simulation, systems models and simulation. | 1 |
| 8 | Discreet event simulation, time advance mechanisms, components of discreet event simulation model. | 1 |
| 9 | Principles of simulation of singular server queuing system. | 1 |
| 10 | Programme organization and logic for single server queuing system. | 1 |
| 11 | Development of algorithm, single server queuing system. | 1 |
| 12 | Solving roots of equation in computers, graphical method. | 1 |
| 13 | Developing algorithm for bisection method, false position method. | 1 |
| 14 | Application of roots of equation to gas laws, open channel flows. | 1 |
| 15 | Application of roots of equation to electric circuits, vibration analysis. | 1 |
| 16 | Solving linear algebraic equation in engineering practices. | 1 |
| 17 | Developing algorithm for Gaussian elimination. | 1 |
| 18 | Pitfalls of elimination methods and remedies. | 1 |
| 19 | Overview of LU decomposition. | 1 |
| 20 | LU decomposition algorithms, calculating inverse of matrix. | 1 |
| 21 | Application of linear algebraic equation to statically determinate truss. | 1 |
| 22 | Application of linear algebraic equation to Circuit analysis. | 1 |
| 23 | Application of linear algebraic equation to spring mass system. | 1 |
| 24 | Introduction to optimization in engineering, Formulation of Problems. | 1 |
| 25 | One dimensional unconstrained optimization, development of algorithm for golden sections. | 1 |
| 26 | One dimensional unconstrained optimization quadratic interpolation. | 1 |
| 27 | Application of optimization to design of tank. | 1 |
| 28 | Application of optimization to waste water treatment problem. | 1 |
| 29 | Application of optimization to power transfer circuits. | 1 |
| 30 | Formulating engineering problems using ordinary differential equation. | 1 |

| | | |
|---|---|---|
| 31 | Solving ordinary differential equation using computers, Euler's method. | 1 |
| 32 | Solving ordinary differential equation using modeling engineering systems, computers, Runge-kutta method. | 1 |
| | **Total** | **32** |

**List of Practicals**

| Sr.No | Topic | No. of Practicals |
|---|---|---|
| 1 | Exercises in developing simple programmes in C. | 1 |
| 2 | Demonstration of solutions using analytical and numerical methods for simple problems. | 1 |
| 3 | Development of programmes for generation of random variables. | 1 |
| 4 | Writing programme for generating random variates. | 1 |
| 5 | Writing programme for event advance mechanism of single server queuing system. | 1 |
| 6 | Writing programme for arrival module of single server queuing system. | 1 |
| 7 | Writing programme for departure module of single server queuing system and statistical performance. | 1 |
| 8 | Writing programme for solution of roots of equation. | 1 |
| 9 | Solving simple engineering problems using roots of equation. | 1 |
| 10 | Development of algorithm for Gaussian elimination. | 1 |
| 11 | Application of Gaussian elimination to mass balance problems and statically determinate truss. | 1 |
| 12 | Application of Gaussian elimination to analysis of electrical circuits. | 1 |
| 13 | Development of algorithm for Golden Sections and application. | 1 |
| 14 | Application of optimization technique to design of tank. | 1 |
| 15 | Application of optimization technique to waste water treatment. | 1 |
| 16 | Predator prey models and chaos. | 1 |
| | **Total** | **16** |

**Suggested Reading:**

1. Chapra S C and Canale R P 1994. *Introduction to Computing for Engineers*. 2nd EditionMcGraw Hill International Edition, New York.
2. Law A M 2015. *Simulation Modeling and Analysis.* McGraw Hill International Edition,New York.
3. Dent J B and Blackie M J 1979. *System Simulation in Agriculture*. Applied Science

Publishers Ltd., London.

4. Schilling R J and Harries S L 2002. *Applied Numerical Methods for Engineers UsingMATLAB and C*.Thomson Asia Pvt .Ltd. Singapore.
5. Balagurusamy E 2000. *Numerical Methods*.Tata McGraw Hill Publishing Company limited, New Delhi.
6. Veerarajan T and Ramachnadran T 2004. *Numerical Methods with Programmes in C andC++*. Tata McGraw Hill Publishing company limited, New Delhi.

## FMPE 515 : Computer Aided Design of Machinery 0+2

### Objectives:

To learn the practice of designing components and assemblies based on computer aideddrafting technique.

### Practical:

Learning 2D drafting: Controlling display settings, setting up units, drawing limits and dimension styles. Drawing and dimensioning simple 2D drawings, keyboard shortcuts. Working with blocks, block commands. Exercise in simple assembly in orthographic. Exercise in measuring and drawing simple farm machinery parts.
Learning 3D Drafting: Advantages of virtual prototyping-starting the 3D drafting environment, self learning tools, help and tutorials. Familiarizing with user interface, creating files and file organization, structuring and streamlining. Features of document window. Concept of coordinate system: Working coordinate system, model coordinate system, screen coordinate system, graphics exchange standards and database management system. Working with feature manager and customizing the environment. Planning and capturing design intent. Documentation of design. Using design journal and design binder. Preliminary design review and layout.
Practice in drawing 2D sketches with sketcher and modifying sketch entries. Adding Reference geometry: Planes and axes. Adding relations and working with relations.Dimensioning a sketch. Exercises.
Parts and features: Sketched features and applied features, pattern and mirror features. Documenting design. Assembly: Creating and organizing assemblies, connecting parts and subassemblies with mates. Organizing the assembly by using layouts.
Exercise in creating drawing: Setting up and working with drawing formats, creating drawing views from the 3D model, making changes and modifying dimensions.
Case studies: Measuring and drawing assemblies of farm implements and their components.

### Course Outcome:

The student will be able to conceptualize spatial concepts and design components and assemblies of Farm machinery and make graphic models using commercial CAD softwarelike Solid Works, Catia and AutoCAD.

### List of Practicals

| S. No. | Topic | No of Practicals |
|---|---|---|
| 1. | Learning 2D drafting: Controlling display settings, setting up units, drawing limits and dimension styles. | 2 |
| 2. | Drawing shortcuts, and dimensioning simple 2D drawings, keyboard | 1 |
| 3. | Working with blocks, block commands. Exercise in simple assembly in orthographic. | 1 |
| 4. | Exercise in measuring and drawing simple farm machinery parts. | 2 |
| 5. | Learning 3D Drafting: Advantages of virtual prototyping-starting the 3D drafting environment, self learning tools, help and tutorials. Familiarizing with user interface, creating files and file organization, structuring and streamlining. Features of document window. | 2 |
| 6. | Concept of coordinate system: Working coordinate system, modelcoordinate system, screen coordinate system, graphics exchange standards and database management system. | 2 |

| | | |
|---|---|---|
| 7. | Working with feature manager and customizing the environment.Planning and capturing design intent. | 2 |
| 8. | Documentation of design. Using design journal and design binder.Preliminary design review and layout. | 1 |
| 9. | Practice in drawing 2D sketches with sketcher and modifying sketch entries. | 2 |
| 10. | Adding Reference geometry: Planes and axes. Adding relationsand working with relations. Dimensioning a sketch. Exercises. | 2 |
| 11. | Parts and features: Sketched features and applied features, pattern and mirror features. Documenting design. | 2 |
| 12. | Assembly: Creating and organizing assemblies, connecting parts and subassemblies with mates. | 2 |
| 13. | Organizing the assembly by using layouts. | 1 |
| 14. | Exercise in creating drawing: Setting up and working with drawing formats, creating drawing views from the 3D model, making changes and modifying dimensions. | 2 |
| 15. | Case studies: Measuring and implements and their components. Drawing assemblies of farm | 5 |
| | **Total** | **32** |

**Suggested Reading:**

1. Jankowski G and Doyle R 2007. *Solid Works*® For Dummies®, 2nd Edition, Published byWiley Publishing, Inc. ISBN: 978-0-470-12978-4

2. Shih R H 2014. *AutoCAD 2014 Tutorial*-First Level: 2D Fundamentals. SDCPublications

**FMPE 516 Advanced Manufacturing Technologies 2+1**

### Objectives:

To learn the modern manufacturing techniques and their application to manufacture of different components and assemblies.

### Unit-I

Material and their characteristics, structure and properties of materials, wood, ferrous, Non- ferrous, alloys, plastic, elastomers, ceramics and composites. Material selection and metallurgy: Equilibrium diagram, time temperature transformation curves, heat treatments,surface treatment: Roughness and finishing.

### Unit-II

Measurement and quality assurance: Quality control, tolerance, limits and clearance. Automated 3-D coordinate measurements. Advance casting processes and powder metallurgy. Forming process: Fundamentals of metal forming, hot and cold rolling, forging processes, extrusion and drawing.

### Unit-III

Workshop practices applied in prototype production, jigs and fixtures. Traditional machining processes: Cutting tools, turning, boring, drilling, milling and related processes. Non traditional machining processes fuzzy c-mean (FCM), electric discharge machining (EDM), laser beam machining (LBM), Abrasive jet machining (AJM), and Wire-electro-discharge machining (EDM).

### Unit-IV

Joining processes: Gas flame processes, arc processes, brazing and soldering, adhesive and bonding.

### Unit-V

Numerical control: Command system codes, programme, cutter position X and Y, incremental movements, linear contouring, Z movements and commands. Manufacturing systems and automation. Robotics and robot arms. 3-D printing. Integrated manufacturing production system.

### Practical:

Identification of material and their application. Study of heat treatment processes and their suitability with respect to materials. Tool and equipments for measurements: Tolerance limits, clearance and surface finish. Site visits for study of advanced manufacturing techniques. Case studies.

### Course Outcome:

The students will be able to select suitable manufacturing technique to fabricate different components used in Farm machinery.

### Teaching Schedule

| Sr.No | Topic | No. of Lectures |
|---|---|---|
| 1 | Material and their characteristics. | 1 |
| 2 | Structure and properties of materials wood, ferrous, Non-ferrous,alloys, plastic, elastomers, ceramics and composites. | 2 |

| | | |
|---|---|---|
| 3 | Material selection and metallurgy: Equilibrium diagram, time temperature transformation curves. | 1 |
| 4 | Heat treatments, surface treatment: Roughness and finishing. | 2 |
| 5 | Measurement and quality assurance: Quality control, tolerance,limits and clearance. | 1 |
| 6 | Automated 3-D coordinate measurements and practice. | 2 |
| 7 | Advance casting processes and powder metallurgy. | 1 |
| 8 | Forming process: Fundamentals of metal forming, hot and cold rolling, forging processes, extrusion and drawing. | 2 |
| 9 | Forging processes, extrusion and drawing. | 1 |
| 10 | Workshop practices applied in prototype production, jigs and fixtures. | 1 |
| 11 | Traditional machining processes: Cutting tools, turning, boring,drilling, milling and related processes. | 2 |
| 12 | Non traditional machining processes fuzzy c-mean (FCM), electricdischarge machining (EDM), laser beam machining (LBM). | 2 |
| 13 | Electric discharge machining (EDM), laser beam machining (LBM). | 1 |
| 14 | Abrasive jet machining (AJM), and wire-electro-dischargemachining (EDM). | 2 |
| 15 | Joining processes: Gas flame processes, arc processes. | 2 |
| 16 | Brazing and soldering processes. | 1 |
| 17 | Adhesive and bonding processes. | 1 |
| 18 | Numerical control: Command system codes. | 1 |
| 19 | NC Programme, Robotics and robot arms. | 2 |
| 20 | Cutter position X and Y, incremental movements, linear contouring,Z movements and commands. | 1 |
| 21 | Manufacturing systems and automation. | 1 |
| 22 | 3-D printing and integrated manufacturing production system. | 2 |
| | **Total** | **32** |

**List of Practicals**

| Sr. No. | Topic | No. of Practicals |
|---|---|---|
| 1. | Identification of material and their application. | 2 |
| 2. | Study of heat treatment processes and their suitability with respectto materials. | 5 |
| 3. | Tool and equipments for measurements: Tolerance limits, clearance and surface finish. | 4 |
| 4. | Site visits for study of advanced manufacturing techniques. | 2 |
| 5. | Case studies. | 3 |
| | **Total** | **16** |

**Suggested Reading:**


1. Polukin P, Gringerg B, Kantenik S, Zhadan V and Vasilye D. *Metal Process Engineering*,MIR Publishers Moscow.
2. Hoyos L 2010. *Fundamentals of Tool Design.* American Society of Tool and Manufacturer Engineers. Sixth Edition
3. Gupta R B 2017. Vol *Production Technology* I - Production Process. Satya Prakashan,New Delhi.
4. Jain, R K 1994. *Production Technology*: A Textbook for Engineering Students. KhannaPublishers, New Delhi .
5. Begeman M L, Ostwald P F and Amstead B H 1979. *Manufacturing Processes:* SIVersion. John Wiley and Sons. 7th Edition
6. Chapman P A J 1996. *Workshop Technology Part III.* CBS Publisher and distributors PvtLtd. 3rd Edition international Edition.

## FMPE 517 : Machinery for Precision Agriculture 2+1

### Objectives:
To learn the principles behind precision agriculture and the systems for implanting the same.

### Unit-I
Importance of precision agriculture. Mapping in farming for decision making. Geographical concepts of PA. Understanding and identifying variability

### Unit-II
Geographical Position System (GPS) Basics (Space Segment, Receiver Segment, Control Segment), Error and correction, Function and usage of GPS. Introduction to Geographic Information system (GIS), function of GIS, use of GIS for decisions. IDI devices usage in Precision Agriculture Yield monitor, variable rate applicator for fertilizers, seed, chemicals etc. Remote sensing Aerial and satellite imagery. Above ground (non-contact) sensors.

### Unit-III
Data analysis, concepts of data analysis, resolution, Surface analysis. Analysis application interpretive products (map, charts, application map etc).

### Unit-IV
Electronics and Control Systems for Variable rate applications, Precision Variable Equipment, Tractor-Implement interface technology, Environmental Implications of Precision Agriculture.

### Unit-V
Goals based on end results of Precision Agriculture, Recordkeeping, Spatial Analysis, Variable Rate Application, Reducing of negative environmental impact, Crop/technology cost optimization. Economic of precision agriculture and determining equipment and software, review of Cost/Benefit of Precision Agriculture, System vs. Parcels. Making a selection.

### Practical:
Calculation of the benefits of Data and Mapping, Determining Latitude/Longitude, UTM or State Plane Position Navigation with Waypoints, Configuring a GPS System. Defining area of field for prescriptive treatment. Making the Grid, The Grid Sampling Process, generationof yield maps, Thematic or Spatial Resolution, Yield Map Example, Surface Analysis in Arc- View.

### Course Outcome:
Knowledge about the principles guiding the concept of precision agriculture and Farm Machinery and equipment systems that make muse of this principle.

### Teaching Schedule

| Sr.No | Topic | No of lectures |
|---|---|---|
| 1. | Introduction to precision agriculture, its importance and applications | 1 |

| | | |
|---|---|---|
| 2. | Mapping in farming for decision making and geographical conceptsof PA. | 2 |
| 3. | Understanding and identifying variability | 1 |
| 4. | Introduction to Geographical Position System (GPS). Function andusage of GPS | 2 |
| 5. | Basics of GPS (Space Segment, Receiver Segment, Control Segment), Error and correction | 2 |
| 6. | Introduction to Geographic Information system (GIS), function of GIS, use of GIS for decisions. | 2 |
| 7. | Remote sensing including aerial and satellite imagery | 2 |
| 8. | IDI devices usage in Precision Agriculture Yield monitor, variable rate applicator for fertilizers, seed, chemicals etc. Above ground (non-contact) sensors | 2 |
| 9. | Data analysis, concepts of data analysis | 2 |
| 10. | Surface analysis. Analysis application interpretive products (map, charts, application map etc) | 2 |
| 11. | Precision Variable Equipment | 2 |
| 12. | Electronics and Control Systems for variable rate applications | 2 |
| 13. | Tractor-Implement interface technology, Environmental Implicationsof Precision Agriculture | 2 |
| 14. | Recordkeeping, Spatial Analysis | 2 |
| 15. | Rate Application, reducing of negative environmental impact, Crop/technology cost optimization | 2 |
| 16. | Economic of precision agriculture and determining equipment | 2 |
| 17. | Review of Cost/Benefit of Precision Agriculture, Making a selection | 2 |
| | **Total** | **32** |

**List of Practicals:**

| **Sr.No** | **Topic** | **No of Practicals** |
|---|---|---|
| 1 | Calculation of the benefits of data and mapping | 1 |

| | | |
|---|---|---|
| 2 | Determining Latitude/Longitude, UTM or State Plane Position Navigation with Waypoints | 1 |
| 3 | Configuring a GPS System | 1 |
| 4 | Defining area of field for prescriptive treatment | 1 |
| 5 | Making the grid and grid sampling process | 2 |
| 6. | Collection of tractor-implement interface data | 1 |
| 7 | Generation of yield maps | 2 |
| 8 | Example of spatial and temporal variability and resolution | 1 |
| 9 | Surface Analysis using software like Arc-View | 2 |
| 10 | Economic of precision agriculture and determining equipment | 2 |
| 11 | Cost/Benefit of Precision Agriculture for making a optimized selection | 2 |
| | **Total** | 16 |

**Reference Books:**


1. Shannon D K, Clay D E and Kitchen N R (editors) 2018. *Precision Agriculture* Basics American Society of Agronomy, Crop Science Society and Soil Science Society of America, 5585Gulford Rd, Madison, WI 53711
2. Clay S A, Clay D E, and Bruggeman S A 2017. *Practical Mathematics for Precision Farming* American Society of Agronomy, Crop Science Society and Soil Science Society of America, 5585Gulford Rd, Madison, WI 53711
3. Henten E J V, Goense D and Lokhorst C 2009. *Precision Agriculture*. Wageningen Academic Publishers
4. Singh A K and Chopra U K 2007. *Geoinformatics Applications in Agriculture*. New India Publishing Agency, PritamPura, New Delhi
5. Ram T, Lohan S K, Singh R and Singh P 2014. *Precision Farming*: A New Approach. Astral International Pvt. Ltd., New Delhi., ISBN: ISBN 978-81-7035-827-5 (Hardbound) ISBN 978-93-5130-258-2 (International Edition)

**FMPE 518 : Machinery for Horticulture and Protected Agriculture 2 + 0**

### Objectives:

To learn about the different machinery used in cultivation of vegetable crops, orchard cropsand also in protected agriculture.

### Unit-I

Vegetable cultivation, nursery machinery, tray seeders, grafting machines, vegetable trans- planters. Machinery for planting crops on raised beds, mulch laying and planting machines. Harvesting of vegetable crops: Harvesting platforms and pickers.

### Unit-II

Machinery for orchard crops: Pit diggers, inter-cultivators and basin forming equipment for orchards. Machinery for transplanting of trees. Harvesters for fruit crops: Shaker harvesters, types and principle of operation. Elevated platforms for orchard management and harvesting. Pruning machines.

### Unit-III

Machinery for orchards, vineyard machinery spraying machines, inter-cultivation machines. High clearance machines and special purpose machinery for crops on trellis. Machinery for special crops: Tea leaf harvesters, pruners and secateurs.

### Unit-IV

Machinery for lawn and garden: Grass cutters, special machinery for turf maintenance. Turf aerators and lime applicators.

### Unit-V

Protected agriculture: Principles, mechanical systems of greenhouse, ventilation systems, shading system, water fogging system, irrigation system, sensors, electrical and electronic system. Intelligent Control system for greenhouses. Machinery for processing of growth media, tray filling machines-tray sowing machines, transplanting machines. Robotic grafting machines. Weeding and thinning equipment. Crop protection and harvest under protected agriculture.

### Course Outcome:

Knowledge about different principles of mechanizing cultivation of horticultural crops and in protected agriculture.

### Teaching Schedule

| Sr. No. | Topic | No. of Lecture |
|---|---|---|
| 1. | History of vegetable cultivation in India and scope of mechanizationin Horticulture | 1 |
| 2. | Methods of Nursery propagation techniques and machinery for nursery and tray seeders | 1 |
| 3. | Machinery for field preparation for vegetables (Disc harrows, Disc plough, offset rotavator, sub soiler, bed makers) | 2 |

| | | |
|---|---|---|
| 4. | Principles of mulch laying and planting machines. Types of vegetabletransplanters and their construction and working | 1 |
| 5. | Working and construction of subsurface drip laying machine. Typesof planters for vegetable crops and its working | 1 |
| 6. | Principles of Pneumatic vegetable seeders and its working. Machinery for harvesting of vegetable crops like root crop harvester, its construction and working | 2 |
| 7. | Types of vegetable extraction machine, its working and construction | 1 |
| 8. | Types of pickers, their construction and working | 1 |
| 9. | Construction and working of different types of post hole diggers | 1 |
| 10. | Types of tractors and their uses in orchards | 1 |
| 11. | Types of inter cultivators and its construction and working. | 1 |
| 12. | Types of brush cutters and its working | 1 |
| 13. | Types of basin forming equipment for orchards. Machinery for transplanting of trees and their construction and working | 1 |
| 14. | Types of elevated platforms for orchard management. Types of TreePruners and principles and its working and construction | 1 |
| 15. | Types of fruit pluckers and its working and construction | 1 |
| 16. | Principles and working and construction of shaker harvesters | 1 |
| 17. | Types of vineyard machinery and its working and construction | 1 |
| 18. | Types of spraying machines and its working and construction. High clearance machines and special purpose machinery for crops on trellis. | 1 |
| 19 | Types of orchard sprayers, its working and construction | 1 |
| 20. | Types of Tea leaf harvesters, pruners and secateurs and its workingand Construction | 1 |
| 21. | Special purpose machinery for crops on trellis | 1 |
| 22. | Types of lawn and garden mowers and its working. | 1 |
| 23. | Studies on special machinery for turf maintenance working and construction of Turf aerators and lime applicators | 1 |
| 24. | Introduction to protected agriculture. Principles of protected agriculture | 1 |

| | | |
|---|---|---|
| 25. | Greenhouses - Mechanical systems, ventilation systems, shading system, water fogging system and irrigation system. | 2 |
| 26. | Sensors, electrical and electronic system. Intelligent Control systemfor greenhouses | 1 |
| 27. | Machinery for processing of growth media, tray filling machines- traysowing machines, transplanting machines | 1 |
| 28. | Robotic grafting machines. Weeding and thinning equipment | 1 |
| 29. | Crop protection and harvest under protected agriculture | 1 |
| | **Total** | **32** |

**Suggested Reading:**


1. Good Agricultural Practices for Greenhouse Vegetable Production in the South East European countries FAO Rome 2017
2. Bell B and Cousins S 1997. *Machinery for Horticulture*. Old Pond Publishing Ltd ISBN-10: 0852363699,ISBN-13: 978-0852363690
3. Ponce P, Molina A, Cepeda P, Lugo E and Mac Cleery B 2014. *Greenhouse Design andControl*. CRC Press, ISBN 9781138026292 - CAT K23481, 1st Edition.

**FMPE-519 : Fundamentals of Agricultural drone 2+1**

**Objectives:**

To make familiar about the components of drone its working, stability and repair and maintenance of drones for agricultural purpose

**Unit I**

Introduction to Drone: Definition of drones, Anatomy of Drone, Importance of Drone Technology, History of Drone, Types of Drone as per structure, Need of Drone Technology in Agriculture.

Components of Drone: Introduction, Antenna, Propellers, Motor, Camera and its accessories, Ground Station, chassis, Propellers, Battery and charger, Types of Battery, battery function in drone, Flight controller and its peripherals, GNSS & RTK Module, Flight Controller, ESC (Electronic speed Controller), Power Module, Radio Transmitter/Receiver.

**Unit II**

Working principles of Drone: Introduction, Working Principle of drone, Definition of Propulsion, Propeller and vertical motion of Drone, Concept of drone flight, Take-off, and landing, Flight Modes and Maneuvering, Dynamics of an aerial system, Principal axes and rotation of aerial systems, on board flight control, Types of Platform and Propulsion system required for drone operation.

**Unit III**

Stability and Control of Drone: Introduction to stability and Control of Drone, Definition of Stability, Definition of Control, Types of Stability required in Drone, Types of Control required in Drone

**Unit IV**

Sensors used in drones: Introduction of Sensor, Definition of Sensor, Working Principle of Sensor, Types of sensors, Accelerometer, Barometer, Gyro Sensor, Magnetometer, Time of Flight Sensors, Thermal Sensors, Chemical Sensors, Distance Sensors, Light - Pulse Distance Sensor, Radio Detection and Ranging and Sonar -Pulse Distance Sensing, Sensors such as Hyper-spectral, Multispectral, Thermal and RGB and other payloads.

**Unit V**

Regulation and Maintenance of Drone: Introduction, Basic Air. Regulations, DGCA regulation, foreign regulatory, FCC compliance, sUAS registration and Federal Aircraft Regulations (FARs). Maintenance of Drones includes flight control box, ground station, Maintenance of ground equipment, batteries and Payloads, Scheduled servicing, Repair of equipment, Fault finding and, Rectification.

**Practicals:**

Study of the drone sensors such as Accelerometer, Barometer, Gyroscope, Compass and Magnetometer. Study of the drone sensors such as GPS, Distance sensor, Hyper-spectral, Multispectral, Thermal and RGB. Study of the Electronic Speed controller, power system of drone. How to choose BLDC, propellers, Chassis, batteries. Radio transmitter and receiver, Drone flight and Flight Modes.

**Teaching Schedule**

| Sr.No. | Topic | No. of lectures |
|---|---|---|
| 1 | Introduction to Drone: Definition of drones, Anatomy of Drone, Importance of Drone Technology, History of Drone, Types of Drone as per structure, Need of Drone Technology in Agriculture. | 3 |
| 2 | Components of Drone: Introduction, Antenna, Propellers, Motor, Camera and its accessories, | 2 |
| 3 | Ground Station, chassis, Propellers, Battery and charger, Types of Battery, battery function in drone, | 2 |
| 4 | Flight controller and its peripherals, GNSS & RTK Module, Flight Controller, ESC (Electronic speed Controller), Power Module, Radio Transmitter/Receiver. | 3 |
| 5 | Working principles of Drone: Introduction, Working Principle of drone, Definition of Propulsion, Propeller and vertical motion of Drone, Concept of drone flight, Take- off, and landing, Flight Modes and Maneuvering, | 3 |
| 6 | Dynamics of an aerial system, Principal axes and rotation of aerial systems, on board flight control, Types of Platform and Propulsion system required for drone operation. | 3 |
| 7 | Stability and Control of Drone: Introduction to stability and Control of Drone, Definition of Stability, Definition of Control, Types of Stability required in Drone, Types of Control required in Drone | 4 |
| 8 | Sensors used in drones: Introduction of Sensor, Definition of Sensor, Working Principle of Sensor, | 2 |
| 9 | Types of sensors, Accelerometer, Barometer, Gyro Sensor, Magnetometer, Time of Flight Sensors, Thermal Sensors, Chemical Sensors, Distance Sensors, Light – Pulse ,Distance Sensor, Radio Detection and Ranging and Sonar -Pulse Distance Sensing, | 4 |
| 10 | Sensors such as Hyper-spectral, Multispectral, Thermal and RGB and other payloads. | 2 |
| 11 | Regulation and Maintenance of Drone: Introduction, Basic Air. Regulations, DGCA regulation, foreign regulatory, FCC compliance, SUAS registration and Federal , Aircraft Regulations (FARs). | 2 |

| | | |
|---|---|---|
| 12 | Maintenance of Drones includes flight control box, ground station, Maintenance of ground equipment, batteries and Payloads, Scheduled servicing, Repair of equipment, Fault finding and, Rectification. | 2 |
| | **Total** | **32** |

**List of Practicals**

| Sr. No. | Topic | No. of practical |
|---|---|---|
| 1 | Study of the drone sensors such as Accelerometer, Barometer, Gyroscope, Compass /Magnetometer. | 3 |
| 2 | Study of the drone sensors such as GPS, Distance sensor. | 2 |
| 3 | Study of the sensors such as Hyper-spectral, Multispectral, Thermal and RGB. | 3 |
| 4 | Study of the Electronic Speed controller. | 1 |
| 5 | Study of the power system of drone. | 1 |
| 6 | Study of the how to choose BLDC, propellers, Chassis, batteries. | 4 |
| 7 | Study of the radio transmitter and receiver. | 1 |
| 8 | Study of Drone flight and Flight Modes. | 1 |
| | **Total** | **16** |

**Suggested Reading:**

1. Krishna K.R. Unmanned Aerial Vehicle System in Crop Production: A compendium, CRC Press Apple Academic Press; 1st edition (11 July 2019): e-book
2. Krishna K.R. Agricultural Drones: A peaceful Pursuit, CRC Press, Apple Academic Press; 1st edition (11 July 2019): e-book

**FMPE 520 : Pesticide Application Equipment 1 +1**

**Objectives:**

To make familiar with the different pesticides application equipments, based on hydraulic energy, gaseous energy, centrifugal energy, kinetic energy, and power etc; their components, working principles and their details for crop protection.

**Unit I**

Role of chemical control and formulations. Target, droplet size, its distribution and determination methods, selection of droplet size, atomizing devices-nozzles, types of sprayers, dusters and granular applicators, manually and power operated sprayers.

**Unit II**

Hydraulic energy, centrifugal energy, hybrid and air blast sprayers, pumps. Agitators, filters, pressure control devices and systems, manually and power operated dusters and granular applicators, fogging machines, aerial application of pesticides, application of pesticides in poly houses, application of pesticides with drone for field crops, calibration of sprayers.

**Unit III**

Design of spraying and dusting equipments, maintenance and selection of spraying equipments

**Unit IV**

Application methods and economics of pest control, safety precautions in pesticide application.

**Practical:**

Study of different types of sprayers, dusters, granular applications, fogging machines, nozzles, calibration of sprayers, selection of pesticides application equipment for field and orchard crops, weedicide application, performance, droplet size, maintenance of different sprayers

**Teaching Schedule**

| Sr. No. | Topic | No. of lecture |
|---|---|---|
| 1. | Role of chemical control and formulations | 1 |
| 2. | Target for spraying | |
| 3. | Importance of droplet size in pest management | |
| 4. | Distribution of droplets on target | 1 |

| | | |
|---|---|---|
| 5. | Determination of droplet size methods, selection of droplet size | |
| 6. | Atomizing devices-nozzles, types etc | 1 |
| 7. | Types of sprayers, stirrup, hand operated knapsack, battery operated knapsack, compression, rocking sprayer etc | 2 |
| 8. | Hydraulic energy, centrifugal energy, hybrid and air blast sprayers etc | 1 |
| 9. | Components of sprayers, pumps, agitators, filters, pressure control devices and systems | 1 |
| 10. | Manually and power operated dusters, Granular applicators, fogging machines etc | 1 |
| 11. | Aerial application of pesticides | 1 |
| 12. | Application of pesticides in poly houses | 1 |
| 13. | Application of pesticides with drone for field crops | 1 |
| 14. | Calibration of sprayers | 3 |
| 15. | Design of spraying and dusting equipments and numerical | |
| 16. | Maintenance and selection of spraying equipments | 1 |
| 17. | Spray Application methods and economics of pest control | 1 |
| 18. | Safety precautions in pesticide application | |
| | **Total** | **16** |

**List of Practicals**

| **Sr. No.** | **Topic** | **No. of practicals** |
|---|---|---|
| 1 | Study of manually Knapsack sprayer | 1 |
| 2 | Study of battery operated knapsack sprayer | 1 |
| 3 | Study of hand compression sprayer | 1 |
| 4 | Study of rocking sprayer | 1 |
| 5 | Study of rocking sprayer | 1 |

| | | |
|---|---|---|
| 6 | Study of centrifugal energy sprayers | 1 |
| 7 | Study of air assisted sprayers | 1 |
| 8 | Study of power sprayers | 1 |
| 9 | Study of mist blower | 1 |
| 10 | Study of different types of dusters | 1 |
| 11 | Study of tractor operated boom sprayer | 1 |
| 12 | Study of fogging machine | 1 |
| 13 | To study the comparative performance of nozzles | 1 |
| 14 | Study the pressure, discharge relationship of different nozzles | 1 |
| 15 | Calibration of sprayer | 1 |
| 16 | Study maintenance of different sprayers | 1 |
| | **Total** | **16** |

**Suggested Reading:**

1. G.A. Mathew. 1985. *Pesticide Application methods*, English language book society, Longman, Harlow, England
2. O.P. Bindra, H. Singh. 1980 *Pesticide application equipments*, Oxford & IBH publishing Co., New Delhi
3. R.A. Kepner, R. Bainer, E.L Barger. 2000. *Principles of Farm Machinery*. CBS Publishers and distributors, New Delhi
4. H. Bernacki, J. Haman Cz. Kanafojske. 1972. *Agricultural machines, theory and construction, Vol-I*, USDA Publications, Warsaw, Poland.

5. N.I. Klein, I.F. Popov and V.A. Sakun. *Agricultural Machines*, Amerind Publishing co. pvt. Ltd.
6. Ram Avtar, *Unmanned Aerial Vehicle: Applications in Agriculture and Environment*, Springer, e- book .(Link: https://bit.ly/34xchDg )

## ME 501 : Mechatronics and Robotics in Agriculture 2+0

**Objectives:**
To introduce the fundamentals of mechatronics and the concepts behind designing mechatronic systems and their subsystems and its application in automation in agriculture.

**Unit-I**
Introduction to mechatronics: Basic definitions, key elements of mechatronics, historical perspective, the development of the automobile as a mechatronic system. Mechatronic design approach, functions of mechatronic systems, ways of integration, information processing systems, concurrent design procedure for mechatronic systems.

**Unit-II**
System interfacing, instrumentation, and control systems. Input/output signals of a mechatronic system, signal conditioning, microprocessor control, microprocessor numerical control, microprocessor input/output control.

**Unit-III**
Microprocessor based controllers and microelectronics: Introduction to microelectronics, digital logic, overview of control computers, microprocessors and microcontrollers, programmable logic controllers, digital communications.

**Unit-IV**
Technologies of robot: Sub systems, transmission system (Mechanics), power generation and storage system, sensors, electronics, algorithms and software. Servo motor drives types and applications. Stepper motor and its concept. Industrial robots: Classification and sub systems. Defining work space area.

**Unit-V**
Application of robots in agriculture: Harvesting and picking, weed control, autonomous mowing, pruning, seeding, spraying and thinning, phenotyping, sorting and packing. Utility platforms. Use of different agrobots in agriculture.

**Course Outcome:**
Ability to understand agricultural machinery that is built on concepts of mechatronics and ability to use robotic machinery in agriculture.

**Teaching Schedule**

| Sr. No. | Topic | No. of Lectures |
|---|---|---|
| 1 | Introduction mechatronics,: Basic definitions, key elements of Mechatronics | 2 |

| | | |
|---|---|---|
| 2 | Historical perspective, the development of the automobile as a mechatronicsystem | 1 |
| 3 | Mechatronic design approach, functions of mechatronic systems, ways of integration, information processing systems, concurrent design procedure for mechatronic systems. | 3 |
| 4 | System interfacing, Instrumentation, and control systems | 2 |
| 5 | Input/output signals of a mechatronic system, signal conditioning | 2 |
| 6 | Microprocessor control, microprocessor numerical control, microprocessor input/output control | 2 |
| 7 | Microprocessor based controllers and microelectronics | 2 |
| 8 | Introduction to microelectronics, digital logic, overview of control computers | 2 |
| 9 | Microprocessors and microcontrollers, programmable logic controllers, digital communications. | 3 |
| 10 | Technologies of robot: Sub systems, transmission system (Mechanics), power generation and storage system | 2 |
| 11 | sensors, electronics, algorithms and software. Servo motor drives types andapplications | 2 |
| 12 | Stepper motor and its concept. Industrial robots: Classification and sub systems. Defining work space area. | 2 |
| 13 | Application of robots in agriculture: Harvesting and picking, weed control | 2 |
| 14 | autonomous mowing, pruning, seeding, spraying and thinning | 2 |
| 15 | phenotyping, sorting and packing. Utility platforms. Use of different agrobots in agriculture. | 3 |
| | **Total** | **32** |

**Suggested Reading:**


1. Shakhatreh and Fareed 2011.*The Basics of Robotics*. Lahti University of Applied Sciences Machine and production technology.
2. Robert H B 2002. *Mechatronic Hand Book*. CRC Press.
3. Alciatore, D G and Histand M.B. 2002.*Introduction to Mechatronics and MeasurementSystem*. Mcgraw Hill Pvt Limited, New Delhi.

**ME 504 : Vibrations 3+0**

**Objectives**

To enable the students to design vibration control sytem,and balancing of rotating and reciprocating masses.

## Unit –I

Vibration motion and its terminology. Undamped free vibrations, equations of motion- natural frequency. Energy method, Rayleigh method; effective mass principle of Virtual work. Equivalent spring stiffness in parallel and in series. Harmonic analysis and Fourier Series

## Unit –II

Damping - viscous, solid, coulomb equivalent dampers. Viscosity damped free vibrations, Logarithmic decrement. Forced vibrations with harmonic excitation and rotating unbalance. Energy dissipated by damping

## Unit –III

Forced vibration with damping, Vibration isolation and force and motion transmissibility. Two degree of freedom systems. Principal modes of vibration, co-ordinate coupling. Vibration absorbers

## Unit-IV

Free vibration equation of motion for multi-degree of freedom systems. Influence coefficients and Maxwell's reciprocal theorem, stiffness coefficients. Numerical methods for finding natural frequencies for multi-degree of freedom systems.

## Unit-V

Vibration of lumped parameter systems and continuous systems. Lagrange equations. Vibration measuring instruments, Vibrometers, velocity pickups, Accelerometer and frequency measuring instruments. Applications of vibrations. Vibration control, balancing of rotating and reciprocating machines, design of vibration isolators.

## Course Outcome

The student will be able to understand the concept of vibrations, analyze the mathematical modeling of the multidegree freedom systems and able to design vibration isolators.

## Teaching Schedule

| Sr No | Topic | No. of Lectures |
|---|---|---|
| 1 | Vibration motion and its terminology. | 2 |
| 2 | Undamped free vibrations, equations of motion-natural frequency. | 2 |
| 3 | Energy method, Rayleigh method; effective massprinciple of Virtual work. | 2 |
| 4 | Equivalent spring stiffness in parallel and in series. | 1 |
| 5 | Harmonic analysis and Fourier Series. | 2 |
| 6 | Damping - viscous, solid, coulomb equivalentdampers. | 3 |
| 7 | Viscosity damped free vibrations, Logarithmicdecrement | 3 |
| 8 | Forced vibrations with harmonic excitation androtating unbalance | 2 |

| | | |
|---|---|---|
| 9 | Energy dissipated by damping. Forced vibration withdamping, | 3 |
| 10 | Vibration isolation and force and motiontransmissibility. | 2 |
| 11 | Two degree of freedom systems. Principal modes of vibration co-ordinate coupling | 3 |
| 12 | Vibration absorbers, | 2 |
| 13 | Free vibration equation of motion for multi-degree offreedom systems. | 2 |
| 14 | Influence coefficients and Maxwell's reciprocaltheorem, stiffness coefficients. | 3 |
| 15 | Numerical methods for finding natural frequencies formulti-degree of freedom systems. | 3 |
| 16 | Vibration of lumped parameter systems andcontinuous systems. | 3 |
| 17 | Lagrange equations. Vibration measuring instruments,Vibrometers, velocity pickups | 3 |
| 18 | Accelerometer and frequency measuring instruments. | 2 |
| 19 | Applications of vibrations. Vibration control,balancing of rotating and reciprocating machines | 3 |
| 20 | Design of vibration isolators. | 2 |
| | **Total** | **48** |

**Suggested Reading**

1. V.P. Singh.2014. Mechanical Vibrations. Dhanpat Rai and Company, New Delhi
2. Rao S S. 2010.Mechanical Vibrations. Pearson Education, Delhi
3. Srinivas P.1983. Mechanical Vibration Analysis. Tata McGraw Hill Company Limited, New Delhi
4. Daniel J Inman.2013. Engineering Vibration. Prentice Hall, New Jersey

**ME 507 Fatigue Design 2+1**

### Objectives:

The course provides an understanding on fatigue design considerations of mechanical components. The causes of fatigue in brittle and ductile materials are taught with focus on crack initiation, propagation and fracture.

### Unit-I

Theories of failure, maximum normal stress, maximum shear stress and distortion energy theory, failure of ductile materials, failure of brittle materials.

### Unit-II

Stress concentration and its evaluation, stress concentration of ductile and brittle materials under static loading and under dynamic loading, determining geometric stress concentration factors, designing to avoid stress concentration.

### Unit-III

Fatigue of machine components, mechanism of fatigue failure, fatigue failure models and their considerations in design of machine elements, fatigue loads. Fatigue testing and presentation of fatigue data. Influence of stress conditions on fatigue strength/endurance limitof metals. Low and high cycle fatigue

### Unit-IV

Cumulative fatigue damage. Designing for finite and infinite life. Improving fatigue resistance of machine elements. Stress corrosion. Corrosion fatigue.

Practical: Fatigue tests on testing machine(s) for specimens of different materials having different discontinuities/stress raisers and various surface conditions. Determination of correlation between fatigue limit and ultimate strength of material. Problems in fatigue designof common machine component.

### Course Outcome:

The students is able to understand technical aspects and principles of fatigue design. The student can design the engineering product having good durability and long fatigue life

### Teaching Schedule

| Sr. No. | Topic | No. of Lectures |
|---|---|---|
| 1 | Introduction to cyclic loading and Fatigue Design | 1 |
| 2 | Types of Loads and Stresses, Different theories of Failure like maximum normal stress, maximum shear stress and distortion energy theory etc. | 3 |
| 3 | Determining stress concentration based on geometric stress concentration factors, Design considerations to avoid stress concentration of ductile and brittle materials. | 3 |
| 4 | Mechanical failure. Macroscopic failure modes, Behavior of brittle and ductile materials in fatigue and stress concentration. Fracture in brittle and ductile materials, characteristics of fracture surfaces, inter-granular and intra- granular failure. | 4 |
| 5 | Cleavage and micro-ductility, growth of fatigue cracks, The ductile/brittle fracture transition, temperature for notched and un notched components. Fracture at elevated temperature. | 3 |

| | | |
|---|---|---|
| 6 | Fatigue of machine components, mechanism of fatigue failure. Low and high cycle with examples mean stress R ratio, strain and load control. S-N curves. | 4 |
| 7 | Goodman's rule and Miners rule. Micro-mechanisms of fatigue damage, fatigue limits and initiation and propagation control, leading to a consideration of factors enhancing fatigue resistance. | 3 |
| 8 | Fatigue loads and mathematical models. Fatigue testing and presentation of fatigue data, Influence of stress conditions on fatigue strength/endurancelimit of metals. | 3 |
| 9 | Total life and damage tolerant approaches to life prediction. Fatigue failure models and their considerations in design of machine elements. Cumulativefatigue damage and Designing for finite and infinite life | 2 |
| 10 | Methods to improve fatigue resistance of machine elements. Improvement of fatigue strength by chemical/metallurgical processes such as nitriding, flame hardening, case carburizing. Fatigue strength enhancement by mechanical work, cold rolling, peening, shot peening. | 3 |
| 11 | Environmental Assisted Cracking: Stress corrosion cracking, Hydrogen embrittlement, Corrosion fatigue. Creep: Creep curves, Mechanisms of creep, Stress rapture test, Life prediction, High temperature alloys. | 3 |
| | **Total** | **32** |

**List of Practicals**

| **Sr. No.** | **Topic** | **No. of Practicals** |
|---|---|---|
| 1 | Load measurement using Load indicator, Load Cells | 1 |
| 2 | Strain measurement using Strain Gauge | 1 |
| 3 | Stress measurement using strain rosette | 1 |
| 4 | Determination of Fatigue strength measurement of S45C or alike material under same loading condition for different stress concentrations factors (like holes, notches, sharp corners for at least 5 different samples). Comparison to be listed. | 5 |
| 5 | Study to improvement Fatigue Design based on at least 5 different processes like flame hardening, case carburizing, nitriding, shot peening, peening etc or alike processes. | 5 |
| 6 | Determination of correlation between fatigue limit and ultimate strength ofcommercially available S45C material for three different samples | 3 |
| | **Total** | **16** |

**Suggested Reading:**


1. Lessells, J.M. 1955. *Strength and resistance of metals*. John Wiley & sons, Michigan.
2. T.L. Anderson. 2005. *Fracture Mechanics Fundamentals and Applications*. CRC press, BocaRaton.
3. Bhandari V.B.2019. *Design of Machine Elements*. Mcgraw Hill Education Pvt Ltd, NewDelhi
4. Peterson, R.E. 1953 *Stress Concentration Design Factors*. John Wiley & Sons, New York.
5. Meguid, S.A.1989 *Engineering Fracture Mechanics*. John Wiley & Sons, New York
6. Kare Hellan.1985. *Introduction to Fracture Mechanics*. Mc Graw Hill Book Co, New York.

## ME 515 Computer Aided Design 2+1

### Objective

The **course** provides an understanding on computer aided design. It provides in depth knowledge about 2-d drawing, 3-D Modeling and finite element analysis for optimumproduct design.

### Unit-I

Introduction to computer aided design, scope of computer aided machine design, design process and design environments. Geometric modeling and interactive graphic, engineering analysis, design review and automated drafting, modeling, viewing,

### Unit-II

solid modeling, boundary representation, constructive solid geometry, feature based modeling. Computer aided analysis and synthesis of common mechanical components, a bar,a beam and a shaft, comparison with analytical results.

### Unit-III

Application of numerical methods and optimization techniques to machine design problems, Computer aided selection of standard mechanical components. Introduction to FEM. FEA using two dimensional and three dimensional elements; plain strain and plain stress problems, finite element mesh, automatic meshing techniques, limitations of FEM.

**Practical:**

Computer aided design problems for machine components, use of standard software, CAD models for other applications. Development of FEM models for analysis of a bar, beam and a shaft. Practice in using an FEM software on other real life problems like spanners, connecting rods.

### Course Outcome:

The students can design a product having better accuracy, less errors, increased productivity and shorter lead times with the help of CAD.

### Teaching Schedule

| Sr. No. | Topic | No. of Lectures |
|---|---|---|
| 1 | Introduction to Engineering Design, design steps and computer aided design. | 2 |
| 2 | Software and workstation selection for CAD. Design process with and withoutCAD | 3 |
| 3 | Input and output devices, Display devices; GKS, IGES and STEP; Modelingand viewing, Application areas of CAD. | 3 |
| 4 | Wireframe model, solid modeling, Boundary Representation (B-rep), Constructive Solid Geometry (CSG). | 3 |
| 5 | Mass , volumetric properties calculations; surface modeling, concepts of hidden-line removal and shading: Mechanical Assembly Kinematics analysis and simulation | 3 |

| | | |
|---|---|---|
| 6 | Parametric Modeling Technique .Non-parametric and parametric representation of curves. | 2 |
| 7 | Parametric representation of Hermite Cubic, Beizer and B-spline curves; Surface and its analysis. Representation of Analytical and synthetic surfaces. | 2 |
| 8 | Numerical methods and optimization techniques to engineering design problems | 3 |
| 9 | Overview of FEM, Advantages and applications, recent advance in FEM, FEA software Basic principles and general procedure of FEM | 3 |
| 10 | Analyzing simple machine elements and comparing with analytical results ofsimple machine elements like bar, beam and a shaft. | 4 |
| 11 | Simple Project. Mathematical modelling and design calculations of machines. | 4 |
| | **Total** | **32** |

**List of Practicals**

| **Sr. No.** | **Topic** | **No. of Practicals** |
|---|---|---|
| 1 | Introduction to 2-D drawing. Use of any relevant software | 2 |
| 2 | Study of drawings in First angle and third angle projections | 1 |
| 3 | 2-D assembly drawing and generation of BOM | 1 |
| 4 | 3-D Modeling. GKS, IGES and STEP; Modeling and viewing. Use of relevant software | 3 |
| 5 | Assembly Design | 2 |
| 6 | Introduction to FEA software. Mesh generation (Nodes and elements).Use ofany other relevant software for FEA | 3 |
| 7 | Practice on Boundary conditions like loads and constraints. | 2 |
| 8 | Study of static and dynamic loading conditions. Study of Machine elementslike bars, beams and shafts or other machine elements. | 2 |
| | Total | 16 |

**Suggested Reading**

1. Mikell P. Groover, Emory W. Zimmers.2000 *CAD/CAM Computer Aided Design andManufacturing*, PHI,
2. Zeid Ibraham.1991. *CAD/CAM - Theory and Practice*, Tata McGraw Hill, New Delhi
3. Chandandeep Grewal & Kuldeep Sareen.2007. *CAD/CAM Theory and Concepts.* S.Chand, New Delhi
4. P. N Rao.2010. *CAD/CAM*. Tata McGraw Hill, New Delhi

## CE 501 Dimensional Analysis and Similitude 2+0

### Objectives:

To acquaint the students with importance of analysis of dimensions and similitude principlesin structuring mathematical/simulation models of various processes under different constraint variables.

### Unit-I

Introduction, Dimensions, Dimensional homogeneity, Non-dimensional parameter, Methods of dimensional analysis: Rayleigh's method, Buckingham-Pi theorem, Choice of variables, Model analysis, Examples on various applications, Dimensional analysis and IntermediateAsymptotic.

### Unit-II

Model studies, Model classification, Dimensionless numbers: Reynolds model, Froude's model, Euler's Model, Webber's model, Mach model, Scale effects, Distorted models, Model laws.

### Unit-III

Similitude: Types of similarities (geometric-kinematic and dynamic similarity), force ratios, similarity laws. Model analysis: Physical models. Similarity methods for nonlinear problem types of models, Scale effect. Numerical problems on Reynolds's and Froude's Model.

### Unit-IV

Use and scope of mathematical modeling, Principles of model formulation, Role and importance of steady-state and dynamic simulation, Classification of models, Model building, Modeling difficulties, Degree-of-freedom analysis, Selection of design variables.

### Course Outcome:

The students will be able to analyze complex problems using dimensional analysis and to develop rules for experiments with scale models and provide basis for analyses and calculations, including simplifications and assumptions made, when formulating mathematical models.

### Teaching Schedule

| S. No. | Topic | No. of Lectures |
|---|---|---|
| 1 | Introduction, Dimensions, Dimensional homogeneity, Non-dimensional Parameter | 2 |
| 2 | Methods of dimensional analysis: Rayleigh's method, Buckingham-Pitheorem, Choice of variables | 3 |
| 3 | Model analysis, Examples on various applications, Dimensional analysis and Intermediate Asymptotic | 2 |
| 4 | Model studies, Model classification, Dimensionless numbers: Reynolds Model | 3 |
| 5 | Froude's model, Euler's Model, Webber's model, Mach model, Scaleeffects | 3 |
| 6 | Distorted models, Model laws. | 2 |
| 7 | Similitude: Types of similarities (geometric-kinematic and dynamicsimilarity), force ratios, similarity laws | 3 |

| | | |
|---|---|---|
| 8 | Model analysis: Physical models. Similarity methods for nonlinear problem types of models, Scale effect | 3 |
| 9 | Numerical problems on Reynolds's and Froude's Model | 3 |
| 10 | Use and scope of mathematical modeling, Principles of model formulation | 2 |
| 11 | Role and importance of steady-state and dynamic simulation | 2 |
| 12 | Classification of models, Model building, Modeling difficulties | 2 |
| 13 | Degree-of-freedom analysis, Selection of design variables | 2 |
| | **Total** | **32** |

**Suggested Reading:**


1. Barenblatt G I 1987. *Dimensional Analysis*. Gordon and Breach Science, New York
2. Langhar HL 1951. *Dimensional Analysis and the Theory of Models*. Wiley, New York.
3. Murphy G 1950.*Similitude in Engineering*. The Ronald Press Company, New York.
4. Zohuri Bahman. *Dimensional Analysis and Self-Similarity Methods for Engineers andScientists*. Springer Publications, New York.

**CE 510 Experimental Stress Analysis 2+1**

## Objectives:

To acquaint the students with importance of analysis of stress, analysis of strain, stress-strain relationship under different constraint conditions in 2-D plane as well as 3-D plane.

### Unit-I

Strain and stress – strain relationship. Generalized Hook's Law. Strain Gauges- Mechanical, optical, electrical, acoustical and pneumatic etc and their use.

### Unit-II

Different types of electrical resistance strain gauges. Semi-conductor strain gauges. Rosetteanalysis. Strain gauge circuits. Strain measurements at high temperatures.

### Unit-III

Two dimensional and three dimensional photo-elastic method of strain analysis. Bifringent coatings and scattered light in photo-elasticity. .

### Unit-IV

Brittle coating methods. Moiré's method of strain analysis. Grid method of strain analysis. Photo elastic strain gauges.

## Course Outcome:

The students will be able to analyze stress, strain and their interrelationships when they are subjected to different end conditions in two dimensional and three dimensional planes and provide basis for analyses and calculations, including simplifications and assumptions made, when formulating for stress and strain.

## Teaching Schedule

| S. No. | Topic | No. of Lectures |
|---|---|---|
| 1 | Strain and stress – strain relationship. Generalized Hook's Law | 3 |
| 2 | Strain Gauges- Mechanical, optical, electrical, acoustical and pneumatic etc. | 3 |
| 3 | Use of different strain gauges. Types of electrical strain gauges. | 3 |
| 4 | Semi-conductor gauges. Rosette analysis. | 3 |
| | Strain gauge circuits. | 2 |
| 5 | Strain measurements at high temperatures. | 2 |
| 6 | Two dimensional photo-elastic method of strain analysis. | 3 |
| 7 | Three dimensional photo-elastic method of strain analysis. | 3 |
| 8 | Bifringent coatings and scattered light in photo-elasticity. | 3 |
| 9 | Brittle coating methods | 3 |
| 10 | Moir's method of strain analysis. | 2 |
| 11 | Grid method of strain analysis. Photo elastic strain gauges. | 2 |
| | **Total** | **32** |

## List of Practicals

| Sr. No. | Topic | No. of Practicals |
|---|---|---|
| 1 | Cementing of an electrical resistance strain gage on a structural member | 1 |
| 2 | To find the gage factor for a resistance type strain gage. | 1 |
| 3 | To measure strain at centre of bream when loaded at greater points by making use of two strain gages one at top surface and 2nd at bottom both along longitudinal direction and fixing both in first and second arm ofthe bridge. | 3 |
| 4 | To measure the modulus of elasticity of the beam making use of four strain gages, two on top and two on bottom, one on longitudinal and one in transversal direction on each face of the beam. | 3 |
| 5 | Deter mine the tension produced in a circular shaft by using strain gages cemented perpendicular to each other. | 1 |
| 6 | Determine the bending moment produced in a circular shaft by using arectangular shaft. | 1 |
| 7 | To align the circular polariscope. | 1 |
| 8 | Study the plane polariscope and circular polariscope with different lightfield arrangements. | 1 |
| 9 | Study of Moiré fringe apparatus and its applications in analysis of structures. | 2 |
| 10 | Calibrate the photoelastic material by use of rectangular beam under pure bending. | 2 |
| | **Total** | **16** |

**Suggested Reading:**

1. L S Srinath, M R Raghavan, K Lingaiah, G Gargesha, BPant and k Ramachandra, *Experimental Stress Analysis*, McGraw-Hill.
2. Sadhu Sing, *Experimental Stress Analysis*, Khanna Publishers
3. James W. Dally and William F. Riley *Experimental Stress Analysis* by, McGraw-Hill.

**MATH 501 Finite Element Methods 2+1**

## Unit-I

Introduction. Historical background, Stress equilibrium, boundary condition, stress strain relation, potential energy and equilibrium. Rayleigh-Ritz method. Galerkin method.

## Unit-II

coordinates and shape functions, potential energy approach, element stiffness matrix, Galerkin approach, assembly of global stiffness matrix. The finite element equation, boundary conditions.

## Unit-III

Trusses: Two dimensional problems, modeling by constant strain triangle, two dimensional iso-parametric elements, the four-node quadrilateral.

## Unit-IV

Scalar field problems, steady state heat transfer, torsion, potential flow, seepage and fluidflow index, dynamic analysis, principles.

## Practical:

Use of simple FEM software for FEM software for understanding, principles of FEM. Working out simple problems using LISA or any simple software with understanding of operation. Solving one dimensional problem. Solution to planar and spatial trusses, solving simple two-dimensional problems, Axisymmetric problems, solution of problems with two dimensional iso-parametric elements, solving simple beams and frames, three dimensional problems, solution to heat transfer problems and flow problems.

## Course Outcome:

Ability to formulate problems based on use of FEM and solve them using software tools.

## Teaching Schedule

| S.No. | Topic | No.of lectures |
|---|---|---|
| 1. | Introduction. Historical background, Stress equilibrium, boundary condition | 4 |
| 2. | Stress strain relation, potential energy and equilibrium, Rayleigh-Ritz method, Galerkin method. | 4 |
| 3. | coordinates and shape functions, potential energy approach, elementstiffness matrix | 3 |
| 4. | Galerkin approach, assembly of global stiffness matrix, The finite element equation, boundary condition | 3 |
| 5. | Trusses: Two dimensional problems, | 3 |
| 6. | modeling by constant strain triangle | 3 |
| 7. | two dimensional iso-parametric elements, the four-node quadrilateral. | 3 |
| 8. | Scalar field problems, steady state heat transfer | 3 |
| 9. | Torsion, potential flow, | 3 |

| | | |
|---|---|---|
| 10. | seepage and fluid flow index, dynamic analysis, principles. | 3 |
| | **Total** | **32** |

**List of Practicals**

| **Sr.No.** | **Topic** | **No.of Practicals** |
|---|---|---|
| 1. | Use of simple FEM software for FEM software for understanding, principles of FEM. | 3 |
| 2. | Working out simple problems using LISA or any simple software with understanding of operation | 3 |
| 3. | Solving one dimensional problem, Solution to planar and spatial trusses | 2 |
| 4. | Solving simple two-dimensional problems, Axisymmetric problems | 2 |
| 5. | Solution of problems with two dimensional iso-parametric elements | 2 |
| 6. | Solving simple beams and frames | 2 |
| 7. | Three dimensional problems, solution to heat transfer problems andflow problems. | 2 |
| | **Total** | **16** |

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**Suggested Reading:**

1. Tirupathi R, ChandruPatla and Ashok D. Belegundu. 1999. *Introduction to Finite Element In Engineering.* Prentice Hall of India Pvt. Ltd, New Delhi
2. Singiresu RaoS. 2001. *The Finite Element Method in Engineering*. Butter worth Heinemann, New Delhi.
3. Rajasekaran S 1999. *Finite Element Analysis in Engineering Design*. Wheeler Publishing,Division of A.h.Wheeler and Co. Ltd, Allahabad.
4. Tutorials and Reference Guide, LISA Finite Element Analysis Software Version 8.0.0 2013

**MATH 502 Numerical Methods for Engineers 2+1**

## Objectives:

To expose students to various numerical methods for solving algebraic equations, ordinary and partial differential equations.

### Unit-I

Solution of Algebraic Equations: Solution of non-linear and transcendental equations in one or more than one variable using bisection, false position, iteration, Newton Raphson, Secant methods. Solution of linear simultaneous equations: Matrix inversion, Gauss elimination, Gauss Jordan, LU decomposition methods, ill-conditioned systems.

### Unit-II

Solution of Ordinary Differential Equations: Initial Value Problem, Taylor series method, Picard's method, Euler method, Modified Euler method, RK class and predictor correctorclass methods. Stiff ODE's and Gear's methods. Boundary Value Problem, Shooting methods, finite difference method. Use of Method of weighted residuals and orthogonal collocation and Galerkin technique to solve BVP in ODEs

### Unit-III

Eigen values and Eigen vectors: Maximum and minimum eigenvalue by Power spectral and Inverse Power Method, all eigenvalues by Fadeev-Leverrier method. Introduction to diagonalization and QR Factorization.Approximation Theory.

### Unit-IV

Finite difference formulae: Forward and backward differences, Richardson's extrapolation, interpolation formulae, polynomial forms, linear interpolation, Lagrange interpolation polynomial, Newton interpolation polynomial.

### Unit-V

Solution of Partial Differential Equations: Classification of PDEs(Parabolic, elliptical and hyperbolic equation), Elliptical equations, standard five pointsformula, diagonal five-point formula. Solution of Laplace equation by Liebman's iteration method.Poisson's equation and its applications.Solution of parabolic equations by Bender–Schmidt method, Bender-Schmidt recurrence equation, Crank-Nicholson difference method.

## Practical:

Use of EXCEL Sheet and MATLAB: Application of EXCEL Sheet and MATLAB to solve the Engineering problems

## Course Outcomes:

Ability to solve algebraic equations, ordinary and partial differential equations coming across in Agricultural Engineering problems using various numerical methods, ability to use latest software's towards numerical problems.

## Teaching Schedule

| S.No. | Topic | No. of lectures |
|---|---|---|
| 1. | Solution of Algebraic Equations: Solution of non-linear and transcendental equations in one or more than one variable using bisection method. | 2 |
| 2. | Solution of Algebraic Equations: Solution of non-linear and transcendental equations in one or more than one variable using false position methods. | 1 |

| | | |
|---|---|---|
| 3. | Solution of Algebraic Equations: Solution of non-linear and transcendental equations in one or more than one variable using iteration. | 1 |
| 4. | Solution of Algebraic Equations: Solution of non-linear and transcendental equations in one or more than one variable using Newton Raphson, Secant methods. | 1 |
| 5. | Solution of linear simultaneous equations: Matrix inversion,Gauss elimination, Gauss Jordan method. | 2 |
| 6. | Solution of linear simultaneous equations: LUdecomposition methods, ill-conditioned systems. | 2 |
| 7. | Solution of Ordinary Differential Equations: Initial Value Problem, Taylor series method, Picard's method, Eulermethod, Modified Euler method | 2 |
| 8. | Solution of Ordinary Differential Equations: RK class and predictor corrector class methods. Stiff ODE's and Gear'smethods. | 1 |
| 9. | Eigen values and Eigen vectors: Maximum and minimumeigenvalue by Power spectral and Inverse Power Method. | 2 |
| 10. | Eigen values and Eigen vectors: all eigenvalues by Fadeev-Leverrier method | 2 |
| 11. | Introduction to diagonalization and QR Factorization. Approximation Theory. | 2 |
| 12. | Finite difference formulae: Forward and backward differences, Richardson's extrapolation, interpolationformulae, polynomial forms. | 2 |
| 13. | Finite difference formulae: linear interpolation, Lagrangeinterpolation polynomial, Newton interpolation polynomial. | 2 |
| 14. | Solution of Partial Differential Equations: Classification of PDEs(Parabolic, elliptical and hyperbolic equation) | 2 |
| 15. | Elliptical equations, standard five pointsformula, diagonal five-point formula. | 2 |
| 16. | Solution of Laplace equation by Liebman's iterationmethod. Poisson's equation and its applications. | 2 |
| 17. | Solution of parabolic equations by Bender–Schmidt method | 2 |
| 18. | Solution of parabolic equations by Bender-Schmidtrecurrence equation, Crank-Nicholson difference method. | 2 |
| | **Total** | **32** |

**List of Practicals**

| S.No. | Topic | No. of Practicals |
|---|---|---|
| 1. | Solution of Algebraic Equations: Solution of non-linear and transcendental equations in one or more than one variable using bisection method. | 1 |

| | | |
|---|---|---|
| 2. | Solution of Algebraic Equations: Solution of non-linear and transcendental equations in one or more than one variable using false position methods. | 1 |
| 3. | Solution of Algebraic Equations: Solution of non-linear and transcendental equations in one or more than one variable using iteration. | 1 |
| 4. | Solution of Algebraic Equations: Solution of non-linear and transcendental equations in one or more than one variable using Newton Raphson, Secant methods. | 1 |
| 5. | Solution of linear simultaneous equations: Matrix inversion,Gauss elimination, Gauss Jordan method. | 1 |
| 6. | Solution of linear simultaneous equations: LU decompositionmethods, ill-conditioned systems. | 1 |
| 7. | Solution of Ordinary Differential Equations: Initial Value Problem, Taylor series method, Picard's method, Euler method, Modified Euler method | 1 |
| 8. | Solution of Ordinary Differential Equations: RK class and predictor corrector class methods. Stiff ODE's and Gear's methods. | 1 |
| 9. | Eigen values and Eigen vectors: Maximum and minimum eigenvalue by Power spectral and Inverse Power Method. | 1 |
| 10. | Eigen values and Eigen vectors: all eigenvalues by Fadeev-Leverrier method | 1 |
| 11. | Introduction to diagonalization and QR Factorization. Approximation Theory. | 1 |
| 12. | Finite difference formulae: Forward and backward differences, Richardson's extrapolation, interpolation formulae, polynomial forms. | 1 |
| 13. | Finite difference formulae: linear interpolation, Lagrangeinterpolation polynomial, Newton interpolation polynomial. | 1 |
| 14. | Solution of Partial Differential Equations: Classification of PDEs(Parabolic, elliptical and hyperbolic equation), Elliptical equations, standard five points formula, diagonal five-point formula. | 1 |
| 15. | Solution of Laplace equation by Liebman's iteration method.Poisson's equation and its applications. | 1 |
| 16. | Solution of parabolic equations by Bender–Schmidt method, Bender-Schmidt recurrence equation, Crank-Nicholsondifference method. | 1 |
| | **Total** | **16** |

**Suggested Reading:**


1. Anderson T W 1958. *An Introduction to Multivariate Statistical Analysis*. John Wiley.
2. Dillon W R and Goldstein M. 1984. *Multivariate Analysis - Methods and Applications.* John Wiley.
3. Electronic Statistics Text Book: http://www.statsoft.com/textbook/stathome.html
4. Goon A M, Gupta M K and Dasgupta B. 1977. *An Outline of Statistical Theory*. Vol. I.The World Press.
5. Goon A M, Gupta M K and Dasgupta B. 1983. *Fundamentals of Statistics*. Vol. I. TheWorld Press.
6. Hoel P G. 1971. *Introduction to Mathematical Statistics*. John Wiley.
7. Hogg R V and Craig T T. 1978. *Introduction to Mathematical Statistics*. Macmillan.
8. Montgomery and Runger 2014. *Applied Statistics and Probability for Engineers*. John Wiley

**CSE 501 Big Data Analytics 2+1**

**Objectives:**

To understand principles of analyzing and mining big data and to use simple tools to extractuseful information from big data sets.

**Unit-I**

Data analysis, data matrix attributes. Data: Algebraic and geometric view, probabilistic view.

**Unit-II**

Basics of data mining and CRISP-DM, organizational and data understanding, purposes, Intents and limitations of data mining, database, data warehouse, data mart and data set, typesof data, privacy and security, data preparation, collation and data scrubbing.

**Unit-III**

Data mining models and methods, correlation, association rules, k-means, clustering understanding of concept, preparation and modelling.

**Unit-IV**

Discriminant analysis, linear regression, logistic regression, understanding, preparation and modeling.

**Unit-V**

Decision trees, neural networks, understanding, preparation and modeling.

**Practical:**

Introduction to OpenOffice and RapidMiner in data analytics and mining. Preparing RapidMiner, Importing data, handling missing data, data reduction, handling Inconsistent data, attribute reduction. Performing different analysis using RapidMiner or suitable software.

**Course Outcome:**

Capability to understand the principles behind analysis of big data and apply the same using simple tools.

**Teaching Schedule**

| S. No. | Topic | No. of Lectures |
|---|---|---|
| 1. | Data analysis, data matrix attributes | 2 |
| 2. | Algebraic and geometric view, probabilistic view. | 4 |
| 3. | Basics of data mining and CRISP-DM | 2 |
| 4. | Organizational and data understanding | 3 |
| 5. | Intents and limitations of data mining, database, data warehouse, data martand data set | 4 |
| 6. | Types of data, privacy and security, data preparation, collation and data scrubbing. | 4 |
| 7. | Data mining models and methods, correlation, association rules | 6 |
| 8. | K-means, clustering understanding of concept, preparation and modelling. | 5 |

| | | |
|---|---|---|
| 9. | Discriminant analysis, linear regression, logistic regression, understanding,preparation and modeling. | 5 |
| 10. | Decision trees, neural networks, understanding, preparation and modeling. | 5 |
| | **Total** | **40** |

**List of Practicals**

| S. No. | Topic | No. of Practicals |
|---|---|---|
| 1 | Working of OpenOffice and RapidMiner | 3 |
| 2 | Preparing RapidMiner Dataset | 3 |
| 3 | Handling the inconsistent data, missing data, attribute reduction | 4 |
| 4 | Performing analysis on dataset using Rapid Miner | 3 |
| | **Total** | **13** |

**Suggested Reading:**

1. Dr. Matthew North Data Mining for the Masses *A Global Text Project Book* ISBN: 0615684378ISBN-13: 978-0615684376.
2. Mohammed J Z, Troy and Wagner M Jr. *Data Mining and Analysis*: *Fundamental Concepts and Algorithms*. Universidade Federal de Minas Gerais, Brazil. Cambridge University Press ISBN 978-0-521-76633-3 Hardback.

**CSE 502 Artificial Intelligence 2+1**

### Objectives:
To introduce students with techniques and capabilities of artificial intelligence (AI) andenable them to do simple exercises.

### Unit-I
Definitions of intelligence and artificial intelligence. What is involved in intelligence? Disciplines important to AI. History of development of AI. Different types of AI. Acting humanly, Turing test. AI systems in everyday life. Applications of AI.

### Unit-II
Classical AI, concept of expert system, conflict resolution, multiple rules, forward chaining, backward chaining. Advantages and disadvantages of expert system. Fuzzy logic and fuzzy rules. Fuzzy expert systems.

### Unit-III
Problem solving using AI, search techniques, breadth first search, depth first search, depth limited search, bidirectional search, heuristic search, problems and examples. Knowledge representation, frames, methods and demons, correlations, decision trees, fuzzy trees.

### Unit-IV
Philosophy of AI, Penrose's pitfall, weak AI, strong AI, rational AI, brain prosthesis experiment, the Chinese room problem, emergence of consciousness, technological singularity, Turing test.

### Unit-V
Modern AI, biological brain, basic neuron model, perceptrons and learning, self-organizing neural network, N-tuple network, evolutionary computing, genetic algorithms, agent methods, agents for problem solving, software agents, multi agents, hardware agents.

### Practical:
Prolog language, syntax and meaning of Prolog programs, Lists, operators, arithmetic. Usingstructures: Example programs, controlling backtracking, input and output. more built-in procedures, programming, style and technique, operations on data structures. Advanced tree representations, basic problem-solving strategies, depth-first search strategy, breadth-first search strategy.

### Course Outcome:
Ability to understand and apply principles of AI in solving simple problems to enable them to get insight into working of AI based systems.

### Lecture Schedule

| S. No. | Topic | No. of Lectures |
|---|---|---|
| 1. | Definitions of intelligence and artificial intelligence. Disciplines important to AI. History of development of AI. | 2 |
| 2. | Different types of AI. Acting humanly, Turing test. AI systems in everyday life. Applications of AI. | 2 |
| 3. | Classical AI, concept of expert system, conflict resolution, multiple rules,forward chaining, backward chaining. | 3 |
| 4. | Advantages and disadvantages of expert system. Fuzzy logic and | 3 |

| | | |
|---|---|---|
| | fuzzy rules. Fuzzy expert systems. | |
| 5. | Problem solving using AI, search techniques, breadth first search, depthfirst search | 4 |
| 6. | Depth limited search, bidirectional search, heuristic search, problems and examples. | 4 |
| 7. | Knowledge representation, frames, methods and demons, correlations,decision trees, fuzzy trees. | 3 |
| 8. | Philosophy of AI, Penrose's pitfall, weak AI, strong AI, rational AI, brain prosthesis experiment, | 2 |
| 9. | Chinese room problem, emergence of consciousness, technological singularity, Turing test. | 3 |
| 10. | Modern AI, biological brain, basic neuron model, perceptrons and learning, self-organizing neural network, | 3 |
| 11. | N-tuple network, evolutionary computing, genetic algorithms, | 2 |
| 12. | Agent methods, agents for problem solving, software agents, | 2 |
| 13. | Multi agents, hardware agents. | 1 |
| | **Total** | **31** |

**List of Practicals**

| **S. No.** | **Topic** | **No. of Practicals** |
|---|---|---|
| 1 | Prolog language, syntax and meaning of Prolog programs, Lists, operators, arithmetic. | 4 |
| 2 | Using structures: Example programs, controlling backtracking, input andoutput. more built-in procedures, programming, style and technique, operations on data structures. | 5 |
| 3 | Advanced tree representations, basic problem-solving strategies, depth-first search strategy, breadth-first search strategy. | 5 |
| | **Total** | **14** |

**Suggested Reading:**

1. Warwick K 2012.*Artificial Intelligence*: The Basics ISBN: 978-0-415-56482-3 (hbk).
2. Ivan Bratko, *Prolog Programming for Artificial Intelligence.*
3. GNU PROLOG A *Native Prolog Compiler with Constraint Solving over Finite Domains* Edition 1.44, for GNU Prolog version 1.4.5 July 14, 2018.

**STAT 501 Statistical Methods for Research Workers 2+1**

## Objectives:

To expose students to various statistical techniques for analysis of data and interpretation of results.

## Unit-I

Probability and probability distributions. Principle of least squares. Linear and non-linear regression. Multiple regression. Correlation analysis. Selection of variables. Validation of models. Sampling techniques. Determination of sample size. Sampling distribution of meanand proportion.

## Unit-II

Hypothesis testing. Concept of p-value. Student's t-test. Large sample tests. Confidence intervals. ANOVA and testing of hypothesis in regression analysis. Analysis of variance forone way and two way classification (with equal cell frequency).Transformation ofdata.

## Unit-III

Advantages and disadvantages of nonparametric statistical tests. Scales of measurements. Run-test. Sign test. Median test. Wilcoxon-Mann Whitney test. Chi-square test. Kruskal- Walli's one way and Friedman's two way ANOVA by ranks. Kendall's Coefficient of concordance.

## Practical:

Fitting of distributions. Sample and sampling distributions. Correlation analysis. Regression analysis (Multivariate, quadratic, exponential, power function, selection of variables, validation of models, ANOVA and testing of hypothesis). Tests of significance (Z-test, t-test, F-test and Chi-square test). Analysis of variance. Non-parametric tests.

## Course Outcome:

The students will be able to understand different techniques for analyzing the data of their research work.

## Teaching Schedule

| S.No. | Topic | No. of lectures |
|---|---|---|
| 1 | Elementary statistics | 1 |
| 2 | Probability theory | 1 |
| 3 | Probability distributions (Binomial, Poisson and Normal) | 2 |
| 4 | Sampling techniques, Determination of sample size | 2 |
| 5 | Sampling distribution of mean and Proportion | 1 |
| 6 | Hypothesis testing concept of p-value | 1 |
| 7 | Large sample (mean, proportion) | 1 |
| 8 | Student’s t-test (Single mean, Difference of mean for independent samples and paired observations) and F-test | 3 |
| 9 | Analysis of variance (one way and two way), Transformation of data | 2 |
| 10 | Correlation analysis and testing (Bivariate, Rank, Intra-class, Partial, Fisher’s Z-transformation) | 2 |
| 11 | Multiple linear regression and model validation | 2 |
| 12 | Testing of coefficient of determination and regression coefficient | 2 |
| 13 | Selection of variables in regression (forward substitution method andstep-wise regression) | 1 |

| | | |
|---|---|---|
| 14 | Non-Linear regression (Quadratic, exponential and Power) | 2 |
| 15 | Introduction to Non-parametric and scales of measurements | 1 |
| 16 | Chi-square test (Goodness of fit, Independence of attributes, homogeneity of variances) | 2 |
| 17 | One Sample test (Sign test, Median test, Run rest,) | 2 |
| 18 | Two sample test (Wilcoxon Sign test, Mann Whitney test, Chi square test for two independent samples) | 1 |
| 19 | K-Sample (Kruskal-Walli's test and Friedman's two way ANOVA) | 2 |
| 20 | Kendall's coefficient of concordance | 1 |
| | **Total** | **32** |

**List of Practicals**

| **S.No.** | **Topics** | **No. of Practicals** |
|---|---|---|
| 1 | Elementary statistics | 1 |
| 2 | Probability distributions (Binomial, Poisson and Normal) | 1 |
| 3 | Sampling techniques, Determination of sample size, Sampling distribution of mean and Proportion | 1 |
| 4 | | |
| 5 | Large sample (mean, proportion) | 1 |
| 6 | Student's t-test (Single mean, Difference of mean for independent samples and paired observations) and F-test | 1 |
| 7 | Analysis of variance (one way and two way), Transformation of data | 2 |
| 8 | Correlation analysis and testing (Bivariate, Rank, Intra-class, Partial,Fisher's Z-transformation) | 1 |
| 9 | Multiple linear regression and model validation | 1 |
| 10 | Testing of coefficient of determination and regression coefficient | |
| 11 | Selection of variables in regression (Forward substitution method andstep-wise regression) | 1 |
| 12 | Non-Linear regression (Quadratic, exponential and Power) | 2 |
| 13 | Introduction to Non-parametric and scales of measurements | |
| 14 | Chi-square test (Goodness of fit, Independence of attributes, homogeneity of variances) | 2 |
| 15 | One Sample test:Sign test, Median test, Run rest, Two sample test: Wilcoxon Sign test, Mann Whitney test, $X^2$ test for two independentsamples | 1 |
| 16 | K-Sample: Kruskal-Walli's test and Friedman's two way ANOVA, Kendall's coefficient of concordance | 1 |
| | **Total** | **16** |

**Suggested Reading:**


1. Anderson T W 1958. *An Introduction to Multivariate Statistical Analysis*. John Wiley.
2. Dillon W R and Goldstein M. 1984. *Multivariate Analysis - Methods and Applications.* John Wiley.
3. Electronic Statistics Text Book: http://www.statsoft.com/textbook/stathome.html
4. Goon A M, Gupta M K and Dasgupta B. 1977. *An Outline of Statistical Theory*. Vol. I.The World Press.
5. Goon A M, Gupta M K and Dasgupta B. 1983. *Fundamentals of Statistics*. Vol. I. TheWorld Press.
6. Hoel P G. 1971. *Introduction to Mathematical Statistics*. John Wiley.
7. Hogg R V and Craig T T. 1978. *Introduction to Mathematical Statistics*. Macmillan.
8. Montgomery and Runger 2014. *Applied Statistics and Probability for Engineers*. John Wiley
9. Morrison D F. 1976. *Multivariate Statistical Methods*. McGraw Hill.
10. Siegel S, Johan N and Casellan Jr. 1956. *Non-parametric Tests for Behavior Sciences*.John Wiley.

# Course Syllabus and Content of Doctoral Degree

## FMPE 601 Advances in Farm Machinery and Power Engineering 2+1

### Objectives:
To familiarize the students about modern developments in construction, design and analysis of farm machinery systems as applied in different areas of agriculture.

### Unit-I
Advances in mechanization as applicable to Indian context. Future outlook for improving agricultural productivity and reducing cost. Mechanization: Review of the applications of some of the advanced mechanization technologies and constraints in adaptability. Levels of mechanization and transition between levels.

### Unit-II
Sustainable mechanization management: Management of compaction of agricultural fields. Strategies to develop machinery and systems that reduce compaction. Concept of Controlled Traffic Farming (CTF) systems. Introduction of wide span mechanization to vegetable production systems to enhance productivity and sustainability.

### Unit-III
Optimization of production processes to minimize energy loss in agriculture. The rationale for the use of photovoltaic systems in farming. The Energy Returned on Energy Invested (EROEI) ratio as an indicator for evaluating the efficiency of renewable energy sources.

### Unit-IV
Machine vision system-hardware and software technologies, and machine learning and image analysis techniques. Unmanned agricultural ground vehicles (UAGVs): UAGVs instrumented mobile platform, on board sensors, computing hardware, algorithms and software. Manipulator type ag-robots: Use in food processing, dairy, horticulture, and orchard industries.

### Unit-V
Precision Livestock Farming (PLF): Individual identification and monitoring of animals, tractability of livestock products. Developments in livestock and building control: Radio telemetry systems to remotely monitor and record physiological parameters. Silage process and their variants. Coordination of machinery system to enhance quality of silage and forage conditioners.

### Practical:
Case studies and presentations on: Mechanization in India-analysis of machinery data- mechanization index and relation between productivity and mechanization. Levels of mechanization in different crops. Design of traffic lanes-field geometry and generating guideline lanes for operation of machinery. Planning use of multiple machinery-sugarcane harvesting system. Measurement of soil compaction due to heavy machinery using cone penetrometer. Machine vision system design–case studies. Challenges in development of robotic machinery in agricultural operations-case studies.

### Course Outcome:

The students will be able to design, operate and maintain surface irrigation systems, surface and sub-surface pressurized irrigation systems, and managing crop productivity with poor quality of waters without deteriorating soil conditions.

**Teaching schedule**

| Sr.No | Topic | No. of lectures |
|---|---|---|
| 1 | Advances in mechanization as applicable to Indian context. | 2 |
| 2 | Mechanization in large scale agricultural fields | 1 |
| 3 | Mechanization in small scale agricultural fields | 1 |
| 4 | Future outlook for improving agricultural productivity and reducing cost. | 1 |
| 5 | Requirements of energy and fuels for machinery operations | 2 |
| 6 | Case studies of the applications of some of the advanced mechanization technologies and constraints in adaptability. | 2 |
| 7 | Case studies of Technology transfer mechanisms in India | 1 |
| 8 | Levels of mechanization and transition between levels. | 1 |
| 9 | Sustainable mechanization management. | 1 |
| 10 | Management of compaction of agricultural fields. | 1 |
| 11 | Strategies to develop machinery and systems that reduce compaction. | 1 |
| 12 | Concept of Controlled Traffic Farming (CTF) systems. | 1 |
| 13 | Introduction of wide span mechanization to vegetable production systems to enhance productivity and sustainability. | 2 |
| 14 | Optimization of production processes to minimize energy loss in agriculture. | 2 |
| 15 | The rationale for the use of photovoltaic systems in farming. | 1 |
| 16 | The Energy Returned on Energy Invested (EROEI) ratio as an indicator for evaluating the efficiency of renewable energy sources. | 2 |
| 17 | Machine vision system-hardware and software technologies, and machine learning and image analysis techniques. | 1 |
| 18 | Unmanned agricultural ground vehicles (UAGVs) | 1 |
| 19 | UAGVs instrumented mobile platform, on board sensors, computing hardware, algorithms and software. | 1 |
| 20 | Manipulator type ag-robots: Use in food processing, dairy, horticulture, | 2 |
| | and orchard industries. | |

| | | |
|---|---|---|
| 21 | Precision Livestock Farming (PLF): Individual identification and monitoring of animals, tractability of livestock products. | 1 |
| 22 | Developments in livestock and building control: Radio telemetry systems to remotely monitor and record physiological parameters. | 2 |
| 23 | Silage process and their variants. Coordination of machinery system toenhance quality of silage and forage conditioners. | 1 |
| 24 | Silage and forage conditioners. | 1 |
| | **Total** | **32** |

**List of Practicals**

| Sr. No. | Topic | No of Practicals |
|---|---|---|
| 1 | Case studies of Mechanization in India | 1 |
| 2 | Case studies of Mechanization in SAARC countries | 1 |
| 3 | To find mechanization index. | 1 |
| 4 | Relation between productivity and mechanization in India and Punjab. | 1 |
| 5 | Relation between productivity and mechanization in developed countries. | 1 |
| 6 | Levels of mechanization in cereal crops like paddy, Wheat etc. | 1 |
| 7 | Levels of mechanization in Horticulture crops | 1 |
| 8 | Levels of mechanization in cotton crop and pulses and oilseed crops | 1 |
| 9 | Design of traffic lanes-field geometry and generating guideline lanes foroperation of machinery. | 1 |
| 10 | Planning use of multiple machinery-sugarcane harvesting system. | 1 |
| 11 | Measurement of soil compaction due to heavy machinery using conepenetrometer. | 1 |
| 12 | Machine vision system design–case studies. | 1 |
| 13 | Machine vision system design–case studies. | 1 |
| 14 | Unmanned agricultural ground vehicles (UAGVs) for different applications like spraying, imaging etc. | 1 |
| 15 | Challenges in development of robotic machinery in agricultural operations-case studies. | 1 |

| | | |
|---|---|---|
| 16 | Developments in livestock and building control: Radio telemetry systems to remotely monitor and record physiological parameters. | 1 |
| | **Total** | **16** |

**Suggested Reading:**


1. Chen G (ed) 2018. *Advances in Agricultural Machinery and Technologies. Boca Raton:* CRC Press, https://doi.org/10.1201/9781351132398.
2. Srivastava A K 2006. *Engineering Principles of Agricultural Machines.* 2nd Edition American Society of Agricultural and Biological Engineers (ISBN) 1-892769-50-6 ASAE Publication 801M0206.
3. Seyyedhasani H 2017. *Using the Vehicle Routing Problem (VRP) to Provide Logistic Solutions in Agriculture.* Ph.D dissertation. University of Kentucky, Kentucky, U.S.A. https://www.researchgate.net/publication/264791116_Advances in Agricultural Machinery Management A Review.
4. Edwards G T C, Hinge G, Skou-Nielsen N and Villa-Henriksen A 2017. *Route PlanningEvaluation of a Prototype Optimized in Field Route Planner for Neutral Material Flow Agricultural Operations.* Biosystems Engineering 153: 149-157. https://www.sciencedirect.com/science/article/pii/S1537511016303713.

## FMPE 602 Advances in Machinery for Precision Agriculture 2+1

### Objectives:

Detailed study of the hardware system used in precision agriculture (PA) and techniques ofusing them in precision agriculture.

### Unit-I

Global navigation satellite system (GNNS). Satellite ranging: Accuracy, standards, components of GIS, data layers, map component, attribute table component, function of a GIS, resolution. Data formats: Vector or raster. GIS for precision farming, data analysis, field calculator, convert to grid, interpolation, reclassification, image classification, band math, interpretation of analysis, farm management information systems, and crop intelligence.

### Unit-II

Yield Monitors: Components, Differential GPS Receiver, GNSS Receiver, mass flow sensors. Impact plates, measuring volume with a photoelectric sensor. Using microwave radiation, and Gamma rays to estimate volume, volumetric flow sensing and alternatives.

Grain moisture sensor, fan speed sensor, elevator speed sensor, header position, yield monitor data, cotton yield monitors.

### Unit-III

Sources of soil variability, general soil sampling basics, systematic variability, selecting a soil sampling strategy. Parameters: Electrical conductivity, electromagnetic sensors, sensing mechanical impedance. Proximal plant sensing systems, crops canopy reflectance and fluorescence. Machine vision thermal sensors, mechanical sensors, acoustic sensors.

### Unit-IV

Remote sensing platforms: Aircraft or satellite. Sensors: Imaging or non imaging, active or passive. Making use of reflected energy or emitted energy. The spectral signature of vegetation, vegetation indices, application to agriculture, nutrient management, weed management, disease and insect management, water management.

### Practical:

Simple programming for automating precision farming calculations. Mathematics of longitude and latitude. Spatial statistics, soil sampling and understanding soil testing results for precision farming, calculations. Supporting management zones, understanding soil, water and yield variability in precision farming. Developing prescriptive soil nutrient maps, essential plant nutrients, fertilizer sources, and application rates calculations. Deriving and using an equation to calculate economic optimum fertilizer and seeding rates cost of crop production.

### Course Outcome:

Ability to understand design and operate PA systems.

### Lecture schedule

| S.No | Topic | No. of lectures |
|---|---|---|
| 1 | Introduction about Global navigation satellite system (GNNS | 1 |
| 2 | Satellite ranging including accuracy, standards etc. | 1 |
| 3 | Differential GNSS Receiver, RTK etc. | 1 |
| 4 | Components of GIS, data layers, map component, | 1 |

| | | |
|---|---|---|
| 5 | Attribute table component, function of a GIS, resolution. | 1 |
| 6 | Data formats: Vector or raster. | 1 |
| 7 | GIS for precision farming, data analysis, field calculator, convert to grid, | 2 |
| 8 | Interpolation, reclassification, image classification, band math and interpretation of analysis. | 1 |
| 9 | Farm management information systems, and crop intelligence. | 1 |
| 10 | Introduction about Yield monitors and its components | 1 |
| 11 | Mass flow and impact plate sensors, measuring volume with a photoelectric sensor. Lecture 12: Microwave radiation and Gamma rays to estimate volume, | 1 |
| 12 | Different types of grain moisture sensor | 1 |
| 13 | Fan speed sensor, elevator speed sensor, header position, yieldmonitor data, | 1 |
| 14 | Yield monitors for non-grain crops | 1 |
| 15 | Sources of soil variability, general soil sampling basics, systematic variability Selecting a soil sampling strategy. | 2 |
| 16 | Proximal and remote sensing based soil sensors | 1 |
| 17 | Electromagnetic based sensors for soil electrical conductivity measurement | 1 |
| 18 | Sensing mechanical impedance based sensors for soil compaction | 1 |
| 19 | Spectroscopy for determination of soil properties | 1 |
| 20 | Introduction about proximal plant sensing systems | 1 |
| 21 | Remote sensing platforms: Aircraft or satellite. | 1 |
| 22 | Type of plant sensors: Imaging or non imaging, active or passive. | 1 |
| 23 | Use of reflected or emitted energy for vegetation detection | 1 |
| 24 | The spectral signature of vegetation, vegetation indices, application to agriculture | 1 |
| 25 | Sensing system for nutrient management, | 1 |
| 26 | Crops canopy reflectance and fluorescence. | 1 |
| 27 | Machine vision thermal sensors, mechanical sensors, acoustic sensors | 1 |
| 28 | Sensors for weed detection and management | 1 |

| | | |
|---|---|---|
| 29 | Sensing Techniques for disease and insect management, | 1 |
| 30 | Different type of sensors/devices for water management. | 1 |
| | **Total** | **32** |

**List of Practicals**

| **S.No** | **Topic** | **No. of Practicals** |
|---|---|---|
| 1 | Simple programming for automating precision farming calculations | 2 |
| 2 | Mathematics of longitude and latitude | 1 |
| 3 | Spatial and temporal statistics using GIS | 1 |
| 4 | Soil sampling strategies, understanding and results for precision farming | 1 |
| 5 | Creation of management zones | 1 |
| 6 | Measurement of yield variability in the field | 1 |
| 7 | Measurement of soil Compaction in the field | 1 |
| 8 | Measurement of soil EC in the field | 1 |
| 9 | Measurement of soil pH in the field | 1 |
| 10 | : Developing and understanding prescriptive soil nutrient maps | 1 |
| 11 | : Measurement of essential plant nutrients in the field | 1 |
| 12 | Fertilizer sources, and application rates calculations | 1 |
| 13 | Deriving and using an equation to calculate economic optimum fertilizer | 1 |
| 14 | Calculation of optimum seeding rates for optimized returns | 1 |
| 15 | Cost of crop production using precision technologies. | 1 |
| | **Total** | **16** |

**Suggested Reading:**


1. Shannon D K, Clay D E, and Kitchen N R Newell 2018. *Precision Agriculture Basics.* American Society of Agronomy, Inc., Madison, WI, USA.
2. Clay D E, Clay S A and Bruggeman S A 2017. *Practical Mathematics for Precision Farming.* American Society of Agronomy, Madison, WI, USA.
3. Van-Henten E J, Goense D and Lokhorst C (ed) 2009. *Precision Agriculture.*

Wageningen Academic Publishers, Wageningen, Netherlands.

4. Singh A K and Chopra U K 2007. *Geoinformatics Applications in Agriculture*. New India Publishing Agency, New Delhi, India .

5. Ram T, Lohan S K, Singh R and Singh P 2014. Precision *Farming: A New approach*. Astral International Pvt. Ltd., New Delhi, India. ISBN: ISBN 978-81-7035-827-5 (Hardbound) ISBN 978-93-5130-258-2 (International Edition).

**FMPE 603 Energy Conservation and Management in Production Agriculture 3+0**

### Objectives:
Detailed study of the hardware system used in precision agriculture (PA) and techniques of using them in precision agriculture.

### Unit-I
Global navigation satellite system (GNNS). Satellite ranging: Accuracy, standards, components of GIS, data layers, map component, attribute table component, function of a GIS, resolution. Data formats: Vector or raster. GIS for precision farming, data analysis, field calculator, convert to grid, interpolation, reclassification, image classification, band math, interpretation of analysis, farm management information systems, and crop intelligence.

### Unit-II
Yield Monitors: Components, Differential GPS Receiver, GNSS Receiver, mass flow sensors. Impact plates, measuring volume with a photoelectric sensor. Using microwave radiation, and Gamma rays to estimate volume, volumetric flow sensing and alternatives. Grain moisture sensor, fan speed sensor, elevator speed sensor, header position, yield monitor data, cotton yield monitors.

### Unit-III
Sources of soil variability, general soil sampling basics, systematic variability, selecting a soil sampling strategy. Parameters: Electrical conductivity, electromagnetic sensors, sensing mechanical impedance. Proximal plant sensing systems, crops canopy reflectance and fluorescence. Machine vision thermal sensors, mechanical sensors, acoustic sensors.

### Unit-IV
Remote sensing platforms: Aircraft or satellite. Sensors: Imaging or non imaging, active or passive. Making use of reflected energy or emitted energy. The spectral signature of vegetation, vegetation indices, application to agriculture, nutrient management, weed management, disease and insect management, water management.

### Practical:
Simple programming for automating precision farming calculations. Mathematics of longitude and latitude. Spatial statistics, soil sampling and understanding soil testing results for precision farming, calculations. Supporting management zones, understanding soil, water and yield variability in precision farming. Developing prescriptive soil nutrient maps, essential plant nutrients, fertilizer sources, and application rates calculations. Deriving and using an equation to calculate economic optimum fertilizer and seeding rates cost of crop production.

### Course Outcome:
Ability to understand design and operate PA systems.

### Lecture Schedule

| Sr.No. | Topic | No. of lectures |
|---|---|---|
| 1 | Introduction | 1 |
| 2 | Classification of energy | 2 |
| 3 | Energy coefficients | 2 |
| 4 | Energy requirements for wheat production | 2 |
| 5 | Energy requirements for paddy production | 2 |
| 6 | Energy requirements for maize production | 2 |
| 7 | Energy requirements for cotton production | 2 |
| 8 | Energy requirements for oil seeds production | 1 |

| | | |
|---|---|---|
| 9 | Energy requirements for pulse production | 2 |
| 10 | Energy requirements for production of other crops | 2 |
| 11 | Energy requirements for vegetable production | 2 |
| 12 | Energy requirements for fruit production | 1 |
| 13 | Energy requirements for fish production | 1 |
| 14 | Energy requirements for meat and milk production | 2 |
| 15 | Limits of energy conservation | 1 |
| 16 | Energy planning, management and forecasting in agriculture | 3 |
| 17 | Design of integrated energy supply system | 2 |
| 18 | Energy conservation and returns | 2 |
| 19 | Assessment of energy conservation technology | 2 |
| 20 | Case studies on application of various techniques of energy conservation and management | 2 |
| | **Total** | **36** |

**Suggested Reading:**

1. Singh S and Singh R S 2014. *Energy for Production Agriculture*. DKMA, ICAR, New Delhi, India.
2. Mittal J P, Panesar B S, Singh S, Singh C P and Mannan K D 1987. *Energy in Production Agriculture and Food Processing.* ISAE and School of Energy Studies for Agriculture, PAU Ludhiana, ISAE Publication.
3. Pimental D 1980. *Handbook of Energy Utilization in Agriculture*. CRC Press. Boca Rotan, USA

**FMPE 604 Mechanics of Tillage in Relation to Soil and Crop 2+1**

## Objectives:

To have deeper understanding of the tillage process in terms of crop requirement, soil characteristics and machinery function.

## Unit-I

Soil condition and soil strength determining factors. General aspects of mechanical behaviorof soil elements. Soil compaction, conditions for its occurrence. Methods of estimation of soil compaction by experimental stress distribution. Concept of soil distortion, deformation at constant volume. Expansion of soil at breaking.

## Unit-II

Occurrence of soil breaking fundamentals. Measures of resistance against breaking. Shearfailure and Coulomb's law. Compaction v/s shear failure. Tensile failure of soil, idealized brittle failure, Griffith's Model. Loading rate and repeated loading effects. Draft calculation using mechanism of rigid soil bodies.

## Unit-III

Crop requirements: Root structure, Soil conditions and purpose of tillage, looseness of soil and depth of loosening. Structure of seed bed. Soil properties, properties affected by tillageand those not affected by tillage. Soil compaction, formation of clods and dust. Effect oftillage on erosion and water logging. Impact of climate factors on soil. Tillage requirement for various types of soils.

## Unit-IV

Tillage operations for special tasks. Preparation of soil for cropping and stubble management. Primary and secondary tillage. Ploughing and its effect on soil. Disc tillage: Appropriateconditions and effect. Requirement of seed bed and techniques of creating proper seed bed. Quality of sowing and sowing methods. Modern trends and objectives of soil tillage.

## Unit-V

Plough bodies: Generalized representation, intake main flow and output process. Main flow under different surface curvatures. Kinetic aspects of plough bodies with different shapes. Draft of plough bodies as affected by moisture, speed and attachments.

## Practical:

Characterization of soil condition before and after tillage. Cone penetrometer resistance, bulk density, moisture content. Measurement of forces on tillage tools under soil bin condition/ field condition. Measurement of soil manipulation by different tillage tools: Pulverization, furrow profile, inversion and mixing. Measurement of energy required for soil breakup by different methods. Field study of crop root development in relation to soil compaction andhard pan. Measurement of moisture movement in different surface configuration: Ridges, furrows, raised bed and flat bed. Field evaluation of plant establishment in relation to planting parameters.

## Course Outcome:

Ability to design tillage machinery based on engineering principles as applied tom tillage science.

**Teaching Schedule**

| Sr. No. | Topic | Lecture No. |
|---|---|---|
| 1. | Soil condition and soil strength determining factors. | |
| 2. | General aspects of mechanical behavior of soil elements. | 1 |
| 3. | Soil compaction, conditions for its occurrence. | 2 |
| 4. | Methods of estimation of soil compaction by experimental stress distribution. | 1 |
| 5. | Concept of soil distortion, deformation at constant volume. | 1 |
| 6. | Expansion of soil at breaking. | 1 |
| 7. | Occurrence of soil breaking fundamentals. | 1 |
| 8. | Measures of resistance against breaking. | 1 |
| 9. | Shear failure and Coulomb's law. | 1 |
| 10. | Compaction v/s shear failure. | 1 |
| 11. | Tensile failure of soil, idealized brittle failure, Griffith's Model. | 1 |
| 12. | Loading rate and repeated loading effects. | 1 |
| 13. | Draft calculation using mechanism of rigid soil bodies. | 1 |
| 14. | Crop requirements: Root structure, Soil conditions and purpose of tillage,looseness of soil and depth of loosening. | 1 |
| 15. | Structure of seed bed. Soil properties, properties affected by tillage and those not affected by tillage. | 2 |
| 16. | Soil compaction, formation of clods and dust. | 1 |
| 17. | Effect of tillage on erosion and water logging. | 1 |
| 18. | Impact of climate factors on soil. | 1 |
| 19. | Tillage requirement for various types of soils. | 1 |
| 20. | Tillage operations for special tasks. | 1 |
| 21. | Preparation of soil for cropping and stubble management. | 1 |
| 22. | Primary and secondary tillage. Ploughing and its effect on soil. | 1 |
| 23. | Disc tillage: Appropriate conditions and effect. | 1 |
| 24. | Requirement of seed bed and techniques of creating proper seed bed. | 1 |
| 25. | Quality of sowing and sowing methods. | 1 |
| 26. | Modern trends and objectives of soil tillage. | 1 |
| 27. | Plough bodies: Generalized representation, intake main flow and output process. | 1 |
| 28. | Main flow under different surface curvatures. | 1 |
| 29. | Kinetic aspects of plough bodies with different shapes. | 1 |
| 30. | Draft of plough bodies as affected by moisture, speed and attachments. | 1 |
| | **Total** | **32** |

**List of Practicals**

| Sr.No. | Topic | No of Practicals |
|---|---|---|
| 1. | Characterization of soil condition before and after tillage. | 2 |
| 2. | Cone penetrometer resistance, bulk density, moisture content. | 2 |
| 3. | Measurement of forces on tillage tools under soil bin condition/ field condition. | 2 |
| 4. | Measurement of soil manipulation by different tillage tools: | 2 |
| | Pulverization, furrow profile, inversion and mixing. | |
| 5. | Measurement of energy required for soil breakup by different methods. | 2 |
| 6. | Field study of crop root development in relation to soil compactionand hard pan. | 2 |
| 7. | Measurement of moisture movement in different surface configuration: Ridges, furrows, raised bed and flat bed. | 2 |
| 8. | Field evaluation of plant establishment in relation to planting parameters. | 2 |
| | **Total** | **16** |

**Suggested Reading:**


1. Birkas M 2014, *Book of Soil Tillage*. Szent Istvan University Press, Godollo, Hungary.ISBN-978-963-269-447-4 (Unit III & IV).
2. Koolen A J and Kuipers H 1983. *Agricultural Soil Mechanics*. Springer-Verlag. New York, USA. ISBN 13:978-3-642-69012-9 (Unit I, II, V).

## FMPE 611 Mechanics of Traction and its Application 2+1

### Objectives:

Learning techniques of modelling soil traction device interaction under different states of wheel and under different soil conditions by analytical and empirical method.

### Unit-I

Tractor performance in soft soils, operational states of wheel: Wismer and Luth. Path traced by point on tyre periphery. Rolling resistance, conditions of wheel soil interaction, theoretical prediction, work on soil deformation, Bekke's model, derivation of resistance offered by flat rigid plate on soft soil. Measurement of sinkage parameters. Soft wheel on soft surface andrigid wheel on soft surface. Empirical prediction of tractive force: Bekker's model, stress deformation relation in soil, analysis of tractive performance of tracks.

### Unit-II

Empirical modelling of tractor performance, tractive performance modelling and mobility number. Empirical models for rolling resistance and traction by Gee-Clough. Derivation of equations for drawbar pull and drawbar power.

### Unit-III

Rigid wheel systems. Rigid wheel at rest: Soil bearing capacity, contact pressure and sinkage. Rigid wheel at driving state: Ground reaction on rigid wheel during driving action, force balance in soil reaction to driving wheel, determination of driving force, compaction resistance and effective driving force. Energy equilibrium under driving wheel.

### Unit-IV

Wheel under braking state: Slip velocity and amount of slippage under braked wheel. Soil deformation under braked wheel. Distribution of shear stresses and normal stress under driving wheel.

### Unit-V

Tyre wheel system-deformation of tyre and area of contact. Deformation of tyre and its measurement. Tyre deformation as function of inflation pressure. Ground reaction during pure rolling of tyre on hard surface. Trafficability in soft terrain, concept of wheel mobility
number-cornering characteristic of wheel forces on a steered wheel under driving and braking conditions. Relation between cornering force and self-aligning torque.

### Practical:

Measurement of soil parameters for modelling traction-simulation of the different traction models to obtain the tractive performance. Calculating the performance of tractor drive wheels, Braking performance of trailer wheels on road, Planter metering drive wheels, Tractor front wheel. Measurement of performance of tyres under soil bin condition/field condition for driving and braking. Measurement of variation in contact patch of tractor tyres under different inflation pressures. Design of lugged wheels for wet puddle soil condition. Field experiment with tractive performance of tractor.

### Course Outcome:

Ability to model vehicle traction mechanics and provide insight into behavior of vehicles under different soil conditions.

**Teaching Schedule**

| Sr. No. | Topic | No. of Lecture |
|---|---|---|
| 1. | Tractor performance in soft soils, operational states of wheel: Wismerand Luth. | 2 |
| 2. | Path traced by point on tyre periphery. | 1 |
| 3. | Rolling resistance, conditions of wheel soil interaction, theoretical prediction, work on soil deformation, Bekke's model, derivation ofresistance offered by flat rigid plate on soft soil. | 4 |
| 4. | Measurement of sinkage parameters. | 1 |
| 5. | Soft wheel on soft surface and rigid wheel on soft surface. | 1 |
| 6. | Empirical prediction of tractive force: Bekker's model, stress deformation relation in soil, analysis of tractive performance of tracks | 2 |
| 7. | Empirical modelling of tractor performance, tractive performancemodelling and mobility number. | 2 |
| 8. | Empirical models for rolling resistance and traction by Gee-Clough. | 1 |
| 9. | Derivation of equations for drawbar pull and drawbar power. | 1 |
| 10. | Rigid wheel systems. Rigid wheel at rest: Soil bearing capacity, contact pressure and sinkage. | 2 |
| 11. | Rigid wheel at driving state: Ground reaction on rigid wheel during driving action. | 2 |
| 12. | Force balance in soil reaction to driving wheel, determination ofdriving force, compaction resistance and effective driving force. | 2 |
| 13. | Energy equilibrium under driving wheel. | 1 |
| 14. | Wheel under braking state: Slip velocity and amount of slippageunder braked wheel. | 2 |
| 15. | Soil deformation under braked wheel. | 1 |
| 16. | Distribution of shear stresses and normal stress under driving wheel. | 1 |
| 17. | Tyre wheel system-deformation of tyre and area of contact. | 1 |
| 18. | Deformation of tyre and its measurement. Tyre deformation asfunction of inflation pressure. | 1 |
| 19. | Ground reaction during pure rolling of tyre on hard surface. | 1 |
| 20. | Trafficability in soft terrain, concept of wheel mobility number-cornering characteristic of wheel forces on a steered wheel under driving and braking conditions. | 2 |
| 21. | Relation between cornering force and self-aligning torque. | 1 |
| | **Total** | **32** |

**List of Practicals**

| **Sr.No.** | **Topic** | **No of Practicals** |
|---|---|---|
| 1 | Measurement of soil parameters for modelling traction-simulation of the different traction models to obtain the tractive performance. | 4 |
| 2 | Calculating the performance of tractor drive wheels, Braking performance of trailer wheels on road, Planter metering drive wheels, Tractor front wheel. | 4 |
| 3 | Measurement of performance of tyres under soil bin condition/field condition for driving and braking. | 2 |
| 4 | Measurement of variation in contact patch of tractor tyres underdifferent inflation pressures. | 2 |
| 5 | Design of lugged wheels for wet puddle soil condition. | 2 |
| 6 | Field experiment with tractive performance of tractor. | 2 |
| | **Total** | **16** |

**Suggested Reading:**


1. Muro T and O'Brien J 2004. *Terramechanics:* Land Locomotion Mechanics. Lisse, Netherlands. ISBN 90 5809 572 X (Unit III, IV, V).
2. Macmillan R H 2010. *The Mechanics of Tractor-Implement Performance*: Theory and Worked Examples: A Textbook for Students and Engineers. Custom Book Centre, University of Melbourne, Australia. http://hdl.handle.net/11343/33718 (Unit I, II).
3. Gill W.R. and Van den Berg G.E. 1968. *Soil Synamics in Tillage and Traction*. Hand Book 316, Agriculture Research Service, US Deptt of Agriculture, Washington DC, 1968

## FMPE 612 Farm Machinery Management and Systems Engineering 2+1

### Objectives:
Understanding Farm Machinery from systems approach and ability to model the Farmmachinery system.

### Unit-I
Mathematical models of field machinery systems: Operational constrains, power constrains, weather constrains. Systems approach to field operations and models of: Tillage, seeding, chemical application, harvesting, storage and irrigation systems.

### Unit-II
Engineering economics: Concept of incremental and differential cost, economic efficiency, time value of money. Equipment investment cost: Operational cost, production cost, income cost and uncertainty cost. B.C. ratio, payback period, IRR machinery replacement policies.

### Unit-III
Uncertainty: Concepts of probability, probability functions, distributions, sampling. Statistics, confidence limits, significance, contingency tables, analysis of variance. Regression and correlation. Monte Carlo methods and applications to farm machinery.

### Unit-IV
System modeling in farm machinery: Numerical methods, analogs, models with uncertainty stochastic service system. Feasibility system design-stability. Deterministic systems and stochastic systems.

### Unit-V
Optimum Design: Trial and error, differential calculus, calculus of variations. Allocations: Linear programming, simplex technique. Transportation and assignment technique. Critical path scheduling, dynamic programming, game and its applications to farm machinery management.

### Practical:
Solving problems of mathematical models of field machinery, constraints, power constraints, weather constraints. Problems relates to tillage seeding chemical application harvesting and storage and irrigation systems. Problem solving in Economics of Engineering, calculation of investment cost, operational cost, and uncertainty cost. Case studies in machine performance modelling, Economics of machine selection, Analog components, Analog modelling stochastic system modelling and critical path scheduling.

### Course Outcome:
Ability to understand and develop model of any farm machinery system to help in selection, management and optimization.

### Teaching Schedule

| Sr. No. | Topic | No. of Lecture |
|---|---|---|
| 1 | Understanding Farm Machinery from systems approach and ability to model the Farm machinery system. | 2 |
| 2 | Mathematical models of field machinery systems: Operational constrains,power constrains, weather constrains. | 2 |

| | | |
|---|---|---|
| 3 | Systems approach to field operations and models of: Tillage, seeding, chemical application, harvesting, storage and irrigation systems. | 3 |
| 4 | Engineering economics: Concept of incremental and differential cost, economic efficiency, time value of money | 1 |
| 5 | Equipment investment cost: Operational cost, production cost, income cost and uncertainty cost. B.C. ratio, payback period, IRR machinery replacement policies. | 2 |
| 6 | Uncertainty: Concepts of probability, probability functions, distributions,sampling | 2 |
| 7 | Statistics, confidence limits, significance, contingency tables, analysis of variance. | 1 |
| 8 | Regression and correlation. Monte Carlo methods and applications to farmmachinery. | 3 |
| 9 | System modeling in farm machinery: Numerical methods, analogs, modelswith uncertainty stochastic service system. | 3 |
| 10 | Feasibility system design-stability | 1 |
| 11 | Deterministic systems and stochastic systems. | 2 |
| 12 | Optimum Design: Trial and error, differential calculus, calculus of variations | 2 |
| 13 | Allocations: Linear programming, simplex technique Transportation andassignment technique | 4 |
| 14 | Critical path scheduling, dynamic programming, game and its applicationsto farm machinery management. | 4 |
| | **Total** | **32** |

**List of Practicals**

| **Sr. No.** | **Topic** | **No. of Practicals** |
|---|---|---|
| 1 | Problems solving of mathematical models of field machinery, constraints,power constraints, weather constraints | 3 |
| 2 | Mathematical problems relates to tillage, seeding, chemical applicationharvesting and storage and irrigation systems | 3 |
| 3 | Problem solving in Economics of Engineering, calculation of investmentcost, operational cost, and uncertainty cost | 3 |

| | | |
|---|---|---|
| 4 | Case studies in machine performance modelling, Economics of machineselection | 3 |
| 5 | Case studies in machine performance modelling | 2 |
| 6 | Economics of Power and machine selection | 2 |
| | **Total** | **16** |

**Suggested Reading:**


1. Hunt D R 1986. *Engineering Models for Agricultural Production*. AVI Pub. Co., Westport, CT, USA.
2. Hunt D and Wilson D 2015. *Farm Power and Machinery Management*. Waveland Press,Illinois, USA.
3. Singh S and Verma S R 2009. *Farm Machinery Maintenance and Management.* DIPA,ICAR, New Delhi.

**FMPE 613 Machinery for Special Farm Operations 2+0**

**Objectives:**

To bring to focus special farm operations that are not covered under conventional operationsand the machinery used for such operations.

**Unit-I**

Machinery for land development. Tractor operated and self-propelled machines for laying drainage system, sub surface drip laying machines, subsoiler, trenchers, laser levelers.

**Unit-II**

Machines for plant protection, pneumatic, thermal type sprayers, aero/drone spraying and other methods of spraying, electrostatic charging, air sleeve boom sprayer, disinfection of seed beds by micro waves and other methods. Safety aids for operator and advances in plant protection method.

**Unit-III**

Field plot machinery and its importance. Fertilizer and manure spreader.

**Unit-IV**

Machines for residue management. Silage and hay making machines.

**Unit-V**

Machinery for horticultural crops. Crop specific machines for cotton, sugarcane, forage/fodder. Machines for processing and handling of agricultural products.

**Course Outcome:**

Understanding of the broad horizon of agricultural machinery used for specializedagricultural operations.

**Teaching Schedule**

| S.No | Topic | No of Lectures |
|---|---|---|
| 1 | Machinery for land development | 1 |
| 2 | Tractor operated and self-propelled machines for laying drainage system, sub surface drip laying machines, subsoiler, trenchers | 2 |
| 3 | Laser levelers | 2 |
| 4 | Machines for plant protection | 1 |
| 5 | Pneumatic, thermal type sprayers | 2 |
| 6 | Aero/drone spraying and other methods of spraying, | 2 |
| 7 | Electrostatic charging, air sleeve boom sprayer | 2 |
| 8 | Disinfection of seed beds by micro waves and other methods | 1 |
| 9 | Safety aids for operator and advances in plant protection method | 2 |

| | | |
|---|---|---|
| 10 | Field plot machinery and its importance | 1 |
| 11 | Fertilizer and manure spreader | 2 |
| 12 | Machines for residue management (in situ) | 4 |
| 12 | Machines for residue management (ex situ) | 2 |
| 14 | Silage and hay making machines | 3 |
| 15 | Machinery for horticultural crops | 2 |
| 16 | Crop specific machines for cotton, sugarcane, forage/fodder | 2 |
| 17 | Machines for processing and handling of agricultural products | 1 |
| | **Total** | **32** |

**Suggested Reading:**


1. Boson E S, Sultan-Shakh E G, Smirnov I I and Verniaev O V 2016. *Theory, Construction and Calculation of Agricultural Machines.* Scientific Publishers.
2. Kanafozski C and Karwowiki T 1976. *Agricultural Machines and Construction.* Vol. I &II, Translated and published by US Dept. of Agriculture and National Science Foundation, Washington, D.C., USA.
3. Kepner R A, Bainer R and Barger E L 2017. *Principles of Farm Machinery*. CBS publishers and Distributors Pvt. Ltd., New Delhi, India.

**FMPE 614 Ergonomics in Working Environment 2+1**

## Objectives:

To enable the student to understand the concept of designing the working environment and designing farm machinery and equipment to ensure operators comfort and safety.

## Unit-I

Musculoskeletal problems in sitting and standing postures-behavioral aspects of posture, body mechanics. Workspace design for standing and seated workers. Display units, controlsand human-machine interaction, design of static work.

## Unit-II

Noise and noise control. Measurement of noise and safe limits. Protection from noise. Vibration and health. Vibrations generated by agricultural machines. Types of vibrations: Whole body vibrations and hand transmitted vibrations. Methods of measurements of
vibrations, hazards of vibrations. Vibration White Fingers (VWF). Vibration reductions inagricultural machines.

## Unit-III

Working environment-heat and cold stress conditions. Thermal balance of human body. Measurement of thermal environment. Heat and cold stress condition. Thermoregulatory system of human body. Heat and cold acclimatization. Effect of climate on human performance. Environmental dust and its measurement: Organic and inorganic dust. Types of dust and their hazards: Respirable, thoracic and inhalable dust. Personal protection from dust.

**Unit-IV**

Time motion study and its purpose. Application of Time motion study in agricultural and processing operations. Recent research works related to ergonomics in agriculture.

## Practical:

Design of workspace for static work in standing and sitting positions. Study of body mechanics and postures in design of agricultural machinery. Human energy expenditure, calibration of subjects, Human work load and its assessment. Study of work and rest schedule. Measurement of visibility of tractors. Measurement and control of noise in tractors and self-propelled machines. Measurement of human vibrations in farm tractors and agricultural machines. Study of dust generated in agricultural operations.

## Course Outcome:

Ability to design working environment of different agricultural machinery for efficient andsafe operations.

## Teaching Schedule

| Sr No. | Topic | No. of lectures |
|---|---|---|
| 1 | Basics of body mechanics, stability and support | 1 |
| 2 | Control of muscle function, fatigue and discomfort | 1 |
| 3 | Musculoskeletal problems in sitting and standing posture | 2 |
| 4 | Behavioural aspects of posture, risk factors formusculoskeletal | 1 |

| | | |
|---|---|---|
| | disorders | |
| 5 | Importance of ergonomics in workspace design | 1 |
| 6 | Workspace design for standing workers | 1 |
| 7 | Workspace design for seated workers | 1 |
| 8 | First hourly examination | 1 |
| 9 | Visual display units, controls and human- machineinteraction | 1 |
| 10 | Design of static work | 1 |
| 11 | Importance of noise control and safe limits for human | 1 |
| 12 | Measurement of noise, reduction and protection | 1 |
| 13 | Machine vibrations, human vibrations and health hazards | 1 |
| 14 | Whole body vibrations and hand transmitted vibrations | 1 |
| 15 | Methods of measurements of vibrations and health hazards | 1 |
| 16 | Vibration reduction techniques for agricultural machines | 1 |
| 17 | Mid-semester examination | 1 |
| 18 | Working environment- heat and cold stress conditions, thermal balance of human body | 1 |
| 19 | Measurement of thermal environment | 1 |
| 20 | Thermo-regulatory system of human body, heat and cold acclimatization, effect of climate on human performance | 2 |
| 21 | Environmental dust and its measurement, type of dust-organic and inorganic dust, dust health hazard | 1 |
| 22 | Respirable, thoracic and inhalable dust, protection from dust | 1 |
| 23 | Time motion study and its purpose | 1 |
| 24 | Application of time motion study in agricultural andprocessing operations | 1 |
| 25 | Recent research work related to physiological parameters of ergonomics in agriculture | 1 |
| 26 | Recent research work related to tractor space layout anddesign of controls | 1 |
| 27 | Recent research work related to noise studies on farmmachines | 1 |
| 28 | Recent research work related to vibrations studies on farm machines | 1 |

| | | |
|---|---|---|
| 29 | Recent research work related to accidents and safety studies on farm machines | 1 |
| 30 | Revision and discussion | 1 |
| | **Total** | **32** |

**List of Practicals**

| Sr.No. | Topic | No. of practical |
|---|---|---|
| 1 | Design of workspace for static work in standing orsitting posture | 1 |
| 2 | Study of body mechanics and posture in design of agricultural machinery | 2 |
| 3 | Study of displays and controls in tractors | 1 |
| 4 | Calibration of subjects on ergometer and treadmill | 2 |
| 5 | Human workload and its assessment | 1 |
| 6 | Study of work and rest schedule | 1 |
| 7 | Measurement of visibility to tractor operators | 1 |
| 8 | Measurement of noise in tractors and self-propelled machines | 1 |
| 9 | Measurement of machine component vibration | 1 |
| 10 | Measurement of hand arm vibrations | 1 |
| 11 | Measurement of whole body vibrations | 1 |
| 12 | Study of dust generated in agricultural operations | 1 |
| 13 | Case study of design improvement in agriculturalmachine/ tool through ergonomic concept | 1 |
| 14 | Practical examination | 1 |
| | **Total** | **16** |

**Suggested Reading:**


1. Bridger R S 2009. *Introduction to Ergonomics.* 3rd edition CRC Press, Boca Raton, USA.
2. Sanders M S and McCormick E J 1993. *Human Factors in Engineering and Design.*McGraw Hill, New York, USA.
3. Astrand P O, Rodahl K, Dahl H A and Stromme S B 2003. *Textbook of Work Physiology: Physiological Bases of Exercise*. Champaign IL: Human Kinetics.
4. Gite L P, Majmudar J, Mehta C R and Khadatkar A 2009. *Anthropometric and Strength Data of Indian Agricultural Workers for Farm Equipment Design*. Central Institute of Agricultural Engineering, Bhopal, India.
5. Pearsons K 2003, *Human Thermal environments: The Effects of Hot, Moderate and Cold Environment on Human Health, Comfort and Performance.* Taylor and

Francis, New York, USA.

6. Kroemer K H E and Grandjean E 1997. *Fitting the Task to the Human: A Textbookof Occupational Ergonomics.* Taylor & Francis, Philadelphia, USA.

7. Gite L P, Agrawal K N, Mehta C R, Potdar R R and Narwariya B S. 2019. *Handbook of Ergonomical Design of Agricultural Tools, Equipment and work Places.* Jain Brothers, New Delhi.

8. Ernest J. McCromick 1976 *Human Factors in Engineering and Design*. McGraw hill. 4th Edition.

9. Grandiean E. 1980. *Fitting the Task to the Man*. Taylor and Francis ltd, London.

10. Murrel K. F. H. 1965. *Ergonomics: man in his Working environment*. Chapman and Hall, London.

**FMPE-615 Machinery for Crop Residue Management and Conservation in Agriculture for Field and Horticultural crops … 2+1**

**Objectives:**
To bring to focus crop residue management in field crops and horticultural crops that are not covered under conventional operations and the machinery used for such operations. To increase productivity and environmental sustainability.

**Unit-I**
Crop residue management ,Introduction, definition, Need of residue management

**Unit -II**
Competing uses of crop residues, generation, utilization, adverse consequences, reasons behind on-farm burning of crop residues, livestock feed, compost making, energy sources, bio-fuel and bio-oil production, biomethanation, gasification, biochar production,

**Unit –III**
Crop residues management strategies, managing crop residues with conservation agriculture, impact of crop residues on soil health and crop yield, pests, constraints of using crop residues with conservation, opportunities to manage crop residues. Methods of crop residue management

**Unit –IV**
Machineries for crop residue management, Happy combo seeder, rotavator, straw baler, straw reaper, reversible mould board plough, disc plough ,mulcher, shredder, harrow, sugarcane trash slasher, mover, hay rake, baler, straw walker, two side discharge shredder.

**Unit-V**

Objectives and principles of conservation agriculture, conservation tillage: Minimum tillage, happy seeder, roto till drill, slit till drill, strip tillage. Resource conservation technology.

**Teaching Schedule**

| Sr. No. | Topic | No. of lectures |
|---|---|---|
| 1. | Introduction to crop residue management, definition and its need. | 2 |
| 2. | Generation, utilization, adverse consequences, reasons behind on-farm burning of crop residues. | 2 |
| 3. | Competing uses of crop residues, livestock feed, compost making, energy sources. | 2 |
| 4. | Bio-fuel and bio-oil production, biomethanation | 2 |
| 5. | Gasification and biochar production. | 2 |
| 6. | Crop residues management strategies, managing crop residues with conservation agriculture. | 1 |
| 7. | Impact of crop residues on soil health and crop yield, pests, constraints of using crop residues with conservation, | 2 |
| 8. | Different opportunities to manage crop residues.<br><br>Methods of crop residue management | 2 |
| 9. | Machineries for crop residue management | 2 |

| | | |
|---|---|---|
| | Construction details, working principles of happy combo seeder, mulcher, rotavator. | |
| 10. | Construction details and working principles of straw baler, shredder, straw reaper, two side discharge shredder. | 3 |
| 11. | Constructional details and working principles of reversible mould board plough, disc plough, harrow. | 3 |
| 12. | Constructional details and working principles of sugarcane trash slasher, mover, hay rake, baler, straw walker | 2 |
| 13. | Objectives and principles of conservation agriculture, | 1 |
| 14. | Conservation tillage: Minimum tillage, happy seeder, roto till drill, slit till drill, strip tillage. | 3 |
| 15. | Resource conservation technology, Mechanization strategy for conservation agriculture | 3 |
| | **Total** | **32** |

**List of Practicals**

| **Sr. No.** | **Topic** | **No. of Practicals** |
|---|---|---|
| 1. | Study of generation, utilization of crop residues, compost making | 1 |
| 2. | Studies on bio-fuel and bio-oil production, biomethanation | 1 |
| 3. | Study of gasification and biochar production. | 2 |
| 4. | Study of mould board plough as a pest management tool on farm | 1 |
| 5. | Study of happy combo seeder, | 2 |
| 6. | Study of mulcher, sugarcane trash slasher, hay rake, baler, straw walker. | 2 |
| 7. | Study of rotavator for crop residue management | 1 |
| 8. | Study of mover, straw baler, straw reaper and shredder, two side discharge shredder | 2 |
| 9. | Study of disc plough and harrow for crop residue management | 2 |
| 10. | Study of conservation tillage: Happy seeder, roto till drill, slit till drill, strip tillage. | 2 |
| | **Total** | **16** |

**Suggested Reading:**


1. Pathak H, Jain N and Bhatia A 2012. *Crop Residues Management with Conservation Agriculture: Potential, Constraints and Policy Needs.* Published by the Director, Indian Agricultural Research Institute, New Delhi 110 012.
2. Kepner R A, Bainer R and Barger E L 2017. *Principles of Farm Machinery.* CBS publishers and Distributors Pvt. Ltd., New Delhi, India.
3. Bosoi E S, Sultan-shakh E G, Smirnov I I and Vernaiev O V 2016. *Theory, Construction and Calculation of Agricultural Machines.* Scientific Publishers.
4. Bastewad T B, Deshmukh V D, Pacharne M M and Pawar D D 2021. *Research Compendium.* AICRP on FIM, Dr. Annasaheb Shinde College of Agricultural Engineering and Technology, MPKV, Rahuri, Maharashtra.

## STAT 501 Statistical Methods for Research Works 2+1

### Objective
To expose students to various statistical techniques for analysis of data and interpretation of results.

### Unit I
Probability and probability distributions. Principle of least squares. Linear and non-linear regression. Multiple regression. Correlation analysis. Selection of variables. Validation of models. Sampling techniques. Determination of sample size. Sampling distribution of mean and proportion.

### Unit II
Hypothesis testing. Concept of p-value. Student's t-test. Large sample tests. Confidence intervals. ANOVA and testing of hypothesis in regression analysis. Analysis of variance for one way and two way classification (with equal cell frequency). Transformation of data.

### Unit III
Advantages and disadvantages of nonparametric statistical tests. Scales of measurements. Run-test. Sign test. Median test. Wilcoxon-Mann Whitney test. Chi-square test. Kruskal-Walli's one way and Friedman's two way ANOVA by ranks. Kendall's Coefficient of concordance.

### Practical
Fitting of distributions. Sample and sampling distributions. Correlation analysis. Regression analysis (Multivariate, quadratic, exponential, power function, selection of variables, validation of models, ANOVA and testing of hypothesis). Tests of significance (Z-test, t-test, F-test and Chi-square test). Analysis of variance. Non- parametric tests.

### Course outcome
The students will be able to understand different techniques for analyzing the data of their research work.

### Teaching Schedule

| S.No. | Topics | No. of Lectures |
|---|---|---|
| 1. | Elementary statistics | |
| 2. | Probability theory | 2 |
| 3. | Probability distributions (Binomial, Poisson and Normal) | 3 |
| 4. | Sampling techniques, Determination of sample size | 2 |
| 5. | Sampling distribution of mean and Proportion | 1 |
| 6. | Hypothesis testing concept of p-value | 1 |
| 7. | Large sample (mean, proportion) | 1 |
| 8. | Student's t-test (Single mean, Difference of mean for independent samples and paired observations) and F-test | 3 |
| 9. | Analysis of variance (one way and two way), Transformation of data | 2 |
| 10. | Correlation analysis and testing (Bivariate, Rank, Intra-class, Partial, Fisher's Z-transformation) | 2 |
| 11. | Multiple linear regression and model validation | 2 |
| 12. | Testing of coefficient of determination and regression coefficient | 2 |
| 13. | Selection of variables in regression (forward substitution method and step-wise regression) | 1 |
| 14. | Non-Linear regression (Quadratic, exponential and Power) | 2 |
| 15. | Introduction to Non-parametric and scales of measurements | 1 |
| 16. | Chi-square test (Goodness of fit, Independence of attributes, | |

| | | |
|---|---|---|
| | homogeneity of variances) | 2 |
| 17. | One Sample test (Sign test, Median test, Run rest,) | 2 |
| 18. | Two sample test (Wilcoxon Sign test, Mann Whitney test, Chi square test for two independent samples) | 1 |
| 19. | K-Sample (Kruskal-Walli's test and Friedman's two way ANOVA) | 2 |
| 20. | Kendall's coefficient of concordance | 1 |
| | **Total** | **33** |

**List of Practicals**

| S.No. | Topics | No. of Practicals |
|---|---|---|
| 1. | Elementary statistics | 1 |
| 2. | Probability distributions (Binomial, Poisson and Normal) | 1 |
| 3. | Sampling techniques, Determination of sample size, Sampling distribution of mean and Proportion | 1 |
| 4. | Large sample (mean, proportion) | 1 |
| 5. | Student's t-test (Single mean, Difference of mean for independent samples and paired observations) and F-test | 1 |
| 6. | Analysis of variance (one way and two way), Transformation of data | 2 |
| 7. | Correlation analysis and testing (Bivariate, Rank, Intra-class, Partial, Fisher's Z-transformation) | 1 |
| 8. | Multiple linear regression and model validation | 1 |
| 9. | Testing of coefficient of determination and regression coefficient | |
| 10. | Selection of variables in regression (Forward substitution method and step-wise regression) | 1 |
| 11. | Non-Linear regression (Quadratic, exponential and Power) | 2 |
| 12. | Introduction to Non-parametric and scales of measurements | |
| 13. | Chi-square test (Goodness of fit, Independence of attributes, homogeneity of variances) | 2 |
| 14. | One Sample test:Sign test, Median test, Run rest, Two sample test: Wilcoxon Sign test, Mann Whitney test, $X^2$ test for two independent samples | 1 |
| 15. | K-Sample: Kruskal-Walli's test and Friedman's two way ANOVA, Kendall's coefficient of concordance | 1 |
| | **Total** | **16** |

**Suggested Reading**


- Anderson T W 1958. *An Introduction to Multivariate Statistical Analysis*. John Wiley.
- Dillon W R and Goldstein M. 1984. *Multivariate Analysis - Methods and Applications*. John Wiley.
- Electronic Statistics Text Book: http://www.statsoft.com/textbook/stathome.html
- Goon A M, Gupta M K and Dasgupta B. 1977. *An Outline of Statistical Theory*. Vol. I. The World Press.
- Goon A M, Gupta M K and Dasgupta B. 1983. *Fundamentals of Statistics*. Vol.

I. The World Press.

- Hoel P G. 1971. *Introduction to Mathematical Statistics*. John Wiley.
- Hogg R V and Craig T T. 1978. *Introduction to Mathematical Statistics*. Macmillan.
- Montgomery and Runger 2014. *Applied Statistics and Probability for Engineers.* John Wiley
- Morrison D F. 1976. *Multivariate Statistical Methods*. McGraw Hill.
- Siegel S, Johan N and Casellan Jr. 1956. *Non-parametric Tests for Behavior Sciences*. John Wiley.

**ME 507 Fatigue Design 2+1**

## Objectives:

The course provides an understanding on fatigue design considerations of mechanical components. The causes of fatigue in brittle and ductile materials are taught with focus on crack initiation, propagation and fracture.

## Unit-I

Theories of failure, maximum normal stress, maximum shear stress and distortion energytheory, failure of ductile materials, failure of brittle materials.

## Unit-II

Stress concentration and its evaluation, stress concentration of ductile and brittle materials under static loading and under dynamic loading, determining geometric stress concentration factors, designing to avoid stress concentration.

## Unit-III

Fatigue of machine components, mechanism of fatigue failure, fatigue failure models and their considerations in design of machine elements, fatigue loads. Fatigue testing and presentation of fatigue data. Influence of stress conditions on fatigue strength/endurance limitof metals. Low and high cycle fatigue

## Unit-IV

Cumulative fatigue damage. Designing for finite and infinite life. Improving fatigue resistance of machine elements. Stress corrosion. Corrosion fatigue.

**Practical:**

Fatigue tests on testing machine(s) for specimens of different materials having different discontinuities/stress raisers and various surface conditions. Determination of correlation between fatigue limit and ultimate strength of material. Problems in fatigue designof common machine component.

## Course Outcome:

The students is able to understand technical aspects and principles of fatigue design. The student can design the engineering product having good durability and long fatigue life

## Teaching Schedule

| Sr. No. | Topic | No. of Lectures |
|---|---|---|
| 1 | Introduction to cyclic loading and Fatigue Design | 1 |
| 2 | Types of Loads and Stresses, Different theories of Failure like maximum normal stress, maximum shear stress and distortion energy theory etc. | 3 |
| 3 | Determining stress concentration based on geometric stress concentration factors, Design considerations to avoid stress concentration of ductile and brittle materials. | 3 |
| 4 | Mechanical failure. Macroscopic failure modes, Behavior of brittle and ductile materials in fatigue and stress concentration. Fracture in brittle and ductile materials, characteristics of fracture surfaces, inter-granular and intra- granular failure. | 4 |

| | | |
|---|---|---|
| 5 | Cleavage and micro-ductility, growth of fatigue cracks, The ductile/brittle fracture transition, temperature for notched and un notched components. Fracture at elevated temperature. | 3 |
| 6 | Fatigue of machine components, mechanism of fatigue failure. Low and high cycle with examples mean stress R ratio, strain and load control. S-N curves. | 4 |
| 7 | Goodman's rule and Miners rule. Micro-mechanisms of fatigue damage, fatigue limits and initiation and propagation control, leading to a consideration of factors enhancing fatigue resistance. | 3 |
| 8 | Fatigue loads and mathematical models. Fatigue testing and presentation of fatigue data, Influence of stress conditions on fatigue strength/endurancelimit of metals. | 3 |
| 9 | Total life and damage tolerant approaches to life prediction. Fatigue failure models and their considerations in design of machine elements. Cumulativefatigue damage and Designing for finite and infinite life | 2 |
| 10 | Methods to improve fatigue resistance of machine elements. Improvement of fatigue strength by chemical/metallurgical processes such as nitriding, flame hardening, case carburizing. Fatigue strength enhancement by mechanical work, cold rolling, peening, shot peening. | 3 |
| 11 | Environmental Assisted Cracking: Stress corrosion cracking, Hydrogen embrittlement, Corrosion fatigue. Creep: Creep curves, Mechanisms of creep, Stress rapture test, Life prediction, High temperature alloys. | 3 |
| | **Total** | **32** |

**List of Practicals**

| **Sr. No.** | **Topic** | **No. of Practicals** |
|---|---|---|
| 1 | Load measurement using Load indicator, Load Cells | 1 |
| 2 | Strain measurement using Strain Gauge | 1 |
| 3 | Stress measurement using strain rosette | 1 |
| 4 | Determination of Fatigue strength measurement of S45C or alike material under same loading condition for different stress concentrations factors (like holes, notches, sharp corners for at least 5 different samples). Comparison to be listed. | 5 |
| 5 | Study to improvement Fatigue Design based on at least 5 different processes like flame hardening, case carburizing, nitriding, shot peening, peening etc or alike processes. | 5 |
| 6 | Determination of correlation between fatigue limit and ultimate strength ofcommercially available S45C material for three different samples | 3 |
| | **Total** | **16** |

**Suggested Reading:**


1. Lessells, J.M. 1955. *Strength and resistance of metals*. John Wiley & sons, Michigan.
2. T.L. Anderson. 2005. *Fracture Mechanics Fundamentals and Applications*. CRC press, BocaRaton.
3. Bhandari V.B.2019. *Design of Machine Elements*. Mcgraw Hill Education Pvt Ltd, NewDelhi
4. Peterson, R.E. 1953 *Stress Concentration Design Factors*. John Wiley & Sons, New York.Meguid,
5. S.A.1989. *Engineering Fracture Mechanics*. John Wiley & Sons, New York
6. Kare Hellan.1985. *Introduction to Fracture Mechanics.* Mc Graw Hill Book Co, New York.

**ME 515 Computer Aided Design 2+1**

## OBJECTIVE

The course provides an understanding on computer aided design. It provides in depth knowledge about 2-d drawing, 3-D Modeling and finite element analysis for optimumproduct design.

### Unit-I

Introduction to computer aided design, scope of computer aided machine design, design process and design environments. Geometric modeling and interactive graphic, engineering analysis, design review and automated drafting, modeling, viewing,

### Unit-II

Solid modeling, boundary representation, constructive solid geometry, feature based modeling. Computer aided analysis and synthesis of common mechanical components, a bar,a beam and a shaft, comparison with analytical results.

### Unit-III

Application of numerical methods and optimization techniques to machine design problems, Computer aided selection of standard mechanical components. Introduction to FEM. FEA using two dimensional and three dimensional elements; plain strain and plain stress problems, finite element mesh, automatic meshing techniques, limitations of FEM.

**Practical:**

Computer aided design problems for machine components, use of standard software, CAD models for other applications. Development of FEM models for analysis of a bar, beam and a shaft. Practice in using an FEM software on other real life problems like spanners, connecting rods.

### Course Outcome:

The students can design a product having better accuracy, less errors, increased productivity and shorter lead times with the help of CAD.

### Teaching Schedule

| Sr. No. | Topic | No. of Lectures |
|---|---|---|
| 1 | Introduction to Engineering Design, design steps and computer aided design. | 2 |
| 2 | Software and workstation selection for CAD. Design process with and withoutCAD | 3 |
| 3 | Input and output devices, Display devices; GKS, IGES and STEP; Modelingand viewing, Application areas of CAD. | 3 |
| 4 | Wireframe model, solid modeling, Boundary Representation (B-rep), Constructive Solid Geometry (CSG). | 3 |
| 5 | Mass , volumetric properties calculations; surface modeling, concepts of hidden-line removal and shading: Mechanical Assembly Kinematics analysis and simulation | 3 |
| 6 | Parametric Modeling Technique .Non-parametric and parametric representation of curves. | 2 |
| 7 | Parametric representation of Hermite Cubic, Beizer and B-spline curves; | 2 |

| | | |
|---|---|---|
| | Surface and its analysis. Representation of Analytical and synthetic surfaces. | |
| 8 | Numerical methods and optimization techniques to engineering design Problems | 3 |
| 9 | Overview of FEM, Advantages and applications, recent advance in FEM, FEA software Basic principles and general procedure of FEM | 3 |
| 10 | Analyzing simple machine elements and comparing with analytical results ofsimple machine elements like bar, beam and a shaft. | 4 |
| 11 | Simple Project. Mathematical modelling and design calculations of machines. | 4 |
| | **Total** | **32** |

**List of Practicals**

| Sr. No. | Topic | No. of Practicals |
|---|---|---|
| 1 | Introduction to 2-D drawing. Use of any relevant software | 2 |
| 2 | Study of drawings in First angle and third angle projections | 1 |
| 3 | 2-D assembly drawing and generation of BOM | 1 |
| 4 | 3-D Modeling. GKS, IGES and STEP; Modeling and viewing. Use of relevant software | 3 |
| 5 | Assembly Design | 2 |
| 6 | Introduction to FEA software. Mesh generation (Nodes and elements).Use ofany other relevant software for FEA | 3 |
| 7 | Practice on Boundary conditions like loads and constraints. | 2 |
| 8 | Study of static and dynamic loading conditions. Study of Machine elementslike bars, beams and shafts or other machine elements. | 2 |
| | **Total** | **16** |

**Suggested Reading**


1. Mikell P. Groover, Emory W. Zimmers.2000 CAD/CAM Computer Aided Design and Manufacturing, PHI,
2. Zeid Ibraham.1991. CAD/CAM - theory and Practice, Tata McGraw Hill, New Delhi
3. Chandandeep Grewal & Kuldeep Sareen.2007. CAD/CAM Theory and Concepts. S.Chand, New Delhi
4. P. N Rao.2010. CAD/CAM. Tata McGraw Hill, New Delhi

**CSE 506 Digital Image Processing 2+1**

## Objectives:

To give an overview of digital image processing including visual perception, image formation, spatial transformations, image enhancement, color image representation and processing, edge detection, image segmentation and morphological image processing.

## Unit-I

Digital image fundamentals, elements of visual perception, light and the electromagnetic spectrum, image sensing and acquisition, image sampling and quantization, basic relationships between pixels, linear and nonlinear operations.

## Unit-II

Image enhancement in the spatial domain, basic gray level transformations, histogram processing, basics of spatial filtering, smoothing spatial filters, sharpening spatial filters.

## Unit-III

Color image processing, color fundamentals, color models, pseudo color image processing, basics of full-color image processing, color transformations, smoothing and sharpening, color segmentation.

## Unit-IV

Image segmentation, detection of discontinuities, edge linking and boundary detection, thresholding, region-based segmentation, segmentation by morphological watersheds.

## Unit-V

Morphological image processing, dilation and erosion, opening and closing, extensions togray-scale images.

## Practical:

To write program to read and display digital image, image processing program using point processing method, program for image arithmetic operations, program for image logical operations, program for histogram calculation and equalization, program for geometric transformation of image, understand various image noise models and to write programs for image restoration and to remove noise using spatial filters. Brief outline of image processing tools.

## Course Outcome:

This course introduces digital image processing. It focuses on the theory and algorithms underlying a range of tasks including acquisition, formation, enhancement, segmentation and representation.

## Teaching Schedule

| Sr. No. | Topic | No. of Lectures |
|---|---|---|
| 1 | Introduction and Fundamentals, Motivation and Perspective, Applications, Components of Image Processing System, | 3 |
| 2 | Element of Visual Perception, A Simple Image Model | 1 |
| 3 | Sampling and Quantization. | 2 |
| 4 | Light and the electromagnetic spectrum, image sensing and acquisition | 2 |

| | | |
|---|---|---|
| 5 | Basic relationships between pixels, linear and nonlinear operations | 2 |
| 6 | Image Enhancement in Spatial Domain | 2 |
| 7 | Introduction; Basic Gray Level Functions | 2 |
| 8 | Histogram Specification | 2 |
| 9 | Basics of spatial filtering, smoothing spatial filters, sharpening spatial filters | 2 |
| 10 | Color image processing, color fundamentals | 1 |
| 11 | Color models, pseudo color image processing | 1 |
| 12 | Color transformations, smoothing and sharpening, color segmentation. | 2 |
| 13 | Image segmentation, detection of discontinuities | 1 |
| 14 | Edge linking and boundary detection, thresholding, region-based segmentation | 2 |
| 15 | Segmentation by morphological watersheds | 1 |
| 16 | Morphological image processing, dilation and erosion | 2 |
| 17 | Opening and closing, extensions to gray-scale images | 2 |
| | **TOTAL** | **30** |

**List of Practical**

| Sr. No. | Topic | No. of Practicals |
|---|---|---|
| 1 | Display digital image, image processing program using point processing method, program for image arithmetic operations | 3 |
| 2 | Program for image arithmetic operations, image logical operations, histogram calculation and equalization | 4 |
| 3 | Program for geometric transformation of image, understand variousimage noise models | 4 |
| 4 | Programs for image restoration and to remove noise using spatial filters | 4 |
| 5 | Brief outline of image processing tools | 1 |
| | **Total** | **16** |

**Suggested Reading:**

1. Rafael C G and Richard E. W. *Digital Image Processing.* Third Edition, Pearson Education.
2. Jayaraman S, Esakkirajan S and Veerakumar T. *Digital Image Processing*. Tata McGrawHill Publication.
3. Sridhar S. *Digital Image Processing.* Oxford University Press

**PFE 511 Engineering Properties of Biological Materials 2+1**

**Objectives**

**Unit 1**
Introduction to engineering properties of biological materials and food quality ;Classification of food properties: Physical and physico-chemical properties - Mechanical properties, Thermal properties, Thermodynamic properties, Mass transfer properties, Electromagnetic properties, Physico-chemical constants. Kinetic properties : Quality kinetic constants, Microbial growth, decline and death kinetic constants, Sensory properties, Tactile properties, Textural properties, Color and appearance, Taste - Odor, Sound,. Health properties : Positive health properties, Negative health properties

**Unit II**
Application of engineering properties of biological materials : Physical properties, Frictional Properties, Aero And Hydro-Dynamic Properties, Thermal Properties, Optical Properties, Dielectric Properties, Acoustic Properties, Electrical Properties, Rheological Properties, Textural Properties

**Unit III**
Physical Properties of Biomaterials : Physical properties of biomaterials like shape, size, volume and surface area, Physical characteristics of biomaterials: volume, density, specific gravity and surface area

**Unit IV**
Engineering Properties : Basics of Thermal properties, Measurement of thermal properties of biomaterials, Aerodynamic properties of biomaterials, Frictional properties of biomaterials

**Unit V**
Rheological Properties of Biomaterials: Some basic concepts of rheology, Fluid flow behavior, Stress relaxation and Creep behavior, Rheological properties measurement and equipment's

**Unit VI**
Food Quality : Introduction to Food Quality, Objective Texture measurement, Concept of colour in food quality, Colour measurement methods, Concept of Flavor in food quality, Flavor extraction and Measurement methods. Food Sampling : FOOD SAMPLING, Liquid Food Samples And Extraction Techniques
Sensory quality :. Importance of Sensory Attributes, Controls for Test Room And Factors Effecting Sensory Evaluation, Methods of Sensory Evaluation, Interpretation of Sensory Results And Statistical Analysis

**UNIT VII**
Quality Control and Management : Total Quality Management, Tools For Quality Improvement : FOOD LAWS-I ( FSSAI, Weights & Measures Act, Essential Commodities Act and other Regulatory Agencies), NATIONAL FOOD LAWS ( BIS, AGMARK, FPO, Consumer Protection Act) Standards and regulations in food quality management : HACCP, Good Manufacturing and Hygienic Practices, Food Safety Management System-Iso 22000:2005

**Practicals**
Determination of Moisture Relations of Biological Materials, Estimation of Mechanical properties of solids. Hands on Acoustic firmness sensing. Evaluation of Mechanical damage. Studies on Rheological properties of liquid foods. Study of Aerodynamic properties. Exercise on NIR spectroscopy. Bulk optical properties of different food materials.

**Suggested Readings**

1. Jowitt, R. (1974). Classification of foodstuffs and physical properties. Lebensmittel-Wissenschaft und Technologie. 7(6): 358-371.
2. Piccolo, D. & D'Elia, A. (2008). A new approach for modelling consumers' preferences. Food Quality and Preference 19 247–259.
3. Rahman M. S. & McCarthy O. J. (1999): A classification of food properties, International Journal of Food Properties, 2:2, 93-99.
4. Guàrdia, M. D., Aguiar, A. P.S., Claret, A., Arnau, J. & Guerrero, L. (2010). Sensory characterization of dry-cured ham using free-choice profiling. Food Quality and Preference, 21: 148–155.
5. Hester, R.E. & Harrison, R.M. 2001. Food safety and Food Quality. The royal society of Chemistry, Cambridge, UK
6. Amin, M.N., Ahammed, S., Roy K.C. & Hossain, M.A. (2005). Coefficient of friction of pulse grains on various surfaces at different moisture content, International Journal of Food Properties, 8:1, 61-67
7. Bourne, M.C. (1982). Food Texture and Viscosity. New York: Academic Press.
8. Jambrak, A. R., Herceg, Z., Šubaric´, D., Babic´, J., Brncic´, M., Brncic´,S. R., Bosiljkov, T., Cvek, D., Tripalo, B., Gelo, J. (2010). Ultrasound effect on physical properties of corn starch. Carbohydrate Polymers, 79, 91–100.
9. Kumar, P., Coronel, P., Simunovic, J. & Sandeep, K.P. (2008). Thermophysical and dielectric properties of salsa con queso and its vegetable ingredients at sterilization temperatures. International Journal of Food Properties, 11:1, 112-126.
10. Lan, Y., Fang, Q., Kocher, M. F. & Hanna, M. A. (2000). Thermal properties of tapioca starch, International Journal of Food Properties, 3:1, 105-116
11. McKenna, B.M., Lyng, J., Brunton, N. & Shirsat, N. (2006). Advances in radio frequency and ohmic heating of meats. Journal of Food Engineering. 77: 215–229
12. Mohsenin, N.N. 1986. Physical Properties of Plant and Animal Materials, 2nd ed.; Gordon and Breach Science Publishers: New York
13. Sahin S. & Sumnu, S. G. 2006. Physical Properties of Foods. Springer, USA
14. Sharma, R., Sogi, D.S. & Balasubramanian, S. (2012). Aerodynamic characteristics of unshelled and shelled sunflower seeds: significance of moisture and cultivars. International Journal of Food Properties, 15:1, 1-10

**RPE 601 Research and Publication Ethics 1+1**

**Aim of the Course:**
This course is mainly focusing on basics of philosophy of science and ethics, research integrity, publication ethics. Hands on sessions are designed to identify research misconduct and predatory publications. Indexing and citation databases, open access publications, research and p metrics and plagiarism tools introduced in the course.

**THEORY**

**Unit 1: Philosophy and Ethics**
1. Introduction to philosophy: definition, nature and scoope, concept, branches
2. Ethics: definitino, moral philosophy, nature of moral judgements and reations.

**Unit 2: Scientific Conduct**
1. Ethics with respcet to science and research
2. Intellectual honest and research integrity
3. Scientific misconducts: falsification, fabrication, and plagiarism.
4. Redundant publications: duplicate and overlapping publications, salami slicing
5. Selective reporting and misrepresentation of data.

**Unit 3: Publication Ethics**
1. Publication ethics: definition, introduction and importance
2. Best practices/standards setting initiatives and guidelines: COPE, WAME, etc.
3. Conflicts of interest
4. Publication misconduct: definition, concept, problems that lead to unethical behavior and vice verse, types
5. Violation of publication ethics, authorship and contributor ship
6. Identification of publication misconduct, complaints and appeals
7. Predatory publishers and journals

**Unit 4: Open Access Publishing**
1. Open access publications and initiatives
2. SHERPA/RoMEO online resourse to check publisher copyright and self-archiving policies.
3. Software tool to identify predatory publications developed by SPPU
4. Journal finder/ journal suggestion tools viz. JANE, Elsevier Journal Finder, Springer Journal Suggester, etc.

**Unit 5: Publication Misconduct**
A. Group Discussions
1. Subject specific ethical issues, FFP, authorship
2. Conflicts of interest
3. Complaints and appeals: examples and fraud from India and abroad

B. Software tools
Use of plagiarism software like Turnitin, Urkund and other open source software tools.

**Unit 6: Databases And Research Metrics**
A Databases
1. Indexing detabeses
2. Citation detabases: Web of Science, Scopus, etc.

B. Research Metrics
Impact Factor of journal as per journal citation report, SNIP, SJR, IPP, Cite Score.
Metrics: h-index, g index, i10 index, altmetrics

**Practicals**

**1. Types of Reaserach**

1. Basic Research:
2. Applied Research:
3. Descriptive Research:
4. Analytical Research:
5. Correlational Research:
6. Qualitative Research:
7. Quantitative Research:
8. Experimental Research:
9. Explanatory Research:
10. Exploratory Research:
11. Selection of Domain/Area of Research:

**2. Formulating a Research Problem and Identification of Keywords:**

1. Literature Survey:
2. Redefining Research Problem, Objectives and Outcomes:
3. Research Proposal:
4. Identifying Variable /Parameters and Research Design:
5. Data Collection and Representation:
6. Testing of Proposed Design on Collected Data/Hypothesis Testing:

**3. Results and Analysis:**

1. Research Report Writing:
2. Features of Good Research Study

**4. Journal Search**

1. Open Access Publishing
2. Impact Factor of journal as per journal citation report, SNIP, SJR, IPP, Cite Score. Metrics: h-index, g index, i10 index, altmetrics

**Suggested Readings**


- Bird,A. (2006). Philosophy of Sciences. Routledge
- MacIntyre, Alasdair (1967). A Short History of Ethics. London
- P.Chandah. (2018). Ethics in Competitive Research: Do not get Scooped; do not get plagiarized.
- National Academy of Sciences, National Academy of Engineering and Institute of Medicine (2009)., National On being a Scientist: A guide to responsible conduct in Research : third edition, National Academies Press
- Hall GM. Book Farthing MJG. How to Write a Paper. UK Blackwell Publishing; 2008
- NAS-NAE-IOM. Responsible Science: Ensuring the Integrity of the Research Process. Washington, DC: National Academy Press; 1992.
- Alexander M. Novikov & Dmitry A. Novikov, Research Methodology: From Philosophy of Science to Research Design, CRC Press Taylor & Francis Group, (2013).
- C. R. Kothari, Research Methodology: Methods and Techniques, New Age International (P) Ltd., New Delhi (2004).

- David Bridges, Philosophy in Educational Research: Epistemology, Ethics, Politics and Quality, Springer International Publishing AG (2017).
- Deepak Chawla & Neena Sondhi, Research Methodology: Concepts and Cases, VIKAS® Publishing House Pvt Ltd, New Delhi (2015).

- Paul Smeyers & Marc Depaepe, Educational Research: Ethics, Social Justice, and Funding Dynamics, Springer International Publishing AG, (part of Springer Nature) (2018).
- Peter Pruzan, Research Methodology: The Aims, Practices and Ethics of Science, Springer International Publishing Switzerland (2016).
- Ranjit Kumar, Research Methodology: a step-by-step guide for beginners, SAGE Publications India Pvt Ltd, New Delhi (2011).
- Richard Pring, Philosophy of Educational Research, Continuum, London (2000).
- Robyn Brandenburg & Sharon McDonough, Ethics, Self-Study Research Methodology and Teacher Education, Springer Nature Singapore Pte Ltd. (2019).
- S. K. Yadav, Elements of Research Writing, UDH Publishers and Distributers, New Delhi (2015).
- Surbhi Jain, Research Methodology in Arts, Science and Humanities, Society Publishing, Oakville, Canada (2019).
- Vinayak Bairagi and Mousami V. Munot, Research Methodology A Practical and Scientific
- Approach, CRC Press Taylor & Francis Group, New York, NY (2019).

# E Resources and List of Journals

- *Advances in Applied Research*
- *Advances in Computational Sciences and Technology [ACST]*
  *Advances in Mechanical Engineering*
  *Advances in Water Resources*
  *Agricultural Engineering*
  *Agricultural Engineering Today*
  *Agricultural Mechanization in Asia, Africa and Latin America*
  *Agricultural Research*
  *Agricultural Reviews*
  *Agricultural Science Digest*
  *Agricultural Water Management*
  *Agronomy Journal (Journal of American Society of Agronomy*
  *American Journal of Food Technology*
  *American Statistician*
  *Annals of Agri Bio Research*
  *Annals of Agricultural Research*
  *Annals of Arid Zone*
  *Annals of Biology*
  *Annals of Horticulture*
  *Annals of Science*
  *Annals of Statistics*
  *Applied Ecology and Environmental Research*
  *Applied Engineering in Agriculture*
  *Applied Ergonomics*
  *Arid Land Research and Management*
  *Asian Journal of Chemistry*
  *Asian Journal of Environmental Science*
  *Atmospheric Research*
  *Australian Journal of Crop Science*
  *Australian Journal of Dairy Technology*
  *Beverage and Food World*
  *CIGR journal*
  *Comptes Rendus Geosciences*
  *Computers and Electronics in Agriculture*
  *Computers & Industrial Engineering*
  *Cotton Research Journal*
  *Current Advances in Agricultural Sciences*
  *Current World Environment*
  *Ecological Engineering*
  *Ecology, Environment and Conservation*
  *Engineering and Technology in India*
  *Environment*
  *Environment and Ecology*
  *Environmental Engineering Science*
  *Environmental Monitoring and Assessment*
  *Environmental Science and Pollution Research*
  *Environmental Science and Technology*
  *Environmental Review*
  *Forage Research*

- *Groundwater*
  *Hydrological Processes*
  *IETE Journal of Research*
  *IETE Journal of Education*
  *Indian Journal of Agricultural Chemistry*
  *Indian Journal of Agricultural Research*
  *Indian Journal of Agricultural Sciences*
  *Indian Journal of Dairy Science*
  *Indian Journal of Extension Education*
  *Indian Journal of Hill Farming*
  *Indian Journal of Radio and Space Physics*
  *Indian Journal of Science and Technology*
  *Indian Journal of Soil Conservation*
  *Indian Research Journal of Extension Education*
  *Institute of Engineers (India)*
  *Journal of Electronics & Tele Communication*
  *International Journal of Agricultural Engineering*
  *International Journal of Agricultural Science and Research*
  *International Journal of Advance Industrial Engineering*
  *International Journal of Advanced Mechanical Engineering [IJAME]*
  *International Journal of Advanced Engineering Technology (IJAET)*
  *International journal of Advanced Research in Engineering & Technology (IJARET)*
  *International Journal of Applied Engineering Research [IJAER]*
  *International Journal of Current Engineering and Technology*
  *International Journal of Design and Manufacturing Technology(IJDMT)*
  *International Journal of Engineering Research and Technology [IJERT]*
  *International Journal of Engineering, Science and Metallurgy*
  *International Journal of Engineering (IJE)*
  *International Journal of Engineering Studies [IJES]*
  *International Journal of Environmental Analytical Chemistry*
  *International Journal of Environmental Research and Public Health*
  *International Journal of Environmental Science and Technology*
  *International Journal of Extension Education*
  *International Journal of Food Engineering*
  *International Journal of Food Microbiology*
  *International Journal of Food Properties*
  *International Journal of Food Science and Nutrition*
  *International Journal of Food Science and Technology*
  *International Journal of Food and Fermentation Technology*
  *International Journal of Innovative Technology and Exploring Engineering (IJITEE)*
  *International Journal of Industrial Engineering & Technology [IJIET]*
  *International Journal of Industrial Engineering Research and*

*Development (IJIERD)*
*The International Journal of Industrial Engineering: Theory,*
- *Application and Practice (IJIETAP)*

*International Journal of Engineering and Management Research (IJEMR)*
*International Journal of Engineering Sciences and Management*
*International Journal of Industrial Engineering Computations*
*International Journal of Engineering and Manufacturing Science [IJEMS]*
*International Journal of Research in Chemistry and Environment*
*International Journal of Research In Mechanical Engineering And Technology (IJRMET)*
*International Journal of Thermal Sciences*
*International Journal of Mechanical Engineering and Robotics Research*
*International Journal of Material and Mechanical Engineering*
*International Journal of Mechanical Engineering & Technology(IJMET)*
*International Journal of Mechanical Engineering and Research(IJMER)*
*International Journal of Mechanical Sciences*
*International Journal of Recent Technology and Engineering(TM) Exploring Innovation*
*International Journal of Industrial & Production Engineering & Tech. [IJIPET]*
*International Journal of Industrial and Systems Engineering*
*International Journal of Advanced Materials Science [IJAMS]*
*International Journal of Research in Mechanical Engineering*
*International Journal of Engineering & Technology Research*
*International Review of Applied Engineering Research [IRAER]*
*International Journal of Mechanical and Materials Engineering*
*International Journal of medical, Health, Biomedical, Bioengineering and Pharmaceutical Engineering*
*International Journal of Production Technology and Management (IJPTM)*
*International Journal of Refrigeration*
*International Journal of Remote Sensing*
*International Journal of Thermal Technologies*
*International Journal of Water Resources Development*
*International Journal on Agricultural Sciences*
*International Journal on Environmental Sciences*
*International Journal of Applied Research on Information Technology and Computing*
*International Journal of Mechanical Engineering*
*International Journal of Mechanical and Production Engineering Research and Development*
*International Scholarly Research Notices, ISRN Mechanical Engineering*
*Irrigation Science*
*Irrigation and Drainage (ICID Bulletin)*
*Irrigation and Drainage System*

*Italian Journal of Food Science*
*Journal of Agricultural Engineering (ISAE)*
*Journal of Agriculture Research and Technology*
- *Journal of Agricultural Safety and Health*
*Journal of Applied Ecology*
*Journal of Applied Probability*
*Journal of Applied Statistics*
*Journal of Arid Environments*
*Journal of Cotton Research and Development*
*Journal of Dairy Research*
*Journal of Dairy Science*
*Journal of Ecology*
*Journal of Energy Engineering - ASCE*
*Journal of Engineering*
*Journal of Engineering computers and Applied Sciences*
*Journal of Engineering Research*
*Journal of Ergonomics*
*Journal of Environmental Engineering*
*Journal of Environmental Monitoring*
*Journal of Environmental Protection and Ecology (JEPE)*
*Journal of Environmental Sciences*
*Journal of Environmental Science and Engineering*
*Journal of Environmental Science, Toxicology and Food Technology*
*Journal of Food Biochemistry (Journal of Food Lipids)*
*Journal of Food Composition and Analysis*
*Journal of Food Engineering*
*Journal of Food Legumes*
*Journal of Food Process Engineering*
*Journal of Food Processing and Preservation*
*Journal of Food Quality*
*Journal of Food Safety*
*Journal of Food Science*
*Journal of Food Science and Technology*
*Journal of Food, Agriculture and Environment*
*Journal of Human Ecology*
*Journal of Hydraulic Engineering – ASCE*
*Journal of Hydraulic Research*
*Journal of Hydrologic Engineering*
*Journal of Hydrology*
*Journal of Indian Society of Agricultural Statistics*
*Journal of Indian Water Resources Society*
*Journal of Industrial Engineering International*
*Journal of Irrigation and Drainage Engineering (ASCE)*
*Journal of Mechanical Engineering*
*Journal of Materials in Civil Engineering*
*Journal of Manufacturing Processes*
*Journal of Research, PAU*
*Journal of Soil and Water Conservation*
*Journal of Soil and Water Conservation, India*
*Journal of Statistical Computation and Simulation*

*Journal of Statistical Planning and Inference*
*Journal of Statistical Theory and Practice*
*Journal of Stored Products Research*
*Journal of Sustainable Agriculture*

# Restructured and Revised Syllabi of Post Graduate Programmes

## M. Tech. and Ph. D. (Agricultural Engineering) in Processing and Food Engineering

**Compiled by**

**Broad Subject Coordinator**
**Associate Dean,**
**Dr. Annasaheb Shinde College of Agricultural Engineering and Technology, MPKV, Rahuri**

**Discipline Coordinator**
**Professor and Head (PFE)**
**College of Agricultural Engineering and Technology, VNMKV, Parbhani**

# CONTENTS

# Preamble

Processing and Food Engineering is a relatively young discipline covering not only factories, equipment and processes but also understanding the product and developing innovative products and packages to satisfy the consumer's needs and wishes. The complexity of the food product and hygienic food production with suitable packaging, compared to chemicals or textile, calls for increasing reliance on the computer in food process research and development. Simulation and modeling constitute an essential step in food process research and development. "Virtualization" becomes a legitimate approach in food engineering research for equipment, mechanization, integrated processing system and hygienic plant design. Further, recent technologies such as Internet of Things, Artificial Intelligence, Nanomaterials, 3D printing, 3D scanning, soft gripping, nondestructive and online/quick analyzing have been found useful for suitable equipment and machineries manufacturing for sustainable food production.

Over the years Food Process Engineering studies emerged as a scientific and industrial discipline describing equipment and means for proper plant operations and environment control considering engineering properties of materials, transport phenomenon, computer aided design, simulation, project engineering and management, post-harvest engineering, storage engineering, additives and preservatives, reaction kinetics, and so on, in ways that preserve value of food and prevent any illness. Processing and Food Engineering has been an area of priority for the food industries, processing plants, plant designers, equipment and plant manufacturers, bulk material handling systems, cold storage, supply chain systems and manufacturers, mega kitchen equipment, analytical instruments, ingredient/chemical producers, consumers, retailers, manufacturers, national and international agencies and regulators. Further, need for mechanization of selected indigenous food products and automation has been felt.

To meet the compliances for efficient use of resources, related equipment, instrumentation, plant and building design, establishment and operation for sustainable food manufacturing; competent human resources at various levels such as process engineers, plant engineers, equipment engineers, service engineers, service in-charges, plant in-charge, auditors, designated officers, equipment and pnstrument handlers, safety officers etc. Development of trained human resource in this scientific and industrial sector is essential for the future growth of food processing and national – international trade from it.

Present Processing and Food Engineering course frame work has its parity with national frame work with credit distribution among the different course types core and optional subject with due credits to seminar, research and industrial exposure. These programme is intended to offer the industry ready professionals for food processing sector on one hand while they would be given training so that they can ponder upon the industry problems to offer solution either through deep scientific research or problem-solving approach for quick industry solution and immediate response. The programme will also be good for who enjoy quality food production, processing, distribution and retailing or interested in strengthening their proficiency in design and assessment of production management systems.

The programme shall also open new vista for entrepreneurs who intend to diversify in Food Process Engineering aspects. While proposing this programme it is believed that this programme will also cover research gap in the area and will provide primary data from the country to be used in best quality indigenous equipment and production system manufacturing with compliance to applicable international reputed standards and codes which has been lacking in the past.

## Committee on Agricultural Engineering and Technology

| ICAR-BSMA Broad Subject | ICAR-BSMA Approved Disciplines | Degree Programmes | | Broad Subject Coordinator (Chairman of all Disciplines' SubCommittees | Discipline Coordinator (Secretary of respective Discipline Sub-Committee) |
|---|---|---|---|---|---|
| Agricultural Engineering and Technology | Farm Machinery and Power Engineering | M.Tech. | Ph.D. | Dr. D.D. Pawar AD, CoAE, MPKV, Rahuri | Dr. P.U. Sahare Dr.BSKKV, Dapoli |
| | Processing and Food Engineering | M.Tech. | Ph.D. | | Dr. (Mrs.) S.U. Khodke Head (PFE) CoAET, VNMKV, Parbhani |
| | Irrigation and Drainage Engineering | M.Tech. | Ph.D. | | Dr. S.B. Wadatkar AD, CoAET, Dr.PDKV, Akola |
| | Renewable Energy Engineering | M.Tech. | Ph.D. | | Dr. A.G. Mohod Dr.BSKKV, Dapoli |
| | Soil and Water Conservation Engineering | M.Tech. | Ph.D. | | Dr. S.B. Nandgude Head (SWCE), MPKV, Rahuri |
| | Agriculture Structure and Environment Management | M.Tech. | Ph.D. | | Dr. Suchita Gupta Head (FS) Dr.PDKV, Akola |

## Organization of Course Contents & Credit Requirements

**Minimum Residential Requirement:**

**M.Tech.: 4 Semesters**
**Ph.D.: 6 Semesters**

**Name of the Departments / Divisions**

- Processing and Food Engineering (PFE)

**Nomenclature of Degree Programme**

**(a) M.Tech. Programme**
M.Tech. (Agrilcultural Engineering) in Processing and Food Engineering

**(b) Ph. D. Programme**
Ph.D. (Agrilcultural Engineering) in Processing and Food Engineering

**Code Numbers**

- All courses are divided into two series: 500-series courses pertain to Master's level, and 600-series to Doctoral level.
- Credit Seminar for Master's level is designated by code no. 591, and the Two Seminars for Doctoral level are coded as 691 and 692, respectively
- Deficiency courses will be of 400 series.
- Master's research: 599 and Doctoral research: 699

**Course Contents**

The contents of each course have been organized into:

- Objective – to elucidate the basic purpose.
- Theory units – to facilitate uniform coverage of syllabus for paper setting.
- Suggested Readings – to recommend some standard books as reference material. This does not obviously exclude such a reference material that may be recommended according to the advancement and local requirement.
- A list of international and national reputed journals pertaining to the discipline is provided at the end which may be useful as study material for 600/700 series courses as well as research topics.
- Lecture schedule and practical schedule has also be given at the end of each course to facilitate the teacher to complete the course in an effective manner.

**Eligibility for Admission**

- **Master's Degree Programme**

  Graduates who have completed four years degree program in any one of the State Agricultural Universities / Colleges affiliated to State Agricultural Universities alone are eligible to apply for Masters programs. The admission will be through CET conducted by the University as per its regulations.

  Bachelor's degree in respective/ related subjects under 10+2+4 system with minimum of 5.50/10 or equivalent OGPA/ equivalent percentage of marks at Bachelor's degree. *(If from other disciplines then will have to complete the Deficiency courses of 6 to 10 credits as proposed by university.)*

**Qualification for admission to M.Tech. degree programme**

| **Name of Degree** | **Eligibility Qualification from recognized/ Accredited University** |
|---|---|
| M.Tech. (Agricultural Engineering) | Bachelor's degree (Four Years) B.Tech. / B.E. degree in Agri. Engineering |

**Doctoral programs**

Candidates who have studied four years degree program and two years Master's program in any one of the State Agricultural Universities / Colleges affiliated to State Agricultural Universities alone are eligible to apply for doctoral programs. The admission will be through CET conducted by the University as per its regulations.

Master's degree in respective/ related subjects under 10+2+4 +2 system with minimum of 6.50/10 or equivalent OGPA/ equivalent percentage of marks at master's degree.

**Qualification for admission to Ph.D. degree programme**

| **Subject of Doctorate Degree** | **Eligibility Qualifications** |
|---|---|
| PhD (Agricultural Engineering) in Processing and Food Engineering | Master's degree in Processing and Food Engineering (PFE)/Process and Food Engineering (PFE)/Agril. Process Engineering (APE)/Agricultural and Food Engineering (AgFE) |

**Credit and Credit Requirements**

| **Course Details** | **Master's degree** | **Doctoral Degree** |
|---|---|---|
| Major Courses | 20 | 12 |
| Minor Courses | 08 | 06 |
| Supporting / Optional | 06 | 05 |
| Common PGS Courses | 05 | - |
| Seminar | 01 | 02 |
| Thesis Research | 30 | 75 |
| **Total** | **70** | **100** |

## Course Layout and Structure for Master's Programme

**Major courses (Requirement: 20 Credits)**

| S.No. | CourseTitle | CourseCode | Credits |
|---|---|---|---|
| 1 | Transport Phenomena in Food Processing | *PFE 501 | 2+1 |
| 2 | Unit Operations in Food Process Engineering | *PFE 502 | 2+1 |
| 3 | Field Crops Process Engineering | *PFE 503 | 2+1 |
| 4 | Horticultural Crops Process Engineering | *PFE 504 | 2+1 |
| 5 | Storage Engineering and Handling of Agricultural Produce | PFE 505 | 2+1 |
| 6 | Food Package Engineering | PFE 506 | 1+1 |
| 7 | Instrumentation and Sensors in Food Processing | PFE 507 | 2+1 |
| 8 | Application of Engineering Properties in Food Processing | PFE 508 | 2+1 |
| 9 | Food Quality and Safety | PFE 509 | 2+1 |
| 10 | Food Processing Technologies | PFE 510 | 2+1 |
| 11 | Food Processing Equipment and Plant Design | PFE 511 | 1+1 |
| 12 | Seed Process Engineering | PFE 512 | 1+1 |
| 13 | Agri-Project Planning and Management | PFE 513 | 2+1 |
| 14 | Farm Structures and Environmental Control | PFE 514 | 2+1 |
| 15 | Dairy Product Processing | PFE 515 | 2+1 |
| 16 | Processing of Meat Poultry and Fish | PFE 516 | 2+1 |
| 17 | Design of Aquacultural Structures | PFE 517 | 2+1 |
| 18 | Thermal Environmental Engineering for Agricultural Processing | PFE 518 | 2+1 |
| 19 | Special Problem | PFE 521 | 0+1 |
| 20 | Internship | PFE 522 | 0+1 |
| **Total** | | | **33+20** |

*CompulsoryCourses

**Minor courses (Requirement:08 Credits)**

**Minor Disciplines**

| Faculty | Disciplines |
|---|---|
| Agricultural Engineering | FMPE/ REE/ CE/ ME/ CSE/ BSCT |
| Agriculture | Economics /Horticulture/Food Science/ Statistics |
| Dairy Science & Technology | Dairy Technology, Dairy Engineering, Dairy Chemistry, Dairy Microbiology |
| Food Technology | Processing Technology /Process Engineering / Safety and Quality |
| Community Science | Food & Nutrition |

**Suggested Minor courses**

| S. No. | Course Title | Course Code | Credits |
|---|---|---|---|
| 1 | Mechatronics and Robotics in Agriculture | ME 501 | 2+0 |
| 2 | Refrigeration Systems | ME 502 | 2+1 |
| 3 | Energy, Ecology and Environment | REE 510 | 3+0 |
| 4 | Energy Management in Food Processing Industries | REE 515 | 1+1 |
| 5 | Management of Farm Power and Machinery System | FMPE 507 | 2+1 |
| 5 | Computer Aided Design of Machinery | FMPE 515 | 0+2 |
| 6 | Advance Manufacturing Technologies | FMPE 516 | 2+0 |
| 7 | Artificial Intelligence | CSE 502 | 2+0 |
| 8 | Packaging and Storage of Fresh Horticultural Produce | PHM 503 | 1+1 |
| 9 | Packaging and Storage of Processed Horticultural Produce | PHM 504 | 1+1 |
| 10 | Any other course(s) of other Department / Faculty other than course(s) from major can be taken as per recommendations of the student's advisory committee. | | |

**Supporting courses (Requirement: 06 Credits)**

**Supporting Disciplines**

| Faculty | Disciplines |
|---|---|
| Agricultural Engineering | FMPE/ REE/CE/ ME/CSE /BSCT |
| Agriculture | Economics /Horticulture/ Food Science/ Statistics |
| Dairy Science & Technology | Dairy Technology, Dairy Engineering, Dairy Chemistry, Dairy Microbiology |
| Food Technology | Processing Technology /Process Engineering / Safety and Quality |
| Community Science | Food & Nutrition |

**Suggested Supporting courses**

| S.No. | Course Title | CourseCode | Credits |
|---|---|---|---|
| 1 | Statistical Methods for Research Works | *STAT 502 | 2+1 |
| 2 | Experimental Designs | STAT 511 | 1+1 |
| 3 | Processing of Vegetable | VSC 513 | 1+1 |
| 4 | Postharvest Management of Vegetable Crops | VSC 514 | 2+1 |
| 5 | Principles and Methods of Fruit and Vegetable Preservation | PHM 505 | 2+1 |
| 6 | Laboratory Techniques in Postharvest Management | PHM 506 | 1+2 |
| | Courses from subject matter fields (other than Major and Minor) relating to area of special interest and research problem can be taken as per recommendations of the student's advisory committee. | | |

*Compulsory Course

**Compulsory Non Credit Common PGS Courses: (5 Credits)**

| Course code | Semester | Course Title | Credits |
|---|---|---|---|
| PGS 501 | I | Library and Information Services | 0+1=1 |
| PGS 504 | II | Basic Concepts in Laboratory Techniques | 0+1=1 |
| PGS 502 | I | Technical Writing and Communications Skills | 0+1=1 |
| PGS 503 | II | Intellectual Property and its management in Agriculture | 1+0=1 |
| PGS 505 | III | Agricultural Research, Research Ethics and Rural Development Programmes | 1+0=1 |
| PGS 506 | III | Disaster Management | 1+0 |

**List of other essential requirements**

| S.No. | CourseTitle | CourseCode | Credits |
|---|---|---|---|
| 1 | Masters Seminar | PFE 591 | 0+1 |
| 2 | Masters Research | PFE 599 | 0+30 |

# Course Layout and Structure for Doctoral Programme

**Major courses (Requirement: 12 Credits)**

| S.No. | Course Title | Course Code | Credits |
|---|---|---|---|
| 1 | Advances in Food Process Engineering | *PFE 601 | 2+1 |
| 2 | Drying and Dehydration of Food Materials | *PFE 602 | 2+1 |
| 3 | Textural and Rheological Characteristics of Food Materials | PFE 603 | 2+1 |
| 4 | Agricultural Waste and By-Products Utilization | PFE 604 | 2+1 |
| 5 | Mathematical Modeling in Food Processing | PFE 605 | 3+0 |
| 6 | Bioprocess Engineering | PFE 606 | 2+1 |
| 7 | Special Problem | PFE 621 | 0+1 |
| 8 | Internship | PFE 622 | 0+1 |
| **Total** | | | **13+7** |

**Minor Courses (Requirement: 06 Credits)**

**Minor Disciplines**

| Faculty | Disciplines |
|---|---|
| Agricultural Engineering | FMPE/ REE/ CE/ ME/ CSE/ BSCT |
| Agriculture | Economics /Horticulture/Food Science/ Statistics |
| Dairy Science & Technology | Dairy Technology, Dairy Engineering, Dairy Chemistry, Dairy Microbiology |
| Food Technology | Processing Technology /Process Engineering / Safety and Quality |
| Community Science | Food & Nutrition |

**Suggested Minor courses**

| S.No. | CourseTitle | CourseCode | Credits |
|---|---|---|---|
| 1 | Digital Image Processing | CSE 506 | 2+1 |
| 2 | Mechatronics and Robotics in Agriculture | ME 501 | 2+0 |
| 3 | Renewable Energy for Industrial Application | REE 610 | 2+1 |
| 4 | Emerging Food Engineering Operations | FPE 501 | 2+1 |
| 5 | Food Packaging | FPT602 | 3+0 |
| 6 | Courses from subject matter fields (other than Major and Minor) relating to area of special interest and research problem can be taken as per recommendations of the student's advisory committee. | | |

**Supporting Courses (Requirement: 05 Credits)**

**Minor Disciplines**

| Faculty | Disciplines |
|---|---|
| Agricultural Engineering | FMPE/ REE/ CE/ ME/ CSE/ BSCT |
| Agriculture | Economics /Horticulture/Food Science/ Statistics |
| Dairy Science & Technology | Dairy Technology, Dairy Engineering, Dairy Chemistry, Dairy Microbiology |
| Food Technology | Processing Technology /Process Engineering / Safety and Quality |
| Community Science | Food & Nutrition |

**Suggestive Supporting Courses**

| S.No. | CourseTitle | CourseCode | Credits |
|---|---|---|---|
| 1 | Research and Publication Ethics | *CPE- RPE 601 | 1+1 |
| 2 | Theory of Designs and Analysis of Experiments | STAT 502 | 1+1 |
| 3 | Courses from subject matter fields (other than Major and Minor) relating to area of special interest and research problem can be taken as per recommendations of the student's advisory committee. | | |

* Compulsory courses

**List of other essential requirements**

| S.No. | CourseTitle | CourseCode | Credits |
|---|---|---|---|
| 1 | Doctoral Seminar-I | PFE 691 | 0+1 |
| 2 | Doctoral Seminar-II | PFE 692 | 0+1 |
| 3 | Doctoral Research | PFE 699 | 0+75 |

## Course Syllabus and Content of Masters Degree

**PFE 501 Transport Phenomena in Food Processing 2+1**

**Objectives:**

To acquaint and equip the students with the principles of heat, mass and momentum transfer and its applications in food processing

**UNIT-I**

Introduction to heat and mass transfer and their analogy. Steady and unsteady state heat transfer. Analytical and numerical solutions of unsteady state heat conduction equations. Useof GurnieLurie and Heisler Charts in solving heat conduction problems: Applications in food processing including freezing and thawing of foods.

**UNIT-II**

Convective heat transfer in food processing systems involving laminar and turbulent flow. Heat transfer in boiling liquids. Heat transfer between fluids and solid foods. Functional design of heat exchangers: shell and tube, plate and scraped surface heat exchangers. Radiation heat transfer: governing laws, shape factors, applications in food processing.

**UNIT-III**

Momentum transfer.Mass flow and balance. Steady and unsteady flow.Theory and equationof continuity.Bernoulli's theorem and application. Flow through immerged bodies, Measurement of flow, pressure and other parameters. Flow driving mechanism.

**UNIT-IV**

Molecular diffusion in gases, liquids and solids.Molecular diffusion in biological solutions and suspensions.Molecular diffusion in solids. Unsteady state mass transfer and mass transfer coefficients.Molecular diffusion with convection and chemical reaction. Diffusion of gases in porous solids and capillaries. Mass transfer applications in food processing.

**Practical:**

Solving problems on steady and unsteady state conduction with or without heat generation.Numerical analysis.Problems in natural and forced convection, radiation.Design of heat exchangers. Experiments on heat conduction, convection and radiation heat transfer.

**Course outcome:**

The course will impart requisite knowledge about transport phenomenon with respect to heat, mass and momentum transfer which is necessary to understand the food processing operations. After going through the course, students will be able to understand, analyze and solve numerically the food processing operations where heat/mass/momentum transfer is involved.

**Teaching Schedule**

| S No | Topic | No. of lectures |
|---|---|---|
| 1. | Introduction to basic heat and mass transfer | 1 |
| 2. | Analogy of heat and mass transfer | 1 |
| 3. | Steady state heat transfer. | 1 |
| 4. | unsteady state heat transfer | 1 |
| 5. | Use of Gurnie-Lurie Charts in solving heat conduction problems | 1 |
| 6. | Use of Heisler Charts in solving heat conduction problems | 1 |
| 7. | Freezing of food and its applications | 1 |
| 8. | Thawing of food and its applications | 1 |
| 9. | Convective heat transfer in food processing systems involving laminar flow | 1 |
| 10. | Convective heat transfer in food processing systems involving turbulent flow | 1 |
| 11. | Heat transfer in boiling liquids foods and solid foods. | 1 |
| 12. | Study of Heat Exchangers used in food industries | 1 |
| 13. | Design of shell and tube; plate and scrapped surface heat exchangers. | 1 |
| 14. | Radiation heat transfer: governing laws, shape factors, | 1 |
| 15. | Applications of radiation energy in food processing. | 1 |
| 16. | Classification of Flow Phenomena, Momentum Flow and Momentum Equation for Laminar Flow, Momentum transfer. Mass flow and balance | 1 |
| 17. | Steady and unsteady flow, Fluid Element Trajectories | 1 |
| 18. | Stream Function and Velocity Potential | 1 |
| 19. | Theory and equation of continuity. | 1 |
| 20. | Bernoulli’s theorem and application | 1 |
| 21. | Flow through immerged bodies, Measurement of flow; | 1 |
| 22. | Measurement of flow pressure and other parameters. | 1 |
| 23. | Flow driving mechanism. | 1 |
| 24. | Mass Transfer (Diffusion), Diffusion: Phenomenological Description, | 1 |
| 25. | Diffusion Coefficient and Fick’s Law | 1 |
| 26. | Driving Force for Diffusion, | 1 |
| 27. | Study of Microscopic Picture of Diffusion | 1 |
| 28. | Molecular diffusion in biological solutions and suspensions. | 1 |
| 29. | Unsteady state mass transfer and mass transfer coefficients. | 1 |
| 30. | Molecular diffusion with convection and chemical reaction | 1 |
| 31. | Diffusion of gases in porous solids and capillaries | 1 |
| 32. | Mass transfer applications in food processing. | 1 |
| **Total** | | **32** |

**List of Practical's**

| S. No. | Topic | No. of Practical |
|---|---|---|
| 1. | Solving problems on steady conduction | 1 |
| 2. | Solving problems on steady conduction with or without heat generation | 1 |
| 3. | Solving problems on unsteady state conduction | 1 |
| 4. | Solving problems on unsteady state conduction with or without heat generation | 1 |
| 5. | Numerical analysis in heat transfer | 1 |
| 6. | Problems in natural convection | 1 |
| 7. | Problems in forced convection | 1 |
| 8. | Solving problems of heat transfer by radiation | 1 |
| 9. | Problems of heat transfer by conduction through different shape | 1 |
| 10. | Solving problems on mass transfer | 1 |
| 11. | Design of parallel flow heat exchanger | 1 |
| 12. | Design of counter flow heat exchangers. | 1 |
| 13. | Design of cross flow heat exchanger | 1 |
| 14. | Solving problems on Bernoulli's theorem | 1 |
| 15. | Experiments on heat conduction, convection | 1 |
| 16. | Experiments on radiation heat transfer | 1 |
| **Total** | | **16** |

**References:**

1. Jorge Welti-Chanes, Jorge F and Velez-Ruiz 2002. *Transport Phenomena in Food Processing*. CRC Press ISBN: 9781566769938Geankoplis.
2. J Christie 1993. Transport Process and Unit Operations. Prentice-Hall of India Private Limited, New Delhi ISBN 0-13-045253-X.
3. Plawsky, Joel L 2014. Transport Phenomena Fundamentals, CRC Press, ISBN: 978-1- 4665-5535-8,1466555351.
4. Bird, Stewart, Lightfoot 2002. Transport Phenomena, John Wiley & Sons.
5. Bodh Raj 2012. Introduction to Transport Phenomena, PHI
6. Greanoplis J C 1999. Transport Process and Unit Operation. Allyn and Bacon.
7. Coulson JM and Richardson J F. 1999.Chemical Engineering. Vol.II,IV. The Pergamon Press.
8. Holman J P 1992. Heat Transfer. McGraw Hill.
9. McCabe W L and Smith J C 1999. Unit Operations of Chemical Engineering. McGraw Hill.

**PFE 502 Unit Operations in Food Process Engineering 2+1**

**Objectives:**

To acquaint and equip the students with different unit operations applicable in food industries.

**UNIT-I**

Review of basic engineering mathematics. Units and dimensions. Mass and energy balance. Principles of fluid flow. Heat transfer: Conduction, convection and radiation. Heat exchangers and their designs.

**UNIT-II**

Drying and dehydration: Psychrometry, theories of drying, EMC, equipment for drying of solid, pastes and liquid foods. Evaporation: Components, heat and mass balance in single and multiple effect evaporators, equipment and applications, steam economy. Thermal processing: Blanching, pasteurization and sterilization, death rate kinetics, process time calculations, sterilizationequipment.

**UNIT-III**

Refrigeration and freezing: Principles, freezing curve, freezing time calculation, freezing equipment, cold chain.

**UNIT-IV**

Mechanical separation: Principle and equipment involved in sieving, filtration, sedimentation and centrifugation, cyclone separation. Material handling: Conveyors and elevators, components and design considerations for belt, chain, bucket and screwconveyors.

**UNIT-V**

Size reduction: Principles of size reduction, size reduction laws. Size reduction equipment: Jaw crusher, gyratory crusher, roller mill, hammermill; Mixing.

**Practical:**

Study of fluid flow properties. Study of heat exchangers, functional design of heat exchangers.Application of psychometric chart.Determination of EMC.Study of driers. Solving problems on single and multiple effect evaporator. Elevating and conveying equipment's. Size reduction equipment's. Cleaning and sorting equipment. Sieve analysis. Kinetics of fruits and vegetables dehydration.Calculation of refrigeration load, solving of numerical problems. Visit to related foodindustry.

**Course outcome:**

The students will get knowledge on various unit operations, backbone of all food processes. Knowledge on basic principles of thermal food processes, size reduction and separation operations involved in food processing and related equipment will prepare students to solve problems related with food processing. This will help students to solve problems of post- production processes and will also enhance employability in food industries.

**Teaching Schedule**

| S. No. | Topic | No. of Lectures |
|---|---|---|

| | | |
|---|---|---|
| 1. | Introduction - Units and dimensions, Calculations of material balance related to various food processes | 2 |
| 2. | Study of energy balance for processing operation and related parameters | 2 |
| 3. | Study of fluid statics, fluid dynamics, flow characteristics | 2 |
| 4. | Modes of heat transfer, Heat exchangers and their designs | 4 |
| 5. | Introduction to basics of Psychometrics | 2 |
| 6. | Study of Dehydration, EMC, Mechanism of drying constant rate period, Falling rate period. | 2 |
| 7. | Study of drying equipments | 3 |
| 8. | Evaporation, types of evaporators, Flow arrangements, Mass & energy balance, Steam economy | 2 |
| 9. | Thermal processing: Blanching, pasteurization and sterilization, death rate kinetics, process time calculations, sterilization equipment. | 3 |
| 10. | Refrigeration and freezing and Thawing: Principles, freezing curve, freezing time calculation, freezing equipment. Cold chain. | 2 |
| 11. | Mechanical separation: Principle and equipment involved in sieving, filtration, sedimentation and centrifugation, cyclone separation. | 2 |
| 12. | Material handling: Conveyors and elevators, components and design considerations for belt, chain, bucket and screw conveyors. | 3 |
| 13. | Study of principles involved in the size reduction and separation. Equipment used: Jaw crusher, gyratory crusher, roller mill, hammer mill. Mixing | 3 |
| | **Total** | **32** |

**List of Practical's**

| S. No | Topic | No. of Practical's |
|---|---|---|
| 1. | Use of units, dimensions and basic mathematical applications | 1 |
| 2. | Numericalon mass and energy balance problems | 1 |
| 3. | To assess the flow rate of fluids through pipes | 1 |
| 4. | To study the heat exchangers and calculation of log mean temperature difference | 1 |
| 5. | To study the cleaning and sorting equipments | 1 |
| 6. | To study the food handling equipments | 1 |
| 7. | To study the design of heat exchangers. | 1 |
| 8. | To determine the EMC of different foods | 1 |
| 9. | To study single effect and multi effect evaporators with numerical | 1 |
| 10. | To calculate the thermal process time using trapezoidal/ Simpson's formulae and graphical method | 1 |
| 11. | Application of psychrometricchart. | 1 |
| 12. | To study different separation equipment's | 1 |
| 13. | To study the size reduction equipment's and Sieve analysis | 1 |

| | | |
|---|---|---|
| 14. | ToverifytheBernoulli'sEquation and their numerical | 1 |
| 15. | Studies on calculation of refrigeration load. | 1 |
| 16. | Visit to related foodindustry | 1 |
| | **Total** | **16** |

**References:**


1. Toledo 2007. *Fundamentals of Food Process Engineering*,Springer
2. Berk 2018. *Food Process Engineering and Technology*, Academic Press, ISBN: 978-0-12-812018-7
3. Smith 2011. *Introduction to Food Process Engineering*,Springer
4. Brennan J G, Butters J R, Cowell N D and Lilly A E I. 1990. *Food Engineering Operations*.Elsevier.
5. Fellows P 1988. *Food Processing Technology: Principle and Practice*. VCHPubl.
6. McCabe W L and Smith J C 1999. *Unit Operations of Chemical Engineering*. McGraw Hill.
7. Sahay K M and Singh K K 1994. *Unit Operation of Agricultural Processing*. Vikas Publ. House.
8. SinghRPandHeldmanDR1993.*IntroductiontoFoodEngineering*.AcademicPress
9. Varzakas 2015. *Food Engineering Handbook*, CRCpress
10. Earle R L 1985. Unit Operations in Food Processing. PergamonPress.
11. Holman J P 1992. Heat Transfer. McGrawHill.
12. R.S. Khurmi and Gupta 2009. *Refrigeration and Air Conditioning*. Eurasia Publishing House (P) Ltd. NewDelhi.

**PFE 503 Field Crops Process Engineering 2+1**

**Objectives:**
To acquaint and equip the students with the post-harvest technology of cereals, pulses and oil seeds with special emphasis on equipment used in the milling and processing.

**UNIT-I**
Production and utilization of cereals and pulses, grain structure of major cereals, pulses and oil seeds and their milling fractions. Grain quality standards and evaluation of physico-chemical properties.

**UNIT-II**
Pre-milling treatments and their effects on milling quality. Parboiling and drying, conventional, modern and integrated rice milling operations. Wheat roller flour milling. Processes for milling of corn, oats, barley, gram, pulses, paddy and flour milling equipment. Layout of milling plants.

**UNIT-III**
Dal milling, by-products, and their utilization. Design characteristics of milling equipment, selection, installation and their performance. Expeller and solvent extraction processing. Assessment of processed product quality. Value added products of cereals, pulses and oilseeds.

**UNIT-IV**
Packaging and storage of processed products and by-products, Quality standards and quality evaluation of grains, its productsand by-products.

**Practical:**
Physical properties of cereals and pulses, raw and milled products quality evaluations: Parboiling and drying, terminal velocities of grains and their fractions, study of paddy, wheat, pulses and oilseeds milling equipments, planning and layout of various milling plants. Development of value-added products for cereals, pulses and oilseeds, visit to related agro processing industry.

**Courseoutcome:**
Student's capability to mill and process (value added products) all kinds of field crops as perrequirementoffoodindustries.

**LectureSchedule**

| S. No. | Topic | No. of Lectures |
|---|---|---|
| 1. | Production and utilization of cereals and pulses, grain structure of major cereals, pulses and oilseeds and their milling fractions. | 2 |
| 2. | Conventional, modern and integrated rice milling process, pre milling treatments, rice parboiling, rice milling equipment and layout of rice milling plant. | 5 |
| 3. | Conventional and roller wheat flour milling process, pre-milling treatments, milling equipment and layout of wheat milling plant. | 4 |
| 4. | Preparation of oilseeds and pre- treatments, conventional and modern oil extraction methods viz expeller, solvent extraction. Milling equipment and layout of oil milling plant. | 4 |

| | | |
|---|---|---|
| 5. | Processes for milling of pulses, pretreatments, milling equipment and layout of pulse milling plant. | 4 |
| 6. | Processes for milling of corn, oats and barley, pretreatments and milling equipments. Layout of milling plant. | 3 |
| 7. | Handling, packaging and storage of milled products, by-products and their utilization. | 3 |
| 8. | Assessment of processed product quality. Quality standards for various grains, processed products. Physico-chemical methods for evaluation of quality Value added products of cereals, pulses and oilseeds. | 3 |
| 9. | Design characteristics of milling equipment, selection, installation and their performance. | 4 |
| | **Total** | **32** |

**List of Practicals**

| S.No. | Topic | No. of Practicals |
|---|---|---|
| 1 | Determination of engineering properties of grains. | 3 |
| 2 | Determination of cooking quality of grains. | 1 |
| 3 | Quality evaluation of milled products. | 2 |
| 4 | Study of paddy milling process and equipments. | 1 |
| 5 | Study of wheat milling process and equipments, | 1 |
| 6 | Study of oil extraction process and equipments, | 1 |
| 7 | Study of pulse milling process and equipments, | 1 |
| 8 | Planning and layout of various milling plants. | 2 |
| 9 | Development of value-added products for cereals, pulses and oil seeds, | 2 |
| 10 | Visit to various agro processing industry. | 2 |
| | **Total** | **16** |

**Suggested Readings**


- Asiedu JJ 1990. Processing Tropical Crops. ELBS/ MacMillan.
- Chakraverty A1995. Post- Harvest Technology of Cereals, Pulses and Oilseeds. Oxford and IBH.
- Morris Lieberman.1983. Post-Harvest Physiology and Crop Preservation. Plenum Press.
- Pandey PH. 1994. Principles of Agricultural Processing. Kalyani.
- Pillaiyar P.1988. Rice-Post Production Manual. Wiley Eastern.
- Sahay KM and Singh KK 1994. Unit Operations in Agricultural Processing.Vikas Publ. House
- Golob 2002. Crop Post-Harvest : Science and Technology Vol.1,Wiley-Blackwell
- Hodges 2004. Crop post-harvest : science and technology Vol.2, Wiley-Blackwell

- Mohesenin NN 1980. Thermal Properties of Foods and Agricultural Materials. Gordon and Breach Science Publisher.
- Mohesenin NN 1980. Physical Properties of Plant and Animal Materials. Gordon & Breach Science Publisher.
- Rao MA and Rizvi SSH 1986. Engineering Properties of Foods. Marcel Dekker.
- Henderson S and Perry SM 1976. Agricultural Process Engineering. 5thEd. AVI Publisher.
- Hall CW 1970. Handling and Storage of Food Grains in Tropical and Sub-Tropical Areas. FAO Publisher Oxford & IBH.

**PFE 504 Horticultural Crops Process Engineering 2+1**

**Objectives:**
To acquaint and equip the students with processing of fruits and vegetables and the design features of the equipment used for their processing.

**Unit-I**
Importance of postharvest technology of fruits and vegetables, structure, cellular components, composition and nutritive value of fruits and vegetables, fruit ripening, spoilage of fruits and vegetables.

**Unit-II**
Harvesting and washing, pre-cooling, blanching, preservation of fruits and vegetables, commercial canning of fruits and vegetables, minimal processing of fruits and vegetables.

**Unit-III**
Cold storage of fruits and vegetables, controlled atmosphere and modified atmosphere packaging of fruits and vegetables, quality deterioration and storage.

**Unit-IV**
Dehydration of fruits and vegetables, methods, osmotic dehydration, foam mat drying, freeze drying, drum drying, microwave heating, applications, radiation preservation of fruits and vegetables, irradiation sources. Drying theory, characteristics and drying model

**Unit-V**
Intermediate moisture foods, ohmic heating principle, high pressure processing of fruits and vegetables, applications, sensory evaluation of fruit and vegetable products, packaging technology for fruits and vegetables, general principles of quality standards and control, FPO, quality attributes.

**Practical:**
Determination of size, shape, density, area-volume-mass relationship of fruits and vegetables, sugar-acid ratio of fruits, evaluation of washer, grader and packaging methods, experiments on drying of fruits and vegetables, controlled atmosphere storage and quality evaluation.

**Course Outcome:**
Student’s capability to mill and process (value added products) all kinds of horticultural crops as per requirement of food industries.

**Teaching Schedule**

| S. No. | Topic | No. of Lectures |
|---|---|---|
| 1. | Importance of postharvest technology of fruits and vegetables, structure, cellular components, composition and nutritive value of fruits and vegetables. | 1 |
| 2. | Techniques for harvesting and washing of fruits and vegetables. Fruit | 2 |

| | | |
|---|---|---|
| | ripening and spoilage. | |
| 3. | Pre-cooling of fruits and vegetables. | 1 |
| 4. | Blanching: importance and objectives, blanching methods, effects on food (nutrition, colour, pigment, and texture). | 1 |
| 5. | Different preservation techniques for fruits and vegetables. | 1 |
| 6. | Commercial canning of fruits and vegetables. | 1 |
| 7. | Minimal processing of fruits and vegetables. | 1 |
| 8. | Modified and CA storage of fruits and vegetables, Cold storage, heat load calculations and design. | 5 |
| 9. | Quality deterioration in fruits and vegetables. | 1 |
| 10. | Different storage techniques for fruits and vegetables. | 1 |
| 11. | Dehydration techniques of fruits and vegetables: osmotic dehydration, foam mat drying, drum drying freeze drying, microwave heating, applications, radiation preservation of fruits and vegetables, irradiation sources. | 4 |
| 12. | Intermediate moisture foods. Drying theory, characteristic and drying models. | 1 |
| 13. | Ohmic heating and high-pressure processing principle for fruits and vegetables. | 2 |
| 14. | Applications of different processing techniques for fruits and vegetables. | 1 |
| 15. | Sensory evaluation of fruit and vegetable products. | 1 |
| 16. | Packaging technology for fruits and vegetables. | 2 |
| 17. | General principles of quality standards and control. | 2 |
| 18. | FPO, quality attributes for fruits and vegetables. | 2 |
| **Total** | | **30** |

**List of Practicals**

| S. No. | Topic | No. of Practicals |
|---|---|---|
| 1 | Determination of size and shape of fruits and vegetables | 1 |
| 2 | Determination of bulk density and true density of fruits and vegetables | 1 |
| 3 | Determination of area-volume-mass relationship of fruits and vegetables | 1 |
| 4 | Determination of sugar-acid ratio of fruits | 1 |
| 5 | Evaluation of different types of washers for fruits and vegetables | 1 |
| 6 | Evaluation of different types of graders for fruits and vegetables | 1 |
| 7 | Different types of packaging methods for fruits and vegetables | 1 |
| 8 | Determination of the water vapor permeability of packaging materials | 1 |
| 9 | Determination of drying characteristics of fruits and vegetables and its products. | 1 |
| 10 | Experiment on drying model fitting for drying of fruits and vegetables. | 1 |

| | | |
|---|---|---|
| 11 | Comparative evaluation of different dryers for fruits and vegetables | 1 |
| 12 | Determination of solid gain and moisture loss during osmotic dehydration in fruits | 1 |
| 13 | Study of components and design of controlled atmosphere storage | 1 |
| 14 | Study of quality evaluation of fruits and vegetables | 2 |
| 15 | Visit to cold storage | 1 |
| **Total** | | **16** |

**References:**


1. Cruess W V 2000. *Commercial Fruit and Vegetable Products*. Agrobios Publisher.
2. Danthy M E 1997.*Fruit and Vegetable Processing*. International Book Publisher.
3. Srivastava RP and KumarS 1994. *Fruit and Vegetable Preservation*. Principles and Practices. International Book Distr.
4. Bhatti S and Varma U 1995. *Fruit and Vegetable Processing*. CBS.
5. Thompson A K 1996. *Post-Harvest Technology of Fruits and Vegetables*. Blackwell.
6. VermaLR and Joshi VK 2000. *Post-Harvest Technology of Fruits and Vegetables*. Vols. I-II. Indus Publisher.
7. Simson 2016. *Post-Harvest Technology of Horticultural crops*. AAP.
8. Singh 2018. *Advances in Post-Harvest Technologies of Vegetable Crops*. AAP.

**PFE 505 Storage Engineering and Handling o fAgricultural Produce 2+1**

**Objectives:**

To acquaint and equip the students with the safe storage of food materials, design of storage structures and the design of different material handling equipment used in the industries.

**Unit-I**

Storage of grains, biochemical changes during storage. Production, distribution and storagecapacity estimation models, storage capacity models, ecology, storage factors affecting losses, storage requirements.

**Unit-II**

Bag and bulk storage, godowns, bins and silos, rat proof godowns and rodent control, method of stacking, preventive method, bio-engineering properties of stored products, function, structural and thermal design of structures, aeration system.

**Unit-III**

Grain markets, cold storage, controlled and modified atmosphere storage, effects of nitrogen,oxygen, and carbon dioxide on storage of durable and perishable commodities, irradiation, storage of dehydrated products, food spoilage and preservation, BIS standards.

**Unit-IV**

Physical factors influencing flow characteristics, mechanics of bulk solids, flow through hoppers, openings and ducts; design of belt, chain, screw, roller, pneumatic conveyors and bucket elevators, principles of fluidization, recent advances in handling of food materials.

**Practical:**

Physical factors influencing flow characteristics, mechanics of bulk solids, flow through hoppers, openings and ducts, design of belt, chain, screw, roller, pneumatic conveyors and bucket elevators; principles of fluidization; recent advances in handling of food materials.

**Course Outcome:**

Student's capability to understand and undertake mechanical handling of food as per requirement of food industries as well as storage devices and systems for safe storage of food for longer period.

**Teaching Schedule**

| S. No. | Topic | No. of Lectures |
|---|---|---|
| 1. | Importance of storage, Types of losses, Principle of storage, Factors causing deterioration of grains, Sources of infestation. | 3 |
| 2. | Food spoilage, biochemical changes estimation models during storage, Grain storage capacity | 2 |
| 3. | Storage requirements. Deep and shallow bins, grains pressure theory | 2 |
| 4. | Types of storagestructures, Bag and bulk storage, godowns, bins and silos. Selection criteria for storage structure | 3 |
| 5. | Rat proof godowns and rodent control, method of stacking, preventive method. | 2 |
| 6. | Functional, structural and thermal design of structures, aeration system. | 2 |

| | | |
|---|---|---|
| 7. | Grain marketing and distribution system in India. Food grains management system. Import, export and food policy. | 2 |
| 8. | Cold storage, Controlled and modified atmosphere storage, Effects of nitrogen, oxygen, and carbon dioxide on storage of durable and perishable commodities. | 3 |
| 9. | Food irradiation, Storage of dehydrated products, BIS standards. | 2 |
| 10. | Physical factors influencing flow characteristics, Rolling resistance, Mechanics of bulk solids - Shear apparatus for determination of flow properties, Yield locus, Time yield locus and effective yield locus. | 3 |
| 11. | Flow through hoppers, openings and ducts – Types of flow along bins or hopper wall, Flow function and Critical flow factor, Critical dimensions of hopper openings; | 2 |
| 12. | Material handling equipment, Design of belt, chain, screw, roller, pneumatic conveyors and bucket elevators. | 4 |
| 13. | Principles of fluidization, recent advances in handling of food materials. | 2 |
| | **Total** | **32** |

**List of Practicals**

| **S. No.** | **Topic** | **No. of Practicals** |
|---|---|---|
| 1. | Determination of angle of repose | 1 |
| 2. | Determination of coefficient of internal friction | 1 |
| 3. | Determination of coefficient of external friction | 1 |
| 4. | Study of physical factors influencing flow characteristics of grains | 1 |
| 5. | Determination of flow properties using Shear apparatus | 1 |
| 6. | Determination of Yield locus, Time yield locus and effective yield locus from Mohr's circle | 1 |
| 7. | Design of hoppers, openings and ducts of storage structures. | 1 |
| 8. | Design of belt conveyors | 1 |
| 9. | Design of chain conveyors | 1 |
| 10. | Design of screw conveyors | 1 |
| 11. | Design of bucket elevators | 1 |
| 12. | Design of roller conveyors | 1 |
| 13. | Design of pneumatic conveyors | 1 |
| 14. | Study of fluidization of grains | 1 |
| 15. | Studies on advance techniques and equipments of handling of food materials | 2 |
| | **Total** | **16** |

**Suggested Readings:**

1. FAO 1984.*Design and Operation of Cold Stores in Developing Countries*. FAO.
2. Hall CW 1970. *Handling and Storage of Food Grains in Tropical and Sub-Tropical Areas*. FAO Publisher Oxford & IBH.
3. Henderson S and Perry SM 1976. *Agricultural Process Engineering*.5$^{th}$Ed. AVI Publisher.
4. Ripp BE 1984. *Controlled Atmosphere and Fumigation in Grain Storage*. Elsevier.
5. Shefelt RL and Prussi SE 1992. *Post-Harvest Handling–A System Approach*. Academic Press.
6. Vijayaraghavan S 1993. *Grain Storage Engineering and Technology*. Batra Book Service.
7. Boumans1985. *Grain Handling and Storage*. Elsevier.
8. Golob 2002. *Crop Post-Harvest : Science and Technology*. Vol 1 Wiley-Blackwell.
9. Hodges 2004. *Crop Post-Harvest : Science and Technology*. Vol 2, Wiley-Blackwell.
10. P. S. Phirke, Processing and Conveying Equipment Design, Jain Brothers, New Delhi.

**PFE506 Food Package Engineering 1+1**

**Objectives:**

To acquaint and equip the students with packaging methods, packaging materials, packaging machineries, modern packaging techniques etc.

**Unit-I**

Introduction of packaging: Package, functions and design. Principle in the development of protective packaging. Deteriorative changes in food stuff and packaging methods of prevention.

**Unit-II**

Food containers: Rigid containers, glass, wooden boxes, crates, plywood and wire bound boxes, corrugated and fiber board boxes, textile and paper sacks, corrosion of containers (tinplate). Flexible packaging materials and their properties. Aluminum as packaging material. Evaluation of packaging material and package performance.

**Unit-III**

Packaging equipment: Food packages, bags, types of pouches, wrappers, carton and other traditional package. Retortable pouches.

**Unit-IV**

Shelf life of packaged food stuff. Methods to extend shelf life. Packaging of perishables and processed foods. Special problems in packaging of foodstuff.

**Unit-V**

Package standards and regulation: Shrink packaging, aseptic packaging, CA and MAP. Biodegradable packaging: Recent advances in packaging, active packaging, smart packaging, antioxidant and antimicrobial packaging, edible films and biodegradable packaging, micro-encapsulation and nano encapsulation.

**Practical:**

Thickness, substance weight, water absorption capability of flexible packaging materials, strength properties of packaging materials, water vapour and gas transmission rate of flexible packaging materials, identification and chemical resistance of plastic films. Packaging of fruits/vegetables: Estimation of shelf-life of packaged food stuff, familiarization of types of packaging material.

**CourseOutcome:**

Student's capability to develop packages for all kinds of food products as per requirement of food industries and there by adding value to the food products.

**Teaching Schedule**

| S. No | Topic | No. of Lectures |
|---|---|---|
| 1. | Introduction to food packaging, Definition, importance, package, functions of packaging, design. | 1 |
| 2. | Principle in the development of protective packaging | 1 |

| | | |
|---|---|---|
| 3. | Deteriorative changes in foodstuff, Factors affecting shelf life of foods during storage, interactions of spoilage agents with environmental factors (water, oxygen, light and pH), packaging methods of prevention | 1 |
| 4. | Food containers: Rigid containers, glass, wooden boxes, crates, plywood and wire bound boxes, corrugated and fiber board boxes, textile and paper sacks, corrosion of containers (tin plate). | 1 |
| 5. | Flexible packaging materials and their properties. Aluminum as packaging material. | 1 |
| 6. | Evaluation of packaging material and package performance: Testing methods for flexible, rigid and semi rigid materials. Paper and paper board:thickness, bursting strength, breaking length, stiffness, tear resistance, folding endurance, ply bond and surface oil absorption, Plastic film and laminates: thickness, tensile strength, gloss, haze and burning test to identify polymer, aluminium foil: thickness and pin holes, Glass containers: visual defects, colour, dimensions and impact strength and metal containers: pressure test and product compatibility | 3 |
| 7. | Packaging equipment for food packages, bags, types of pouches, Retortable pouches, wrappers, carton and other traditional packages | 2 |
| 8. | Shelf life of packaged foodstuff. Methods to extend shelf life. | 1 |
| 9. | Packaging of perishables and processed foods, Special problems in packaging of food stuff | 1 |
| 10. | Package standards and regulation: Shrink packaging, aseptic packaging, CA and MAP | 2 |
| 11. | Recent advances in packaging, active packaging, smart/intelligent packaging, Tetra packaging, antioxidant and antimicrobial packaging, edible films and biodegradable packaging, | 1 |
| 12. | Microencapsulation and nano encapsulation | 1 |
| | **Total** | **16** |

**List of Practicals**

| S. No. | Topic | No. of Practicals |
|---|---|---|
| 1. | Studies on different types of packaging material | 1 |
| 2. | Determination of thickness of different types of packaging materials | 1 |
| 3. | To determine water absorption capability of flexible packaging materials | 1 |
| 4. | Determination of tensile strength of packaging material | 1 |
| 5. | Determination of compressive strength of packaging material | 1 |
| 6. | Determination of water vapour transmission rate of packaging material | 1 |
| 7. | Determination of gas transmission rate of packaging material | 1 |

| | | |
|---|---|---|
| 8. | Studies on different types of plastic films | 1 |
| 9. | Testing of chemical and grease resistance of packaging materials | 1 |
| 10. | Determination of bursting strength of different packages | 1 |
| 11. | Evaluation of food package strength by Drop test | 1 |
| 12. | Studies on Vacuum packaging of various food products | 1 |
| 13. | Studies on Nitrogen packaging of food products | 1 |
| 14. | To study the effect of shrink wrapping on shelf life of fruits and vegetables | 1 |
| 15. | To study the effect of active modified atmosphere packaging on shelf life of fruits and vegetables | 1 |
| 16. | Visit to relevant industries | 1 |
| | **Total** | 16 |

**References:**


1. Crosby NT 1981. *Food Packaging Materials*. Applied Science Publisher.
2. Frank A1992. *A Handbook of Food Packaging* Springer.
3. Mahadeviah M and Gowramma RV 1996. *Food Packaging Materials*. Tata McGraw Hill.
4. Palling SJ 1980. *Developments in Food Packaging*. Applied Science Publisher.
5. Robertson GL2013. *Food Packaging-Principles and Practice*.3rd Ed Taylor & Francis.
6. Sacharow S & Grittin RC1980. *Principles of Food Packaging*. AVI Publisher.
7. P Jacob John Handbook on Food Packaging.
8. F. A. Palne and H. Y. Palne A handbook of food Packaging Springer- science-business media.

**PFE 507 Instrumentation and Sensors in Food Processing 2+1**

**Objectives:**
To acquaint and equip the students with instrumentation and use of sensors in food processing operations.

**Unit-I**
Basic instrumentation systems and transducer principles. Displacement transducers, Potential meters, LDVT, Piezoelectric and capacitive transducers, Digital transducers, velocity transducers.

**Unit-II**
Acceleration and absolute motion measurement, Force transducer, Strain gauge, Hydraulic load cell, Cantilever type and probing ring. Method of separation of force: Torque, power and energy measuring technique.

**Unit-III**
Temperature measurement using bi-metals, thermisters, thermocouples, humidity measurement, manometers. Flow transducer, positive displacement, venturi meter, Rotameter, Dragforce, hot wire anemometer.

**Unit-IV**
Theory and classifications of chemical sensors, biosensors, fiberoptic sensors, gas sensors etc. Biosensor : Concepts, types of biosensors, methods of immobilizing biosensors, application. Imaging methods : X-ray imaging, Computed tomography, MRI, Ultrasound, Hyperspectral imaging. Spectroscopy and chemometrics: UV and visual spectroscopy, NIR spectroscopy, FTIR spectroscopy.

**Practical:**
Identification of components of generalized measuring system: Calibration of instruments, experiment on LVDT, strain gauge transducer, force, torque, power and pressure, fluid flow rates, temperature, calorific value, vibration measurement. Use of data loggers and data storage devices, spectroscopy, imaging systems.

**Course Outcome:**
Student’s capability to control the process operations through precise instrumentation and knowledge of sensors for precision analysis of food quality in food industries.

**Teaching Schedule**

| S.No | Topic | No. of Lectures |
|---|---|---|
| 1. | Basic instrumentation systems | 1 |
| 2. | Transducer principles | 1 |
| 3. | Displacement transducers, Potentialmeters, LDVT, Piezoelectric and capacitive transducers, Digital transducers, velocity transducers. | 3 |
| 4. | Acceleration and absolute motion measurement, Force transducer, Strain gauge, Hydraulic load cell, Cantilever type and probing ring. | 3 |

| | | |
|---|---|---|
| 5. | Different methods of separation of force: Torque, power and energy measuring technique | 3 |
| 6. | Temperature measurement using bi-metals, thermistors, thermocouples, Humidity measurement, manometers. | 3 |
| 7. | Flow transducer, positive displacement, venturimeter, Rotameter, Drag force, hotwire anemometer. | 3 |
| 8. | Theory and classification of chemical sensors, biosensors, fiberoptic sensors, gas sensors etc. | 4 |
| 9. | Biosensor: Concepts, types of biosensors, methods of immobilizing biosensors, application. | 3 |
| 10. | Imaging methods for foods, Principles, equipment, food applications- X-ray imaging, Computed tomography, MRI, Ultrasound, Hyperspectral imaging. | 4 |
| 11. | Various methods of spectroscopy and chemometrics, principles, equipment, food applications- UV and visual spectroscopy, NIR spectroscopy, FTIR spectroscopy. | 4 |
| | **Total** | **30** |

**List of Practicals**

| S.No. | Topic | No. of Practicals |
|---|---|---|
| 1. | Identification of components of generalized measuring system for temperature, pressure, relative humidity, moisture etc. | 1 |
| 2. | Calibration of moisture measuring equipment | 1 |
| 3. | Calibration of temperature control and measuring devices | 1 |
| 4. | To study the working of Bourdon Pressure Gauge and to check the calibration of the gauge in a deadweight pressure gauge calibration setup. | 1 |
| 5. | To study various temperature measuring instruments e.g. Mercury-in-Glass thermometer, Thermocouple, Electrical resistance thermometer, laser thermometer and to estimate their response times | 1 |
| 6. | To determine the calorific value of different food products usinga bomb calorimeter having temperature sensing device | 1 |
| 7. | To study a Linear Variable Differential Transformer (LVDT) and use it in a simple experimental set up to measure a small displacement | 1 |
| 8. | To measure torque of a rotating shaft using torsionmeter/ straingauge torque transducer | 1 |
| 9. | To measure the speed of a motor shaft with the help of non-contact type pick-ups (magnetic orphoto electric) | 1 |
| 10. | To measurestatic/dynamic pressure of fluid in pipe/ tube using pressure transducer/ pressure cell | 1 |

| | | |
|---|---|---|
| 11. | To determine the hardness/ firmness of food samples using a texture analyzer | 1 |
| 12. | To study the effect of vibrations during transportation on the quality of Food (damage/ bruising/ texture etc) using a simulated vibration test | 1 |
| 13. | To study and use the data logging and data storage devices | 1 |
| 14. | To study and understand the working principle of UV and visual spectroscopy for measurement of food properties | 1 |
| 15. | To study and understand the working principle of NIR and FTIR spectroscopy for measurement of food properties | 1 |
| 16. | To study the working principle of X-ray imaging, Computed tomography, MRI, Ultrasound and Hyper spectral imaging for measurement of food quality | 1 |
| | **Total** | **16** |

**References:**

1. Doebelin EO1990. *Measurement Systems Applications and Design*. Tata McGraw Hill.
2. Erika KR and Brimelow JB 2001. *Instrumentation and Sensors for the Food Industry*. CRC Woodhead.
3. Paré JRJ and Bélanger JMR 1997. *Instrumental Methods in Food Analysis*. Elsevier Academic Press.
4. Nakra BC and Chaudhary KK 2004. *Instrumentation Measurement and Analysis*. Tata McGraw Hill.
5. Mukhopadhyay SC 2017. *Sensors for Everyday Life.*Springer.
6. Mukhopadhyay SC. 2014. *Novel Sensors for Food Inspection: Modelling, Fabrication and Experimentation.* Springer.

**PFE 508 Application of Engineering Properties in Food Processing 2+1**

**Objectives:**
To acquaint the students with different techniques of measurement of engineering properties and their application in the design of processing equipment.

**Unit-I**
Physical characteristics of different food grains, fruits and vegetables: Shape and size, description of shape and size, volume and density, porosity, surface area. Rheology: ASTM standard, terms, physical states of materials, classical ideal material, rheological models and equations, viscoelasticity, creep-stress relaxation, non-Newtonian fluid and viscometry, rheological properties, force, deformation, stress, strain, elastic, plastic behaviour.

**Unit-II**
Contact stresses between bodies, Hertz problems, firmness and hardness, mechanical damage, deadload and impact damage, vibration damage, friction, effect ofload, sliding velocity, temperature, waterfilm and surface roughness. Friction in agricultural materials, rolling resistance, angle of internal friction, angle of repose, flow of bulk granular materials, aerodynamics of agricultural products, drag coefficients, terminal velocity.

**Unit-III**
Thermal properties: Specific heat, thermal conductivity, thermal diffusivity, methods of determination, steady state and transient heat flow. Electrical properties: Dielectric loss factor, loss tangent, A.C. conductivity and dielectric constant, method of determination, energy absorption from high frequency electric field.

**Unit-IV**
Application of engineering properties in design and operation of agricultural equipment and structures.

**Practical:**
Experiments for the determination of physical properties like length, breadth, thickness, surface area, bulk density, porosity, true density, coefficient of friction, angle of repose and colour for various food grains, fruits, vegetables, spices and processed foods, aerodynamic properties like terminal velocity, lift and drag force for food grains, thermal properties like thermal conductivity, thermal diffusivity and specific heat. Rheological properties : firmness and hardness of grain, fruits and stalk, electrical properties like dielectric constant, dielectric loss factor, loss tangent and A.C. conductivity of various food materials.

**Course Outcome:**
Student's capability to apply properties of food for design of equipment and structures.

**Teaching Schedule**

| S.No. | Topic | No. of Lectures |
|---|---|---|
| 1. | Physical characteristics of different food grains, fruits and vegetables: Shape | 3 |

| | | |
|---|---|---|
| | and size, description of shape and size. | |
| 2. | Volume and density, porosity, surface area. | 2 |
| 3. | Rheology: ASTM standard, terms, physical states of materials, classical ideal material. | 2 |
| 4. | Rheological models and equations, viscoelasticity. | 2 |
| 5. | Creep-stress relaxation, non-Newtonian fluid and viscometry. | 1 |
| 6. | Rheological properties, force, deformation, stress, strain, elastic, plastic behavior. | 2 |
| 7. | Contact stresses between bodies, Hertz problems, firmness and hardness | 1 |
| 8. | Mechanical damage, dead load and impact damage. | 2 |
| 9. | Vibration damage, friction, effect of load, sliding velocity. | 1 |
| 10. | Temperature, water film and surface roughness. | 1 |
| 11. | Friction in agricultural materials, rolling resistance, angle of internal friction, angle of repose. | 2 |
| 12. | Flow of bulk granular materials. | 1 |
| 13. | Aerodynamics of agricultural products, drag coefficients, terminal velocity. | 2 |
| 14. | Thermal properties: Specific heat, thermal conductivity, thermal diffusivity. | 2 |
| 15. | Methods of determination, steady state and transient heat flow | 1 |
| 16. | Electrical properties: Dielectric loss factor, loss tangent. | 1 |
| 17. | A.C. conductivity and dielectric constant, method of determination. | 2 |
| 18. | Energy absorption from high frequency electric field. | 1 |
| 19. | Application of engineering properties in design and operation of agricultural equipment and structures. | 3 |
| | **Total** | **32** |

**List of Practicals:**

| S. No. | Topic | No. of Practicals |
|---|---|---|
| 1. | To determine the moisture content of grains, fruits and vegetables by using different methods | 1 |
| 2. | To determine the size of grains, spices, fruitsand vegetables. | 1 |
| 3. | To determine the shape of various food grains and fruits and vegetables. | 1 |
| 4. | To determine the bulk density of food grains and fruits and vegetables. | 1 |
| 5. | To determine the particle density/true density and porosity of solid grains. | 1 |
| 6. | To study the comparison pycnometer for finding the particle density of food grains. | 1 |
| 7. | To determine the angle of repose of grains, oilseeds etc. | 1 |

| | | |
|---|---|---|
| 8. | To find the coefficient of external friction for different food grains. | 1 |
| 9. | To determine the coefficient of internal friction of different food grains. | 1 |
| 10. | To determine colour of grains, fruits and vegetables using colorimeter. | 1 |
| 11. | To determine terminal velocity of food grain sample in a vertical wind tunnel (Aspirator column). | 1 |
| 12. | To study the thermal properties (thermal conductivity, thermal diffusivity and specific heat) of food grains. | 2 |
| 13 | To determine the Rheological properties: firmness and hardness of grain, fruits, stalk and vegetables. | 1 |
| 14. | To study the electrical properties (dielectric constant, dielectric loss factor) of various food materials. | 1 |
| 15. | To study the electrical properties (losstangent and A.C. conductivity) of various food materials. | 1 |
| | **Total** | **16** |

**References:**

1. Ludger F and Teixeira AA 2007. *Food Physics Physical Properties-Measurement and Application*. Springer
2. Mohesenin NN 1980. *Thermal Properties of Foods and Agricultural Materials*. Gordon and Breach Science Publisher.
3. Mohesenin NN1980. *Physical Properties of Plant and Animal Materials*. Gordon & Breach Science Publisher.
4. Peter B 2007. *The Chemical Physics of Food*. Wiley-Blackwell.
5. Peleg M and Bagelay EB1983. *Physical Properties of Foods*. AVI Publisher.
6. Rao MA and Rizvi SSH 1986. *Engineering Properties of Foods*. Marcel Dekker.
7. Sitkei1 986. *Mechanics of Agricultural Materials*. Elsevier.
8. Singhal OP and Samuel DVK 2003. *Engineering Properties of Biological Materials*. Saroj Prakasan.

**PFE 509 Food Quality and Safety 2+1**

**Objectives:**
To acquaint and equip the students with the latest standards to maintain food quality and safety.

**Unit-I**
Food safety:Need for quality control and safety, strategy and criteria, microbiological criteria for safety and quality, scope of food toxicology, toxic potential and food toxicants, biological and chemical contaminants.

**Unit-II**
Food additives and derived substances, factors affecting toxicity, designing safety in products and processes, intrinsic factors, establishing a safe raw material supply, safe and achievable shelf life.

**Unit-III**
Process equipment and machinery auditing, consideration of risk, environmental consideration, mechanical quality control.

**Unit-IV**
Personnel hygienic standards, preventative pest control, cleaning and disinfesting system, biological factors underlying food safety.

**Unit-V**
Preservation and stability, contaminants of processed foods, adulteration, prevention and control, FSSAI, ISO, Codex, GMP, BIS and HACCP.Practices, principles, standards, specifications, application establishment and implementation, HACCP and quality management system.Food Safety Management Systems (FSMS), Traceability.

**Practical:**
Microbiological examination of food, hazard analysis, premises design, HACCP project plan, CCP, CCP Decision tree, HACCP control chart. HACCP case studies: Survey, BIS, FPO, Codex standards and specifications. Visits to food industries to study the various quality and safety aspects adopted.

**Course Outcome:**
Student's capability to measure food quality as well as ensure food safety in food supply chain.

**Teaching Schedule**

| S. No. | Topic | No. of Lectures |
|---|---|---|
| 1. | Food safety: Need for quality control and safety, strategy and criteria. | 2 |
| 2. | Microbiological criteria for safety and quality. | 1 |
| 3. | Scope of food toxicology, toxic potential and food toxicants. | 2 |
| 4. | Biological and chemical contaminants. | 1 |
| 5. | Food additives and derived substances, factors affecting toxicity. | 2 |
| 6. | Designing safety in products and processes, intrinsic factors. | 2 |
| 7. | Establishing a safe raw material supply, safe and achievable shelf life. | 2 |

| | | |
|---|---|---|
| 8. | Process equipment and machinery auditing. | 1 |
| 9. | Consideration of risk, environmental consideration. Biological factors underlying food safety. | 2 |
| 10. | Personnel hygienic standards, preventative pest control. Cleaning and disinfesting system. | 2 |
| 11. | Preservation and stability, contaminants of processed foods, adulteration, prevention and control | 3 |
| 12. | FSSAI-Practices, principles, standards, specifications, application establishment and implementation | 2 |
| 13. | ISO-Practices, principles, standards, specifications, application establishment and implementation. | 2 |
| 14. | Codex, GMP and BIS - Practices, principles, standards, specifications, application establishment and implementation. | 3 |
| 15. | HACCP and quality management system. | 1 |
| 16. | Food Safety Management Systems (FSMS), Traceability. | 2 |
| **Total** | | **30** |

**List of Practicals**

| S. No. | Topic | No. of Practicals |
|---|---|---|
| 1. | Determination of microbial load of food products (microbial load, total plate count) | 1 |
| 2. | To conduct hazard analysis for any food industry. | 2 |
| 3. | To study the premises design for food safety and quality. | 2 |
| 4. | To study the HACCP through different module | 1 |
| 5. | To prepare CCP and CCP Decision tree. | 1 |
| 6. | Evaluation of textural quality of raw and processed food by objective method | 1 |
| 7. | To conduct the Survey and study BIS- standards and specifications. | 1 |
| 8. | To study the FPO standards and specifications. | 1 |
| 9. | To study the codex standards and specifications. | 1 |
| 10. | Determination of water activity of low medium and high intermitted moisture food. | 1 |
| 11 | Determination of PH, TSS, Ascorbic acid and acidity of different food products. | 1 |
| 12 | Estimation of food additive and adulteration of different food products. | 1 |
| 13 | Determination of proximate composition of different food products | 1 |
| 14. | Visits to food industries to study the various quality and safety aspects adopted. | 1 |

| Total | 16 |
|---|---|

**Suggested Readings:**


1. Herschdoerfer, S M1984.*Quality Control in the Food Industry.* Vol. 1 Academic Press.
2. Herschdoerfer S M2012. *Quality Control in the Food Industry.* Vol. 2 Elsevier Science.
3. Mahadeviah M and Gowramma R V 1996. *Food Packaging Materials*. Tata McGraw Hill.
4. Mehmet M 2011.*Biosensors in Food Processing, Safety, and Quality Control.* CRC Press.
5. Palling SJ1980. *Developments in Food Packaging*. Applied Science Publisher.
6. Sacharow S and Grittin R C 1980. *Principles of Food Packaging*. AVI Publisher.
7. Hubbard M R 2003.*Statistical Quality Control for the Food Industry.* Springer.
8. Yanbo H, Whittaker A D and Lacey R E 2001.*Automation for Food Engineering.* Food Quality Quantization and Process Control- CRC Press.

**PFE 510 Food Processing Technologies 2+1**

**Objectives:**
To acquaint and equip the students with different unit operations to be performed in food industries and related equipment.

**Unit-I**
Mixing and homogenization: Principles of solid and liquid mixing, types of mixers for solids, liquid and pastes homogenization. Emulsification: Principles and equipments.

**Unit-II**
Novel dehydration technologies: Osmotic dehydration, foam mat drying, puff drying, freeze drying, microwave drying, dehumidified air drying. Extrusion: Theory, equipment, applications.

**Unit-III**
Non-thermal processing: Principles and equipment involved in ohmic heating, pulsed electric field preservation, hydrostatic pressure technique (vacuum processing, high pressure processing of Foods), ultrasonic technology, irradiation, quality changes and effects on microorganisms, nanotechnology in food processing.

**Unit-IV**
Distillation, leaching and extraction: Principles and equipment for distillation, crystallization, phase equilibria, multistage calculations, leaching principles and equipment, solvent extraction, super-critical fluid extraction, near critical fluid extraction: Equipment and experimental techniques used in NCF extraction and industrial application, advanced methods for extraction of food components and aroma recovery.

**Unit-V**
Food plant hygiene: Cleaning, sterilizing, waste disposal methods, Food processing plant utilities, steam requirements in food processing, HACCP in food processing industries.

**Practical:** Conducting experiments and solving problems on mixing and mixing indices, homogenization, distillation, crystallization, extraction, leaching, membrane separation, reverse osmosis and ultrafiltration, design of plate and packed tower, visit to related food industry.

**Course Outcome:**
Student's capability to develop food products using recent techniques as per requirement of food industries.

**Teaching Schedule**

| S. No. | Topic | No. of Lectures |
|---|---|---|
| 1. | Mixing and homogenization: Principles of solid and liquid mixing. | 1 |
| 2. | Types of mixers for solids, liquid and pastes homogenization. | 2 |
| 3. | Emulsification: Principles and equipments. | 1 |
| 4. | Novel dehydration technologies: Osmotic dehydration, foam mat | 2 |

| | | |
|---|---|---|
| | drying, puff drying. | |
| 5. | Freeze drying, microwave drying, and dehumidified air drying. | 2 |
| 6. | Extrusion: Theory, equipment, applications. | 2 |
| 7. | Non-thermal processing: Principles and equipment involved in ohmic heating, pulsed electric field preservation. | 2 |
| 8. | Hydrostatic pressure technique (vacuum processing, high pressure processing of Foods), ultrasonic technology. | 2 |
| 9. | Irradiation, quality changes and effects on microorganisms, nanotechnology in food processing. | 2 |
| 10. | Distillation: Principles and equipment for distillation. | 2 |
| 11. | Leaching: Principles and equipment. | 2 |
| 12. | Extraction: Solvent extraction, crystallization, phase equilibria, multistage calculations. | 3 |
| 13. | Super-critical fluid extraction, near critical fluid extraction: Equipment and experimental techniques used in NCF extraction and industrial application. | 3 |
| 14. | Advanced methods for extraction of food components and aroma recovery. | 1 |
| 15. | Food plant hygiene: Cleaning, sterilizing, waste disposal methods. Food processing plant utilities, steam requirements in food processing. | 2 |
| 16. | HACCP in food processing industries. | 1 |
| **Total** | | **30** |

**List of Practicals**

| **S. No.** | **Topic** | **No. of Practicals** |
|---|---|---|
| 1. | To study the mixing unit operation & numerical. | 2 |
| 2. | To conduct the experiment on homogenization. | 2 |
| 3. | To study the process of crystallization. | 1 |
| 4. | To conduct the experiment on extraction. | 2 |
| 5. | To study the leaching process. | 1 |
| 6. | To study the membrane separation process. | 1 |
| 7. | To conduct the experiment on reverse osmosis technique. | 1 |
| 8. | To conduct the experiment on ultrafiltration process. | 1 |
| 9. | Design of plate and packed tower. | 2 |
| 10. | Visit to related food industry. | 2 |
| **Total** | | **15** |

**Suggested Readings:**


1. Brennan JG, Butters JR, Cowell ND and Lilly AEI 1990. *Food Engineering Operations*. Elsevier.
2. Earle R L 1985. *Unit Operations in Food Processing*. Pergamon Press.
3. Fellows P 1988. *Food Processing Technology: Principle and Practice*. VCH Publisher.
4. Geankoplis J C 1999. *Transport Process and Unit Operations*. Allyn& Bacon.
5. Gould G W 1996.*New Methods of Food Preservation*. Blackie Academic & Professional.
6. Heldman D R and Lund B D 1992. *Hand Book of Food Engineering*.Marcel Dekker.
7. McCabe W L and Smith JC 1999. *Unit Operations of Chemical Engineering*. McGraw Hill.
8. Sahay KM and Singh KK 1994. *Unit Operation of Agricultural Processing*. Vikas Publ. House.
9. Singh RP and Heldman DR 1993. *Introduction to Food Engineering*. Academic Press.
10. Singh RP 1991. *Fundamentals of Food Process Engineering*. AVI Publisher.

**PFE 511 Food Processing Equipment and Plant Design 1+1**

**Objectives:**
To acquaint and equip the students with the design features of different food processing equipment being used in the industries along with the layout, planning of different food processing plants.

**Unit-I**
Design considerations of processing agricultural and food products.

**Unit-II**
Design of machinery for drying, milling, separation, grinding, mixing, evaporation, condensation, membrane separation.

**Unit-III**
Human factors in design, selection of materials of construction and standard component, design standards and testing standards. Plant design concepts and general design considerations: Plant location, location factors and their interaction with plant location, location theory models, and computer aided selection of the location.

**Unit-IV**
Feasibility analysis and preparation of feasibility report: Plant size, factors affecting plant size and their interactions, estimation of break-even and economic plant size. Product and process design, process selection, process flow charts, computer aided development of flow charts.

**Unit-V**
Hygienic design aspects and worker's safety, functional design of plant building and selection of building materials, estimation of capital investment, analysis of plant costs and profitability's, management techniques in plant design including applications of network analysis, preparation of project report and its appraisal.

**Practical:**
Detailed design and drawing of mechanical dryers, milling equipment, separators, evaporators, mixers and separators. Each individual student will be asked to select a food processing plant system and develop a plant design report which shall include product identification and selection, site selection, estimation of plant size, process and equipment selection, process flow-sheeting, plant layout, and its evaluation and profitability analysis.

**Course Outcome:**
Student's capability to deal with food processing equipment and plant, techno-economic feasibility analysis of the project as needed in food industries.

**Teaching Schedule**

| S. No | Topic | No. of Lectures |
|---|---|---|
| 1. | Design considerations of processing agricultural and food products. Plant design concepts - situations giving rise to plant design problems. | 2 |
| 2. | General design considerations, Food Processing Unit Operations, Design of machinery for drying, milling and grinding | 2 |
| 3. | Design principles of separation, mixing machines | 1 |
| 4. | Design of evaporation, condensation, membrane separation machines | 2 |
| 5. | Human factors in design, selection of materials of construction and standard component | 1 |
| 6. | Design standards and testing standards | 1 |
| 7. | Plant location, location factors and their interaction with plant location, location theory models, and computer aided selection of the location. | 2 |
| 8. | Pre-Selection / Pre-feasibility stage, Analysis Stage: Market Analysis, Situational analysis related to market | 1 |
| 9. | Technical analysis, Financial Analysis, Sensitivity and risk analysis, Feasibility cost estimates | 1 |
| 10. | Break Even Analysis: Introduction, Break-Even Chart, Fixed Costs, Variable costs, Breakeven point calculation | 1 |
| 11. | Product and process design, process selection, process flow charts, computer aided development of flow charts. | 1 |
| 12. | Hygienic design aspects and worker's safety, functional design of plant building and selection of building materials | 1 |
| 13. | Estimation of capital investment, analysis of plant costs and profitability's. Management techniques in plant design including applications of network analysis. Project report and its appraisal. | 2 |
| **Total** | | **18** |

**List of Practicals**

| S. No | Topic | No. of Practicals |
|---|---|---|
| 1. | Detailed design and drawing of mechanical dryers | 2 |
| 2. | Detailed design and drawing of milling equipment | 2 |
| 3. | Design of separators | 2 |
| 4. | Design of evaporators | 2 |
| 5. | Design of mixers and separators | 2 |
| 6. | Project report preparation by students. (Individual student will select a processing plant, develop design report include product identification, | 6 |

| | | |
|---|---|---|
| | site selection, estimation of plant size, process and equipment, process flow-sheeting, plant layout, its evaluation and profitability analysis | |
| **Total** | | **16** |

**Suggested Readings:**


1. Antonio L G and Gustavo V BC2005. *Food Plant Design*. CRC Press.
2. Couper 2012.*Chemical Process Equipment*. Selection and DesignElsevier.
3. George S and Athanasios E K2015.*Handbook of Food Processing Equipment.* Springer.
4. Lloyd E B and Edwin H Y 1959.*Process Equipment Design*. Wiley-Inter-science.
5. Michael M C 2013. *Food Plant Sanitation: Design, Maintenance, and Good Manufacturing Practices.* CRC Press.

**PFE 512 Seed Process Engineering 1+1**

**Objectives:**
To acquaint and equip the students with seed processing along with the design features of the equipment used in their processing.

**Unit-I**
Processing of different seeds and their engineering properties, principles and importance of seed processing.

**Unit-II**
Performance characteristics of different unit operations such as precleaning, grading, conveying, elevating, drying, treating, blending, packaging and storage, seed processing machines like scalper, debreader, huller, velvet separator, spiral separator, cleaner-cum- grader, specific gravity separator, indent cylinder, disc separator, and colour sorter, seed treater, weighing and bagging machines, their operation and maintenance, installation and determination of their capacity, seed quality maintenance during processing, plant design and layout, economy and safety consideration in plant design.

**Unit-III**
Seed drying principles and methods, theory of seed drying, introduction to different types of heated air dryers, significance of moisture equilibrium, method of maintaining safe seed moisture, thumb rule and its relevance.

**Unit-IV**
Importance of scientific seed storage, types of storage structures to reduce temperature and humidity, management and operation/cleanliness of seed stores, packaging-principles, practices, materials and hermetic packaging, seed treatment methods and machines used, method of stacking and their impact, design features of medium and long term seed storage building.

**Practical:**
Study of various seed processing equipments such as pre-cleaners, scalpers, air screen cleaners, graders, spiral and pneumatic separators, seed treating equipment, bag closures, scale etc. and their performance evaluation, design and layout of seed processing plant and its economics, analysis of cost of operation and unit cost of processed product, effect of drying temperature and duration of seed germination and storability.

**Course Outcome:**
Student’s capability to understand processing and storage requirement of seed maintaining its vigor and viability, suitable equipment for seed processing as per requirement of seed industries.

**Teaching Schedule**

| S. No. | Topic | No. of Lectures |
|---|---|---|
| 1. | To study the engineering properties of different seeds. | 1 |
| 2. | Principles and importance of seed processing. | 1 |
| 3. | Performance characteristics of different unit operations such as pre-cleaning, grading, conveying, elevating, drying. | 1 |
| 4. | Treating, blending, packaging and storage, seed processing machines like scalper, de-breeder, huller. | 1 |
| 5. | Velvet separator, spiral separator, cleaner-cum-grader, specific gravity separator, indent cylinder, disc separator, and colour sorter. | 1 |
| 6. | Seed treater, weighing and bagging machines, their operation and maintenance, installation and determination of their capacity. | 1 |
| 7. | Seed quality maintenance during processing. | 1 |
| 8. | Plant design and layout, economy and safety consideration in plant design. | 2 |
| 9. | Seed drying principles and methods, theory of seed drying. | 1 |
| 10. | To study different types of heated air dryer for seed.. | 1 |
| 11. | Significance of moisture equilibrium, method of maintaining safe seed moisture, thumb rule and its relevance. | 1 |
| 12. | Importance of scientific seed storage, types of storage structures to reduce temperature and humidity. | 1 |
| 13. | Management and operation/cleanliness of seed stores, packaging-principles, practices, materials and hermetic packaging. | 1 |
| 14. | Seed treatment methods and machines used, method of stacking and their impact. | 1 |
| 15. | Design features of medium and long term seed storage building. | 1 |
| **Total** | | **16** |

**List of Practical**

| S. No. | Topic | No. of Practicals |
|---|---|---|
| 1. | To study performance evaluation of seed processing equipment such as pre-cleaners and scalpers. | 2 |
| 2. | To study the performance evaluation of graders. | 2 |
| 3. | To study the performance evaluation of air screen cleaners. | 1 |
| 4. | To study the performance evaluation spiral and pneumatic separators. | 2 |
| 5. | To study the performance evaluation of seed treating equipment, bag closures and scale. | 2 |
| 6. | To study design and layout of seed processing plant and its economics. | 2 |
| 7. | To analyze the cost of operation and unit cost of processed product. | 2 |

| | | |
|---|---|---|
| 8. | To study the effect of drying temperature and duration of seed germination and storability. | 2 |
| **Total** | | **15** |

**Suggested Readings:**


1. Babasaheb 2004. *Seeds Handbook: Processing and Storage.* CRC.
2. Gregg *et al* 1970. *Seed Processing*. NSC.
3. Guar 2012. *A Handbook of Seed Processing and Marketing* Agrobios.
4. Henderson S and Perry S M 1976. *Agricultural Process Engineering*. 5th Ed. AVI Publisher.
5. Mathad 2017. *Seed Processing: A Practical Approach.* NIPA.
6. Sahay K M and Singh K K 1994. *Unit Operation of Agricultural Processing*. Vikas Publisher House.
7. Vaugha 1968. *Seed Processing and Handling*.https://www.mcia.msstate.edu/pdf/seed-processing-and-handling_1.pdf.

**PFE 513 Agri-Project Planning and Management 2+1**

**Objectives:**
To acquaint and equip the students with the techniques of project development and evaluation along with different standards.

**Unit-I**
Project development, market survey and time motion analysis.
**Unit-II**
Selection of equipment, technology option, techno-economic feasibility and processing in production catchment.
**Unit-III**
Product and process design, PERT, CPM, transport model, simplex, linear and dynamic programming, operation log book. Material balance and efficiency analysis, performance testing, performance indices, energy requirement and consumption. Marketing of agricultural products, market positioning.
**Unit-IV**
BIS/ FSSAI /ISO standards/ guidelines on best practices, equipment and their design and operation for handling, processing and storage of food/feed.
**Practical:**
Preparation of project and feasibility report. Salient features, designand layout of different food processing units: MSME, large processing unit. Record keeping related to production, financeandmarketing.Techno-economicfeasibilityandSWOTanalysisforStart-ups.
**Course Outcome:**
Student's capability to plan, scheduling of activities and manage a food related project as per requirement of food industries.

**Teaching Schedule**

| S. No. | Topic | No. of Lectures |
|---|---|---|
| 1. | Project development. | 2 |
| 2. | Market survey and time motion analysis. | 2 |
| 3. | Selection of equipment for agro project planning. Technology option. | 4 |
| 4. | Techno-economic feasibility and processing in production catchment. | 3 |
| 5. | Product and process design. | 2 |
| 6. | PERT, CPM. | 2 |
| 7. | Transport model, simplex, linear and dynamic programming, operation logbook. | 3 |

| | | |
|---|---|---|
| 8. | Material balance and efficiency analysis. | 3 |
| 9. | Performance testing, performance indices, energy requirement and consumption. | 3 |
| 10. | Marketing of agricultural products, market positioning. | 2 |
| 11. | BIS/FSSAI/ISO standards/ guidelines on best practices. | 3 |
| 12. | Equipment and their design and operation for handling, processing and storage of food/feed. | 3 |
| | **Total** | **32** |

**List of Practicals**

| **S. No.** | **Topic** | **No. of practical's** |
|---|---|---|
| 1. | To study the preparation of project and feasibility report. | 2 |
| 2. | To design salient features, design and layout of MSME. | 2 |
| 3. | Design and layout of different food processing units | 2 |
| 4. | To study record keeping related to production. | 2 |
| 5. | To study record keeping related to finance and marketing. | 2 |
| 6. | To conduct experiment on agro project management and design techno- economic feasibility. | 2 |
| 7. | To conduct SWOT analysis for different Start-ups. | 3 |
| 8. | Visit to food processing industries | 1 |
| | **Total** | **16** |

**Suggested Readings:**


1. Ahmed T 1997. *Dairy Plant Engineering and Management*. 4$^{th}$Ed Kitab Mahal.
2. Anandajayasekeram P 2004.*Agricultural Project Planning andAnalysis.*
3. Albert L 2017.*Project Management, Planning andControl.*
4. *Henderson, S. M. and Perry R. L. 1955. Agricultural Process Engineering.*

**PFE 514 Farm Structures and Environmental Control 2+1**

**Objectives:**

To acquaint and equip the students with the different types of farm structures and techniques, to control atmospheric parameters and to create favourable environment in the agricultural structures.

**Unit-I**

Farmstead planning, survey and data collection for information bank. Analysis of data, Lay outs. Cost estimation and appraisal. Project development: Time, motion and input analysis, flow charts and drawings andcasestudies.

**Unit-II**

Farm structures (farmstead, livestock, poultry, storage godowns, farm machinery storage, biogas, green house, net house etc), their design, constructional details and design of low-cost structures. Heating, ventilating and exhaust systems, air distribution and air cleaning, combustion of fuels and equipment.

**Unit-III**

Drying and dehumidification system, air-water contact operations and evaporation, process and product air conditioning, energy efficient environmental control practices. Rural electrification, households electric wiring, rural water supply and sanitation.

**Unit-IV**

Instruments and measurements: Codes and standards.

**Practical:**

Calculation of heating and cooling load, design calculation of moisture condensation in agricultural buildings, study of moisture migration behaviour in storage bins, design aspect of green house, net house, septic tank, grain storage structures, cold storage.

**Course Outcome:**

Student's capability to design new farm structures and create suitable atmosphere within it.

**Teaching Schedule**

| S. No. | Topic | No. of Lectures |
|---|---|---|
| 1. | Farmstead Planning, types and objectives. Planning principles and layout, design and construction of farmstead. | 3 |
| 2. | Survey and data collection for information bank. Analysis of data, Lay outs. Cost estimation and appraisal. | 2 |
| 3. | Project development: Time, motion and input analysis, flow charts and drawings and case studies. | 2 |
| 4. | Farm structure, layout and structural design of shelters for dairy animals (cow, buffaloes, calves, bulls etc). | 3 |

| | | |
|---|---|---|
| 5. | Layout and structure design of modern poultry houses (cage type) along with other associated structures. | 2 |
| 6. | Familiarization with various rural grain storage structures. Layout, design and constructional detail of grain and feed storage structures like bins and silos. | 3 |
| 7. | Layout and structural design of storage structures for farm inputs like farm machinery, seeds, weedicides, insecticidesand fertilizers. | 2 |
| 8. | Heating, ventilating and exhaust systems: Ventilation utility in farm buildings; principles of natural ventilation; psychometric processes; heat and mass balance equation for ventilation;ventilation rates for temperature moisture and odour control. | 3 |
| 9. | Rural electrification, households electric wiring, rural water supply and sanitation. | 2 |
| 10. | General design considerations, operational and maintenance of biogas plant. | 2 |
| 11. | Drying and dehumidification system, air-water contact operations and evaporation, process and product air conditioning, energy efficient environmental control practices. | 3 |
| 12. | Environmental indices like THI: wet bulb depression; daily range; degree days; effective temperature; black globe temperature; mean radiant temperature, etc. Basic solar-earth angles and sol-air temperature. | 3 |
| 13. | Instruments and measurements: Codes and standards. | 2 |
| | **Total** | **32** |

**List of Practical's**

| S. No. | Topic | No. of Practicals |
|---|---|---|
| 1. | Planning and layout of a farmstead. | 1 |
| 2. | Instruments for measurements of environmental parameters. | 1 |
| 3. | Design of a farm fencing system. | 1 |
| 4. | Study of moisture migration behaviour in storage bins. | 1 |
| 5. | Design aspect of Septic tank. | 1 |
| 6. | Design aspect of Net house. | 1 |
| 7. | Design aspect of Grain storage structures. | 1 |
| 8. | Design aspect of Green house. | 1 |
| 9. | Design aspect of Cold storage. | 1 |
| 10. | Design of a feed/fodder storage structures. | 1 |
| 11. | Design of a biogas plant. | 1 |

| | | |
|---|---|---|
| 12. | Calculation of heating and cooling load. | 1 |
| 13. | Design calculation of moisture condensation in agricultural buildings. | 1 |
| 14. | Design of ventilation system for dairy and poultry house. | 1 |
| 15. | Visit to Green/ Net house and cold storage. | 1 |
| 16. | Visit to grain storage structures / warehouse/ godowns | 1 |
| | **Total** | **16** |

**Suggested Readings:**


1. Albright LD 1990. *Environmental Control for Animals and Plants.* ASAE Text books.
2. Esmay ML and Dixon JE 1986. *Environmental Control for Agricultural Buildings*. The VICORP.
3. Gaudy A F and Gaudy E T 1988. *Elements of Bioenvironmental Engineering*. Engineering Press.
4. Moore FF 1994.*Environmental Control Systems: Heating, Cooling, Lighting*. Chapman and Hall.
5. Threlkeld J L 1970. *Thermal Environmental Engineering*. PrenticeHall.
6. *K. S. Peavy, "Environmental Engineering", McGraw-Hill, International Ed., New York – 1985.*

**PFE 515 Dairy Product Processing 2+1**

**Objectives:**
To acquaint and equip the students with the various dairy products, processing methods and related equipment.

**Unit-I**
Procurement, transportation and processing of market milk, cleaning, and sanitization of dairy equipment. Special milks such as flavoured, sterilized, recombined, and reconstituted toned and double toned.

**Unit-II**
Condensed milk: Methods of manufacture and related equipment, evaluation of condensed and evaporated milk. Dried milk: Definition, methods of manufacture of skim andwhole milk powder, instantiation, physiochemical properties, evaluation, defects in dried milk powder. Cream: Cream separation, neutralization, sterilization, pasteurization and cooling of cream, defects in cream, Butter: methods of manufacture, defects in butter.

**Unit-III**
Ice cream: Methods of manufacture and related equipment, defects in ice cream, technology of softy manufacture. Cheese: Methods of manufacture, cheddar, Gouda, cottage and processed cheese, defects in cheese.

**Unit-IV**
Indigenous milk products: Method of manufacture of *Yoghurt, Dahi, Khoa, Burfi, Kalakand, Gulab Jamun, Rosogolla, Srikhand, Chhana, Paneer, Ghee, Lassi* etc. Probiotic milk product.

**Practical:**
Estimation and fat and SNF in milk.Operation of LTLT and HTST Pasteurization.Preparation of special milks. Cream separation and standardization of milk. Preparation and evaluation of table butter, ice-cream, cheese and indigenous milk product such as *Khoa, Chhana, Paneer, Ghee, Rosogolla, Gulabjamun, Shrikhand, Lassi, Burfi* etc. Visit to dairyplants.

**Course Outcome:**
Student's capability to mechanize processing operations in dairyindustries for manufacturing of dairy products.

**Teaching Schedule**

| S. No. | Topic | No. of Lectures |
|---|---|---|
| 1 | Collection and transportation of milk; Practices for collection of milk, preservation at farm, refrigeration, natural microbial inhibitors, lactoperoxidase system. | 1 |
| 2 | Reception and treatment of milk: Reception, chilling, clarification and storage. General practices. Homogenization: pretreatments, theories, synchronization of homogenizer with operation of pasteurizer (HTST), effect of homogenization on | 3 |

| | | |
|---|---|---|
| | physical properties of milk. Bactofugation: Theory and microbiology. | |
| 3 | Principles of thermal processing: kinetics of microbial destruction, thermal death curve, arrhenius equation, D value, Z value, F0 value, Q10 value. Factors affecting thermal destruction of micro-organisms.<br>Definition and description of processes: Pasteurization, thermisation, sterilization, UHT Processing. | 2 |
| 4 | Cleaning and sanitization of dairy equipment | 1 |
| 5 | Manufacture of special milks: flavoured, sterilized milk, recombined and reconstituted toned and doubled toned. | 2 |
| 6 | Manufacture of evaporated milk, sweetened condensed milk and recombined sweetened condensed milk and related equipment | 2 |
| 7 | Physico-chemical changes taking place during manufacture of condensed milk, Heat stability of milk and condensed milk, Physico-chemical properties of condensed milk, Chemical defects in condensed milk, their causes and prevention. | 3 |
| 8 | Dried Milks: Definition, grading and quality of raw milk for dried milks,<br>Manufacture of skim milk powder (SMP), whole milk powders and heat classified powders, | 2 |
| 9 | Physico-chemical changes taking place during manufacture of dried milks, Physical properties of dried milks, Defects in dried milk during manufacture and storage, their causes and prevention. | 2 |
| 10 | Cream: Definition, Efficiency of cream separation and factors affecting it; Neutralization, standardization, pasteurization and cooling of cream; Defects in cream | 2 |
| 11 | Butter: Definition, Introduction to the butter making process; theory of churning, Technology of Butter manufacture, Batch and continuous methods, Defects in butter. | 2 |
| 12 | History of ice cream industry, composition of ice cream, stabilizers and emulsifiers, properties and role in quality of ice cream | 1 |
| 13 | Ice cream: Manufacturing, Ice cream plant components, Types of freezers, refrigeration control / instrumentation, Technology of softy manufacture. | 2 |
| 14 | Defects in ice cream, their causes and prevention | 1 |
| 15 | Cheese: Manufacture of different varieties of cheese: Cheddar, Gouda, Cottage and processed cheese. Microbiological defects in cheese; their causes and prevention. | 3 |
| 17 | Indigenous milk products: Product description, methods of manufacture of Yoghurt, *Dahi, Khoa, Burfi, Kalakand, Gulabjamun, Rosogolla, Srikhand and, Chhana, Paneer, Ghee, Lassi* etc. Probiotic milk product. | 3 |
| | **Total** | **32** |

**List of Practicals**

| S. No. | Topic | No. of Practicals |
|---|---|---|

| | | |
|---|---|---|
| 1. | Estimation of fat and SNF in milk. | 1 |
| 2. | Operation of LTLT and HTST Pasteurizer. | 1 |
| 3. | Standardization of milk. | 1 |
| 4. | Preparation of special milks. | 1 |
| 5. | Study of Cream separator. | 1 |
| 6. | Preparation of table butter using the power-driven churn. | 1 |
| 7. | Preparation of plain and fruit flavoured ice-cream. | 1 |
| 8. | Preparation and analysis of khoa from cow and buffalo milk. | 1 |
| 9. | Preparation and analysis of chhana from cow and buffalo milk. | 1 |
| 10. | Preparation and analysis of paneer from cow and buffalo milk. | 1 |
| 11. | Preparation and analysis of lassi from cow and buffalo milk. | 1 |
| 12. | Preparation of ghee from cream and butter. | 1 |
| 13. | Preparation of rosogolla and gulabjamun. | 1 |
| 14. | Preparation of srikhand and burfi. | 1 |
| 15. | Preparation of cheese. | 1 |
| 16. | Visit to dairy plant. | 1 |
| | **Total** | **16** |

**Suggested Readings:**

1. Adnan T 2009.Dairy Powders and Concentrated Products (Society of Dairy Technology). Wiley-Blackwell.
2. Adnan T 2006.Probiotic Dairy Products (Society of Dairy Technology series). Wiley-Blackwell.
3. Britz2008.Advanced Dairy Science and Technology. Blackwell Publisher: Blackwell Publisher Professional.
4. De 2001.Outlines of Diary Technology. Oxford.
5. Hui Y H 1992.Dairy Science and Technology Handbook. VolI, II, and III Wiley.
6. Spreer E 2017. Milk and Dairy Product Technology. Taylor and Francis.
7. Walstra P, Jan T M, Wouters and Geurts T J 2006.Dairy Science and Technology. CRC, Taylor and Francis.
8. Farall A.W. Engineering for dairy and food products. Robert E.Krieger publishing company
9. Farall A.W. Food engineering system Vol.I. AVI publishing Co. INC Connecticut.
10. Earle, R. L. Unit operations in Food processing. Pergamon Press, New York. USA.
11. J.G. Brennan. Food engineering operation. Applied science publisher Ltd, London\
12. Sukumar De. Outline of Dairy Technology. Oxford University Press

**PFE 516 Processing of Meat, Poultry and Fish 2+1**

**Objectives:**

To acquaint and equip the students with processing of meat, fish and poultry and the design features of the equipment used for their processing.

**Unit-I**

Meat: Automation for the modern slaughterhouse, hot boning of meat, new spectroscopic techniques for online monitoring of meat quality, new developments in decontaminating raw meat, automated meat processing, developments in chilling and freezing of meat, high pressure processing of meat, approaches for the development of functional meat products, new techniques for analysing raw meat, modified atmosphere packaging, perspectives for the active packaging of meat products.

**Unit-II**

Poultry: quality of poultry, stunning and slaughter of poultry, processing and packaging of poultry, new techniques of preservation of poultry, production of turkeys, geese, ducks and game birds, microbial hazards in poultry production and processing, latest trends in measuring quality of poultry and poultry products, treatment and disposal of poultry processing waste.

**Unit-III**

Fish and seafood: Fresh fish handling and chill storage, modified atmospheric packaging of seafoods, fish odours and flavours, assessment of freshness of fish and seafoods, traditional dried and salted fish products, proteolysed fish products, minced fish technology, retort pouch processing technology, irradiation and microwave in fish handling and processing, advanced freezing technology for fish storage, high pressure processing of seafoods, value addition of freshwater and aqua cultured fish products, application of enzymes in fish processing and quality control, toxins, pollutants and contaminants in fish and seafoods.

**Unit-IV**

Milk: Physical, chemical and nutritional properties of milk components, improvements in the pasteurization and sterilization of milk. Flavour generation in dairy products, controlling texture of fermented dairy products, functional dairy products, on-line measurement of product quality in dairy processing, high pressure processing of milk products, novel separation technologies to produce dairy ingredients, new technologies to increase shelf-life of dairy products, genetic engineering of milk proteins, production and utilization of functional milk proteins, methods of improving nutritional quality of milk, significance of milk fat in dairy products, chromatographic, spectrometric, ultrasound and other techniques for analysis of milk lipids.

**Practical:**

Analysis of fresh and processed meat, fish, poultry and milk products, preservation of fresh meat and fish, processing and production of different products from fresh meat, fish and milk, shelf life studies on different meat, fish and milk products. Visit to processing plants.

**Course Outcome:**

Student's capability to process meat, fish and poultry and manufacture value added products as per requirement of food industries.

**Teaching Schedule**

| S. No. | Topic | No. of Lectures |
|---|---|---|
| 1. | Different farm animals for better meat quality. | 1 |
| 2. | Developments in automation of the modern slaughterhouses | 1 |
| 3. | Study of hot-boning process of meat and its benefits. | 1 |
| 4. | New spectroscopic techniques for online monitoring of meat quality, | 1 |
| 5. | Study of different methods for the detection of pathogens in meat. | 1 |
| 6. | Automated meat processing | 1 |
| 7. | developments in chilling and freezing of meat | 1 |
| 8. | High pressure processing of meat | 1 |
| 9. | approaches for the development of functional meat products | 1 |
| 10. | New techniques for analyzing raw meat, | 1 |
| 11. | modified atmosphere and active packaging of meat products. | 1 |
| 12. | quality of poultry and its product | 1 |
| 13. | Stunning and slaughter of poultry, | 1 |
| 14. | Processing and packaging of poultry | 1 |
| 15. | New techniques of storage and preservation of poultry products. | 1 |
| 16. | Production of turkeys, geese, ducks and game birds. | 1 |
| 17. | Microbial hazards in poultry production and processing, | 1 |
| 18. | Different treatments and disposal of poultry processing waste | 1 |
| 19. | Latest trends in measuring quality of poultry | 1 |
| 20. | Latest trends in measuring quality of poultry products | 1 |
| 21. | Fish and seafood: Fresh fish handling and chill storage; modified atmospheric packaging for fish and fish products | 1 |
| 22. | Assessment of freshness of fish and seafoods | 1 |
| 23. | Different traditional and proteolysed fish products | 1 |
| 24. | study of minced fish technology and products | 1 |
| 25. | Retort pouch processing technology, irradiation and microwave in fish processing, Advanced freezing technology for fish storage | 1 |
| 26. | Value addition of freshwater and aqua cultured fish products | 1 |
| 27. | application of enzymes in fish processing. | 1 |
| 28. | Quality control: toxins, pollutants and contaminants in fish and sea foods. | 1 |
| 29. | Physical, chemical and nutritional properties of milk components, improvements in the pasteurization and sterilization of milk. | 1 |
| 30. | Flavour generation in dairy products, controlling of texture in fermented | 1 |

| | | |
|---|---|---|
| | dairy products. | |
| 31. | Functional dairy products, on-line measurement of product quality, high pressure processing, Novel separation technologies to produce dairy ingredients, new technologies to increase shelf-life of dairy products. | 1 |
| 32. | Methods of improving nutritional quality of milk, significance of milk fat in dairy products and different techniques for analysis of milk lipids. | 1 |
| **Total** | | **32** |

**List of Practicals**

| **S. No.** | **Topic** | **No. of Practical's** |
|---|---|---|
| 1. | Analysis of fresh and processed meat products | 1 |
| 2. | Analysis of fresh and processed fish products | 1 |
| 3. | Analysis of fresh and processed poultry products | 1 |
| 4. | Analysis of fresh and processed milk products | 1 |
| 5. | Preservation of fresh meat and fish | 1 |
| 6. | Processing of fresh meat | 1 |
| 7. | Production of different products from fresh meat | 1 |
| 8. | Processing and production of different products from fresh fish | 2 |
| 9. | Processing and production of different products from fresh poultry | 2 |
| 10. | Processing and production of different products from fresh milk | 1 |
| 11. | Shelf life studies on different meat, fish and milk products | 2 |
| 12. | Visit to processing plants | 1 |
| **Total** | | **16** |

**Suggested Readings:**

1. Chooksey M K and Basu S 2003. *Practical Manual on Fish Processing and Quality Control*. CIFE, Kochi.
2. Chooksey M K 2003.*Fish Processing and Product Development*. CIFE, Kochi.
3. Hall G M 1997.*Fish Processing Technology*. Blabie Academic and Professional.
4. Lawrie R S 1985.*Developments in Meat Sciences*. Vol III Applied Science Publishers.
5. Mead G C 1989. *Processing of Poultry*. Elsevier.
6. Pearson AM and Tauber F W 1984. *Processed Meats*. AVI Publishers.
7. Stadelman W J andCotterill O J 1980. *Egg Science and Technology*. AVI Publishers.
8. Henricksons. 1978. Meat Poultry and Sea Food Technology/ Prentice Hall
9. Robert RJ. 2012. Fish Technology/ Wiley-Blackwell. Mountney GJ. 1988. Poultry Meat and Egg Production/ Springer, Netherlands.
10. Levie A. 1979. Meat Hand Book, Avi Pub.

11. Mead G. 2004. Poultry meat processing and quality Woodhead Publishing.
12. Sinha R. 2017. HACCP in Meat, Poultry and Fish Processing/ Random Publications.
13. Sahoo J and Chatli MK. 2015. Textbook on Meat, Poultry and Fish Technology/ Daya Pub.House.
14. Badapanda KC. 2012. Basics of Fisheries Science/ Narendra Publishing House.
15. Sahoo J, Sharma DK and Chatli MK. 2016. Practical Handbook on Meat Science and Technology/ Daya Pub. House.

**PFE 517 Design of Aquacultural Structures 2+1**

**Objectives:**
To acquaint and equip the students with aquaculture structures and their design features.

**Unit-I**
Inland fish farming and associated considerations.

**Unit-II**
Fish physiology and micro-climatic considerations.Site selection for aquaculture structures.

**Unit-III**
Design of dykes, sluice, channels etc. Aeration and feeding systems: Design of fish rearing structures, hatcheries, containers for live fish, fingerlings, fish seeds.

**Unit-IV**
Aquaculture in recirculatory systems, oxygen and aeration, sterilization and disinfection. Recirculation of water:Reuse systems, water exchange, design of re-use systems, Inlet and outlet structures and water treatment plants.

**Practical:**
Aeration and feeding systems of fish ponds, fish farming structures, water treatment plants, containers for live fish. Design of re-use systems. Inlet and outlet structures.

**Course Outcome:**
Student's capability to design suitable aquaculture structures.

**Teaching Schedule**

| S. No. | Topic | No. of Lectures |
|---|---|---|
| 1. | Inland fish farming. | 1 |
| 2. | Considerations in site selection for designing inland fish farms. | 2 |
| 3. | Preparatory work for designing inland fish farms: technological requirements, general technical, hydrological and meteorological data. | 3 |
| 4. | Fish physiology. | 2 |
| 5. | Micro-climatic considerations for fish farms. | 1 |
| 6. | Design of dykes, sluice, channels etc. | 3 |
| 7. | Aeration and feeding systems. | 1 |
| 8. | Design of fish rearing structures. | 1 |
| 9. | Hatcheries. | 2 |
| 10. | Containers for live fish, fingerlings, fish seeds. | 1 |
| 11. | Fish pond arrangements: Barrage Ponds, Contour Ponds, Paddy Ponds. | 2 |
| 12. | Earth structures in fish farms: Dams and Dikes, Feeder Canals, Drainage canals, Drain Ditch, Internal Pond Drains, Borrow Pits and Internal Harvesting Pits. | 3 |
| 13. | Aquaculture in recirculatory systems. | 2 |

| | | |
|---|---|---|
| 14. | Oxygen and aeration in fish farms. Sterilization and disinfection in fish farms. | 2 |
| 15. | Recirculation of water: Reuse systems, water exchange, design of re-use systems, Inlet and outlet structures. | 3 |
| 16. | Water treatment plants in fish farms. | 1 |
| | **Total** | **30** |

**List of Practicals**

| **S. No.** | **Topic** | **No. of Practicals** |
|---|---|---|
| 1 | Study of aeration systems of fishponds. | 1 |
| 2 | Study of feeding systems of fishponds. | 1 |
| 3 | Design of dykes in fish farming structures. | 1 |
| 4 | Design of feeder canals in fish farming structures. | 2 |
| 5 | Design of drainage canals in fish farming structures. | 1 |
| 6 | Design of drain ditch in fish farming structures. | 1 |
| 7 | Design of internal pond drains in fish farming structures. | 1 |
| 8 | Design of borrow pits in fish farming structures. | 1 |
| 9 | Design of internal harvesting pits in fish farming structures. | 1 |
| 10 | Study of waste water management through aquaculture. | 1 |
| 11 | Design of recirculatory ponds for wastewater treatment in fish farms. | 1 |
| 12 | Different types of containers for live fish. | 1 |
| 13 | Design of re-use systems in fish farms. | 1 |
| 14 | Different types of inlet and outlet structures in fish farms. | 1 |
| | **Total** | **15** |

**Suggested Readings:**


1. FAO 1983 *Inland Aquaculture Engineering.* ISBN 92-5-102168-6
2. Chandrakant, M.H. (2003). Selection of suitable site for Aquaculture,: Course Manual Aquaculture
3. Engineering, Short-Term Training Programme on AquaculturalEngineering. Central Institute of Fisheries Education, Mumbai pub. No (238):6-49pp
4. S. Vardaraju and J. Stephen Sampath Kumar, Aquacultural Engineering.

**PFE 518 Thermal Environmental Engineering for Agricultural Processing 3+0**

**Objectives:**
To acquaint and equip the students with the concept of thermodynamic properties of air and its application in food processing.

**Unit-I**
Requirements of temperature and moisture in food preservation, processing, storage, animal and plant production systems, human comfort etc.

**Unit-II**
Thermodynamic properties of moist air, psychrometric chart, psychrometric processes and applications. Mass transfer and evaporation of water from free surfaces, theory of psychrometer, direct contact transfer processes between moist air and water-air washer, cooling tower, heating and cooling of moist air by extended surface coils, dehumidification using moisture absorbing materials. Solar irradiations on structures, calculation of heating and cooling loads in buildings/ storage structures.

**Unit-III**
Design of air conditioning systems, air distribution and duct design, air flow pattern and control, equipment, components and controls.Instruments for measurement and control of temperature and moisture.

**Unit-IV**
Thermal insulation materials for environmental control systems, applications of environmental control in green house, dairy industry, potato storage etc.

**Course Outcome:**
Student’s capability to design environmental control systems related to different unit operation in food processing industry.

**Teaching Schedule**

| S. No. | Topic | No. of Lectures |
|---|---|---|
| 1. | Requirements of temperature and moisture in food preservation, processing, storage, animal and plant production systems, | 3 |
| 2 | Requirements of temperature and moisture in human comfort etc. | 2 |
| 3 | Various thermal indices for human comfort | 1 |
| 2. | To study the different temperature, moisture and relative humidity measuring instruments. | 3 |
| 4. | Thermodynamic properties of moist and dry air | 3 |
| 5 | Construction of the Chart, | 2 |
| 6 | Use of Psychrometric Chart to Evaluate Complex Air-Conditioning Processes | 3 |

| | | |
|---|---|---|
| 7 | Mass transfer and evaporation of water from free surfaces, | 1 |
| 8. | Direct contact transfer processes between moist air and water-air washer, cooling tower, heating and cooling of moist air by extended surface coils, dehumidification using moisture absorbing materials. | 4 |
| 6. | Solar irradiations on structures, calculation of heating and cooling loads in buildings/ storage structures. | 3 |
| 7. | Introduction to air conditioning systems and design considerations. | 4 |
| 8. | air distribution and duct design, components and controls. | 4 |
| 9. | air flow pattern and its control in air condition system | 2 |
| 10. | Instruments for measurement and control of temperature and moisture in air conditioning. | 2 |
| 11. | Thermal insulation materials for environmental control systems. Comparative performance of these materials. | 4 |
| 12 | Applications of environmental control in farm buildings, farmstead, poultry shed, green house etc. | 5 |
| 13 | Applications of environmental control in dairy industry, potato storage, onion storage etc. | 2 |
| **Total** | | **48** |

**Suggested Readings :**


1. Threlkald JL. *Thermal Environmental Engineering*, Pearson
2. *Perry's Chemical Engineers' Handbook*, Section 12. (2007).
3. R. Paul Singh and Dennis R. Heldman, *Introduction to Food Engineering, Food Science and Technology International Series.*
4 Earle R L 1985. Unit Operations in Food Processing. Pergamon Press.

## Course Syllabus and Contents of Doctoral Degree

### PFE 601 Advances in Food Process Engineering 2+1

**Unit-I**

Preservation of foods: Physical and chemical methods, microbiological aspects, thermo bacteriology, process calculation and selection. Thermal processing of canned foods: Introduction, commercial sterilization systems, thermalin activation, kinetics of bacterialspores, heat transfer in canned foods, process calculations, and numerical computer simulation of heat transfer, aseptic processing.

**Unit-II**

Low temperature preservation: Cooling and cold storage. Hurdle technology: Principles and applications. Food irradiation: Advantages and applications, beneficial chemical and biological effects on foods, mechanisms of food irradiation, sources of food irradiation, criteria for judging the efficacy, dosimetry, radiation tolerance of foods, upper irradiation dose for foods, safety of irradiated foods. Microwave processing: Interaction with food materials, microwave equipment. Hydrostatic pressure treatment of food: Equipment, processing and effect on microorganisms. High pressure processing: Introduction, equipment and operation principles. Chemical and thermo dynamic principles. Applications of HP to foods. Commercial high pressure equipment and applications. Membrane concentration of liquid foods: Principles, thermodynamics and osmotic pressure, mechanisms of membrane transport, membrane transport models.

**Unit-III**

Application of heat energy and ultra sound: Effects of different environmental factors on microbial ultrasonic resistance, effects of treatment parameters on lethal effect of ultrasound, mechanism of action of inactivation of microorganisms and enzymes, cavitation. Electrical resistance heating of food: Heat generation. Ohmicheating and moderate electric field: Introduction, microbial death kinetics, electrolytic effects, applications, ohmic heater, heating models. Pulsed electric field preservation: Principles and application, microbial inactivation mechanism, determinant factors in PEF technology, influence on food ingredients, pulsed electric field treatment unit, modeling PEF microbial inactivation, alternative applications of PEF technology, decontamination of microorganisms by surface treatment.

**Unit-IV**

Extrusion cooking: Rheology of extrudates, Newtonian models of single-screw extruder performance, non-Newtonian models of single-screw extruder performance, single-screw extruder leakage flows, extruder die and its interaction with extruder behaviour, screw power demand, non-isothermal screw operation, feed zone, behavior of more complex single-screw designs, multiple-screw extruders, partially filled screws, analysis of complex screws, heat transfer in extruders, extruder residence-time distributions, recent developments, methods, equipment, design criteria of extruders.

**Practical:**

Thermal processing of foods, sterilization, irradiation, membrane concentration, ultra sound, ohmicheating, pulsed electric field preservation, extrusion cooking, product quality determination. Visit of related food industries.

**Course Outcome:**

Student's capability to process and preserve food products using advance techniques as per requirement of food industries.

**Teaching Schedule**

| S.No. | Topic | No. of Lectures |
|---|---|---|
| 1 | Preservation of foods: Physical and chemical methods, microbiological aspects, thermo bacteriology, process calculation and selection. | 3 |
| 2 | Thermal processing of canned foods: Introduction, commercial sterilization systems, thermalin activation, kinetics of bacterialspores, heat transfer in canned foods, process calculations, and numerical computer simulation of heat transfer, aseptic processing. | 4 |
| 3 | Low temperature preservation: Cooling and cold storage. | 3 |
| 4 | Hurdle technology: Principles and applications | 2 |
| 5 | Food irradiation: Advantages and applications, beneficial chemical and biological effects on foods, mechanisms of food irradiation, sources of food irradiation, criteria for judging the efficacy, dosimetry, radiation tolerance of foods, upper irradiation dose for foods, safety of irradiated foods. | 2 |
| 6 | Microwave processing: Interaction with food materials, microwave equipment. | 2 |
| 7 | Hydrostatic pressure treatment of food: Equipment, processing and effect on microorganisms. High pressure processing: Introduction, equipment and operation principles. Chemical and thermo dynamic principles. Applications of HP to foods. Commercial high pressure equipment and applications. | 2 |
| 8 | Membrane concentration of liquid foods: Principles, thermodynamics and osmotic pressure, mechanisms of membrane transport, membrane transport models. | 2 |
| 9 | Application of heat energy and ultra sound: Effects of different environmental factors on microbial ultrasonic resistance, effects of treatment parameters on lethal effect of ultrasound, mechanism of action of inactivation of microorganisms and enzymes, cavitation. | 2 |
| 10 | Electrical resistance heating of food: Heat generation. Ohmicheating and moderate electric field: Introduction, microbial death kinetics, electrolytic effects, applications, ohmic heater, heating models. | 2 |
| 11 | Pulsed electric field preservation: Principles and application, microbial inactivation mechanism, determinant factors in PEF technology, influence on food ingredients, pulsed electric field treatment unit, modeling PEF microbial inactivation, alternative | 2 |

| | | |
|---|---|---|
| | applications of PEF technology, decontamination of microorganisms by surface treatment. | |
| 12 | Extrusion cooking: Rheology of extrudates, Newtonian models of single-screw extruder performance, non-Newtonian models of single-screw extruder performance, single-screw extruder leakage flows, extruder die and its interaction with extruder behaviour, screw power demand, non-isothermal screw operation, feed zone, behavior of more complex single-screw designs, multiple-screw extruders, partially filled screws, analysis of complex screws, heat transfer in extruders, extruder residence-time distributions, recent developments, methods, equipment, design criteria of extruders. | 4 |
| | **Total** | **30** |

**List of Practicals**

| **S.No.** | **Topic** | **No. ofPractic als** |
|---|---|---|
| 1. | Study of thermal processing of foods and equipment viz pasteurization and sterilization and tutorials. | 2 |
| 2. | Study of different irradiation processes and equipments. | 1 |
| 3. | Study of different membrane separation processes and equipments. | 1 |
| 4. | Study of different ultrasound processes and equipments | 1 |
| 5. | Study of different ohmicheating method and equipments. | 1 |
| 6. | Study of different pulsed electric field preservation processes and equipments. | 1 |
| 7. | Study of different extrusion cooking method and equipments. | 2 |
| 8. | Product quality determination | 2 |
| 9. | Visit of various food industries. | 3 |
| 10. | Development of experimental setup by students | 1 |
| | **Total** | **15** |

**Suggested Readings:**


1. Brennan JG, Butters JR, Cowell ND and Lilly AEI. 1990. *Food Engineering Operations*. Elsevier Publications.
2. Fellows P 1988. *Food Processing Technology: Principle and Practice*. VCH Publications.
3. Geankoplis J Christie1999. *Transport Process and Unit Operations*. Allyn & Bacon.
4. Henderson S and Perry SM1976. *Agricultural Process Engineering*. 5thEd. AVI Publishing Company.
5. McCabe WL and Smith JC1999. *Unit Operations of Chemical Engineering*. McGraw Hill.

6. Sahay KM and Singh KK1994. *Unit Operation of Agricultural Processing*. Vikas Publishing House Pvt Ltd.
7. Singh RP and Heldman DR 1993. *Introduction to Food Engineering*. Academic Press.
8. Singh RP1991. *Fundamentals of Food Process Engineering*. AVI Publishing Company.

**PFE 602 Drying and Dehydration of Food Materials 2+1**

**Objectives:**
To acquaint and equip the students with the latest technologies of dehydration of food products and the design features of different dryers.

**Unit-I**
Importance of drying, principles of drying, moisture determination, equilibrium moisture content, determination of EMC, methods and water activity isotherm models. Psychrometry: Psychrometric terms, construction and use of psychrometric charts.

**Unit-II**
Airflow and resistance, principles and equipment for air movement and heating, drying methods and theory of drying, dryers, classification and other allied equipment, thin layer drying of cereal grains, deep bed and continuous flow drying, drying models.

**Unit-III**
Heat requirements and thermal efficiency of drying system, aeration, tempering and dehydration, operation of dryers and their controls, selection of dryers, performance testing of grain dryers, drying characteristics of cereals, pulses and oilseeds, microwave drying, radio frequency drying and tunnel drying, principles and equipment.

**Unit-IV**
Drying of liquid foods, spray drying, drum drying, freeze drying, foam mat drying, heat pump drying, refractance window drying, infra red drying osmotic dehydration, solar drying. Principles, methods, construction and adjustments, selection of dryers, heat utilization factor and thermal efficiency.

**Practical:**

Experiments on batch type thin layer dryer, fluidized bed dryer, continuous flow mixing type dryer, continuous flow non mixing type dryer, sand medium dryer (conduction type drying), agricultural waste fired furnace dryer, spray dryer, drum dryer, foam mat drying and osmotic dehydration to evaluate the thermal efficiency and heat utilization factor.

**CourseOutcome:**
Student's capability to develop dehydrated food products with higher retention of nutrients using different drying techniques and equipments.

**Teaching Schedule**

| S.No. | Topic | No. of Lectures |
|---|---|---|
| 1. | Importance of drying, principles of drying, moisture content determination, equilibrium moisture content, determination of EMC. | 3 |
| 2. | Basic concepts associated with drying–Intermolecular forces, Water activity, Molecular mobility, Glass transition temperature, Isotherm models– Langmuir, BET Isotherm | 3 |
| 3. | Psychrometry: Psychrometric terms, construction and use of psychrometric charts. | 3 |
| 4. | Airflow and resistance, principles and equipment for air movement and heating | 3 |

| | | |
|---|---|---|
| 5. | Theory of drying, Dryers, Classification and other allied equipment, | 2 |
| 6. | Thin layer drying of cereal grains, deep bed and continuous flow drying, drying models. | 3 |
| 7. | Heat requirements and thermal efficiency of drying system, aeration, tempering and dehydration. | 3 |
| 8. | Operation of dryers and their controls, selection of dryers, performance testing of grain dryers Drying characteristics of cereals, pulses and oilseeds, | 3 |
| 9. | Microwave drying, radio frequency drying and tunnel drying, principles and equipment. | 2 |
| 10. | Drying ofl iquid foods, spray drying, drum drying. Principles, methods, construction and adjustments. | 3 |
| 11. | Freeze drying, foam mat drying, heat pump drying, refractance window drying, infrared drying, and osmotic dehydration. Principles, methods, construction and adjustments. | 3 |
| 12. | Selection of dryers, heat utilization factor and thermal efficiency. | 1 |
| | **Total** | **32** |

**List of Practicals**

| S.No. | Topic | No. of Practicals |
|---|---|---|
| 1. | Determination of moisture content with Oven method. | 1 |
| 2. | Determination of moisture content (w.b.) with Universal/ Digital moisture meter. | 1 |
| 3. | Determination of moisture content (wb) with Infrared moisture meter. | 1 |
| 4. | Determination of Equilibrium moisture content of grains. | 1 |
| 5. | To evaluate the thermal efficiency and heat utilization factor of batch type thin layer dryer for food grains | 1 |
| 6. | To determine the drying characteristics, moisture diffusivity and activation energy of food products. | 1 |
| 7. | To study the drying characteristics of food materials in a solar cabinet/ tunnel drying system. | 1 |
| 8. | To study the drying characteristics of food materials in continuous flow mixing type dryer. | 1 |
| 9. | To evaluate the performance of refractance window dryer. | 1 |
| 10. | To determine the drying efficiency of agricultural waste fired furnace dryer. | 1 |
| 11. | To determine thermal efficiency and heat utilization factor of food material in a spray dryer | 1 |
| 12. | To evaluate the performance of a freeze/ vacuum/ drum dryer. | 1 |
| 13. | To study the foam mat drying process for fruit leather/ powder. | 1 |
| 14. | To study the osmotic dehydration of fruits and vegetables. | 1 |
| 15. | To determine the quality parameters of dried food products by using tray dryer. | 2 |
| | **Total** | **16** |

**Suggested Readings:**


1. Bala BK 1998. *Drying and Storage of Cereal Grains*. Oxford and IBH.
2. Brooker DB, Bakker Arkema FW and Hall CW 1974. *Drying Cereal Grains*. The AVI Publishing Company.
3. Chakraverty A and De DS 1999. *Post-Harvest Technology of Cereals, Pulses and Oilseeds*. Oxford & IBH.
4. Hall CW 1970. *Drying Farm Crops*. Lyall Book Depot.
5. Kudra and Mujumdar 2009. *Advanced Drying Technologies*. CRC press.

## PFE 603 Textural and Rheological Characteristics of Food Materials 2+1

**Objectives:**

To acquaint and equipthe students with advances in measurement of textural and rheological characteristics affecting the food quality.

**Unit-I**

Rheological properties of foods: Food rheology, physical states of materials, classical idealmaterial, rheological models, elements in the models, electrical equivalence, maxwell model, Kelvin model and four element burger's model, stress-strain behavior. Elastic–plastic behavior, visco-elastic behavior, creep behavior, dynamic visco-elastic behavior, flow behavior of fluids, creep, stress relaxation.

**Unit-II**

Viscometry: Capillary viscometry, Cassonmodel, flow rate equation, friction losses in pumping, turbulent flow, Newtonian fluid, power law fluid, cone and plate viscometry, parallel plate viscometry, mixer viscometry. Flow through a converging die, Cogswell's equations, Gibson's equations, empirical method. Applications of stress and strain, shear modulus and shear loss modulus, storage compliance and loss compliance, comparison of moduli and compliances.

**Unit-III**

Objective and subjective measurements of texture: Texture classification, relation of food texture with structure and rheology, principles and practices of objective or instrumental texture measurements, fundamental rheological tests, physiological aspects, mechanical aspects and viscosity measurements and relationship between fundamental tests and sensory evaluation. Imitative and empirical measurements of texture: Tenderometer, Brabender farinograph, firmness meter, texture profile method, dynamic methods for evaluation of food texture, dimensional analysis of food texture, firmness and hardness measurement.

**Unit-IV**

Mathematical models and their application along with pipeline design and pump selection for non-Newtonian fluids. Recent advances in textural, rheological and visco - elastic characteristics of foods and their associated mathematical models.

**Practical:**

Determination of viscosity of liquid foods, gumminess, chewiness, springiness and hardness of various fruits, vegetables and processed foods using texture profile analysis. Determination of force-distance relationship. Sensory evaluation/ subjective measurement and correlation between subjective and objective measurements of foods.

**Course Outcome:**

Student's capability to determine textural and rheological properties of food materials and their application in control of food processing operations.

**Teaching Schedule**

| S.No. | Topic | No. ofLectures |
|---|---|---|
| 1. | Objective and subjective measurements of texture: Texture classification, relation of food texture with structure and rheology. | 3 |
| 2. | Principles of Objective Texture Measurement. | 2 |
| 3. | Practices of objective or instrumental texture measurements. | 2 |
| 4. | Fundamental rheological tests, physiological aspects, mechanical aspects and viscosity measurements and relationship between fundamental tests and sensory evaluation. | 2 |
| 5. | Imitative and empirical measurements of texture: Tenderometer, brabender farinograph, firmness meter, texture profile method, dynamic methods for evaluation of food texture, dimensional analysis of food texture, firmness and hardness measurement. | 2 |
| 6. | Rheological properties of foods: Food rheology, physical states of materials, classical ideal material. | 2 |
| 7. | Elastic–plastic behavior, visco-elastic behavior, creep behavior, dynamic visco-elastic behavior, flow behavior of fluids, creep, stress relaxation. | 2 |
| 8. | Rheological models, elements in the models, electrical equivalence, Maxwell model, Kelvin model and four element burger's model, stress- strain behavior. | 2 |
| 9. | Viscometry: Capillary viscometry, Casson model, flow rate equation, friction losses in pumping, turbulent flow, Newtonian fluid, power law fluid, cone and plate viscometry, parallel plateviscometry, mixer viscometry. | 2 |
| 10. | Flow through a converging die, Cogswell's equations, Gibson's equations, and empirical method. | 2 |
| 11. | Applications of stress and strain, shear modulus and shear loss modulus, storage compliance and loss compliance, comparison of moduli and compliances. | 2 |
| 12. | Correlation between physical measurements and sensory assessments of texture and viscosity. | 2 |
| 13. | Mathematical models and their application along with pipe-line design and pump selection for non-Newtonian fluids. | 2 |
| 14. | Recent advances in textural, rheological and visco elastic characteristics of foods and their associated mathematical models. | 2 |
| | **Total** | **30** |

**List of Practicals**

| S.No. | Topic | No. of Practical |
|---|---|---|
| 1 | Introduction to Texture analyzer | 1 |
| 2 | Study of different attachments of texture analyzer used in texture analysis of various agricultural commodities. | 1 |

| | | |
|---|---|---|
| 3 | To study the texture profile curve for food material | 1 |
| 4 | To study the textural profile kinetics of various fruits | 2 |
| 5 | To study the textural profile kinetics of various vegetables | 2 |
| 6 | To study the textural profile kinetics of various processed foods | 2 |
| 7 | To study the textural properties of liquid food | 1 |
| 8 | To study the Compression, puncture, elongation and bending tests for food materials | 3 |
| 9 | Introduction to Rapid Viscoanalyzer | 2 |
| 10 | Subjective measurement and correlation between subjective and objective measurements of foods. | 1 |
| | **Total** | **16** |

**Suggested Readings:**


1. Bourne MC 2002. *Food Texture and Viscosity: Concept and Measurement*. Academic Press.
2. Deman JM 1976. *Rheology and Texture in Food Quality*. AVI Publications.
3. Mohsanin NN 1989. *Physical Properties of Plant and Animal Material. Vol.I ,II*. Gordon and Breach Science Publications.
4. Steffe JF 1992. *Rheology and Texture in Food Quality*.AVI Publications.

## PFE 604 Agricultural Waste and By-Products Utilization 2+1

**Objectives:**

To acquaint and equip the students with the techniques of utilization of agricultural waste and by-products and also about development of value added products from wastes.

**Unit-I**

Conversion processes: Thermo-chemical conversions, densification, combustion and gasification, extraction, biological conversions, anaerobic digestion, biochemical digestion process, digestion systems, energy from anaerobic digestion, cellulose degradation, fermentation process. Agricultural wastes as paper, boards and fuel.

**Unit-II**

Briquetting: Briquetted fuel from husk, hull and other wastes selection, design of briquetting machines. Utilization of shell, stem and stalk: Production of activated carbon. By-products of agro-industries: Rice mill, oil mill, cattle feed mill, valuable constituents and composition. Utilization of rice husk: Production of silica and cement from rice husk. Stabilization and storage of rice bran, extraction of rice bran oil.

**Unit-III**

By-products of oil refining: Fatty acids/ soap stock, wax and gum, characteristics and utilization. Rice germ and broken rice. Production of starch and infant food, industrial uses of starch. By-products of oil milling: Oil cake and defatted oilcake, cattle feed and industrial uses. Utilization of starch and other industrial wastes: Micro crystalline cellulose, production of ethanol, wastes of tapioca starch industries, thippi-utilization as fuel, extraction of starch by hydrolysis, utilization of starch for food, adhesives and feed purposes.

**Unit-IV**

By-products of sugar industry: Sugarcane tops, bagasse, molasses and press mud, utilization as animal feed. By-products of fruits and vegetables based agro-industries: Mango seed kernel and pineapple waste.

**Practical:**

Exercises on stepped grate and fixed grate rice husk furnaces, waste fired furnace, briquette machine, production o f alcohol from waste materials, production and testing of paper boards and particle boards from agricultural wastes.

**Course Outcome:**

Student's capability to develop processes for effective utilization of wastes generated through milling and processing of food materials.

**Teaching Schedule**

| S.No. | Topic | No. of Lecture |
|---|---|---|
| 1. | Introduction to by-products and waste generation in agricultural production and processing system. Generation of agricultural and agro industrial by-products/ wastes, their properties, onsite handling, storage and processing. | 2 |

| | | |
|---|---|---|
| 2. | Thermo-chemical conversions, biological conversions, anaerobic digestion, biochemical digestion process, digestion systems, energy from anaerobic digestion, cellulose degradation, fermentation process. | 3 |
| 3. | Combustion and its types, theory, basic requirements for combustion, extraction. | 2 |
| 4. | Gasification process, gasifiers-types and their functioning, factors affecting gasification process. | 2 |
| 5. | Densification process, methods to densify materials, factors to be considered. | 1 |
| 6. | Utilization of wastes for paper production, production of particle board. | 1 |
| 7. | Briquetting process, methods, design of machinery used for briquette formation, basic requirements, factors affecting briquetting from husk, hull and other wastes selection. | 2 |
| 8. | Utilization of ricehusk: Production of silica and cement from ricehusk, Stabilization and storage of rice-bran, extraction of rice-bran oil. | 2 |
| 9. | Utilization of shell, stem and stalk: Production of activated carbon. | 1 |
| 10. | By-products from rice milling operations, ricehusk, rice bran, utilization in different materials. | 3 |
| 11. | Waste from oil mill, cattle feed mill,their valuable constituents and composition, utilization. | 2 |
| 12. | By-products of oil refining: Fatty acids/ soap stock, wax and gum, characteristics and utilization. | 1 |
| 13. | Rice germ and broken rice. Production of starch and infant food, industrial uses of starch. | 1 |
| 14. | By-products of oil milling: Oil cake and defatted oil cake, cattle feed and industrial uses. | 1 |
| 15. | Utilization of starch and other industrial wastes: Micro crystalline cellulose, production of ethanol, wastes of tapioca starch industries. | 2 |
| 16. | Thippi-utilization as fuel, extraction of starch by hydrolysis, utilization of starch for food, adhesives and feed purposes. | 2 |
| 17. | By-products of sugar industry: Sugar cane tops, bagasse, molasses and pressmud, utilization as animal feed. | 2 |
| 18. | By-products of fruits and vegetables based agro-industries: Mango seed kernel and pineapple waste. | 2 |
| | **Total** | **32** |

**List of Practicals:**

| S.No. | Experiment | No. of Practical |
|---|---|---|
| 1. | To determine moisture content of biomass. | 1 |
| 2. | To determine ash content of biomass. | 1 |
| 3. | To determine Proximate analysis of biomass/ waste/ residue. | 2 |
| 4. | Exercises on stepped grate and fixed grate rice husk furnaces . | 2 |

| | | |
|---|---|---|
| 5. | Exercises on waste fired furnaces. | 1 |
| 6. | Exercises on combustion calculation. | 1 |
| 7. | To study the briquetting machine. | 1 |
| 8. | To study the various quality parameters of briquettes. | 1 |
| 9. | To study the production of alcohol from waste materials. | 2 |
| 10. | To study the production of paper boards and particle boards from agricultural wastes. | 2 |
| 11. | To determine the properties of paper boards and particle boards from agricultural wastes. | 2 |
| | **Total** | **16** |

**Suggested Readings:**


1. ASAE Standards1984.*Manure Production and Characteristics.*
2. Bor SL(Ed.) 1980. *Rice: Production and Utilization*. AVI Publ.
3. Chahal DS 1991. *Food, Feed and Fuel from Biomass.* Oxford & IBH.
4. Chakraverty A1989. *Biotechnology and other Alternative Technologies for Utilization of Biomass/ Agricultural Wastes*. Oxford & IBH.
5. Donald LK and Emert HG1981. *Fuels from Biomass and Wastes*. Ann. Arbor. Science Publ.
6. Srivastava PK, Maheswari RC and Ohja TP1995. *Biomass Briquetting and Utilization*. Jain Bros.
7. USDA 1992. *Agricultural Waste Management Field Handbook*. USDA.

**PFE 605 Mathematical Modeling in Food Processing 3+0**

**Objectives:**

To acquaint and equip the students with the mathematical modeling techniques and their applications in food processing

**Unit-I**

An overview of the modeling process. Introduction to mathematical, correlative and explanatory models. Formulation, idealization and simplification of the problems.

**Unit-II**

Probability models, series and linear mathematical approximation, dynamic and interacting dynamic processes.

**Unit-III**

Applications of mathematical modelling techniques to food processing operations like parboiling, convective drying, pasteurization, dehydration, shelf-life prediction, fermentation, aseptic processing, moisture diffusion, deep fat drying, microwave processing, infrared heating and ohmic heating.

**Unit-IV**

Stochastic finite element analysis of thermal food processes. Neural networks approach to modelling food processing operations.

**Course Outcome:**

Student's capability to develop models for food processing operations for prediction and control of operations.

**Teaching Schedule**

| S.No. | Topic | No. of Lectures |
|---|---|---|
| 1. | An overview of the modeling process. | 2 |
| 2. | Introduction to mathematical, correlative and explanatory models. Formulation, idealization and simplification of the problems. | 3 |
| 3. | Probability models, series and linear mathematical approximation | 3 |
| 4. | Dynamic Mathematical Model, Analysis of Dynamic Mathematical Models, dynamic and interacting dynamic processes. | 3 |
| 5. | Basic Concepts of Systems Analysis and Simulation. | 3 |
| 6. | Common Heat and Mass Transfer Models Dimensional Analysis. | 3 |
| 7. | Model-based techniques in food processing. | 2 |
| 8. | Applications of mathematical modeling techniques to parboiling of rice, convective drying/ dehydration, deep fat drying etc. | 4 |
| 9. | Applications of mathematical modeling techniques to pasteurization of milk and juices. | 4 |
| 10. | Applications of mathematical modeling techniques to fermentation, aseptic processing, moisture diffusion. | 4 |
| 11. | Applications of mathematical modeling techniques in shelf-life prediction of agricultural commodities. | 4 |
| 12. | Applications of mathematical modelling techniques to microwave heating, infrared heating and ohmic heating. | 4 |

| | | |
|---|---|---|
| 13. | Stochastic finite element analysis of thermal food processes. | 3 |
| 14. | Probability models, series and linear mathematical approximation | 3 |
| 15. | Neural networks approach to modeling food processing operations. | 3 |
| | **Total** | **48** |

**Suggested Readings:**

1. Fischer M, Scholten HJ and Unwin D1996. *Spatial Analytical Perspectives on GIS*. Taylor & Francis.
2. Fish NM and Fox RI 1989. *Computer Application in Fermentation Technology: Modelling and Control of Biotechnological Processes*. Elsevier.
3. Gold HJ1977. *Mathematical Modelling of Biological Systems-An Introductory Guidebook.* John Wiley & Sons.
4. Hunt DR1986. *Engineering Models for Agricultural Production.* The AVI Publ.
5. Koeing HE, Tokad Y, Kesacan HK and Hedgers HG1967. *Analysis of Discrete Physical Systems*. McGraw Hill.
6. Meyer JW2004. *Concepts of Mathematical Modeling*. McGraw Hill.
7. Peart RM and Curry RB1998. *Agricultural Systems, Modelling and Simulation.* Marcel Dekker.
8. Tijms HC1984. *Modelling and Analysis. A Congrtational Approach*. Wiley Publ.
9. Das H. K. Food Process Modelling.

**PFE 606 Bioprocess Engineering 2+1**

**Objectives:**
To acquaint and equip the students with the basic principles of biochemical process engineering.

**Unit-I**
Applications of engineering principles: Mass and energy balance, fluid flow principles, Unit operations of process engineering.

**Unit-II**
Fundamentals of growth kinetics, maintenance energy and yield concepts, principles of media sterilization, media formulations of industrial fermentation.

**Unit-III**
Aerobic and agitated rheology of fermentative fluids, design and scale-up of bioreactors, enzyme reactors.

**Unit-IV**
Principles of recovery of fermented products in bio-processing, instrumentation, transport phenomenon.

**Practical:**

Kinetics of one substitute reactions, kinetics of growth in batch cultures, design consideration for bioreactors, media preparation and sterilization, microprocessor-based monitoring of bioprocess parameters.

**Course Outcome:**
Student's capability to calculate the mass and energy balances in plant process operations, understanding growth kinetics and design bioreactors as per requirement of food industries.

**Teaching Schedule**

| S.No. | Topic | No. of Lectures |
|---|---|---|
| 1. | Basic engineering principles and their applications. Use of units and dimensions. | 3 |
| 2. | Mass balance: steady and unsteady. Problem solving involving blending, separation, drying, growth, recycling etc. | 3 |
| 3. | Energy balance in food processing operations. Use of steam tables in calculation of heat requirements etc. | 3 |
| 4. | Fluid flow principles: Static and dynamic. Concept of viscosity. Types of flow. Flow through pipes. Mass and energy balance in fluid flow. Calculation of pressure drop in pipes. | 4 |
| 5. | Fundamentals of growth kinetics, maintenance energy and yield concepts. | 3 |
| 6. | Principles of media sterilization, media formulations of industrial fermentation. | 3 |
| 7. | Aerobic and agitated rheology of fermentative fluids. | 3 |
| 8. | Design and scale-up of bioreactors, enzyme reactors. | 3 |
| 9. | Principles of recovery of fermented products in bio-processing, instrumentation, transport phenomenon. | 5 |
| | **Total** | **30** |

**List of Practicals**

| S.No | Topic | No. of Practicals |
|---|---|---|
| 1. | To study the instruments used for measurement of temperature, relative humidity, flow rate, pressure, wind velocity, solar radiation etc. | 1 |
| 2. | Use of units, dimensions and basic mathematical applications. | 1 |
| 3. | To judge the students ability for solving mass balance problems. | 2 |
| 4. | To judge the student's ability for solving Energy balance problems. | 2 |
| 5. | To study the kinetics of one substitute reactions. | 1 |
| 6. | To assess the kinetics of growth in batch cultures. | 1 |
| 7. | To study the order of reactions involving single/ multiple reactants/ products. | 1 |
| 8. | To study the various thermal and structural parameters affecting the Design of bioreactors. | 1 |
| 9. | To assess the student's ability for design of bioreactors by solving Related numerical problems. | 2 |
| 10. | To prepare various media cultures and assess their effectiveness with time. | 1 |
| 11. | To study the mechanism of sterilization of cultures. | 1 |
| 12. | To study the various electronic gadgets for continuous monitoring of bioprocess parameters. | 1 |
| | **Total** | **15** |

**Suggested Readings:**


1. Brennan JG, Butters JR, Cavell ND and Lilly AEI.1990. *Food Engineering Operations*. Elsevier.
2. Coulson J M and Richadson JF. 1999. *Chemical Engineering. Vols. II,IV*. The Pergamon Press.
3. Greanoplis JC. 1999. *Transport Process and Unit Operation*. Allyn & Bacon
4. Treybal RE 1981. *Mass Transfer Operations.* 3rdEd. Harper & Row.

## Course Syllabus and Content of Minor and Supporting Courses

ME 501 : Mechatronics and Robotics in Agriculture 2+0

**Objectives:**
To introduce the fundamentals of mechatronics and the concepts behind designing mechatronic systems and their subsystems and its application in automation in agriculture.

**Unit-I**
Introduction to mechatronics: Basic definitions, key elements of mechatronics, historical perspective, the development of the automobile as a mechatronic system. Mechatronic design approach, functions of mechatronic systems, ways of integration, information processing systems, concurrent design procedure for mechatronic systems.

**Unit-II**
System interfacing, instrumentation, and control systems. Input/output signals of a mechatronic system, signal conditioning, microprocessor control, microprocessor numerical control, microprocessor input/output control.

**Unit-III**
Microprocessor based controllers and microelectronics: Introduction to microelectronics, digital logic, overview of control computers, microprocessors and microcontrollers, programmable logic controllers, digital communications.

**Unit-IV**
Technologies of robot: Sub systems, transmission system (Mechanics), power generation and storage system, sensors, electronics, algorithms and software. Servo motor drives types and applications. Stepper motor and its concept. Industrial robots: Classification and sub systems. Defining work space area.

**Unit-V**
Application of robots in agriculture: Harvesting and picking, weed control, autonomous mowing, pruning, seeding, spraying and thinning, phenotyping, sorting and packing. Utility platforms. Use of different agrobots in agriculture.

**Course Outcome:**
Ability to understand agricultural machinery that is built on concepts of mechatronics and ability to use robotic machinery in agriculture.

**Teaching Schedule**

| Sr. No. | Topic | No. of Lectures |
|---|---|---|
| 1 | Introduction mechatronics,: Basic definitions, key elements of Mechatronics | 2 |
| 2 | Historical perspective, the development of the automobile as a mechatronic system | 1 |
| 3 | Mechatronic design approach, functions of mechatronic systems, ways of integration, information processing systems, concurrent design procedure for mechatronic systems. | 3 |
| 4 | System interfacing, Instrumentation, and control systems | 2 |
| 5 | Input/output signals of a mechatronic system, signal conditioning | 2 |
| 6 | Microprocessor control, microprocessor numerical control, microprocessor input/output control | 2 |
| 7 | Microprocessor based controllers and microelectronics | 2 |
| 8 | Introduction to microelectronics, digital logic, overview of control computers | 2 |
| 9 | Microprocessors and microcontrollers, programmable logic controllers, digital communications. | 3 |
| 10 | Technologies of robot: Sub systems, transmission system (Mechanics), power generation and storage system | 2 |
| 11 | sensors, electronics, algorithms and software. Servo motor drives types andapplications | 2 |
| 12 | Stepper motor and its concept. Industrial robots: Classification and sub systems. Defining work space area. | 2 |
| 13 | Application of robots in agriculture: Harvesting and picking, weed control | 2 |
| 14 | autonomous mowing, pruning, seeding, spraying and thinning | 2 |
| 15 | phenotyping, sorting and packing. Utility platforms. Use of different agrobots in agriculture. | 3 |
| | **Total** | **32** |

**Suggested Reading:**


1. Shakhatreh and Fareed 2011.*The Basics of Robotics*. Lahti University of Applied Sciences Machine and production technology.
2. Robert H B 2002. *Mechatronic Hand Book.* CRC Press.
3. Alciatore, D G and Histand M.B. 2002.*Introduction to Mechatronics and Measurement*

*System*. Mcgraw Hill Pvt Limited, New Delhi.

**ME 502 Refrigeration Systems 2+1**

**Objectives:**
To acquire the skills required to model, analyze and design different refrigeration processes and components.

**Unit-I**
Reversed Carnot cycle, Carnot, Brayton and aircraft refrigeration systems.

**Unit-II**
Vapour compression refrigeration systems: Use of p-h chart, effect of pressure changes on COP, subcooling of condensate on COP and capacity, super heating, single stage, multi-stage and cascade systems.

**Unit-III**
Vapour absorption systems: Theory of mixtures, temperature-concentration and enthalpy concentration diagrams, adiabatic mixing of two systems, diabatic mixing, throttling process, ammonia water and water lithium-bromide systems.

**Unit-IV**
Thermo electric refrigeration systems: Advantages, comparison with vapour compression system. Vortex tube refrigeration system and its thermo dynamic analysis. Ultra- low temperature refrigeration. Ejection refrigeration. Water refrigeration: Centrifugal and steam jet refrigeration systems, characteristics of steam jet refrigeration system, effect of boiler efficiency on overall COP, actual steam jet system, two-fluid jet refrigeration.

**Practical:**
Numerical on air refrigeration cycle, Study of vapour compression refrigeration systems, Determination of the coefficient of performance of the refrigeration system, Study of vapour absorption (electrolux) refrigeration systems, Study and application of P-V,T-s and P-h chart in refrigeration, Study and performance testing of domestic refrigerator, Study of domestic water cooler, Study of actual and theoretical COP of Cascade Refrigeration System, Visit to cold storage plants.

**Course outcome:**
After studying this course, students shall be able to analyze air and vapour compression refrigeration cycle, and perform thermodynamic analysis of absorption, steam jet, thermoelectric and vortex tube refrigeration systems.

**Teaching Schedule**

| S. No. | Topic | No. of Lectures |
|---|---|---|
| 1 | Reversed Carnot cycle, Carnot cycle | 2 |
| 2 | Brayton refrigeration systems | 2 |
| 3 | Aircraft refrigeration systems | 4 |
| 4 | Vapour compression refrigeration systems, Single stage vapour compression refrigeration, Use of p-h chart | 3 |
| 5 | Effect of pressure changes on COP, sub cooling of condensate on COP and capacity, super heating | 2 |

| | | |
|---|---|---|
| 6 | Multi-stage vapour compression refrigeration systems | 3 |
| 7 | Cascade vapour compression refrigeration systems | 2 |
| 8 | Vapour absorption systems: Theory of mixtures, temperature-concentration and enthalpy concentration diagrams, adiabatic mixing of two systems, diabatic mixing, throttling process, | 3 |
| 9 | Ammonia water vapour absorption systems. | 1 |
| 10 | Water lithium-bromide vapour absorption systems. | 1 |
| 11 | Thermo electric refrigeration systems: Advantages, comparison with vapour compression system. | 1 |
| 12 | Vortex tube refrigeration system and its thermo dynamic analysis. | 1 |
| 13 | Ultra low temperature refrigeration. | 3 |
| 14 | Water refrigeration, Centrifugal refrigeration | 1 |
| 15 | Ejection refrigeration, Steam jet refrigeration systems, characteristics of steam jet refrigeration system, effect of boiler efficiency on overall COP, actual steam jet system, two-fluid jet refrigeration. | 3 |
| **TOTAL** | | **32** |

**List of Practicals**

| **S. No.** | **Topic** | **No. of Practicals** |
|---|---|---|
| 1 | Numerical on air refrigeration cycle | 2 |
| 2 | Study of vapour compression refrigeration systems | 1 |
| 3 | Determination of the coefficient of performance of the refrigeration system | 1 |
| 4 | Study of vapour absorption (electrolux) refrigeration systems | 2 |
| 5 | Study and application of P-V, T-S and P-h chart in refrigeration | 3 |
| 6 | Study and performance testing of domestic refrigerator, | 2 |
| 7 | Study of domestic water cooler | 1 |
| 8 | Study of actual and theoretical COP of Cascade Refrigeration System | 2 |
| 9 | Visit to cold storage plants. | 2 |
| **TOTAL** | | **16** |

**Suggested Readings:**

1. Ahmadul A. *Refrigeration and Air Conditioning*. PHI India.

2. Arora CP. *Refrigeration and Air Conditioning*. McGraw-Hill India Publishing Ltd.

3. Arora R. *Refrigeration and Air Conditioning*. Prentice Hall of India.
4. Crouseand Anglin. *Automobile Air Conditioning*. McGraw Hill Publications.

5. Dossat RJ. *Principles of Refrigeration*. Pearson Education.

6. Jordon and Prister. *Refrigeration and Air Conditioning*. Prentice Hall of India Pvt. Ltd.

7. Prasad M. *Refrigeration and Air Conditioning*. New Age International Publisher.

8. Stocker WF and Jones JW. *Refrigeration and Air Conditioning*. McGraw-Hill.

**REE 510 Energy, Ecology and Environment 3+0**

**Objective :**
To provide detailed knowledge of carbon cycle, ecosystem, climate change and global environmental change and inter linkages of renewable energy sources.

**Theory**
**Unit I**
Global carbon cycle. Carbon reservoirs flow and human interventions. Global warming and climate change. Energy efficient technology: Efficiency hierarchy, energy dependent activities, energy policies, linkage between energy use and economic growth and environment. Layers of Atmosphere.
**Unit II**
Ecosystem: Kinds, transfection, components of ecosystem, ecosystem development of evaluation, major ecosystem of the world, physical environment and metrology.
**Unit III**
Climate change: Impact and models. Energy for sustainable development: Development indices, pillars, subsystems, principles and dimensions. Low carbon technologies: Energy efficiency projects, carbon trading. Renewable and non-renewable energy sources.
**Unit IV**
Environment, Environmental degradation: Thermal and chemical pollution, primary and secondary pollutant, air pollution, water pollution, unclear energy hazard, radioactive hazards, mining hazards, land use, oil spills and gas leaks.
**Unit V**
Global environmental changes: United Nations Framework Convention on Climate Change (UNFCC), Kyoto protocol and clean development mechanism: Overview, administration, participation, institutions, procedures, project design and formulation. Soil and noise pollution, acid rain, solid waste management sources, causes and effect, Role of individuals in prevention of pollution.
**Learning outcome**
Students will be able to understand the relationship between carbon cycle, energy policies, energy use and economic growth and factors affecting the environment.

**Teaching Schedule**

| S.No. | Topic | No. of Lectures |
|---|---|---|
| 1. | Global carbon cycle. | 1 |
| 2. | Carbon reservoirs flow and human interventions. | 2 |
| 3. | Global warming and climate change. | 2 |
| 4. | Energy efficient technology: Efficiency hierarchy, energy dependent activities, energy policies, linkage between energy use and economic growth and environment. Layers of Atmosphere | 4 |
| 4. | Ecosystem: Kinds, transfection, components of ecosystem, | 3 |
| 5. | Ecosystem development of evaluation, major ecosystem of the world, | 3 |

| | | |
|---|---|---|
| | physical environment and metrology. | |
| 6. | Climate change: Impact and models. | 3 |
| 7 | Energy for sustainable development: Development indices, pillars, subsystems, principles and dimensions. renewable and non renewable energy sources. | 2 |
| 8. | Low carbon technologies: Energy efficiency projects, carbon trading. | 3 |
| 9. | Environment, Environmental degradation | 1 |
| 10. | Thermal and chemical pollution, primary and secondary pollutant, air pollution, | 3 |
| 11. | Water pollution | 1 |
| 12. | unclear energy hazard | 1 |
| 13. | Radioactive hazards, mining hazards, land use, oil spills and gas leaks. | 3 |
| 14. | Global environmental changes: United Nations Framework Convention on Climate Change (UNFCC) Soil and noir pollution, Acid rain. | 4 |
| 15. | Kyoto protocol and clean development mechanism: Overview, administration, participation, institutions, procedures, project design and formulation. Solid water management sources cause effect role of individuals in prevention of pollution. | 4 |
| | **Total** | **40** |

**Suggested Reading**


- Canter LC. 1979. *Environmental Impact Assessment.* McGraw Hill Pub. Co., New York.
- Coley D. 2008. *Energy and Climate Change*. John Wiley & Sons, Ltd., New Jersey.
- Dessler A. 2011. *Introduction to Modern Climate Change*. Cambridge University Press, Cambridge, England.
- Essam E and Hinnami EI. 1991. *Environmental Impact of Production and Use of Energy*. Tycooly Press Ltd, Dublin.
- Fowler JM. 1984. *Energy and the Environment, Second Edition*. McGraw-Hill, New York.
- Kaushika ND and Kaushik K. 2004. *Energy, Ecology and Environment: A Technological Approach.* Capital Publishing, New Delhi.
- Mathur AN, Rathore NS and Vijay VK. 1995. *Environmental Awareness*, Himanshu Pub., Udaipur.
- Puppy HG. *Energy and Environment, Mankind and Energy Needs*. Elsevier Pub. Co., New York.
- Rathore NS and Kurchania AK. 2001. *Climatic Changes and their Remedial Measures*. Shubhi Publications, Gurgaon.
- Thomdike EH. 1978. *Energy and Environment: A Premier for Scientists and Engineers*. Adson, Wesley Pub. Co., Boston, US.
- Wilson R and Jones WJ. 1974. *Energy, Ecology and the Environment*. Academic Press Inc., Cambridge, Massachusetts, US.
- C. manoharo chary, p. jayarams Reddy. Principles of Environmental studies (Ecology, Economics management and law) , B S publications Hyderabad.
- RituBir. Environmental studies , Vayu. Eduction of India.

- V. K. Ahliwalissanitamalhotra. Environmental science. Ane Books PVT. LTD. 2009.
- DurgaNathDhar, TrilokiVaishShalinkumar. Environmental Science and ethics, , Vayu Education of India New Delhi 2009.
- R. Rajagopalan. Environmental Studies from crisis to cure Second edition, Oxford university press.

## REE 515 Energy Management in Food Processing Industries 1+1

**Objectives :**
To acquaint and equip the students with different energy management techniques including energy auditing of food industries.

**Theory**
**Unit I**
Energy forms and units, energy perspective, norms and scenario, energy auditing, data collection and analysis for energy conservation in food processing industries.
**Unit II**
Sources of energy, its audit and management in various operational units of the agro-processing units, passive heating, passive cooling, sun drying and use of solar energy, biomass energy and other non-conventional energy sources in agro-processing industries.
**Unit III**
Reuse and calculation of used steam, hot water, chimney gases and cascading of energy sources. Energy accounting methods, measurement of energy, design of computer-based energy management systems, economics of energy use.
**Practical**
Study of energy use pattern in various processing units i.e., rice mills, sugar mills, dal mills, oil mills, cotton-ginning units, milk plants, food industries etc. Energy audit study and management strategies in food processing plants. Identification of energy efficient processing machines. Assessment of overall energy consumption, production and its cost in food processing plants, visit to related food processing industry.
**Learning outcome**
Student's capability to understand energy sources, analyze energy requirement in food processing operations and to economize it in food industries.

**Teaching Schedule**

| S.No. | Topic | No. of Lectures |
|---|---|---|
| 1. | Energy forms and units, energy perspective, norms and scenario | 2 |
| 2. | Energy auditing: definition, types of energy audit, planning | 2 |
| 3. | Data collection and analysis for energy conservation in food processing industries. | 2 |
| 4. | Sources of energy, its audit and management in various operational units of the agro-processing units | 2 |
| 5. | Passive heating, passive cooling, sun drying and use of solar energy in agro-processing industries. | 1 |
| 6. | Use of biomass energy and other non-conventional energy sources in agro-processing industries. | 2 |
| 7. | Reuse and calculation of used steam, hot water, chimney gases and cascading of energy sources. | 2 |

| | | |
|---|---|---|
| 8. | Energy accounting methods, measurement of energy | 1 |
| 9. | Design of computer-based energy management systems, economics of energy use. | 2 |
| | **Total** | **16** |

I.

**List of Practical's**

| S.No. | Topic | No. of Practical's |
|---|---|---|
| 1. | Study of energy use pattern in rice mill | 1 |
| 2. | Study of energy use pattern in sugar mill | 1 |
| 3. | Study of energy use pattern in dal mill | 1 |
| 4. | Study of energy use pattern in oil mill | 1 |
| 5. | Study of energy use pattern in cotton-ginning unit | 1 |
| 6. | Study of energy use pattern in milk plant | 1 |
| 7. | Energy management strategies in rice mill | 1 |
| 8. | Energy management strategies in sugar mill | 1 |
| 9. | Energy management strategies in oil mill | 1 |
| 10. | Energy management strategies in milk plant | 1 |
| 11. | Identification of energy efficient processing machines | 2 |
| 12. | Assessment of overall energy consumption, production and its cost in food processing plants | 2 |
| 13. | Visit to related food processing industry | 2 |
| | **Total** | **16** |

**Suggested Reading**

1. Pimental D. 1980. Handbook of Energy Utilization in Agriculture. CRC Press.
2. Rai GD. 1998. Non-conventional Sources of Energy. Khanna Publisher.
3. Twindal JW and Wier AD. 1986. Renewable Energy Sources. E & F. N. Spon Ltd.
4. Verma SR, Mittal JP and Singh S. 1994. Energy Management and Conservation in Agricultural Production and Food Processing. USG Publisher and Distributors, Ludhiana.
5. Surendrasingh, R.S. Singh. 2014. Energy for Production Agriculture, DIPA, ICAR, New Delhi.
6. Bureau of Energy efficiency. Guide books Vol. 1 , 2 and 3. BEE, New Delhi.

**FMPE 507 : Management of Farm Power and Machinery System 2+1**

**Objectives:**

To understand how principles of management are applied to farm machinery systems to makethem more effective and profitable.

**Theory**

**Unit-I**

Importance and objectives of farm mechanization in Indian agriculture, its impact, strategies, myths and future needs. Estimation of operating cost of tractors and farm machinery. Management and performance of power, operator, labour. Economic performance of machinery, field capacity, field efficiency and factors affecting field efficiency.

**Unit-II**

Tractor power performance in terms of PTO, drawbar and fuel consumption. Power requirement problems to PTO, DBHP.

**Unit-III**

Selection of farm machinery, size selection, timeliness of operation, optimum width and problem related to its power selection. Reliability of agricultural machinery. Replacement of farm machinery and inventory control of spare parts.

**Unit-IV**

Systems approach to farm machinery management and application of programming techniques to farm machinery selection and scheduling. Network Analysis: Transportation, CPM and PERT, dynamic programming, Markov chain.

**Practicals**

Study of latest development of different agricultural equipment and implements in India and other developing countries. Size selection of agricultural machinery. Experimental determination of field capacity of different farm machines. Study of farm mechanization in relation to crop yield. Determination of optimum machinery system for field crop and machine constraints. To develop computer program for the selection of power and machinery.

**Course Outcome:**

The student will be able to understand how farm machinery is selected and operated to make them economically viable.

**Teaching Schedule**

| Sr No | Topic | No of lectures |
|---|---|---|
| 1. | Importance and scope of farm mechanization in Indian Agriculture | 1 |
| 2. | Cost analysis of Farm Machinery and tractor, Breakdown analysis, Inflation. | 2 |
| 3. | Measurement of power performance (PTO power, drawbar power and fuel consumption) of tractor and power tiller | 3 |
| 4. | Study of field capacity and field efficiency of different farm machinery and factor affecting them | 1 |
| 5. | Selection of Farm Machinery size wrto power source and timeliness of operation | 4 |
| 6. | Application of programming technique to problem of farm power and | 4 |

| | | |
|---|---|---|
| | machinery selection. | |
| 7. | Replacement models, spare parts and inventory control | 2 |
| 8. | Maintenance and scheduling of operations. | 2 |
| 9. | Network analysis – transportation | 2 |
| 10. | Network analysis – critical path method, PERT | 2 |
| 11. | Network analysis – dynamic programming | 3 |
| 12. | Network analysis – markov chain | 3 |
| 13. | Linear programming, multivariable system, simplex algorithm. Theoryof network. | 3 |
| | **Total** | **32** |

**List of Practicals**

| Sr. No | Topic | No of practicals |
|---|---|---|
| 1. | Introduction to latest development of advanced agricultural equipment's in India | 3 |
| 2. | Experimental determination of field capacity of different farm machines | 3 |
| 3. | Case studies on optimum size selection of agricultural machinery | 3 |
| 4. | Determination of inventory of different farm machines for a farm of size 50 ha as per regional crop rotations | 3 |
| 5. | To develop computer program regarding selection of farm machinery size and power requirement for a 10, 50 and 100 ha farm size | 4 |
| | Total | 16 |

**Suggested Reading:**


1. Hunt D 1979. *Farm Power and Machinery Management*. Iowa State University Press,USA
2. Kapoor V K 2012. *Operation Research: Concepts, Problems and Solutions*. Sultan Chandand Sons, India.
3. Culpin C 1996. *Profitable Farm Mechanization*. Lock Wood and Sons, London.
4. Singh, S and Verma, S R. *Farm Machinery Maintenance and Management*. DIPA, ICAR,KAB-I, New Delhi.
5. Carveille, L A 1980. *Selecting Farm Machinery*. Louisiana Cooperative Extn. ServicesPublication.
6. FAO 1990. *Agricultural Engineering in Development: Selection of Mechanization Inputs.* FAO, Agri service Bulletin
7. S.C. Jain and Grace Philip. 2003. *Farm Machinery- An Approach*. Standard Publishers. Delhi-6
8. Surendra Singh. *Farm Machinery: Principles and Applications*. DIPA-ICAR, New Delhi.

**FMPE 515 : Computer Aided Design of Machinery 0+2**

**Objectives:**
To learn the practice of designing components and assemblies based on computer aideddrafting technique.

**Practical:**
Learning 2D drafting: Controlling display settings, setting up units, drawing limits and dimension styles. Drawing and dimensioning simple 2D drawings, keyboard shortcuts. Working with blocks, block commands. Exercise in simple assembly in orthographic. Exercise in measuring and drawing simple farm machinery parts.
Learning 3D Drafting: Advantages of virtual prototyping-starting the 3D drafting environment, self learning tools, help and tutorials. Familiarizing with user interface, creating files and file organization, structuring and streamlining. Features of document window. Concept of coordinate system: Working coordinate system, model coordinate system, screen coordinate system, graphics exchange standards and database management system. Working with feature manager and customizing the environment. Planning and capturing design intent. Documentation of design. Using design journal and design binder. Preliminary design review and layout.
Practice in drawing 2D sketches with sketcher and modifying sketch entries. Adding Reference geometry: Planes and axes. Adding relations and working with relations. Dimensioning a sketch. Exercises.
Parts and features: Sketched features and applied features, pattern and mirror features. Documenting design. Assembly: Creating and organizing assemblies, connecting parts and subassemblies with mates. Organizing the assembly by using layouts.
Exercise in creating drawing: Setting up and working with drawing formats, creating drawing views from the 3D model, making changes and modifying dimensions.
Case studies: Measuring and drawing assemblies of farm implements and their components.

**Course Outcome:**
The student will be able to conceptualize spatial concepts and design components and assemblies of Farm machinery and make graphic models using commercial CAD softwarelike Solid Works, Catia and AutoCAD.

**List of Practicals**

| S. No. | Topic | No of Practicals |
|---|---|---|
| 1. | Learning 2D drafting: Controlling display settings, setting up units, drawing limits and dimension styles. | 2 |
| 2. | Drawing shortcuts, and dimensioning simple 2D drawings, keyboard | 1 |
| 3. | Working with blocks, block commands. Exercise in simple assembly in orthographic. | 1 |
| 4. | Exercise in measuring and drawing simple farm machinery parts. | 2 |

| | | |
|---|---|---|
| 5. | Learning 3D Drafting: Advantages of virtual prototyping-starting the 3D drafting environment, self learning tools, help and tutorials. Familiarizing with user interface, creating files and file organization, structuring and streamlining. Features of document window. | 2 |
| 6. | Concept of coordinate system: Working coordinate system, modelcoordinate system, screen coordinate system, graphics exchange standards and database management system. | 2 |
| 7. | Working with feature manager and customizing the environment.Planning and capturing design intent. | 2 |
| 8. | Documentation of design. Using design journal and design binder.Preliminary design review and layout. | 1 |
| 9. | Practice in drawing 2D sketches with sketcher and modifying sketch entries. | 2 |
| 10. | Adding Reference geometry: Planes and axes. Adding relationsand working with relations. Dimensioning a sketch. Exercises. | 2 |
| 11. | Parts and features: Sketched features and applied features, pattern and mirror features. Documenting design. | 2 |
| 12. | Assembly: Creating and organizing assemblies, connecting parts and subassemblies with mates. | 2 |
| 13. | Organizing the assembly by using layouts. | 1 |
| 14. | Exercise in creating drawing: Setting up and working with drawing formats, creating drawing views from the 3D model, making changes and modifying dimensions. | 2 |
| 15. | Case studies: Measuring and implements and their components. Drawing assemblies of farm | 5 |
| | **Total** | **32** |

**Suggested Reading:**

1. Jankowski G and Doyle R 2007. *Solid Works*® For Dummies®, 2nd Edition, Published by Wiley Publishing, Inc. ISBN: 978-0-470-12978-4
2. Shih R H 2014. *AutoCAD 2014 Tutorial*-First Level: 2D Fundamentals. SDCPublications

**FMPE 516 Advanced Manufacturing Technologies 2+1**

**Objectives:**
To learn the modern manufacturing techniques and their application to manufacture of different components and assemblies.

**Theory**
**Unit-I**
Material and their characteristics, structure and properties of materials, wood, ferrous, Non-ferrous, alloys, plastic, elastomers, ceramics and composites. Material selection and metallurgy: Equilibrium diagram, time temperature transformation curves, heat treatments, surface treatment: Roughness and finishing.
**Unit-II**
Measurement and quality assurance: Quality control, tolerance, limits and clearance. Automated 3-D coordinate measurements. Advance casting processes and powder metallurgy. Forming process: Fundamentals of metal forming, hot and cold rolling, forging processes, extrusion and drawing.
**Unit-III**
Workshop practices applied in prototype production, jigs and fixtures. Traditional machining processes: Cutting tools, turning, boring, drilling, milling and related processes. Non traditional machining processes fuzzy c-mean (FCM), electric discharge machining (EDM), laser beam machining (LBM), Abrasive jet machining (AJM), and Wire-electro-discharge machining (EDM).
**Unit-IV**
Joining processes: Gas flame processes, arc processes, brazing and soldering, adhesive and bonding.
**Unit-V**
Numerical control: Command system codes, programme, cutter position X and Y, incremental movements, linear contouring, Z movements and commands. Manufacturing systems and automation. Robotics and robot arms. 3-D printing. Integrated manufacturing production system.
**Practical:**
Identification of material and their application. Study of heat treatment processes and their suitability with respect to materials. Tool and equipments for measurements: Tolerance limits, clearance and surface finish. Site visits for study of advanced manufacturing techniques. Case studies.
**Course Outcome:**
The students will be able to select suitable manufacturing technique to fabricate different components used in Farm machinery.

**Teaching Schedule**

| Sr.No | Topic | No. of Lectures |
|---|---|---|
| 1 | Material and their characteristics. | 1 |
| 2 | Structure and properties of materials wood, ferrous, Non-ferrous, alloys, plastic, elastomers, ceramics and composites. | 2 |

| | | |
|---|---|---|
| 3 | Material selection and metallurgy: Equilibrium diagram, time temperature transformation curves. | 1 |
| 4 | Heat treatments, surface treatment: Roughness and finishing. | 2 |
| 5 | Measurement and quality assurance: Quality control, tolerance, limits and clearance. | 1 |
| 6 | Automated 3-D coordinate measurements and practice. | 2 |
| 7 | Advance casting processes and powder metallurgy. | 1 |
| 8 | Forming process: Fundamentals of metal forming, hot and cold rolling, forging processes, extrusion and drawing. | 2 |
| 9 | Forging processes, extrusion and drawing. | 1 |
| 10 | Workshop practices applied in prototype production, jigs and fixtures. | 1 |
| 11 | Traditional machining processes: Cutting tools, turning, boring, drilling, milling and related processes. | 2 |
| 12 | Non traditional machining processes fuzzy c-mean (FCM), electric discharge machining (EDM), laser beam machining (LBM). | 2 |
| 13 | Electric discharge machining (EDM), laser beam machining (LBM). | 1 |
| 14 | Abrasive jet machining (AJM), and wire-electro- discharge machining (EDM). | 2 |
| 15 | Joining processes: Gas flame processes, arc processes. | 2 |
| 16 | Brazing and soldering processes. | 1 |
| 17 | Adhesive and bonding processes. | 1 |
| 18 | Numerical control: Command system codes. | 1 |
| 19 | NC Programme, Robotics and robot arms. | 2 |
| 20 | Cutter position X and Y, incremental movements, linear contouring, Z movements and commands. | 1 |
| 21 | Manufacturing systems and automation. | 1 |
| 22 | 3-D printing and integrated manufacturing production system. | 2 |
| | **Total** | **32** |

**List of Practicals**

| **Sr. No.** | **Topic** | **No. of Practicals** |
|---|---|---|
| 1. | Identification of material and their application. | 2 |
| 2. | Study of heat treatment processes and their suitability with respectto materials. | 5 |
| 3. | Tool and equipments for measurements: Tolerance limits, clearance and surface finish. | 4 |
| 4. | Site visits for study of advanced manufacturing techniques. | 2 |
| 5. | Case studies. | 3 |
| | **Total** | **16** |

**Suggested Reading:**


1. Polukin P, Gringerg B, Kantenik S, Zhadan V and Vasilye D. *Metal Process Engineering*, MIR Publishers Moscow.
2. Hoyos L 2010. *Fundamentals of Tool Design.* American Society of Tool andManufacturer Engineers. Sixth Edition
3. Gupta R B 2017. Vol *Production Technology* I - Production Process. Satya Prakashan, New Delhi.
4. Jain, R K 1994. *Production Technology*: A Textbook for Engineering Students. Khanna Publishers, New Delhi .
5. Begeman M L, Ostwald P F and Amstead B H 1979. *Manufacturing Processes:* SI Version. John Wiley and Sons. 7th Edition
6. Chapman P A J 1996. *Workshop Technology Part III.* CBS Publisher and distributors Pvt Ltd. 3rd Edition international Edition.

**CSE 502 Artificial Intelligence 2+1**

**Objectives:**

To introduce students with techniques and capabilities of artificial intelligence (AI) and enable them to do simple exercises.

**Theory :**

**Unit-I**

Definitions of intelligence and artificial intelligence. What is involved in intelligence? Disciplines important to AI. History of development of AI. Different types of AI. Acting humanly, Turing test. AI systems in every day life. Applications of AI.

**Unit-II**

Classical AI, concept of expert system, conflict resolution, multiple rules, forward chaining, backward chaining. Advantages and disadvantages of expert system. Fuzzy logic and fuzzy rules. Fuzzy expert systems.

**Unit-III**

Problem solving using AI, search techniques, breadth first search, depth first search, depth limited search, bidirectional search, heuristic search, problems and examples. Knowledge representation, frames, methods and demons, correlations, decision trees, fuzzy trees.

**Unit-IV**

Philosophy of AI, Penrose's pitfall, weak AI, strong AI, rational AI, brain prosthesis experiment, the Chinese room problem, emergence of consciousness, technological singularity, Turing test.

**Unit-V**

Modern AI, biological brain, basic neuron model, perceptrons and learning, self-organizing neural network, N-tuple network, evolutionary computing, genetical gorithms, agent methods, agents for problem solving, software agents, multi agents, hardware agents.

**Practical:**

Prolog language, syntax and meaning of Prolog programs, Lists, operators, arithmetic. Using structures: Example programs, controlling back tracking, input and output. More built-in procedures, programming, style and technique, operations on data structures. Advanced tree representations, basic problem-solving strategies, depth-first search strategy, breadth-first search strategy.

**Course Outcome:**

Ability to understand and apply principles of AI in solving simple problems to enable them to get in sight into working of AI based systems.

**Teaching Schedule**

| S. No. | Topic | No. of Lectures |
|---|---|---|
| 1. | Definitions of intelligence and artificial intelligence. Disciplines important to AI. History of development of AI. | 2 |
| 2. | Different types of AI. Acting humanly, Turing test AI systems in every day life. Applications of AI. | 2 |

| | | |
|---|---|---|
| 3. | Classical AI, concept of expert system, conflict resolution, multiple rules, forward chaining, backward chaining. | 3 |
| 4. | Advantages and disadvantages of expert system. Fuzzy logic and fuzzy rules. Fuzzy expert systems. | 3 |
| 5. | Problem solving using AI, search techniques, breadth first search, depth first search | 4 |
| 6. | Depth limited search, bi-directional search, heuristic search, problems and examples. | 4 |
| 7. | Knowledge representation, frames, methods and demons, correlations, decision trees, fuzzy trees. | 3 |
| 8. | Philosophy of AI, Penrose's pitfall, weak AI, strong AI, rational AI, brain prosthesis experiment, | 2 |
| 9. | Chinese room problem, emergence of consciousness, technological singularity, Turing test. | 3 |
| 10. | Modern AI, biological brain, basic neuron model, perceptrons and learning, self-organizing neural network, | 3 |
| 11. | N-tuple network, evolutionary computing, genetic logarithms, | 2 |
| 12. | Agent methods, agents for problem solving, software agents, | 2 |
| 13. | Multiagents, hardware agents. | 1 |
| **TOTAL** | | **31** |

**List of Practicals**

| **S. No.** | **Topic** | **No. of Practicals** |
|---|---|---|
| 1 | Prolog language, syntax and meaning of Prolog programs, Lists, operators, arithmetic. | 4 |
| 2 | Using structures: Example programs, controlling back tracking, input and output. More built-in procedures, programming, style and technique, operations on data structures. | 5 |
| 3 | Advanced tree representations, basic problem-solving strategies, depth-first search strategy, breadth-first search strategy. | 5 |
| **TOTAL** | | **14** |

**References:**


1. Warwick K 2012. *Artificial Intelligence: The Basics.* ISBN:978-0-415-56482-3(hbk).
2. Ivan Bratko, *Prolog Programming for Artificial Intelligence*.
3. GNUPROLOG. *A Native Prolog Compiler with Constraint Solving over Finite Domains* Edition1.44, for GNU Prolog version1.4.5 July14, 2018.

**PHM 503 Packaging and Storage of fresh Horticultural Produce 1+1**

**Objectives:**

Being a potential source of minerals, vitamins and proteins and carbohydrates, horticultural commodities play an important role in the health and nutritional security of the people. Proper packaging and storage will utilize market surplus during glut season and thus give boost to the food industry. Horticultural produce is highly perishable particularly under tropical conditions of India. The spoilage of these commodities can be reduced to a large extent by this storage technology. Hence this customized course

**Theory**

**Block 1: Storage Systems**

**Unit I:**

Importance of storage of horticultural produce, present status and future scope. Principles and methods of storage – field storage structures and designs for bulk storage of horticultural produce- onion and potato, etc. Evaporative cool chambers. Physiological changes during storage.

**Unit II:**

Refrigerated storage – principles of refrigeration, types of refrigerants, refrigeration equipments. Cold storage rooms – Calculation of refrigeration load. Storage requirements of different fruits, vegetables, flowers. Storage disorder symptoms and control.

**Unit III:**

Controlled or modified atmosphere (CA/MA) storage – principles, uses, structures and equipments, methods and requirements. Effect of CA storage on the physiology of stored produce. Hypobaric storage principle, uses, and requirements. Storage disorders.

**Block 2: Packaging**

**Unit I:**

Importance of packaging of fresh horticultural produce, present status and future scope. Gaps in packaging concepts. Packaging requirements of fresh horticultural produce. Packaging patterns and methods. Food packaging systems: Different forms of packaging such as rigid, semi-rigid, flexible forms. Traditional, improved and specialized packages. Paper based packages: corrugated fibre board boxes – raw material and types of boxes. Flexible packaging materials – types and their properties. Consumer and intermediate flexible bulk containers. Testing of flexible packaging material. Barrier properties of packaging materials. Cushioning material

**Unit 2:**

New technology in packaging – stretch wrapping system, vacuum packaging, gas packaging, controlled atmosphere (active and intelligent)packaging, vibra packaging, skin packaging, shrink packaging, smart packaging, Nano Silver packaging, Packaging machines. Quality control and safety aspects of packaging materials.

**Practical**

- Study of special storage structures for bulk storage of onion/ potato, etc.;
- Study of storage behaviour of different fruits and vegetables in zero energy cool chamber;

- Determination of refrigeration requirements (capacity) for given quantity of fruitsand vegetables;
- Study of storage behaviour of different fruits and vegetables in cold room;
- Study of chilling injury and storage disorders;
- Study of shelf-life of fruits and vegetables in modified atmosphere packaging.
- Visit to special storage structures, cold storage units.
- Study of types of packaging materials, types of plastic films and their properties;
- Determination of water vapour transmission rate (WVTR) and gas transmission rate (GTR) of packaging material;
- Applications of packaging material for fresh fruits and vegetables, flowers, spice produce;
- Determination of shelf-life of fresh produce in different types of packages;
- Study of packaging machines – vacuum packaging machine, shrink wrapping machine, etc.
- Visit to packaging unit.

**Suggested Reading**

Ahvenainen R. 2003. Novel Food Packaging Techniques, CRC Press, ISBN 0849317894.

Ahvenainen R. 2001. *Novel Food Packaging Techniques*. CRC.

Burg SP (Ed.). 2004. *Postharvest physiology and hypobaric storage of fresh produce*, CABI Publishing, ISBN 0851998011.

Chattopadhya SK. 2007. *Handling, transportation and storage of fruits and vegetables*. Gene-Tech books, New Delhi.

Chandra Gopala Rao. 2015. *Engineering for Storage of Fruits and Vegetables*; Academic Press,1st Edition.

Coles R, McDowell D and Kirwan MJ. (Eds.). 2003. *Food Packaging Technology*, Blackwell Publishing, ISBN 1841272213.

Mahadevaiah M and Gowramma RV. 1996. *Food packaging materials*. Tata McGraw Hill.

Painy FA. 1992. *A handbook of food packaging*. Blackie Academic.

Pantastico B. 1975. Postharvest Physiology, Handling and Utilization of Tropical and Subtropical Fruits and Vegetables. AVI Publ.

Robertson GL. (Ed.). 2010. Food packaging and shelf life: a practical guide CRC Press, ISBN 9781420078442.

Thompson AK. 2010. *Controlled atmosphere storage of fruits and vegetables* (2nd Edition), CABI International, ISBN 9781845936464.

Wilson CL. (Ed.). 2007. *Intelligent and active packaging for fruits and vegetables*, CRC Press, ISBN 9780849391668.

**Websites**

Storage practices and structures UCANR. http://ucanr.edu/datastoreFiles/234-1303.pdf

Low cost storage technologies for preservation-IARI. http://www.iari.res.in/download/pdf/story4_eng.pdf.

https://energypedia.info/wiki/Cold_Storage_of_Agricultural_Products

**PHM 504 Packaging and Storage of Processed Horticultural Produce 1+1**

**Objective:**
Horticulture industry is dominated by market interaction in terms processing and their packaging. Much of the total cost of produce is determined by nature of packaging and packaging material used. Packaging cost sometimes exceed the raw material cost, depending on the nature of the produce, time and period. This course helps in understanding the packaging interaction with produce, environment and time. And it also helps to take informed decision on package requirement for horticulture produce.

**Theory**
**Block 1: Packaging principles and functions**
**Unit I:**
Principals and functions of packaging; Type of packaging materials; Selection of packaging material for different foods; Selective properties of packaging film; Methods of packaging and packaging equipment.
**Unit II:**
Mechanical strength of different packaging materials; Printing of packages; Barcodes and other marking; Interactions between packaging material and foods; Environmental and cost consideration in selecting packaging materials.
**Unit III:**
Manufacture of packaging materials; Potential of bio-composite materials for food packaging; Packaging regulations; Packaging and food preservation; Disposal of packaging materials.
**Unit IV:**
Metal cans: types, fabrication, lacquering and tin quality. Double seaming technology – defects and causes. Glass containers – types; testing quality – thermal shock resistance, thermal shock breakage, impact breakage.
**Unit V:**
Testing of packaging; Rigid and semi rigid containers; Flexible containers; Sealing Equipment. Labeling; Aseptic and shrink packaging; Secondary and transport packaging. Different packaging systems for dehydrated, frozen and processed fruits and vegetables.
**Block II: Storage of Processed product**
**Unit I:**
Handling and storage of processed product, Chemical changes during storages; Spoilage during storages of processed products

**Practical**
- Testing of packaging material: compression strength/drop test/thermal shock test/seam evaluation/ seam defects;
- Determination of shelf-life of processed products in different types of packages;
- Study of packaging machines – vacuum packaging machine, shrink wrapping machine, double seamer, etc.;
- Visit to packaging units.

- Chemical changes during storage of processed products.
- Handling and storage studies of processed products.
- Visit to storage unit in processing industry.

**Suggested Reading**

Ahvenainen R. 2001. *Novel Food Packaging Techniques*.CRC

Ahvenainen R. 2003. *Novel Food Packaging Techniques*, CRC Press, ISBN 0849317894.

Coles R, McDowell D and Kirwan MJ. (Eds.) 2003. *Food Packaging Technology*, Blackwell Publishing, ISBN 1841272213.

Joseph H Hotchkiss. 1987. *Food and Packaging Interactions*, (ACS symposium series -365,April 5-10, 1987. American Chemical Society, Washington DC. 1988)

Mahadevaiah M and Gowramma RV. 1996. *Food packaging materials*. Tata McGraw Hill.

Painy FA. 1992. A handbook of food packaging. Blackie Academic.

Robertson G. L. Ed. 2010. *Food packaging and shelf life: a practical guide CRC Press*, ISBN 9781420078442.

Thompson AK. 2010. *Controlled Atmosphere Storage of Fruits and Vegetables*, CABI Publishing;2nd revised edition.

Wilson CL. (Ed.). 2007. *Intelligent and active packaging for fruits and vegetables*, CRC Press,ISBN 9780849391668.

**STAT501 Statistical Methods for Research Workers 2+1**

**Objectives:**
To expose students to various statistical techniques for analysis of data and interpretation of results.

**Unit-I**
Probability and probability distributions. Principle of least squares. Linear and non-linear regression. Multiple regression. Correlation analysis. Selection of variables. Validation of models. Sampling techniques. Determination of sample size. Sampling distribution of mean and proportion.

**Unit-II**
Hypothesis testing. Concept of p-value. Student's t-test. Large sample tests. Confidence intervals. ANOVA and testing of hypothesis in regression analysis. Analysis of variance for one way and two way classification (with equal cell frequency). Transformation of data.

**Unit-III**
Advantages and disadvantages of non parametric statistical tests. Scales of measurements. Run-test. Sign test. Median test. Wilcoxon-Mann Whitney test. Chi-square test. Kruskal-Walli's one way and Friedman's two-way ANOVA by ranks. Kendall's Coefficient of concordance.

**Practical:**
Fitting of distributions. Sample and sampling distributions. Correlation analysis. Regression analysis (Multivariate, quadratic, exponential, power function, selection of variables, validation of models, ANOVA and testing of hypothesis). Tests of significance (Z-test, t-test, F-test and Chi-square test). Analysis of variance. Non-parametric tests.

**Course Outcome:**
The students will be able to understand different techniques for analyzing the data of their research work.

**Teaching Schedule**

| S.No. | Topics | No. of Lectures |
|---|---|---|
| 1 | Elementary statistics | |
| 2 | Probability theory | 2 |
| 3 | Probability distributions (Binomial, Poisson and Normal) | 3 |
| 4 | Sampling techniques, Determination of sample size | 2 |
| 5 | Sampling distribution of mean and Proportion | 1 |
| 6 | Hypothesis testing concept of p-value | 1 |
| 7 | Large sample (mean, proportion) | 1 |
| 8 | Student’s t-test (Single mean, Difference of mean for independent samples and paired observations) and F-test | 3 |
| 9 | Analysis of variance (one way and two way), Transformation of data | 2 |

| | | |
|---|---|---|
| 10 | Correlation analysis and testing (Bivariate, Rank, Intra-class, Partial, Fisher's Z-transformation) | 2 |
| 11 | Multiple linear regression and model validation | 2 |
| 12 | Testing of coefficient of determination and regression coefficient | 2 |
| 13 | Selection of variables in regression (forward substitution method and step-wise regression) | 1 |
| 14 | Non-Linear regression (Quadratic, exponential and Power) | 2 |
| 15 | Introduction to Non-parametric and scales of measurements | 1 |
| 16 | Chi-square test (Goodness of fit, Independence of attributes, homogeneity of variances) | 2 |
| 17 | One Sample test (Sign test, Median test, Runrest) | 2 |
| 18 | Two sample test (Wilcoxon Sign test, Mann-Whitney test, Chi square test for two independent samples) | 1 |
| 19 | K-Sample (Kruskal-Walli's test and Friedman's two-way ANOVA) | 2 |
| 20 | Kendall's coefficient of concordance | 1 |
| | **Total** | **33** |

**List of Practicals**

| S.No. | Topics | No. of Practicals |
|---|---|---|
| 1 | Elementary statistics | 1 |
| 2 | Probability distributions (Binomial, Poisson and Normal) | 1 |
| 3<br>4 | Sampling techniques, Determination of sample size, Sampling distribution of mean and Proportion | 1 |
| 5 | Large sample(mean, proportion) | 1 |
| 6 | Student's t-test (Single mean, Difference of mean for independent samples and paired observations) and F-test | 1 |
| 7 | Analysis of variance (one way and two way), Transformation of data | 2 |
| 8 | Correlation analysis and testing (Bivariate, Rank, Intra-class, Partial, Fisher's Z-transformation) | 1 |
| 9 | Multiple linear regression and model validation | 1 |
| 10 | Testing of coefficient of determination and regression coefficient | |
| 11 | Selection of variables in regression (Forward substitution method and step wise regression) | 1 |
| 12 | Non-Linear regression (Quadratic, exponential and Power) | 2 |
| 13 | Introduction to Non-parametric and scales of measurements | |
| 14 | Chi-square test (Goodness of fit, Independence of attributes, homogeneity of variances) | 2 |
| 15 | OneSampletest:Signtest,Mediantest,Runrest,Twosampletest:Wilcox onSigntest,MannWhitneytest,$X^2$testfortwoindependentsamples | 1 |
| 16 | K-Sample: Kruskal-Walli's test and Friedman's two-way ANOVA, Kendall's coefficient of concordance | 1 |
| | **Total** | **16** |

**References:**


1. Anderson TW 1958. *An Introduction to Multivariate Statistical Analysis*. John Wiley.
2. Dillon WR and Goldstein M.1984.*Multivariate Analysis-Methods and Applications*. John Wiley.
3. Electronic Statistics Text Book: http://www.statsoft.com/textbook/stathome.html
4. Goon AM, Gupta MK and Dasgupta B.1977. *An Outline of Statistical Theory*. Vol.I. The World Press.
5. Goon AM, Gupta MK and Dasgupta B.1983. *Fundamentals of Statistics*. Vol.I. The World Press.
6. Hoel PG.1971.*Introduction to Mathematical Statistics*. John Wiley.
7. Hogg RV and Craig TT.1978. *Introduction to Mathematical Statistics*. Macmillan.
8. Montgomery and Runger 2014. *Applied Statistics and Probability for Engineers.* John Wiley
9. Morrison DF.1976.*Multivariate Statistical Methods*. McGraw Hill.
10. Siegel S, Johan N and Casellan Jr.1956. *Non-parametric Tests for Behavior Sciences*. John Wiley.

**STAT 511 Experimental Designs 1+1**

**Objectives:**
To acquaint and equip the students with the basic principles of theory of designs and analysis of experiments.

**Theory**
**Unit-I**
Basic principles of experimental designs. Uniformity trials. Completely randomized design, randomized block design and latin square designs. Multiple comparison tests.
**Unit-II**
Missing plot techniques. Analysis of covariance. Factorial experiments: $2^2$, $2^3$ and $3^2$. Split plot design. Strip plot design. Factorial in split plot design.
**Unit-III**
Cross over designs. Balanced incomplete block design. Response surface designs. Groups of experiments.

**Practical**:
Uniformity trials. Completely randomized design. Randomized block and latin square designs. Missing plot and analysis of covariance Split plot designs. Factorial in split plot design. Strip plot designs. Cross over and balanced incomplete block designs. Groups of experiments.
**Course Outcome:**
The students will be able to plan and design the experiments for their research. They will also be exposed to statistical software for the analyzing the data pertaining to designs of this course.

**Teaching Schedule**

| S.No. | Topics | No. of Lectures |
|---|---|---|
| 1 | Basic principles of experimental designs, | 1 |
| 2 | Completely randomized design | 1 |
| 3 | Randomized block design | 1 |
| 4 | Latin square design | 1 |
| 5 | Multiple comparison tests | 1 |
| 6 | Missing plot techniques | 1 |
| 7 | Analysis of covariance | 1 |
| 8 | Factorial experiments | 2 |
| 9 | Split plot design | 1 |
| 10 | Strip plot design | 1 |
| 11 | Factorial in split plot design | 1 |
| 12 | Crossover designs | 1 |
| 13 | Balanced incomplete block design | 1 |
| 14 | Response surface designs | 1 |
| 15 | Groups of experiments | 1 |
| **Total** | | **16** |

**List of Practicals**

| S.No. | Topics | No. of Parcticals |
|---|---|---|
| 1 | Basic principles of experimental designs, | 1 |
| 2 | Completely randomized design | 1 |
| 3 | Randomized block design | 1 |
| 4 | Latin square design | 1 |
| 5 | Multiple comparison tests | 1 |
| 6 | Missing plot techniques | 1 |
| 7 | Analysis of covariance | 1 |
| 8 | Factorial experiments | 2 |
| 9 | Split plot design | 1 |
| 10 | Strip plot design | 1 |
| 11 | Factorial in split plot design | 1 |
| 12 | Crossover designs | 1 |
| 13 | Balanced incomplete block design | 1 |
| 14 | Response surface designs | 1 |
| 15 | Groups of experiments | 1 |
| **Total** | | **16** |

**Suggested Readings**


1. Cochran WG and Cox GM 1957. *Experimental Designs*. 2ndEd. John Wiley.
2. Dean AM and Voss D1999. *Design and Analysis of Experiments*. Springer.
3. Design Resources Server: www. iasri.res.in/design.
4. Examination of Theory and Practice. John Wiley.
5. Federer WT 1985. *ExperimentalDesigns*.MacMillan.
6. Fisher RA1953. *Design and Analysis of Experiments*. Oliver & Boyd.
7. Montogomery 2013. *Designand analysis of experiments*. John Wiley & Sons.
8. Nigam AK and Gupta VK 1979. *Hand book on Analysis of Agricultural Experiments*. IASRI Publ.
9. Pearce SC 1983. *The Agricultural Field Experiment: A Statistical Examination of Theory and Practice.* John Wiley & Sons

## VSC 513 Processing of Vegetable Crops 1+1

**Theory**

Unit I : Present status- Present status and future prospects of vegetable preservation industry in India

Unit II : Spoilage and biochemical changes- Spoilage of fresh and processed vegetable produce; biochemical changes and enzymes associated with spoilage of vegetable produce; Principal spoilage organisms, food poisoning and their control measures; Role of microorganisms in food preservation

Unit III : Processing equipments- Raw material for processing; Primary and minimal processing; Processing equipments; Layout and establishment of processing industry; FPO license; Importance of hygiene; Plant sanitation

Unit IV : Quality control- Quality assurance and quality control, TQM, GMP; Food standards- FPO, PFA, etc.; Food laws and regulations; Food safety- hazard analysis and critical control points (HACCP); Labeling and labeling act and nutrition labeling

Unit V : Value addition- Major value added vegetable products; Utilization of byproducts of vegetable processing industry; Management of processing industry waste; Investment analysis; Principles and methods of sensory evaluation of fresh and processed vegetables

**Practical**

1. Study of machinery and equipments used in processing of vegetable produce
2. Chemical analysis for nutritive value of fresh and processed vegetable
3. Study of different types of spoilage in fresh as well as processed vegetable produce
4. Classification and identification of spoilage organisms
5. Study of biochemical changes and enzymes associated with spoilage
6. Laboratory examination of vegetable products
7. Sensory evaluation of fresh and processed vegetables
8. Study of food standards- National, international, CODEX Alimentarius
9. Visit to processing units to study the layout, hygiene, sanitation and waste management

**Teaching Schedule**

| Lecture No. | Topics | Weightage (%) |
|---|---|---|
| **Unit I- Present status** | | |
| 1-2 | Present status and future prospects of vegetable preservation industry in India | 10 |
| **Unit II- Spoilage and biochemical changes** | | |
| 3 | Spoilage of fresh and processed vegetable produce. | 15 |
| 4-5 | Biochemical changes and enzymes associated with spoilage of vegetable produce. | |
| 6 | Principal spoilage organisms, food poisoning and their control measures, Role of microorganisms in food preservation. | 10 |
| **Unit III- Processing equipments** | | |
| 7 | Raw materials for processing and processing equipments. | 15 |
| 8 | Primary and minimal processing, processing equipments; Layout | |

| | | |
|---|---|---|
| | and establishment of processing industry | |
| 9 | FPO license; Importance of hygiene; Plant sanitation | 05 |
| **Unit IV- Quality control** | | |
| 10 | Quality assurance and quality control, TQM, GMP. Food standards – FPO, PFA, etc. Food laws and regulations. | 10 |
| 11 | Food safety- hazard analysis and critical control points (HACCP). Labeling and labeling act, nutrition labeling. | 10 |
| **Unit V- Value addition** | | |
| 12-13 | Major value added products from vegetables. Utilization of byproducts of vegetable processing industry. | 15 |
| 14-15 | Management of waste from processing factory. Investment analysis. | 10 |
| 16 | Principles and methods of sensory evaluation of fresh and processed vegetables. | |

**List of Practical**

| Practical No. | TOPICS |
|---|---|
| 1-2 | Study of machinery and equipments used in processing of vegetable produce. |
| 3-4 | Chemical analysis for nutritive value of fresh and processed vegetables. |
| 5-6 | Study of different types of spoilages in fresh as well as processed vegetable produce. |
| 7 | Classification and identification of spoilage organisms. |
| 8-9 | Study of biochemical changes and enzymes associated with spoilage. |
| 10-11 | Laboratory examination of vegetable products. |
| 12 | Sensory evaluation of fresh and processed vegetables. |
| 13-14 | Study of food standards –National, international, CODEX Alimentarius. |
| 15-16 | Visit to processing units to study the layout, equipments, hygiene, sanitation and residual / waste management. |

**Suggested Readings :**


1. Arthey, D. and Dennis, C., 1996, Vegetable processing. Blackie/Springer-Verlag.
2. Chadha, D.S., 2006, The Prevention of food adulteration act. Confed. of Indian Industry.
3. Desrosier, N.W., 1977, Elements and technology. AVI Publ. Co. FAO., 1997, Fruit and Vegetable processing. FAO. FAO., CODEX Alimentarius: Joint FAO/WHO food standards programme. 2nd Ed. Vol. VB. tropical fresh fruits and vegetables. FAO.
4. FAO., Food quality and safety systems- training manual on food hygiene and haccp. FAO.
5. Fellow’s, P., 1988, Food processing technology. Ellis Horwood International.
6. Frazier, W.C. and Westhoff, D.C., 1995, Food microbiology. 4th Ed. Tata McGraw Hill.
7. Giridharilal, G.S., Siddappa and Tandon, G.L., 1986, Preservation of fruits and vegetables. ICAR.
8. Gisela, J., 1985, Sensory evaluation of food- theory and practices. Ellis Horwood.
9. Graham, H.D., 1980, Safety of foods. AVI Publ. Co.
10. Hildegrade, H. and Lawless, H.T., 1997, Sensory evaluation of food. CBS.
11. Joslyn, M. and Heid, Food processing operations.AVI Publ. Co.
12. Mahindru, S.N., 2004, Food safety: concepts and reality. APH Publ. Corp.

13. Ranganna, S., 1986, Handbook of analysis and quality control for fruit and vegetable products. 2nd Ed. Tata-McGraw Hill.
14. Shapiro, R., 1995, Nutrition labeling handbook. Marcel Dekker.
15. Srivastava, R.P. and Kumar, S., 2003, Fruit and vegetable preservation: principles and practices. 3rd Ed. International Book Distri. Co.
16. Tressler and Joslyn, M.A., 1971, Fruit and vegetable juice processing technology. AVI Publ. Co.
17. Verma, L.R. and Joshi, V.K., 2000, Postharvest technology of fruits and vegetables: handling, processing, fermentation and waste management. Indus Publ. Co.

**VSC 514 Postharvest Management of Vegetable Crops 2+1**

**Theory:**

Unit I : Importance and scope- Importance and scope of post-harvest management of vegetables

Unit II : Maturity indices and biochemistry- Maturity indices and standards for different vegetables; Methods of maturity determination; Biochemistry of maturity and ripening; Enzymatic and textural changes; Ethylene evolution and ethylene management; Respiration and transpiration along with their regulation methods

Unit III : Harvesting and losses factors- Harvesting tools and practices for specific market requirement; Postharvest physical and biochemical changes; Pre-harvest practices and other factors affecting postharvest losses

Unit IV : Packinghouse operations- Packing house operations; Commodity pretreatments chemicals, wax coating, pre-cooling and irradiation; Packaging of vegetables, prevention from infestation, management of postharvest diseases and principles of transportation

Unit V : Methods of storage- Ventilated, refrigerated, modified atmosphere and controlled atmosphere storage, hypobaric storage and cold storage; Zero-energy cool chamber, storage disorders like chilling injury in vegetables

**Practical**

1. Studies on stages and maturing indices
2. Ripening of commercially important vegetable crops
3. Studies of harvesting, pre-cooling, pre-treatments, physiological disorders-chilling injury
4. Improved packaging
5. Use of chemicals for ripening and enhancing shelf life of vegetables
6. Physiological loss in weight, estimation of transpiration, respiration rate and ethylene release
7. Storage of important vegetables
8. Cold chain management
9. Visit to commercial packinghouse, cold storage and control atmosphere storage

**Teaching Schedule**

| Lecture No. | Topics | Weightage (%) |
|---|---|---|
| **Unit I- Importance and scope** | | |
| 1-2 | Importance and scope of post-harvest management of vegetables | 10 |
| **Unit II- Maturity indices and biochemistry** | | |
| 3-4 | Maturity indices and standards for different vegetables; Methods of maturity determination. | 10 |
| 5-6 | Ethylene evolution and ethylene management; Respiration and transpiration along with their regulation methods. | 10 |
| 7-8 | Biochemistry of maturity and ripening; Enzymatic and textural changes. | 10 |

| Unit III- Harvesting and losses factors | | |
|---|---|---|
| 9 | Harvesting tools and practices for specific market requirement. | 05 |
| 10-11 | Postharvest physical and biochemical changes; Pre-harvest practices and other factors affecting postharvest losses. | 15 |
| **Unit IV- Packinghouse operations** | | |
| 12 | Packing house operations; commodity pretreatments chemicals, wax coating, pre-cooling and irradiation. | 10 |
| 13 | Packaging of vegetables, prevention from infestation, management of postharvest diseases and principles of transportation. | 10 |
| **Unit V- Methods of storage** | | |
| 14 | Ventilated, refrigerated, modified atmosphere and controlled atmosphere storage, hypobaric storage and cold storage. | 10 |
| 15 | Zero-energy cool chamber. | 10 |
| 16 | Storage disorders like chilling injury in vegetables. | |

**List of Practical**

| Practical No. | TOPICS |
|---|---|
| 1-2 | Studies on stages and maturing indices of vegetable crops. |
| 3-4 | Ripening of commercially important vegetable crops. |
| 5-6 | Studies of harvesting, pre-cooling, pre-treatments, physiological disorders-chilling injury. |
| 7 | Improved packaging in vegetable crops. |
| 8-9 | Use of chemicals for ripening and enhancing shelf life of vegetables. |
| 10-11 | Physiological loss in weight, estimation of transpiration, respiration rate and ethylene release. |
| 12 | Storage of important vegetable crops. |
| 13-14 | Cold chain management |
| 15-16 | Visit to commercial packinghouse, cold storage and control atmosphere storage |

**Suggested Readings :**


1. Chadha, K.L. and Pareek, O.P., 1996, Advances in horticulture. Vol. IV. Malhotra Publ. House.
2. Chattopadhyay, S.K., 2007, Handling, transportation and storage of fruit and vegetables. Gene-Tech books, New Delhi.
3. Haid, N.F. and Salunkhe, S.K., 1997, Postharvest physiology and handling of fruits and vegetables. Grenada Publ.
4. Mitra, S.K., 1997, Postharvest physiology and storage of tropical and sub-tropical fruits. CABI.
5. Paliyath G., Murr D.P., Handa, A.K. and Lurie, S., 2008, Postharvest biology and technology of Fruits, vegetables and flowers. Wiley-Blackwell, ISBN: 9780813804088.
6. Ranganna, S., 1997, Handbook of analysis and quality control for fruit and vegetable Products. Tata McGraw-Hill.

7. Stawley, J. K., 1998, Postharvest physiology of perishable plant products. CBS publishers.
8. Sudheer, K.P. and Indira, V., 2007, Postharvest technology of horticultural crops. New India Publ. Agency.
9. Thompson, A.K. (Ed.), 2014, Fruit and vegetables: harvesting, handling and storage (Vol. 1 and 2) Blackwell Publishing Ltd, Oxford, UK. ISBN: 9781118654040.
10. Verma, L.R. and Joshi, V.K., 2000, Postharvest technology of fruits and vegetables: handling, processing, fermentation and waste management. Indus Publishing Company, New Delhi, India. ISBN 8173871086.
11. Willis, R, McGlassen, W.B., Graham, D. and Joyce, D., 1998, Postharvest: An introduction to the physiology and handling of fruits, vegetables and ornamentals. CABI.
12. Wills, R.B.H. and Golding, J., 2016, Postharvest: an introduction to the physiology and handling of fruit and vegetables, CABI Publishing, ISBN 9781786391483.
13. Wills, R.B.H. and Golding, J., 2017, Advances in postharvest fruit and vegetable technology, CRC Press, ISBN 9781138894051.

**PHM 505 Principles and Methods of Fruit and Vegetable Preservation 2+1**

**Objective :**
To Understanding spoilage, underlying principles and methods of processing of fruits and vegetables. The students are expected to be able to Understand Principles and different methods of preservation. Principal spoilage organisms, food poisoning and their control measures. Canning of fruits and vegetables. Processing equipments and layout of processing industry

**Theory**
**Block 1: Principles and Methods of Fruit and Vegetable Preservation**
**Unit I:** Introduction, Historical development in food processing, type of food and causes for food spoilage. Basic principles of fruits and vegetables processing;
**Unit II:** Thermal processing, pH classification of foods, heat resistance of micro organism; Heat resistance of enzymes in foods, Spoilage of thermal processed food; Containers – canning, rigid tin plates and cans, aluminium cans, glass containers – types; flexible packaging materials, Composite can, specification, corrosion of cans, heat penetration into containers and methods for determination of process time.
**Unit III:** Effects of low temperature on fresh commodities and prepared product. Freezing preservation, freezing points of foods, slow and quick freezing, Cryogenic freezing and frozen food storage. Drying and dehydration, sun drying solar dehydration, mechanical drying types of driers, osmotic dehydration.
**Unit IV:** Food fermentation – alcoholic, acetic and lactic fermentation. Pickling and curing; Effect of salt on food preservation, types of salt cured products. Traditional and new products; chemical preservation, SO2, benzoic acid, ascorbic acid, antioxidants and antibiotics, newer preservatives. Preservation by controlling water activity – high sugar products, intermediate moisture food, juice concentrates.
**Unit V:** Food irradiation, principles, types and sources of radiation, mode of action of ionizing radiation; radiation effect on food constituents and regulation.

**Practical**
- List and cost of equipment, utensils, and additives required for small scale processing industry;
- Chemical analysis for nutritive value of fresh and processed fruits and vegetables;
- Preparation and preservation of fruit based beverages and blended products from fruits and vegetables;
- Evaluation of pectin grade; preparation and quality evaluation of fruit jam;
- Preparation of papain;
- Blanching and its effects on enzyme;
- Preparation of dehydrated vegetables;
- Study of different types of spoilages in fresh as well as processed horticultural produce;
- Study of biochemical changes and enzymes associated with spoilage;
- Sensory evaluation of fresh and processed fruits and vegetables;

- Visit to processing units.

**Suggested Reading**


1. Barret DM, Somogyi LP and Ramaswamy H. Eds. 2005. *Processing Fruits: Science and Technology* (2nd Edition), CRC Press, ISBN 9780849314780.
2. FAO. 2007. *Handling and Preservation of Fruits and Vegetables by Combined Methods for Rural Areas- Technical Manual*. FAO Agricultural Services Bulletin 149.
3. Fellows PJ. 2009. Food Processing Technology: Principles and Practice (3rd Edition), Woodhead Publishing, ISBN 9781845692162.
4. Lal G, Siddappa GS and Tandon GL. 1998. Preservation of Fruits and Vegetables. ICAR, ISBN 9788171640904.
5. Ramaswamy H and Marcotte M. 2006. *Food Processing: Principles and Applications*. Taylor &Francis.
6. Salunkhe DK and Kadam SS. 1995. Handbook of Fruit Science and Technology: Production, Composition and Processing. Marcel Dekker.
7. Srivastava RP and Kumar S. 2014. *Fruit and Vegetable Preservation: Principles and Practices* (3$^{rd}$Edition), CBS Publishing, ISBN 9788123924373.
8. Verma LR and Joshi VK. 2000. *Postharvest Technology of Fruits and Vegetables: Handling, Processing, Fermentation and Waste Management*. Indus Publishing Company, New Delhi, India. ISBN 8173871086.


**Websites**

http://agriinfo.in/default.aspx?page=topic&superid=2&topicid=2065

http://www.fao.org/docrep/x0209e/x0209e02.htm

http://www.cstaricalcutta.gov.in/images/CTS%20Fruits_and_Vegetables%20NSQF.pdf

**PHM 506 Laboratory Techniques in Postharvest Horticulture 1+2**

**Objectives :**

To familiarize with the conventional analysis of raw and processed food products of all commodity technologies used for routine quality control in food industry, and their role on nutritional labeling, and to familiarise students with advances in instrumentation and Postharvest management.

**Theory**

**Block 1: Laboratory Techniques in Postharvest Management**

**Unit I:** Rheological techniques and instrumentation used in food industry. Analysis of food additives like food colour, antioxidants, emulsifier, etc.

**Unit II:** Analysis of pesticide residues, metallic contaminants, aflatoxin. Analysis of food flavours.

**Unit III:** Quality analysis of processed fruits and vegetables, coffee, tea and spices. Identification and enumeration of microbial contaminants.

**Unit IV:** Principles of chromatography (GC, GCMS, HPLC, LCMS), spectrophotometry (Atomic absorption spectrophotometer, ICAP spectrophotometer), ICP-MS, ICPOES, NMR, ESR, amino acid analyser, flame photometry, electrophoresis.

**Unit V:** Colour measurement in foods, IRGA, Radio-isotopic techniques. Nondestructive quality evaluation (NDQE)- E-nose, E-tongue, machine vision.

**Practical**

- Sample preparation for quality analysis. Energy calculation, sample calculations;
- Texture analysis, Rheology of different foods;
- Instrumental colour analysis;
- Sensory evaluation and microbiological examinations of fresh and processedproducts;
- Estimation of tannin/ phytic acid by spectrometric method;
- Moisture and fat analysis by NIR spectroscopy;
- Separation and identification of sugars in fruit juices;
- Separation and identification of carotenoids by column chromatography;
- Estimation of respiration in fruits and vegetables;
- Flavour profile in essential oils using GC;
- Identification and determination of organic acids by HPLC;
- Capsaicin content and Scoville Heat Units in chillies;
- Heavy metal analysis using atomic absorption spectrometry;
- Residue analysis.

**Suggested Reading**

1. Lundanes E., Reubsaet L and Greibrokk T. 2013. *Chromatography: Basic Principles, Sample Preparations and Related Methods*, ISBN-13: 978-3527336203, Wiley VCH
2. Mark F Vitha. 2016. *Chromatography: Principles and Instrumentation*. John Wiley & Sons, ISBN 9781119270881

3. Suzanne NS. 2010. *Introduction to Food Analysis*, ISBN 978-1-4419-1478-1, Springer.
4. Ranganna S. 2001. *Handbook of Analysis and Quality Control for Fruit and Vegetable Products*, Tata McGraw-Hill ISBN 9780074518519.
5. Semih Otles (Ed). 2016. *Methods of Analysis of Food Components and Additives* (*Chemical and Functional Properties of Food Components*) CRC Press, ISBN-13: 978-1138199149,

**CSE 506 Digital Image Processing 2+1**

**Objectives:**

To give an overview of digital image processing including visual perception, image formation, spatial transformations, image enhancement, color image representation and processing, edge detection, image segmentation and morphological image processing.

**Theory**

**Unit-I**

Digital image fundamentals, elements of visual perception, light and the electromagnetic spectrum, image sensing and acquisition, image sampling and quantization, basic relationships between pixels, linear and non linear operations.

**Unit-II**

Image enhancement in the spatial domain, basic gray level transformations, histogram processing, basics of spatial filtering, smoothing spatial filters, sharpening spatial filters.

**Unit-III**

Color image processing, color fundamentals, color models, pseudo color image processing, basics of full-color image processing, color transformations, smoothing and sharpening, color segmentation.

**Unit-IV**

Image segmentation, detection of discontinuities, edge linking and boundary detection, thresholding, region-based segmentation, segmentation by morphological watersheds.

**Unit-V**

Morphological image processing, dilation and erosion, opening and closing, extensions to gray-scale images.

**Practical:**

To write program to read and display digital image, image processing program using point processing method, program for image arithmetic operations, program for image logical operations, program for histogram calculation and equalization, program for geometric transformation of image, understand various image noise models and to write programs for image restoration and to remove noise using spatial filters. Brief outline of image processing tools.

**Course Outcome:**

This course introduces digital image processing. It focuses on the theory an dalgorithms underlying a range of tasks including acquisition, formation, enhancement, segmentation and representation.

**Teaching Schedule**

| S. No. | Topic | No.of Lectures |
|---|---|---|
| 1 | Introduction and Fundamentals, Motivation and Perspective, Applications, Components of Image Processing System, | 3 |
| 2 | Element of Visual Perception, A Simple Image Model | 1 |
| 3 | Sampling and Quantization. | 2 |

| | | |
|---|---|---|
| 4 | Light and the electromagnetic spectrum, image sensing and acquisition | 2 |
| 5 | Basic relationships between pixels, linear and nonlinear operations | 2 |
| 6 | Image Enhancement in Spatial Domain | 2 |
| 7 | Introduction; Basic Gray Level Functions | 2 |
| 8 | Histogram Specification | 2 |
| 9 | Basics of spatial filtering, smoothing spatial filters, sharpening spatial filters | 2 |
| 10 | Color image processing, color fundamentals | 1 |
| 11 | Color models, pseudo color image processing | 1 |
| 12 | Color transformations, smoothing and sharpening, color segmentation. | 2 |
| 13 | Image segmentation, detection of discontinuities | 1 |
| 14 | Edge linking and boundary detection, thresholding, region-based segmentation | 2 |
| 15 | Segmentation by morphological watersheds | 1 |
| 16 | Morphological image processing, dilation and erosion | 2 |
| 17 | Opening and closing, extensions to gray-scale images | 2 |
| **TOTAL** | | **30** |

**List of Practical**

| S. No. | Topic | No.of Practicals |
|---|---|---|
| 1 | Display digital image, image processing program using point processing method, program for image arithmetic operations | 3 |
| 2 | Program for image arithmetic operations, image logical operations, histogram calculation and equalization | 4 |
| 3 | Program for geometric transformation of image, understand and various image noise models | 4 |
| 4 | Programs for image restoration and to remove noise using spatial filters | 4 |
| 5 | Brief outline of image processing tools | 1 |
| **TOTAL** | | **16** |

**Suggested Readings:**

1. Rafael CG and Richard EW. *Digital Image Processing*. Third Edition, Pearson Education.
2. Jayaraman S, Esakkirajan S and Veerakumar T. *Digital Image Processing*. Tata McGraw Hill Publication.
3. Sridhar S. *Digital Image Processing*. Oxford University Press.

**REE 610 Renewable Energy for Industrial Application 2+1**

**Objectives**:

To provide the knowledge regarding the energy consumption pattern in agro based industries, quantification techniques and identification of opportunities for renewable energy sources.

**Theory**

**Unit I**

Elucidation of unit operations in industry. Energy quantification techniques, system boundary, estimation of productivity, plant capacity utilization, energy density ratio and energy consumption pattern. Energy flow diagram conservation opportunities identification.

**Unit II**

Solar energy for industrial application: Solar water heating, steam solar cooking system, industrial solar dryer and solar process heat, solar cooling system (refrigeration, air conditioning and solar architecture technology), solar furnace and solar green house technology for high-tech cultivation. Solar photovoltaic technology for industrial power.

**Unit III**

Bio energy for industrial application: Quantification of industrial bio-waste, characterization, power generation through bio-methanation, gasification and dendro thermal power plant.

**Unit IV**

Wind energy: Aero generator of new era and national and international state of art in wind power generation. Other renewable energy sources: Magneto hydro dynamics, fuel cells technology and micro-hydro energy technology.

**Practical**

Elucidation and energy consumption for unit operations in industry. Study of energy quantification and identification of opportunities for RET's. Design of solar dryers. Design of solar photovoltaic system. Design of gasifiers for thermal energy and power generation. Design of combustor (gasifier stove). Study of solar greenhouse. Study of biogas engine generator set. Case study of agro-industrial energy estimation and visit to RSE power generation site.

**Teaching Schedule**

| S.No. | Topic | No. of Lectures |
|---|---|---|
| 1. | Elucidation of unit operations in industry. | 1 |
| 2. | Energy quantification techniques, system boundary, | 2 |
| 3. | Estimation of productivity, plant capacity utilization, | 2 |
| 4. | Energy density ratio and energy consumption pattern. | 2 |
| 5. | Energy flow diagram conservation opportunities identification. | 1 |
| 6. | Solar energy for industrial application. | 1 |
| 7. | Solar water heating. | 1 |

| | | |
|---|---|---|
| 8. | Steam solar cooking system. | 1 |
| 9. | Industrial solar dryer and solar process heat. | 2 |
| 10. | Solar cooling system (refrigeration, air conditioning and solar architecture technology). | 2 |
| 11. | Solar furnace. | 1 |
| 12. | Solar greenhouse technology for high-tech cultivation. | 2 |
| 13. | Solar photovoltaic technology for industrial power. | 1 |
| 14. | Bio energy for industrial application | 1 |
| 15. | Quantification of industrial bio-waste, its characterization | 2 |
| 16. | Power generation through bio-methanation, | 2 |
| 17. | Gasification and dendro thermal power plant. | 2 |
| 18. | Wind energy: Aero generator of new era. | 1 |
| 19. | National and international state of art in wind power generation. | 2 |
| 20. | Other renewable energy sources: Magneto hydro dynamics, fuel cells technology and micro-hydro energy technology. | 3 |
| | **Total** | **32** |

**List of Practical's**

| **S.No.** | **Topic** | **No. Of Practical's** |
|---|---|---|
| 1 | Elucidation and energy consumption for unit operations in industry | 1 |
| 2 | Study of energy quantification and identification of opportunities for RET's | 1 |
| 3 | Design of solar dryers. | 2 |
| 4 | Design of solar photovoltaic system. | 2 |
| 5 | Design of gasifiers for thermal energy and power generation. | 2 |
| 6 | Design of combustor (gasifier stove). | 2 |
| 7 | Study of solar greenhouse. | 1 |
| 8 | Study of biogas engine generator set. | 1 |
| 9 | Case study of agro-industrial energy estimation | 2 |
| 10 | Visit to RSE power generation site | 1 |
| | **Total** | **15** |

**Suggested Reading**


- Duffie JA and Beakman WA. 2006. *Solar Energy Thermal Process*. John Wiley and Sons, New York.

- Kumar S. 2011. *Energy Conservation Building User Code Guide*. Bureau of Energy Efficiency, New Delhi.
- Rathore NS, Kurchania AK and Panwar NL. 2007. *Non Conventional Energy Sources*. Himanshu Publications, Udaipur, Rajasthan.
- Sayigh AAM. 2012. *Solar Energy Engineering*. Academic Press, New York.
- Singh P, Kurchania AK, Rathore NS and Mathur AN. 2005. *Sustainable Development through Renewable Energy Sources*. Yash Publications, Bikaner, Rajasthan.
- Bureau of Energy efficiency 2012 Vol.1 and 2 BEE, New Delhi.

**FPE 501 Emerging Food Engineering Operations 2+1**

**Theory**

**Unit I**

Ionizing and non-ionizing radiation processing system operations: types of radiations, generation, microwave assisted processing systems, IR assisted processing systems, radio frequency systems, $O^3$, UV and X-ray assisted processing systems, gamma irradiations systems, e-beam radiation systems and applications.

**Unit II**

Pulse electric field (PEF) generation system and applications, cold plasma generation systems and applications, high pressure processing systems and applications, ultrasonic processing systems and applications.

**Unit III**

Extrusion systems, batch and continuous ohmic heating systems and applications, inductive heating systems and applications, applications of nanotechnology.

**Unit IV**

Drying systems: superheated steam drying, refractance window drying, heat pump drying, freeze drying, spray drying, foam bed drying, microwave drying, instant pressure drop (DIC) drying and hybrid drying systems.

**Unit V**

Membrane processing systems: UF, MF, NF, reverse osmosis and vapour permeation, pervaporation, membrane distillation. Supercritical fluid extraction: concept, property of near critical fluids (NCF), extraction methods. Cryoprocessing-cryogens properties, systems and their different applications.

**Practical**

- To evaluate the characteristics of treated water and selected liquid foods using membrane systems (NF, UF, RO, etc)
- To study super critical fluid extraction system and application
- To study microwave system and microwave assisted food processing
- To study efficacy of hot water, steam, microwave, ultrasound blanching of selected fruits and vegetables
- To study the ultrasonicator and applications
- To study cryogenic processing applications
- To prepare Nano emulsion and study of their characteristics
- To study ohmic/inductive heating systems applications
- To study cold plasma applications
- To study gamma irradiation applications
- To study drying kinetics using different drying systems
- To study operations in 3 D printing
- Solving problems in food processing and case studies
- Visits of food industries utilizing advance food processing systems.

**Suggested Reading**

1. Datta AK. 2001. *Handbook of Microwave Technology for Food Application*. CRC Press.
2. Purkait MK and Singh R. 2018. *Membrane Technology in Separation Science*. CRC Press Taylor and Francis Group.

3. Frame ND. 1994. *The Technology of Extrusion Cooking*. Blackie.
4. Gould GW. 2012. *New Methods of Food Preservation*. Springer Science & Business Media.
5. Berk Z. 2018. *Food process engineering and technology*. Academic press.
6. Nema PK, Kaur BP and Mujumdar AS. 2019. *Drying technologies for foods: Fundamentals and applications*. CRC Press
7. Meredith RJ. 1998. *Engineers' Handbook of Industrial Microwave Heating* (No. 25). Iet.
8. Arvanitoyannis IS. 2010. *Irradiation of food commodities: techniques, applications, detection, legislation, safety and consumer opinion*. Academic Press.
9. Yanniotis S. 2008. *Solving problems in food processing and case studies*. Springer

**FPT 602 Food Packaging 3+0**

**Theory**

**Unit I**

Recent advances in active and intelligent packaging like Antimicrobial food packaging, Non-migratory bioactive polymers, Freshness indicator, Recycling, biodegradable packaging, Edible Films and Coatings, aseptic packaging, self heating and hydrate packages.

**Suggested Reading**

1. Ahvenainen R. 2001. *Novel Food Packaging Techniques*, CRC Press.
2. Rooney ML. 1988. *Active Food Packaging*, Chapman & Hall.
3. Coles R and Kirwan M. 2011. *Food and Beverage Packaging Technology*, Wiley-Blackwell.
4. Han J and Han J. 2005. *Innovations in Food Packaging*, Academic Press.
5. Yam K and Lee D. 2012. *Emerging Food Packaging Technologies*, Woodhead Publishing.
6. Mihindukulasuriya SDF and Lim LT. 2014. *Nanotechnology Development in Food Packaging a Review. Trends in Food Science and Technology*, 149-167.
7. Souza VGL and Fernando L. 2016. *Nano-particles in Food Packaging-Biodegradibility and Potential Migration to Food – A Review. Food Packaging and Shelf Life*, 63-70.

**RPE 601 Research and Publication Ethics 1+1**

**Aim of the Course:**
This course is mainly focusing on basics of philosophy of science and ethics, research integrity, publication ethics. Hands on sessions are designed to identify research misconduct and predatory publications. Indexing and citation databases, open access publications, research and p metrics and plagiarism tools introduced in the course.

**THEORY**

**Unit 1: Philosophy and Ethics**
1. Introduction to philosophy: definition, nature and scoope, concept, branches
2. Ethics: definitino, moral philosophy, nature of moral judgements and reations.

**Unit 2: Scientific Conduct**
1. Ethics with respcet to science and research
2. Intellectual honest and research integrity
3. Scientific misconducts: falsification, fabrication, and plagiarism.
4. Redundant publications: duplicate and overlapping publications, salami slicing
5. Selective reporting and misrepresentation of data.

**Unit 3: Publication Ethics**
1. Publication ethics: definition, introduction and importance
2. Best practices/standards setting initiatives and guidelines: COPE, WAME, etc.
3. Conflicts of interest
4. Publication misconduct: definition, concept, problems that lead to unethical behavior and vice verse, types
5. Violation of publication ethics, authorship and contributor ship
6. Identification of publication misconduct, complaints and appeals
7. Predatory publishers and journals

**Unit 4: Open Access Publishing**
1. Open access publications and initiatives
2. SHERPA/RoMEO online resourse to check publisher copyright and self-archiving policies.
3. Software tool to identify predatory publications developed by SPPU
4. Journal finder/ journal suggestion tools viz. JANE, Elsevier Journal Finder, Springer Journal Suggester, etc.

**Unit 5: Publication Misconduct**
A. Group Discussions
1. Subject specific ethical issues, FFP, authorship
2. Conflicts of interest
3. Complaints and appeals: examples and fraud from India and abroad

B. Software tools
Use of plagiarism software like Turnitin, Urkund and other open source software tools.

**Unit 6: Databases And Research Metrics**

A Databases

1. Indexing detabeses
2. Citation detabases: Web of Science, Scopus, etc.

B. Research Metrics

Impact Factor of journal as per journal citation report, SNIP, SJR, IPP, Cite Score.

Metrics: h-index, g index, i10 index, altmetrics

**Practicals**

**1. Types of Reaserach**

1. Basic Research:
2. Applied Research:
3. Descriptive Research:
4. Analytical Research:
5. Correlational Research:
6. Qualitative Research:
7. Quantitative Research:
8. Experimental Research:
9. Explanatory Research:
10. Exploratory Research:
11. Selection of Domain/Area of Research:

**2. Formulating a Research Problem and Identification of Keywords:**

1. Literature Survey:
2. Redefining Research Problem, Objectives and Outcomes:
3. Research Proposal:
4. Identifying Variable /Parameters and Research Design:
5. Data Collection and Representation:
6. Testing of Proposed Design on Collected Data/Hypothesis Testing:

**3. Results and Analysis:**

1. Research Report Writing:
2. Features of Good Research Study

**4. Journal Search**

1. Open Access Publishing
2. Impact Factor of journal as per journal citation report, SNIP, SJR, IPP, Cite Score.
   Metrics: h-index, g index, i10 index, altmetrics

**Suggested Readings**


- Bird,A. (2006). Philosophy of Sciences. Routledge
- MacIntyre, Alasdair (1967). A Short History of Ethics. London
- P.Chandah. (2018). Ethics in Competitive Research: Do not get Scooped; do not get plagiarized.

- National Academy of Sciences, National Academy of Engineering and Institute of Medicine (2009)., National On being a Scientist: A guide to responsible conduct in Research : third edition, National Academies Press
- Hall GM. Book Farthing MJG. How to Write a Paper. UK Blackwell Publishing; 2008
- NAS-NAE-IOM. Responsible Science: Ensuring the Integrity of the Research Process. Washington, DC: National Academy Press; 1992.
- Alexander M. Novikov & Dmitry A. Novikov, Research Methodology: From Philosophy of Science to Research Design, CRC Press Taylor & Francis Group, (2013).
- C. R. Kothari, Research Methodology: Methods and Techniques, New Age International (P) Ltd., New Delhi (2004).
- David Bridges, Philosophy in Educational Research: Epistemology, Ethics, Politics and Quality, Springer International Publishing AG (2017).
- Deepak Chawla & Neena Sondhi, Research Methodology: Concepts and Cases, VIKAS® Publishing House Pvt Ltd, New Delhi (2015).

- Paul Smeyers & Marc Depaepe, Educational Research: Ethics, Social Justice, and Funding Dynamics, Springer International Publishing AG, (part of Springer Nature) (2018).
- Peter Pruzan, Research Methodology: The Aims, Practices and Ethics of Science, Springer International Publishing Switzerland (2016).
- Ranjit Kumar, Research Methodology: a step-by-step guide for beginners, SAGE Publications India Pvt Ltd, New Delhi (2011).
- Richard Pring, Philosophy of Educational Research, Continuum, London (2000).
- Robyn Brandenburg & Sharon McDonough, Ethics, Self-Study Research Methodology and Teacher Education, Springer Nature Singapore Pte Ltd. (2019).
- S. K. Yadav, Elements of Research Writing, UDH Publishers and Distributers, New Delhi (2015).
- Surbhi Jain, Research Methodology in Arts, Science and Humanities, Society Publishing, Oakville, Canada (2019).
- Vinayak Bairagi and Mousami V. Munot, Research Methodology A Practical and Scientific
- Approach, CRC Press Taylor & Francis Group, New York, NY (2019).

| | | |
|---|---|---|
| Theory of Designs and Analysis of Experiments | STAT 502 | 1+1 |

E Resources and List of Journals

- *Advances in Applied Research*
- *Advances in Computational Sciences and Technology [ACST]*

*Advances in Mechanical Engineering*
*Advances in Water Resources*
*Agricultural Engineering*
*Agricultural Engineering Today*
*Agricultural Mechanization in Asia, Africa and Latin America*
*Agricultural Research*
*Agricultural Reviews*
*Agricultural Science Digest*
*Agricultural Water Management*
*Agronomy Journal (Journal of American Society of Agronomy*
*American Journal of Food Technology*
*American Statistician*
*Annals of Agri Bio Research*
*Annals of Agricultural Research*
*Annals of Arid Zone*
*Annals of Biology*
*Annals of Horticulture*
*Annals of Science*
*Annals of Statistics*
*Applied Ecology and Environmental Research*
*Applied Engineering in Agriculture*
*Applied Ergonomics*
*Arid Land Research and Management*
*Asian Journal of Chemistry*
*Asian Journal of Environmental Science*
*Atmospheric Research*
*Australian Journal of Crop Science*
*Australian Journal of Dairy Technology*
*Beverage and Food World*
*CIGR journal*
*Comptes Rendus Geosciences*
*Computers and Electronics in Agriculture*
*Computers & Industrial Engineering*
*Cotton Research Journal*
*Current Advances in Agricultural Sciences*
*Current World Environment*
*Ecological Engineering*
*Ecology, Environment and Conservation*
*Engineering and Technology in India*
*Environment*
*Environment and Ecology*
*Environmental Engineering Science*

*Environmental Monitoring and Assessment*
*Environmental Science and Pollution Research*
*Environmental Science and Technology*
*Environmental Review*
*Forage Research*

- *Groundwater*

*Hydrological Processes*
*IETE Journal of Research*
*IETE Journal of Education*
*Indian Journal of Agricultural Chemistry*
*Indian Journal of Agricultural Research*
*Indian Journal of Agricultural Sciences*
*Indian Journal of Dairy Science*
*Indian Journal of Extension Education*
*Indian Journal of Hill Farming*
*Indian Journal of Radio and Space Physics*
*Indian Journal of Science and Technology*
*Indian Journal of Soil Conservation*
*Indian Research Journal of Extension Education*
*Institute of Engineers (India)*
*Journal of Electronics & Tele Communication*
*International Journal of Agricultural Engineering*
*International Journal of Agricultural Science and Research*
*International Journal of Advance Industrial Engineering*
*International Journal of Advanced Mechanical Engineering [IJAME]*
*International Journal of Advanced Engineering Technology (IJAET)*
*International journal of Advanced Research in Engineering & Technology (IJARET)*
*International Journal of Applied Engineering Research [IJAER]*
*International Journal of Current Engineering and Technology*
*International Journal of Design and Manufacturing Technology(IJDMT)*
*International Journal of Engineering Research and Technology [IJERT]*
*International Journal of Engineering, Science and Metallurgy*
*International Journal of Engineering (IJE)*
*International Journal of Engineering Studies [IJES]*
*International Journal of Environmental Analytical Chemistry*
*International Journal of Environmental Research and Public Health*
*International Journal of Environmental Science and Technology*
*International Journal of Extension Education*
*International Journal of Food Engineering*
*International Journal of Food Microbiology*

*International Journal of Food Properties*
*International Journal of Food Science and Nutrition*
*International Journal of Food Science and Technology*
*International Journal of Food and Fermentation Technology*
*International Journal of Innovative Technology and Exploring Engineering (IJITEE)*
*International Journal of Industrial Engineering & Technology [IJIET]*
*International Journal of Industrial Engineering Research and Development (IJIERD)*
*The International Journal of Industrial Engineering: Theory,*
- *Application and Practice (IJIETAP)*

*International Journal of Engineering and Management Research (IJEMR)*
*International Journal of Engineering Sciences and Management*
*International Journal of Industrial Engineering Computations*
*International Journal of Engineering and Manufacturing Science [IJEMS]*
*International Journal of Research in Chemistry and Environment*
*International Journal of Research In Mechanical Engineering And Technology (IJRMET)*
*International Journal of Thermal Sciences*
*International Journal of Mechanical Engineering and Robotics Research*
*International Journal of Material and Mechanical Engineering*
*International Journal of Mechanical Engineering & Technology(IJMET)*
*International Journal of Mechanical Engineering and Research(IJMER)*
*International Journal of Mechanical Sciences*
*International Journal of Recent Technology and Engineering(TM) Exploring Innovation*
*International Journal of Industrial & Production Engineering & Tech. [IJIPET]*
*International Journal of Industrial and Systems Engineering*
*International Journal of Advanced Materials Science [IJAMS]*
*International Journal of Research in Mechanical Engineering*
*International Journal of Engineering & Technology Research*
*International Review of Applied Engineering Research [IRAER]*
*International Journal of Mechanical and Materials Engineering*
*International Journal of medical, Health, Biomedical, Bioengineering and Pharmaceutical Engineering*
*International Journal of Production Technology and Management (IJPTM)*
*International Journal of Refrigeration*
*International Journal of Remote Sensing*

*International Journal of Thermal Technologies*
*International Journal of Water Resources Development*
*International Journal on Agricultural Sciences*
*International Journal on Environmental Sciences*
*International Journal of Applied Research on Information Technology and Computing*
*International Journal of Mechanical Engineering*
*International Journal of Mechanical and Production Engineering Research and Development*
*International Scholarly Research Notices, ISRN Mechanical Engineering*
*Irrigation Science*
*Irrigation and Drainage (ICID Bulletin)*
*Irrigation and Drainage System*
*Italian Journal of Food Science*
*Journal of Agricultural Engineering (ISAE)*
*Journal of Agriculture Research and Technology*

- *Journal of Agricultural Safety and Health*

*Journal of Applied Ecology*
*Journal of Applied Probability*
*Journal of Applied Statistics*
*Journal of Arid Environments*
*Journal of Cotton Research and Development*
*Journal of Dairy Research*
*Journal of Dairy Science*
*Journal of Ecology*
*Journal of Energy Engineering - ASCE*
*Journal of Engineering*
*Journal of Engineering computers and Applied Sciences*
*Journal of Engineering Research*
*Journal of Ergonomics*
*Journal of Environmental Engineering*
*Journal of Environmental Monitoring*
*Journal of Environmental Protection and Ecology (JEPE)*
*Journal of Environmental Sciences*
*Journal of Environmental Science and Engineering*
*Journal of Environmental Science, Toxicology and Food Technology*
*Journal of Food Biochemistry (Journal of Food Lipids)*
*Journal of Food Composition and Analysis*
*Journal of Food Engineering*
*Journal of Food Legumes*
*Journal of Food Process Engineering*
*Journal of Food Processing and Preservation*
*Journal of Food Quality*
*Journal of Food Safety*

*Journal of Food Science*
*Journal of Food Science and Technology*
*Journal of Food, Agriculture and Environment*
*Journal of Human Ecology*
*Journal of Hydraulic Engineering – ASCE*
*Journal of Hydraulic Research*
*Journal of Hydrologic Engineering*
*Journal of Hydrology*
*Journal of Indian Society of Agricultural Statistics*
*Journal of Indian Water Resources Society*
*Journal of Industrial Engineering International*
*Journal of Irrigation and Drainage Engineering (ASCE)*
*Journal of Mechanical Engineering*
*Journal of Materials in Civil Engineering*
*Journal of Manufacturing Processes*
*Journal of Research, PAU*
*Journal of Soil and Water Conservation*
*Journal of Soil and Water Conservation, India*
*Journal of Statistical Computation and Simulation*
*Journal of Statistical Planning and Inference*
*Journal of Statistical Theory and Practice*
*Journal of Stored Products Research*
*Journal of Sustainable Agriculture*

# Restructured and Revised Syllabi of Post Graduate Programmes

# M. Tech. and Ph. D. (Agriculture Engineering)

# in

# Irrigation and Drainage Engineering

**Compiled**
**by**

**Broad Subject Co-ordinator**
**Associate Dean,**
**Dr. Annasaheb Shinde College of Agricultural Engineering and Technology, MPKV, Rahuri**

**Discipline Coordinator**
**Associate Dean**
**College of Agricultural Engineering and Technology, Dr. PDKV, Akola**

CONTENTS

## Preamble

A State Core Group has been constituted by Deans and Directors of Instruction Coordination Committee for modification of Academic Regulations for Masters and Ph.D. programmes, defining names and curricula of Masters' and Ph.D. disciplines for uniformity and revision of syllabi for courses of Masters' and Ph.D. degree in the discipline of Irrigation and Drainage Engineering in the State of Maharashtra. A state level committees have been constituted for revising the syllabus in the discipline of Irrigation and Drainage Engineering. The committees have conducted a meeting with the concerned experts and stakeholders and developed the syllabus for their respective subjects. While developing the syllabi, various provisions of National Education Policy-2020 have also been considered and complied to provide quality higher education and develop good, thoughtful, well-rounded, and creative individuals. Necessary provisions have been made in the curricula to enable an individual to study major and minor specialized areas of interest at a deep level, and also develop intellectual curiosity, scientific temper and creativity.

I express my gratefulness to Dr S. S.. Narkhede, Chairman, DICC and Director of Instruction, Dr. Babasaheb Sawant Kokan Krishi Vidyapeeth, Dapoli and Dr. D. D. Pawar, Associate Dean, College of Agricultural Engineering and Broad Subject Coordinator under whose guidance the syllabi for Master's and Doctoral programme is completed. I am extremely thankful to State Level Committee for their stupendous job in restructuring and articulating curricula in the light of technological developments and employability prospects in Irrigation and Drainage Engineering.

My deep sense of gratitude goes to Deans, Professors, Heads, and faculty members at the universities who contributed by their effective participation and interaction.

Dr. S. B. Wadatkar

Discipline Coordinator

**Committee on Agricultural Engineering**
**(Irrigation and Drainage Engineering)**

| ICAR-BSMA Broad Subject | ICAR-BSMA Approved Disciplines | Degree Programmes | | Broad Subject Coordinator (Chairman of all Disciplines' Sub Committees | Discipline Coordinator (Secretary of respective Discipline Sub-Committee) |
|---|---|---|---|---|---|
| Agriculture Engineering and Technology | Irrigation and Drainage Engineering | M.Tech. | Ph.D | Dr. D.D. Pawar, Associate Dean CoAE, MPKV, Rahuri | Dr. S.B Wadatkar Associate Dean College of Agricultural Engineering and Technology, Dr. PDKV, Akola |

**List of committee members who attended meeting held on 11.04.2022 for revision of PG and Ph.D. syllabus of Irrigation and Drainage Engineering discipline**

| Sr. No. | Name | Designation | Address |
|---|---|---|---|
| 1 | Prof. Dr S. B. Wadatkar | Discipline Coordinator | Associate Dean (Engg), CAET, Dr. PDKV, Akola and Head, Deptt. of IDE, Dr. PDKV, Akola |
| 2 | Prof. Dr. S. D. Gorantiwar | Member | Head, Deptt. of Agricultural Engineering, MPKV, Rahuri |
| 3 | Dr. N. N. Firake | Member | Head, Deptt. of Irrigation and Drainage Engineering, MPKV, Rahuri |
| 4 | Dr. M. M. Deshmukh | Member | Assoc. Prof. Deptt. of Irrigation and Drainage Engineering, Dr. PDKV, Akola |
| 5 | Dr. S. B. Jadhav | Member | Asstt. Prof., Deptt. of Irrigation and Drainage Engineering, VNMKV, Parbhani |
| 6 | Dr. V. K. Ingle | Member | Asstt. Prof., Deptt. of Irrigation and Drainage Engineering, VNMKV, Parbhani |
| 7 | Dr. A. N. Mankar | Member | Asstt. Prof. Deptt. of Irrigation and Drainage Engineering, Dr. PDKV, Akola |
| 8 | Dr. M. U. Kale | Member Secretary | Asstt. Prof. Deptt. of Irrigation and Drainage Engineering, Dr. PDKV, Akola |

**Organization of Course Contents and Credit Requirements:**

**Minimum Residential Requirement:**

**M. Tech.: 4 Semesters**

**Ph.D.: 6 Semesters**

**Name of the Departments / Divisions**

Irrigation and Drainage Engineering

**Nomenclature of Degree Programme**

**(a) M. Tech. Programme**

M. Tech. (Agricultural Engineering) in Irrigation and Drainage Engineering

**(b) Ph. D. Programme**

Ph.D. (Agricultural Engineering) in Irrigation and Drainage Engineering

**Code Numbers**

- All courses are divided into two series: 500-series courses pertain to Master's level, and 600- series to Doctoral level.
- Credit Seminar for Master's level is designated by code no. 591, and the Two Seminars for Doctoral level are coded as 691 and 692, respectively
- Master's research: 599 and Doctoral research: 699

**Course Contents**

The contents of each course have been organized into:

- Objective – to elucidate the basic purpose.
- Theory units – to facilitate uniform coverage of syllabus for paper setting.
- Suggested Readings – to recommend some standard books as reference material. This does not obviously exclude such a reference material that may be recommended according to the advancement and local requirement.
- A list of international and national reputed journals pertaining to the discipline is provided at the end which may be useful as study material for 600/700 series courses as well as research topics.
- Teaching schedule and practical schedule has also be given at the end of each course to facilitate the teacher to complete the course in an effective manner.

## Eligibility for PG and Ph.D. Programme in Agricultural Engineering (Irrigation and Drainage Engineering)

### A) M. Tech. Agricultural Engineering (Irrigation and Drainage Engineering)

i) B. Tech. (Agricultural Engineering) OR

B. E. (Agricultural Engineering)

### B) Ph.D. Agricultural Engineering (Irrigation and Drainage Engineering)

M. Tech. Agricultural Engineering (Irrigation and Drainage Engineering) / M. Tech. Agricultural Engineering (Soil and Water Engineering) / M. Tech. (Water Resources Development and Management) / M. E. Agricultural Engineering (Irrigation and Drainage Engineering) / M. E. Agricultural Engineering (Irrigation Water Management Engineering)

**OR**

M. Tech. Civil Engineering (Environmental Engineering) / M. Tech. Civil Engineering (Water Resources Engineering) ***provided that either UG/PG degree from Agricultural Engineering***

Students having M. Tech. / M.E. in Civil Engineering have to offer 6 – 10 credits as deficiency courses at Ph.D. level

# Credit requirements for PG and Ph.D. Programmes

**Course and Credit Requirements**

| **Course Details** | **Masters Degree** | **Doctoral Degree** |
|---|---|---|
| Major Courses | 20 | 12 |
| Minor Courses | 08 | 06 |
| Supporting / Optional | 06 | 05 |
| Common PGS Courses | 05 | 05* |
| Seminar | 01 | 02 |
| Research | 30 | 75 |
| **Total** | **70** | **100** |

*if not completed at Master's level

**Supporting Courses**

The following courses are being offered by various disciplines

| Course Code | Course Title | Credit Hours |
|---|---|---|
| MCA 513 | Mathematics for Applied Sciences | 2+0 |
| STAT 502 | Statistical Methods for Applied Sciences | 3+1 |
| STAT 511 | Experimental Designs | 2+1 |
| STAT 512 | Basic Sampling Techniques | 2+1 |
| STAT 521 | Applied Regression Analysis | 2+1 |
| STAT 522 | Data Analysis Using Statistical Packages | 2+1 |
| MCA 501 | Computers Fundamentals and Programming | 2+1 |
| MCA 502 | Computer Organization and Architecture | 2+0 |
| MCA 511 | Introduction to Communication Technologies, Computer Networking and Internet | 1+1 |
| MCA 512 | Information Technology in Agriculture | 1+1 |
| BIOCHEM 501 | Basic Biochemistry | 3+1 |
| BIOCHEM 505 | Techniques in Biochemistry | 2+2 |

## Course Title with Credit Load
## M.Tech. in Irrigation and Drainage Engineering

**Major Courses (Requirement: 20 Credits)**

| Course Code | Course Title | Credits |
|---|---|---|
| IDE 501 | Design of Surface Irrigation Systems | 1+1 |
| *IDE 502 | Design of Farm Drainage Systems | 2+1 |
| IDE 503 | Command Area Management | 2+1 |
| IDE 504 | Water and Nutrient Management Under Protected Cultivation | 2+1 |
| *IDE 505 | Design of Drip and Sprinkler Irrigation Systems | 2+1 |
| *IDE 506 | Ground Water Engineering | 2+1 |
| SWCE 507/IDE 507 | Remote Sensing and GIS for Land and Water Resource Management | 2+1 |
| IDE 508 | Waste Water Management and Utilization in Agriculture | 2+1 |
| IDE 509 | Water Conveyance and Distribution | 2+1 |
| IDE 510 | Minor Irrigation | 2+1 |
| IDE 511 | Design of Pumps for Irrigation and Drainage | 2+0 |
| IDE 512 | Crop Environmental Engineering | 2+0 |
| IDE 513 | Water Resources Systems Engineering | 2+1 |
| IDE 514 | Irrigation Economics, Planning and Management | 2+0 |
| IDE 515 | Sensing and Automation in Irrigation Systems | 3+0 |
| | Total | 30+11 |

*Compulsory course

**Minor Courses (Requirement: 08 Credits)**

**Disciplines for Minor Courses:**

1. Renewable Energy Engineering
2. Farm Machinery and Power Engineering
3. Irrigation and Drainage Engineering
4. Soil and Water Conservation Engineering
5. Civil Engineering
6. Computer Science and Information Technology
7. Basic Sciences

**Suggestive Minor courses**

| Course Code | Course Title | Credits |
|---|---|---|
| SWCE 505 | Watershed Management and Modeling | 2+1 |
| SWCE 506 | Flow Through Porous Media | 2+0 |
| SWCE 508 | Climate Change and Water Resources | 3+0 |
| SWCE 510 | Dryland Water Management Technologies | 2+0 |
| FMPE 517 | Machinery for Precision Agriculture | 2+1 |

| | | |
|---|---|---|
| REE 513 | Energy, Ecology and Environment | 3+0 |
| CE 501 | Dimensional Analysis and Similitude | 2+0 |
| CSE 501 | Big Data Analytics | 2+0 |
| CSE 502 | Artificial Intelligence | 2+0 |
| CSE 504 | Soft Computing Techniques in Engineering | 2+1 |
| MATH 501 | Finite Element Methods | 2+0 |
| MATH 502 | Numerical Methods for Engineers | 2+0 |
| ME 501 | Mechatronics and Robotics in Agriculture | 2+0 |
| | Any other course(s) of other department can be taken as per recommendations of the student's advisory committee. | |

**Supporting Courses (Requirement: 06 Credits)**

**Disciplines for Supporting Courses:**

1. Statistics
2. Computer Science and Information Technology
3. Soil and Water Conservation Engineering
4. Irrigation and Water Management
5. Basic Sciences

| Course Code | Course Title | Credits |
|---|---|---|
| *STAT 501 | Statistical Methods for Research Works | 2+1 |
| | Courses from subject matter fields (other than Major and Minor) relating to area of special interest and research problem can be taken as per recommendations of the student's advisory committee. | |
| BSCT 501 | Computer Graphics | 2+1 |
| BSCT 502 | Computer Languages for Engineering Applications | 2+1 |
| STAT 502 | Statistical Methods for Applied Sciences | 2+1 |
| STAT 511 | Experimental Design | 2+1 |

*Compulsory Course

**Common Non Credit Compulsory PGS Courses (Requirement: 05 Credits)**

| S. No. | Course Title | Course Code | Credits |
|---|---|---|---|
| 1 | Library and Information Services | *PGS 501 | 0+1 |
| 2 | Technical Writing and Communications Skills | *PGS 502 | 0+1 |
| 3 | Intellectual Property and its management in Agriculture | *PGS 503 | 1+0 |
| 4 | Basic Concepts in Laboratory Techniques | *PGS 504 | 0+1 |
| 5 | Agricultural Research, Research Ethics and Rural Development Programs | *PGS 505 | 1+0 |

*Compulsory Course

**List of Other Essential Requirements**

| Course Code | Course Title | Credits |
|---|---|---|
| IDE 591 | Masters Seminar | 0+1 |
| IDE 599 | Masters Research | 0+30 |

# Course Contents and Syllabus of Masters Degree

**I. Course Title : Design of Surface Irrigation Systems**

**II. Course Code : IDE 501**

**III. Credit Hours : 1+1**

**IV. Aim of the course**

To acquaint students for design and evaluation of various surface irrigation methods, design optimum layout, conveyance network for efficient use of water in surface irrigation system.

**V. Theory**

**Unit I**

Basic concepts of water management, principles of irrigation, irrigation water requirement, alternative irrigation scheduling techniques. Losses in irrigation: conveyance, distribution, application. Irrigation efficiencies. Estimation techniques of effective rainfall and evapotranspiration.

**Unit II**

Farm irrigation systems. Irrigation water quality and salinity management techniques. Design of water conveyance, control and distribution systems.

**Unit III**

Hydraulics, design and operation of border, check basin and furrow irrigation systems. Alternate furrow, skip irrigation, Cablegation and surge irrigation techniques. Automation of irrigation system.

**Unit IV**

Irrigation softwares for estimation of evapotranspiration and irrigation scheduling CROPWAT, AQUACROP, PhuleJal and PhuleIrrigation Scheduler. Water budgeting. Integrated approach to irrigation water management. Economic feasibility

**VI. Practical**

Design and evaluation of border, check basin and furrow irrigation systems. Design of underground water conveyance systems. Software for irrigation scheduling, Economics of irrigation methods. Visit to mechanized farms.

**VII. Learning outcome**

The students will be able to plan and design various surface irrigation systems and irrigation scheduling techniques for efficient use of water. They will also be exposedto irrigation softwares used for design purpose.

**VIII. Teaching Schedule**

| S. No. | Topic | No. of Lectures |
|---|---|---|
| 1. | Climate and irrigation water requirement | 1 |
| 2. | Irrigation principles, losses, conveyance, distribution, application and water budgeting | 2 |
| 3. | Estimation techniques of effective rainfall | 2 |
| 4. | Irrigation softwares; CROPWAT, AQUACROP | 2 |
| 5. | Farm irrigation systems. Irrigation efficiencies, Economic feasibility | 2 |

| | | |
|---|---|---|
| 6. | Irrigation water quality and salinity management techniques | 2 |
| 7. | Design of water conveyance, control and distribution systems | 2 |
| 8. | Hydraulics; Design and operation of border, check basin and Furrow irrigation systems. | 5 |
| 9. | Basic water management concepts and objectives | 2 |
| 10. | Alternative irrigation scheduling techniques | 1 |
| 11. | Integrated approach to irrigation water management | 2 |
| | **Total** | **23** |

## IX. List of Practicals

| S.No. | Topic | No. of Practicals |
|---|---|---|
| 1. | Estimation of various techniques of effective rainfall | 1 |
| 2. | Estimation of various techniques of evapotranspiration | 1 |
| 3. | Irrigation softwares for estimation of evapotranspiration and irrigation scheduling: CROPWAT, AQUACROP, PhuleJal and Phule Irrigation Scheduler | 3 |
| 4. | Design and evaluation of border irrigation method | 2 |
| 5. | Design and evaluation of furrow irrigation method | 2 |
| 6. | Design and evaluation of check basin method | 2 |
| 7. | Design of water conveyance, control and distribution systems | 1 |
| 8. | Design of underground water conveyance systems | |
| 9. | Study of automation of irrigation system | 1 |
| 10. | Study of economics of irrigation methods | 2 |
| 11. | Visit to mechanized farms | 1 |
| | **Total** | **16** |

## X. Suggested Reading


- Finkel HJ. 1983. Handbook of Irrigation Technology. Vols. I-II, CRC Press.
- James LG. 1988. Principles of Farm Irrigation System Design. John Wiley and Sons, New York, USA.
- Karmeli D, Peri G and Todes M. 1985. Irrigation Systems: Design and Operation. Oxford
- University Press.
- Michael AM. 2008. Irrigation Theory and Practices. Vikas Publishing House Pvt. Ltd, New Delhi.
- Pillsbury AF. 1972. Sprinkler Irrigation. FAO Agricultural Development Paper No. 88,
- FAO.
- Rydzewski. 1987. Irrigation Development Planning. John Wiley and Sons.
- Sivanappan RK 1987. Sprinkler Irrigation. Oxford and IBH.

- Sivanappan RK, Padmakumari O and Kumar V. 1987. Drip Irrigation. Keerthy Publ, House.
- CROPWAT: https://www.fao.org/land-water/databases-and-software/cropwat/en/
- AQUACROP: https://www.fao.org/aquacrop/en/
- PhuleJal: https://mpkv.ac.in/Uploads/MpkvProduct/Phule%20%20Unit_20191127034252.pdf
- PhuleIrrigation Scheduler: https://www.rkvyiwras.ac.in/software/android-apps/phule-irrigation-schedular

**I. Course Title : Design of Farm Drainage Systems**

**II. Course Code : IDE 502**

**III. Credit Hours : 2+1**

**IV. Aim of the course**

To provide in depth knowledge of water logging and salt affected areas, surface and sub-surface drainage systems, design and reclamation of waterlogged and salt affected areas.

**V. Theory**

**Unit I**

Waterlogging and salt affected areas in India. Water quality criteria and brackish water use for agriculture. Drainage requirements and crop growth under waterlogged and salt affected soil.

**Unit II**

Concept of critical water table depth for waterlogged soil and crop growth. Drainage investigations and drainage characteristics of various soils. Methods of drainage system and drainage coefficient.

**Unit III**

Theories and applications of surface and subsurface drainage. Planning, design and installation of surface and subsurface drainage systems for waterlogged and saline soils. Theories and design of vertical drainage, horizontal subsurface drainage and multiple well point system. Drainage materials.

**Unit IV**

Steady and unsteady state drainage equations for layered and non-layered soils. Principle and applications of Hooghoudt, Kirkham, Ernst, Glover-Dumm and Kraijenhoff-van-de-leur equations. Drainage for salinity control.

**Unit V**

Salt balance, leaching requirement and management practices under drained conditions. Disposal of drainage effluents. Case study for reclamation of salt affected waterlogged areas.

**VI. Practical**

Measurement of in-situ hydraulic conductivity. Estimation of drainage coefficient and leaching requirements. Delineation of waterlogged areas through isobar, isobath and topographic maps. Design of surface and subsurface drainage systems. Design of filter and envelop materials.

**VII. Learning outcome**

The students will able to develop surface as well as subsurface drainage network in the agriculture field, install and laying of the drainage pipe with fitting of all accessories at their place and derive equation for different flow in drainage system and their approaches.

**VIII. Teaching Schedule**

| S.No. | Topic | No. of Lectures |
|---|---|---|
| 1. | Waterlogging, causes of waterlogging, salt built up in waterlogged soil, solute transport in salt affected soil. | 2 |

| | | |
|---|---|---|
| | Recent salt affected areas in different states and country as whole | |
| 2. | Technology and approach for reclamation of waterlogged and salt affect areas | 2 |
| 3. | Drainage requirement and crop growth under salt affected waterlogged soil. Drainage water/ brackish water quality and it's criteria for use in agriculture | 2 |
| 4. | Concept of critical water table depth for waterlogged soil and crop growth | 1 |
| 5. | Drainage investigations and drainage characteristics of various soils. | 2 |
| 6. | Methods of drainage system: surface, sub surface, well drainage and bio-drainage and drainage coefficient | 1 |
| 7. | Theories and applications of surface and sub surface drainage | 3 |
| 8. | Planning, design and installation of surface and subsurface Drainage systems for waterlogged and saline soils | 3 |
| 9. | Theories of vertical and horizontal subsurface drainage systems | 2 |
| 10. | Theory, design and application of multiple well point system | 1 |
| 11. | Drainage materials. Design of filter and envelop for drainage System with different materials | 2 |
| 12. | Steady state drainage equations for layered and non layer soils | 2 |
| 13. | Unsteady state drainage equations for layered and non layer soils | 3 |
| 14. | Principle and application of Hooghoudt and Khirkham equation | 3 |
| 15. | Principles and application of Ernst, Glover Dumm, Karigenth off–van-de-law equation | 2 |
| 16. | Drainage for salinity control, salt balance equation, leaching requirement and management practices under drained conditions, Disposal of drainage effluents | 3 |
| 17. | Case study: Integrated planning, design and installation of drainage system for reclamation of salt affected waterlogged areas | 2 |
| | **Total** | **36** |

## IX. List of Practicals

| S.No. | Topic | No. of Practicals |
|---|---|---|
| 1. | Delineation of waterlogged areas through isobar, isobath and topographic maps | 3 |
| 2. | Measurement of in-situ hydraulic conductivity | 1 |
| 3. | Estimation of drainage coefficient from rainfall data | 2 |
| 4. | Determination of leaching requirements for reclamation of salt affected land | 2 |
| 5. | Design of surface drainage systems | 2 |

| | | |
|---|---|---|
| 6. | Design of subsurface drainage systems | 2 |
| 7. | Design of filter and envelop materials | 2 |
| 8. | Visit to drainage installation site/Institute | 2 |
| | **Total** | **16** |

**X. Suggested Reading**


- Bhattacharaya AK and Michael AM. 2003. *Land Drainage*. Vikas Publ.
- Clande Ayres and Daniel Scoates AE. 1989. *Level Drainage and Reclamation*. Mc.Graw Hill.
- Luthin JN. 1978. *Drainage Engineering*. Wiley Eastern.
- Ritzema HP (Ed.) 1994. *Drainage Principles and Applications*. ILRI
- Roe CE. 1966. *Engineering for Agricultural Drainage*. McGraw Hill.
- Schilfgaarde Jan Van (Editor). 1974. *Drainage for Agriculture*. Monograph No. 17. American Society of Agronomy Madison, Wisconsin, USA.
- Kadam US, Thokal RT, Gorantiwar SD, Powar AG. 2008. *Agricultural Drainage – Principal and Practices*. Westville Publishing House. New Delhi

I. **Course Title : Command Area Management**

II. **Course Code : IDE 503**

III. **Credit Hours : 2+1**

IV. **Aim of the course**

To acquaint students about the concept of command area management, assessment and appraisal of water availability in command areas, water management problems in command areas and their possible remedies including socio-economic aspects of irrigation command.

V. **Theory**

**Unit I**

Concept of command area development as an integrated approach. Command area project formulation, major, medium and minor projects. Command areas in India, command area activities and their prioritization. Source of budget for CAD works. Structure of command area development, organization, role and responsibilities of CADA.

**Unit II**

Laser based land grading survey and levelling in command areas. Design of lined and unlined canals. Diversion head works and canal head regulators, cross drainage works, canal falls, canal breaches. Design of On Farm Water Distribution Network, operation and maintenance of canal.

**Unit III**

Assessment and appraisal of water availability in command areas. Water management problems in command areas and their possible remedies. Duty of water, its determination and factors affecting it. Methods of improving duty of canal water. Feasibility of drip irrigation in irrigated command areas.

**Unit IV**

Single and multi-objective command area planning for the better management and allocation of irrigation water. Conjunctive use of canal water and groundwater. Real time canal irrigation scheduling.

**Unit IV**

Canal performance indices. Diagnostic analysis and perform appraisal of command area projects. Water user's association–functions, problems encountered during formation of WUA and strategy and overcome the problems. Participatory irrigation management efforts and strategy for preparing PIM. Socio economic aspects of irrigation management in command areas.

VI. **Practical**

Study of canal, tank and tube well in a command area. Study of design and operational parameters of a command area. Study of water balance in a command. Study the impact of command area project on crop yield and environment. Conflict resolution through PRA exercise. Diagnostic analysis of the problems of command area through PRA and field observations. Analysis of equity in water distribution. Considerations for preparation of roistering schedules. Study of the functioning of irrigation cooperatives/water user's associations. Preparation of command area development plan.

**VII. Learning outcome**

The students will be able to understand the concept of command area and its management, to analyze problem diagnostics and remedies of command area and able to understand the performance evaluation procedure of command area.

**VIII. Teaching Schedule**

| S.No. | Topic | No. of Lectures |
|---|---|---|
| 1. | Concept of command area development as an integrated approach | 1 |
| 2. | Command area project formulation, major, medium and minor projects | 2 |
| 3. | Command areas in India | 1 |
| 4. | Command area activities and their prioritization | 1 |
| 5. | Source of budget for CAD works | 1 |
| 6. | Structure of command area development | 1 |
| 7. | Organization, role and responsibilities of CADA | 1 |
| 8. | Laser based land grading survey and levelling in command areas | 1 |
| 9. | Design of lined and unlined canals | 2 |
| 10. | Diversion head works and canal head regulators, cross drainage works, canal falls, canal breaches | 2 |
| 11. | Design of On Farm Water Distribution | 1 |
| 12. | Network, operation and maintenance of canal | 1 |
| 13. | Assessment and appraisal of water availability in command areas | 1 |
| 14. | Water management problems in command areas and their possible remedies | 2 |
| 15. | Duty of water, its determination and factors affecting it. Methods of improving duty of canal water | 2 |
| 16. | Feasibility of drip irrigation in irrigated command areas | 1 |
| 17. | Single and multi-objective command area planning for the better management and allocation of irrigation water | 1 |
| 18. | Conjunctive use of canal water and groundwater | 1 |
| 19. | Real time canal irrigation scheduling | 1 |
| 20. | Canal performance indices | 1 |
| 21. | Diagnostic analysis and perform appraisal of command area projects | 1 |
| 22. | Water user's association–functions, problems encountered during formation of WUA and strategy and overcome the problems | 2 |
| 23. | Participatory irrigation management efforts and strategy for preparing PIM | 2 |
| 24. | Socio economic aspects of irrigation management in command areas | 2 |
| | **Total** | **32** |

## IX. List of Practicals

| S.No. | Topic | No. of Practicals |
| --- | --- | --- |
| 1. | Study of canal, tank and tube well in a command area | 1 |
| 2. | Study of design and operational parameters of a command area | 2 |
| 3. | Study of water balance in a command | 1 |
| 4. | Study the impact of command area project on crop yield and environment | 2 |
| 5. | Study about conflict resolution through PRA exercise | 2 |
| 6. | Diagnostic analysis of the problems of command area through PRA and field observations | 2 |
| 7. | Analysis of equity in water distribution | 1 |
| 8. | Considerations for preparation of roistering schedules | 1 |
| 9. | Study of the functioning of irrigation cooperatives/water user's associations | 2 |
| 10. | Preparation of command area development plan | 2 |
| | **Total** | **16** |

## X. Suggested Reading


1. Jos´eLiria Montanes. 2006. Design, Construction, Regulation and Maintenance. Taylor and Francis Publication.
2. Modi PN. Irrigation Water Resources and Water Power Engineering. Standard Publishers.
3. Singh VP. 2014. Entropy Theory in Hydraulic Engineering: An Introduction. ASCE Press.
4. Sharma SK. Irrigation Water Resources and Water Power Engineering. Standard Publishers.
5. Swamee PK and Chahar BR. Design of Canals. Springer Publications.

**I. Course Title : Water and Nutrient Management under Protected Cultivation**

**II. Course Code : IDE 504**

**III. Credit Hours : 2+1**

**IV. Aim of the course**

To acquaint students about the concept of soilless culture in agriculture, water and nutrient management, water potential in soilless media and automation for climate control under protected cultivation.

**V. Theory**

**Unit I**

Significance of soilless culture in agriculture. Functions of the root system. Response of root growth to local nutrient concentrations. Interactions between environmental conditions and form of N nutrition.

**Unit II**

Roots as source and sink for organic compounds and plant hormones. Physical and chemical properties of soilless media.

**Unit III**

Water content and water potential in soilless media. Water movement in soilless media. Uptake of water by plants in soilless media and water availability.

**Unit IV**

Production technology for vegetables under protected conditions in soil and soilless media. Automation for climate control in protected structures. Thermal modeling of greenhouse environment for protected cultivation.

**VI. Practical**

Filter types and its selection criteria. Design and installation of drip irrigation system for vegetables and orchards. Irrigation and fertigation scheduling for vegetables and horticultural crops. Study of different types of sensors, relay and control mechanism for controlled irrigation and fertigation. Design of automated system for irrigation and fertigation. Design and installation of different protected structures as per the guidelines of NHM. Design and fabrication of soilless medium for crop/ flower production. Economic evaluation of automated irrigation system and soilless medium for crop/flower production.

**VII. Learning outcome**

The students will able to understand the concept of soilless farming including nutrient management, water content and water potential in soilless media along with automation for climate control under protected cultivation.

**VIII. Teaching Schedule**

| S. No. | Topic | No. of Lectures |
|---|---|---|
| 1. | Significance of soilless culture in agriculture | 1 |

| | | |
|---|---|---|
| 2. | Functions of the root systems | 1 |
| 3. | Response of root growth to local nutrient concentrations | 2 |
| 4. | Interactions between environmental conditions and form of N nutrition | 2 |
| 5. | Roots as source and sink for organic compounds and plant hormones | 2 |
| 6. | Physical and chemical properties of soilless media | 2 |
| 7. | Water content and water potential in soilless media | 2 |
| 8. | Water movement in soilless media: water retained, drainage, plant use, etc | 2 |
| 9. | Uptake of water by plants in soilless media and water availability | 3 |
| 10. | Production technology for vegetables under protected conditions in soil and soilless media | 4 |
| 11. | Automation for climate control in protected structures | 3 |
| 12. | Thermal modeling of greenhouse environment using multiple regressions | 2 |
| 13. | Thermal modeling of greenhouse environment using energy and mass balance approaches | 4 |
| | **Total** | **30** |

**IX. List of Practicals**

| S.No. | Topic | No. of Practicals |
|---|---|---|
| 1. | To study the filter types and their selection criteria | 1 |
| 2. | Design and installation of drip irrigation system for vegetables | 1 |
| 3. | Design and installation of drip irrigation system for orchards | 1 |
| 4. | Irrigation and fertigation scheduling for vegetables and horticultural crops | 1 |
| 5. | Study of different types of sensors, relay and control mechanism for controlled irrigation and fertigation | 1 |
| 6. | Design of automated system for irrigation and fertigation | 1 |
| 7. | Design and installation of different protected structures as Per guidelines of NHM | 6 |
| 8. | Design and fabrication of soilless medium for vegetable crops | 1 |
| 9. | Design and fabrication of soilless medium for flower production | 1 |
| 10. | Economic evaluation of automated irrigation system and Soilless medium for crop/flower production | 1 |
| | **Total** | **15** |

**x. Suggested Reading**


- Howard M Resh. *Hydroponic Food Production.* CRC Press, New York.
- Michael Raviv and Heinrich J Lieth 2014. *Soilless Culture*. CRC Press.
- Meier Schwarz. *Soilless Culture Management*. Springer publications, New York.

**I. Course Title : Design of Drip and Sprinkler Irrigation Systems**

**II. Course Code : IDE 505**

**III. Credit Hours : 2+1**

**IV. Aim of the course**

To provide exposure of new cutting-edge technologies to the students in design of drip and sprinkler irrigation systems including selection of pipe and fertigation techniques.

**V. Theory**

**Unit I**

Suitability of sprinkler and drip irrigation systems under Indian conditions. Basic hydraulics of sprinkler and micro irrigation systems including pipe flow analysis, friction losses and pressure variation.

**Unit II**

Components of drip and sprinkler irrigation systems along-with their details including classification, types, specifications, constructions etc. Flow in nozzles and emitters.

**Unit III**

Irrigation scheduling of drip and sprinkler irrigation systems based on weather and soil moisture concepts. Software for irrigation scheduling: CROPWAT, AQUACROP, PhuleJal and PhuleIrrigation Scheduler

**Unit IV**

Design, layout and evaluation of sprinkler and micro irrigation systems in relation to source, soil, climate and topographical conditions. Selection of pipe size, pumps and power units. Economics of sprinkler and drip irrigation systems. Computer software for design: IRRICAD/EPANET

**Unit V**

Fertigation through sprinkler and micro irrigation systems. Fertigation techniques used in drip and sprinkler irrigation systems, Fertigation scheduling software: Phule Fertigation Scheduler. Other micro-irrigation systems: micro-sprinkler and bubbler irrigation systems.

**VI. Practical**

Design of drip and sprinkler irrigation system. Calculation of total head. Evaluation of drip and sprinkler irrigation systems. Numerical on hydraulics of dripper. Software for irrigation scheduling and design of drip and sprinkler irrigation systems. Calculation of cost benefits of drip and sprinkler irrigation system.

**VII. Learning outcome**

Students will understand design aspects of various drip and sprinkler irrigation systems including friction losses and flow variations. They may also expose to various fertigation techniques involved in the system.

## VIII. Teaching Schedule

| S. No. | Topic | No. of lectures |
|---|---|---|
| 1 | Plant-soil-atmosphere relationships | 3 |
| 2 | Evapotranspiration, methods for estimation of evapotranspiration, Irrigation water requirements, Irrigation principles, Numerical Problems | 2 |
| 3 | Drip irrigation, adaptability, limitations, components and classification of systems | 2 |
| 4 | Pipe flow analysis, types of friction losses in main, sub-main and lateral, pressure variation in drip irrigation system and their calculations | 2 |
| 5 | Design of drip irrigation system based on source of irrigation, soil, climate and topographical conditions and hydraulics of drip components with numerical problems | 3 |
| 6 | Selection of pipe, pump and power unit | 2 |
| 7 | Fertigation: advantages, limitations, methods, fertilizers solubility and their compatibility, precautions, frequency, duration and injection rate, Emitter clogging and prevention | 2 |
| 8 | Performance evaluation of drip irrigation system | 1 |
| 9 | Sprinkler irrigation, adaptability, limitations, components and classification of systems | 2 |
| 10 | Pipe flow analysis, types of friction losses, pressure variation in sprinkler irrigation system and their calculations | 2 |
| 11 | Flow in nozzles, drop size distribution, spray evaporation | 1 |
| 12 | Hydraulic and engineering design of sprinkler irrigation system on source of irrigation, soil, climate and topographical conditions, numerical problems | 3 |
| 13 | Fertigation techniques in sprinkler irrigation | 1 |
| 14 | Selection of pipe, pump and power unit | 2 |
| 15 | Performance evaluation of sprinkler irrigation system | 1 |
| 16 | Irrigation scheduling techniques and automation in drip and sprinkler irrigation system | 2 |
| 17 | Benefit cost ratio of drip and sprinkler irrigation system | 1 |
| | **Total** | **32** |

## IX. List of Practicals

| S.No. | Topic | No. of Practicals |
|---|---|---|
| 1. | Study of different components of drip and sprinkler irrigation systems | 1 |
| 2. | Irrigation scheduling of drip irrigation systems (weather and moisture based) | 1 |
| 3. | Irrigation scheduling of sprinkler irrigation systems (weather | |

| | | |
|---|---|---|
| | and moisture based) | 1 |
| 4. | Use of software for irrigation scheduling (CROPWAT, AQUACROP, PhuleJal and PhuleIrrigation Scheduler) | 1 |
| 5. | Estimation of total head in drip and sprinkler irrigation systems | 1 |
| 6. | Design of drip irrigation system for orchards | 1 |
| 7. | Design of drip irrigation system for row crops | 1 |
| 8. | Design of sprinkler irrigation system for vegetable and field crops | 1 |
| 9. | Determination of filtration efficiency of different filters | 1 |
| 10. | Evaluation of drip irrigation system | 1 |
| 11. | Irrigation design software: IRRICAD/EPANET | 1 |
| 12. | Evaluation of sprinkler irrigation system (UC, discharge etc) | 1 |
| 13. | Study of hydraulics and Pressure-discharge relationship of drippers | 1 |
| 14. | Estimation of fertigation rate in drip irrigation system | 1 |
| 15. | Study of Automation in micro-irrigation system including IoT enabled Techniques such as AutoPIS and PSMISS | 1 |
| 16. | Calculation of cost benefits of drip and sprinkler irrigation system | 1 |
| | **Total** | **16** |

**X. Suggested Reading**


- Jensen ME. (Editor). 1983. *Design and Operation of Farm Irrigation Systems*. ASAE, Monograph No. 3. USA.
- James LG. 1988. *Principles of Farm Irrigation System Design.* John Wiley and Sons, New York, USA.
- CROPWAT: https://www.fao.org/land-water/databases-and-software/cropwat/en/
- AQUACROP: https://www.fao.org/aquacrop/en/
- PhuleJal: https://mpkv.ac.in/Uploads/MpkvProduct/Phule%20%20Unit_20191127034252.pdf

**I. Course Title : Ground Water Engineering**

**II. Course Code : IDE 506**

**III. Credit Hours : 2+1**

**IV. Aim of the course**

To provide comprehensive knowledge to the students in aquifers, groundwater flow, artificial groundwater recharge techniques, well hydraulics and groundwater models.

**V. Theory**

**Unit I**

Water resources of India. Occurrence, storage and movement of groundwater in alluvial and hard rock formations. Principles of groundwater flow. Interaction between surface water and groundwater.

**Unit II**

Natural and artificial groundwater recharge. Conjunctive use of surface and groundwater. Groundwater balance. Fluctuation of water table beneath a recharge site. Delineation of groundwater potential zones using RS and GIS, MODFLOW equation.

**Unit III**

Derivation of hydraulics of fully and partially penetrating wells in confined, leakyand unconfined aquifers. Flow net analysis.

**Unit IV**

Analysis of multi aquifers. Flow analysis in interfering wells. Pumping tests for estimation of aquifer parameters. Wells near recharge and impermeable boundaries. Skimming well technology.

**Unit V**

Design of well field. Salt water intrusion in inland and coastal aquifers. Application of groundwater models for groundwater management. Calibration and validation of models.

**VI. Practical**

Water table contour maps and determination of groundwater flow. Estimation of aquifer characteristics. Problems on non-leaky and leaky aquifers. Analysis of pumping test data. Computation of interference of wells. Groundwater computer simulation models.

**VII. Learning outcome**

The student will be able to analyze storage, movement and flow characteristics of different aquifers and also model ground water and plan for ground water recharge including delineation of potential groundwater recharge zones.

**XI. Teaching Schedule**

| S.No. | Topic | No. of Lectures |
|---|---|---|
| 1. | Water Resources of India. Occurrence, movement of Groundwater and storage of groundwater in geological formation | 2 |

| | | |
|---|---|---|
| 2. | Study of hydro geological formation in India | 1 |
| 3. | Principal of Groundwater flow. Interaction between surface water and groundwater. | 1 |
| 4. | Natural and artificial groundwater recharge. Conjunctive use of surface and groundwater | 1 |
| 5. | Groundwater balance and fluctuation of water table beneath recharge sites | 2 |
| 6. | Delineation of groundwater potential zones using RS and GIS | 2 |
| 7. | Study of MODFLOW and its application | 2 |
| 8. | Hydraulics of wells | 1 |
| 9. | Steady state flow to fully penetrating well in unconfined, Confined and leaky aquifer | 2 |
| 10. | Unsteady state flow to fully penetrating wells in unconfined, confined and leaky aquifer | 3 |
| 11. | Steady state flow to partially penetrating well in unconfined, Confined and leaky aquifer | 2 |
| 12. | Unsteady state flow to partially penetrating wells in unconfined, confined and leaky aquifer | 3 |
| 13. | Flow net analysis for groundwater flow | 1 |
| 14. | Steady and Unsteady flow in Multi aquifers | 2 |
| 15. | Flow analysis in interfering multiple wells | 2 |
| 16. | Pumping tests for estimation of aquifer parameters | 1 |
| 17. | Flow to wells near recharge and impermeable boundaries | 2 |
| 18. | Design of well field and skimming well technology (multiple well point system) | 2 |
| 19. | Salt water intrusion in inland and coastal aquifers | 2 |
| 20. | Groundwater modelling approaches | 1 |
| 21. | Study of various groundwater models | 2 |
| 22. | Application of groundwater models for groundwater management | 2 |
| 23. | Calibration and validation of models | 2 |
| | **Total** | **41** |

## IX. List of Practicals

| S.No. | Topic | No. of Practicals |
|---|---|---|
| 1. | Delineation of water table contour maps. | 2 |
| 2. | Determination of groundwater flow using contour maps | 1 |
| 3. | Estimation of aquifer characteristics by Theis and Cooper-Jacob method | 2 |
| 4. | Estimation of aquifer characteristics by Chow’s and Theis recovery method | 2 |
| 5. | Hand on exercise for analysis groundwater flow through well | |

| | | |
|---|---|---|
| | In leaky aquifers. | 2 |
| 6. | Hand on exercise for analysis groundwater flow through well In non-leaky aquifers. | 2 |
| 7. | Analysis of pumping test data for estimation of aquifer parameters. | 1 |
| 8. | Computation of drawdown and discharge under interference of wells. | 2 |
| 9. | Simulation of groundwater flow using various computer Models (MODFLOW, etc) | 2 |
| | **Total** | **16** |

**X. Suggested Reading**


- Boonstra J and de Ridder NA. 1981. *Numerical Modeling of Groundwater Basins*. ILRI.
- Demenico PA. 1972. *Concept and Models in Groundwater Hydrology*. McGraw Hill.
- Huisman L 1972. *Ground Water Recovery*. Mac Millan.
- Jat ML and SR Bhakar 2008. *Ground Water Hydrology*. Agro-tech Publishing Academy.Udaipur.
- Polubarinova Kochina P Ya. 1962. *Theory of Ground Water Movement*. Princeton Univ. Press.
- Raghunath HM 1992. *Ground Water*. Wiley Eastern.
- Todd DK 1997. *Ground Water Hydrology*. Wiley Eastern.

**I. Course Title : GIS and Remote Sensing for Land and Water Resource Management**

**II. Course Code : IDE 507/SWCE 507**

**III. Credit Hours : 2+1**

**IV. Aim of the course**

To acquaint students with recent technology of RS and GIS including satellite data analysis, digital image processing and thematic mapping of land use, surface and ground water.

**V. Theory**

**Unit I**

Physics of remote sensing. Electromagnetic radiation (EMR), interaction of EMR with atmosphere, earth surface, soil, water and vegetation. Remote sensing platforms: Monitoring atmosphere, land and water resources: LANDSAT, SPOT, ERS, IKONOS and others. Indian Space Programme.

**Unit II**

Satellite data analysis. Visual interpretation. Digital image processing. Image pre- processing. Image enhancement. Image classification. Data merging.

**Unit III**

Basic components of GIS. Map projections and co-ordinate system. Spatial data structure: Raster, vector. Spatial relationship. Topology. Geodatabase models: Hierarchical, network, relational, object-oriented models. Integrated GIS database. Common sources of error. Data quality: Macro, micro and Usage level components, Meta data. Spatial data transfer standards.

**Unit IV**

Thematic mapping. Measurement in GIS: Length, perimeter and areas. Query analysis. Reclassification, Buffering and Neighbourhood functions. Map overlay: Vector and raster overlay analysis. Interpolation and network analysis. Digital elevation modelling. Analytical Hierarchy Process. Object oriented GIS, AM/FM/GIS and Web Based GIS.

**Unit V**

Spatial data sources. 4M's GIS approach for water resources system. Thematic maps. Rainfall runoff modelling, groundwater modelling and water quality modelling. Flood inundation mapping and modelling. Drought monitoring. Cropping pattern change analysis. Performance evaluation of irrigation commands. Site selection for artificial recharge. Reservoir sedimentation.

**VI. Practical**

Familiarization with the remote sensing instruments and satellite imagery. Aerial Photograph and scale determination with stereoscope. Interpretation of satellite imagery and aerial photograph. Determination of Parallaxes in images. Introduction to digital image processing software and GIS software and their working principles. Generation of digital elevation model (DEM) for land and water resource management. Case studies on mapping, monitoring and management of natural resources using remote sensing and GIS. Thematic map generation using DEM.

**VII. Learning outcome**

The student will be able to use satellite remote sensing to perform image analysis and classification for developing thematic maps and also able to integrate satellite data with GIS to undertake recourse mapping and lanning studies.

**VIII. Teaching Schedule**

| S.No. | Topic | No. of Lectures |
|---|---|---|
| 1. | Introduction and brief history of RS and GIS, applications of RS and GIS | 1 |
| 2. | Physics of remote sensing. Electromagnetic radiation (EMR), Interaction of EMR with atmosphere, earth surface, soil, water and vegetation. | 1 |
| 3. | Remote sensing platforms: Monitoring atmosphere, land and water resources: LANDSAT, SPOT, ERS, IKONOS and others. Indian Space Programme | 2 |
| 4. | Satellite data analysis. Visual interpretation. | 1 |
| 5. | Digital image processing- Image pre-processing, Image enhancement, Image classification, data merging. | 3 |
| 6. | Basic components of GIS- Map projections and co-ordinate system. | 2 |
| 7. | Spatial data sources, Thematic maps. | 1 |
| 8. | Spatial data structure: Raster, vector data, Spatial relationship-Topology | 1 |
| 9. | Geodatabase models: Hierarchical, network, relational, object-oriented models. Integrated GIS database | 3 |
| 10. | Data quality, Common sources of error, Macro, micro and usage level components, Meta data and Spatial data transfer standards | 2 |
| 11. | Measurement in GIS- Length, perimeter and areas. | 1 |
| 12. | Query analysis. Reclassification, Buffering and Neighbourhood functions. | 1 |
| 13. | Map overlay: Vector and raster overlay | 1 |
| 14. | Interpolation and network analysis | 1 |
| 15. | Digital elevation modelling. Analytical Hierarchy Process. Object oriented GIS, AM/FM/GIS and Web Based GIS. | 3 |
| 16. | GIS approach to Rainfall runoff modelling, Flood inundation Mapping and modelling. | 2 |
| 17. | GIS approach to Groundwater modelling and water quality modelling, | 2 |
| 18. | Site selection for artificial recharge. Reservoir sedimentation | 1 |

| | | |
|---|---|---|
| 19. | Drought monitoring | 1 |
| 20. | Performance evaluation of irrigation commands | 1 |
| 21. | Cropping pattern change analysis | 1 |
| | **Total** | **32** |

## IX. List of Practicals

| S.No. | Topic | No. of Practicals |
|---|---|---|
| 1. | Familiarization with the remote sensing instruments and Satellite imagery | 1 |
| 2. | Methods of establishing ground truth survey and Comparison Between ground truth and remotely sensed data | 2 |
| 3. | Aerial Photograph and scale determination with stereoscope | 1 |
| 4. | Interpretation of satellite imagery and aerial photograph | 1 |
| 5. | Determination of Parallaxes in images | 1 |
| 6. | Demonstration on GPS; Provision of Ground Control by GPS In different mode | 1 |
| 7. | Introduction to digital image processing software | 1 |
| 8. | Introduction to GIS software | 1 |
| 9. | Data input; Data editing and Topology creation - Digitization of point,line and polygon features | |
| 10. | SRTM and CARTO DEM download from web and Georeferencing of an image | 1 |
| 11. | Delineation of Watershed, DEM based thematic map generation: slope, Aspect, flow direction, flow accumulation, Drainage, network and morphometric analysis | 2 |
| 12. | LULC by supervised classification and LULC by Unsupervised classification | 1 |
| 13. | Application of Remote Sensing data and GIS for water quality parameters | 1 |
| 14. | Temporal satellite data analysis for vegetation condition, crop water requirement calculation | 1 |
| 15. | Erosion mapping using aerial and satellite Data | 1 |
| | **Total** | **17** |

## X. Suggested Reading


- Charles Elach and Jakob van Zyl. 2006. *Introduction to the Physics and Techniques ofRemote Sensing*. John Wiley & Sons publications.
- Ian Heywood Sarah, Cornelius and Steve Carver. 2002. *An Introduction to Geographical Information Systems.* Pearson Education. New Delhi.
- James B Campbell and Randolph H Wynne. 2011. *Introduction to Remote Sensing*. The Guilford Press.
- Lillesand TM and Kiefer RW. 2008. *Remote Sensing and Image Interpretation.* John Wiely and Sons.
- Paul Curran PJ. 1985. *Principles of Remote Sensing*. ELBS Publications.

- Rees WG. 2001. *Physical Principles of Remote Sensing*. Cambridge University Press.
- Thanappan Subash. 2011. *Geographical Information System*. Lambert Academic Publishing.

**I. Course Title : Waste Water Management and Utilization in Agriculture**

**II. Course Code : IDE 508**

**III. Credit Hours : 2+1**

**IV. Aim of the course**

To acquaint students about status of waste water and water quality requirements, standards both for domestic and irrigation purposes and also to provide in depth knowledge of waste water treatment methods and utilization in agriculture.

**V. Theory**

**Unit I**

Status of wastewater in India. Sources of contamination and characterization of urban and rural wastewater for irrigation. Water quality: Physical, chemical and biological parameters of wastewater.

**Unit II**

Water quality requirement: Potable water standards, wastewater effluent standards, water quality indices. Irrigation water quality standards and guidelines for their restricted and unrestricted uses. Selection of appropriate forestry trees, fruits, vegetables, oilseeds and food grain crop for wastewater utilization.

**Unit III**

Control measures for preventing soil and other surface/groundwater source contamination. Different types of wastewater, pollutants and contaminants. Impact of wastewater on ecosystem, eutrophication, biomagnification, water borne diseases.

**Unit IV**

Wastewater treatment methods: Physical, chemical and biological. General water treatments: Wastewater recycling, constructed wetlands, reed bed system. Carbon foot prints of wastewater reuse. Environmental standards.

**Unit V**

Regulation and environmental impact assessment (EIA): Environmental standards- CPCB Norms for discharging industrial effluents to public sewers. Stages of EIA- Monitoring and Auditing. Environmental clearance procedure in India.

**VI. Practical**

Measurement of water quality indices in the lab. Field demonstration of impact of waste water on eco-system and human health. Waste water treatment methods and effect of waste water in contamination of ground water. Visit of waste water treatment plant near by area.

**VII. Learning outcome**

The students will be able to understand sources and treatment methods of waste water quality with standard norms of water quality for domestic and irrigation purposes and also be exposed to waste water recycling and environmental standards.

**VIII. Teaching Schedule**

| S. No. | Topic | No. of Lectures |
|---|---|---|
| 1. | Status of wastewater in India, Sources of contamination and | |

| | | |
|---|---|---|
| | characterization of urban and rural wastewater for irrigation | 2 |
| 2. | Water quality: Physical, chemical and biological parameters of wastewater | 2 |
| 3. | Wastewater quality requirement: Potable water standards, wastewater effluent standards, water quality indices. Irrigation water quality standards both national and global and guidelines for their restricted and unrestricted uses. | 2 |
| 4. | Different types of wastewater, pollutants and contaminants. | 1 |
| 5. | Impact of wastewater on ecosystem, eutrophication, Biomagnifications water borne diseases. | 2 |
| 6. | Key drivers of wastewater use in agriculture and existing Approaches for regulating wastewater reuse in agriculture | 2 |
| 7. | Selection of appropriate forestry trees, fruits, vegetables, oilseeds and food grain crop for wastewater utilization and practices used for irrigation | 3 |
| 8. | Health Risks Associated with the Use of Wastewater for Irrigation | 1 |
| 9. | Wastewater treatment methods: Physical, chemical and biological. | 3 |
| 10. | Choice of (Cost-Effective) Wastewater Treatment Systems for Irrigation | 2 |
| 11. | General water treatments: Wastewater recycling, constructed wetlands, reed bed system. | 2 |
| 12. | Carbon foot prints of wastewater reuse. Environmental standards. | 2 |
| 13. | Management of health and environmental risks of wastewater irrigation | 1 |
| 14. | Regulation and environmental impact assessment (EIA): Environmental standards-CPCB Norms for discharging industrial effluents to public sewers. Valuation of environmental impacts. | 3 |
| 15. | Impact on groundwater resources and soil health, EIA process, Stages of EIA-monitoring and auditing. Environmental clearance procedure in India | 3 |
| 16. | Economics of wastewater irrigation | 1 |
| | **Total** | **33** |

**IX. List of Practicals**

| S.No. | Topic | No. of Practicals |
|---|---|---|
| 1. | Study on physical, chemical and biological parameters of wastewater | 1 |
| 2. | Determination of EC and pH of wastewater | 1 |
| 3. | Determination of BOD of wastewater | 1 |
| 4. | Determination of COD of wastewater | 1 |
| 5. | Determination of TSS and TDS of wastewater | 1 |

| | | |
|---|---|---|
| 6. | Determination RSC of wastewater | 1 |
| 7. | Determination of e-coli in the wastewater | 1 |
| 8. | On field demonstration of wastewater use for the irrigation | 1 |
| 9. | Determination of nutrient (N, P and K) concentration in wastewater | 2 |
| 10. | Field demonstration of impact of waste water on eco-system and human health. | 1 |
| 11. | Study on various wastewater treatment methods | 2 |
| 12. | Study on effect of wastewater on contamination of ground water | 1 |
| 13. | Visit of village pond treatment nearby area | 1 |
| 14. | Visit of sewerage treatment plant nearby area | 1 |
| | **Total** | **16** |

**X. Suggested Reading**


- Charis Michel Galanakis. *Sustainable Water and Wastewater Processing.* Elsevier Publication, Amsterdam.
- Sean X Liu. 2014. *Food and Agricultural Wastewater Utilization and Treatment*. Wileu Blackwell New York.
- Shirish H, Sonawane Y, Pydi Setty T, Bala Narsaiah and S Srinu Naik. 2017. *Innovative Technologies for the Treatment of Industrial Wastewater: A Sustainable Approach*. CRC Press.
- Stuetz Richard. *Principles of Water and Wastewater Treatment Processes* (*Water and Wastewater Process Technologies*). IWA Publishing.
- Syed R Qasim and Guang Zhu. 2018. *Wastewater Treatment and Reuse: Theory and Design Examples*. CRC Press.

**I. Course Title : Water Conveyance and Distribution**

**II. Course Code : IDE 509**

**III. Credit Hours : 2+1**

**IV. Aim of the course**

To develop the common understanding of different conveyance structure in irrigation network and provide knowledge of various flow and their computations including sediment transport in channels.

**V. Theory**

**Unit I**

Channel characteristics. Prismatic and non-prismatic channel. Steady, unsteady, uniform and non-uniform flow. Open channel and their properties. Energy and momentum, critical flow computation and application. Basic Concepts of free surface flow, classification of flow, velocity and pressure distribution.

**Unit II**

Uniform flow, conservation laws and specific energy. Application of momentum and energy equation. Channel transition. Study of critical flow, uniform flow, gradually varied flow, rapid varied flow, spatially varied flow and unsteady flow and theircomputations.

**Unit III**

Energy dissipation. Flow control structures and flow measurement. Theories and methods of open channel design.

**Unit IV**

Sediment transport in channels. Regime flow theories. Tractive force theory. Designof stable channels.

**Unit V**

Basic principles of pipe flow, pipe flow problems and equivalent pipe. Principles of network synthesis. Pipe network analysis. Water transmission lines. Cost considerations: Single-Input source. Branched systems: Single-Input source. Looped Systems: Multi-Input source. Branched systems: Multi-Input source, Looped systems. Decomposition of a large water system and optimal zone size.

**VI. Practical**

Computation and use of geometrical and hydraulic elements of open channel. Use of flow measuring devices and methods and their limitations. Examination of velocity distribution and calculation of energy and momentum coefficients. Solution of channel design problems. Appraisal of flow control and distribution structures. Analysis and computation of flow profiles.

**VII. Learning outcome**

The student will be able to infuse the knowledge about different types of channel flow and their behavior and also able to gain the knowledge of appraisal of flow control and distribution structures including design of stable channel.

**VIII.** Teaching **Schedule**

| S.No. | Topic | No. of Lectures |
|---|---|---|
| 1. | Channel characteristics. Prismatic and non-prismatic channel | 1 |
| 2. | Steady, unsteady, uniform and non-uniform flow | 1 |
| 3. | Open channel and their properties | 2 |
| 4. | Energy and momentum, critical flow computation and application | 2 |
| 5. | Basic Concepts of free surface flow, classification of flow, velocity and pressure distribution | 2 |
| 6. | Uniform flow, conservation laws and specific energy | 2 |
| 7. | Application of momentum and energy equation | 1 |
| 8. | Channel transition | 1 |
| 9. | Study of critical flow, uniform flow, gradually varied flow, rapid varied flow | 2 |
| 10. | Spatially varied flow and unsteady flow and their computations | 2 |
| 11. | Energy dissipation | 1 |
| 12. | Flow control structures and flow measurement | 1 |
| 13. | Theories and methods of open channel design | 2 |
| 14. | Sediment transport in channels | 1 |
| 15. | Regime flow theories | 1 |
| 16. | Tractive force theory | 1 |
| 17. | Design of stable channels | 1 |
| 18. | Basic principles of pipe flow, pipe flow problems and equivalent pipe | 1 |
| 19. | Principles of network synthesis. Pipe network analysis | 1 |
| 20. | Water transmission lines. Cost considerations: Single-Input source. Branched systems: Single-Input source | 2 |
| 21. | Looped Systems: Multi-Input source. Branched systems: Multi-Input source, Looped systems | 2 |
| 22. | Analysis and computation of flow profiles | 2 |
| | **Total** | **32** |

**IX. List of Practicals**

| S.No. | Topic | No. of Practicals |
|---|---|---|
| 1. | Computation and use of geometrical and hydraulic elements of open channel | 2 |
| 2. | Study of Flow measuring devices,methods and their limitations | 2 |
| 3. | Examination of velocity distribution | 2 |
| 4. | Calculation of energy and momentum coefficients | 2 |
| 5. | Channel design: problems and its solution | 3 |
| 6. | Appraisal of flow control and distribution structures | 2 |

| | | |
|---|---|---|
| 7. | Analysis and computation of flow profiles | 3 |
| | **Total** | **16** |

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**X. Suggested Reading**


- Chaudhry MH. 1993. *Open Channel Flow*. Prentice-Hall, NJ.
- Chow VT. 1979. *Open Channel Hydraulics*. McGraw Hill Inc. N York.
- French RH. 1986. *Open Channel Hydraulics*. McGraw Hill Pub Co., N York
- Henderson FM. 1966. *Open Channel Flow*. Macmillan Co. New York.
- Prabhata K Swamee and Ashok K Sharma. *Design of Water Supply Pipe Networks*. John Wiley New York.
- Subramanya K. 2008. *Flow in Open Channels*. Tata McGraw Hill Pub.
- Terry Sturm. 2011. *Open Channel Hydraulics*. Tata McGraw Hill Pub.

**I. Course Title : Minor Irrigation**

**II. Course Code : IDE 510**

**III. Credit Hours : 2+1**

**IV. Aim of the course**

To acquaint students about the need and scope of minor irrigation in India. To provide in-depth knowledge in design and operation of surface and groundwater- based irrigation practices.

**Unit I**

Definition, scope, historical background and progress in minor irrigation works in India, Assessment of surface water resource. Design and operation of surface waterstorage structures.

**Unit II**

Evaporation and seepage control. Groundwater development methods and their scope. Groundwater extraction devices and methods. Aquifer characteristic and their evaluation. Wells in alluvial and rocky aquifers.

**Unit III**

Well interference, spacing and multiple well point system for controlled groundwater pumping. Safe yield from wells. Augmentation of well yield through pumping and recovery time management.

**Unit IV**

Open well design, drilling and construction. Tube well, tube well strainers, gravel packing and resistance to flow. Pumps and prime movers for groundwater lifting. Diagnosis of sick and failed wells and their remediation.

**Unit V**

Conjunctive use of surface and groundwater. Legislation for groundwater development and management. Techniques of groundwater recharge and its use.

**V. Practical**

Measurement of seepage loss from reservoirs. Estimation of inflow to surface reservoir. Measurement of evaporation loss from surface reservoirs. Pumping test and determination of aquifer parameters. Establishment of draw down-discharge characteristic. Well log analysis and deciding on length and placement of strainers. Computation of well interference and deciding on well spacing. Estimation of irrigation for given discharge from well. Estimating pumping cost for irrigation. Analysis of ground water quality. Problems on well design.

**VI. Learning outcome**

The students will be able to understand minor irrigation practices and their importance in Indian agriculture. They will also expose to conjunctive use of surface and groundwater and able to perform groundwater development legislation, recharge and utilization practices.

**VII. Teaching Schedule**

| S.No. | Topic | No. of Lectures |
|---|---|---|
| 1. | Definition and scope of minor irrigation works in India | 1 |

| | | |
|---|---|---|
| 2. | Historical background and progress in minor irrigation works in India | 2 |
| 3. | Assessment of surface water resource | 1 |
| 4. | Design and operation of surface water storage structures | 2 |
| 5. | Evaporation and seepage control | 1 |
| 6. | Groundwater development methods and their scope | 2 |
| 7. | Groundwater extraction devices and methods | 1 |
| 8. | Aquifer characteristic and their evaluation | 2 |
| 9. | Wells in alluvial and rocky aquifers | 1 |
| 10. | Well interference | 2 |
| 11. | Spacing and multiple well point system for controlled groundwater pumping | 2 |
| 12. | Safe yield from wells | 1 |
| 13. | Augmentation of well yield through pumping and recovery time management | 2 |
| 14. | Well design, drilling and construction | 2 |
| 15. | Tube well strainers | 1 |
| 16. | Gravel packing and resistance to flow | 2 |
| 17. | Pumps and prime movers for groundwater lifting | 2 |
| 18. | Diagnosis of sick and failed wells and their remediation | 1 |
| 19. | Conjunctive use of surface and groundwater | 1 |
| 20. | Legislation for groundwater development and management | 1 |
| 21. | Groundwater recharge and its use | 2 |
| | **Total** | **32** |

## VIII. List of Practicals

| S.No. | Topic | No. of Practicals |
|---|---|---|
| 1. | Measurement of seepage loss from reservoirs | 1 |
| 2. | Estimation of inflow to surface reservoir | 2 |
| 3. | Measurement of evaporation loss from surface reservoirs | 1 |
| 4. | Pumping test and determination of aquifer parameters | 2 |
| 5. | Establishment of draw down-discharge characteristic | 2 |
| 6. | Well log analysis and deciding on length and placement of strainers | 2 |
| 7. | Computation of well interference and deciding on well spacing | 2 |
| 8. | Estimation of irrigation for given discharge from well | 1 |
| 9. | Estimating pumping cost for irrigation | 1 |
| 10. | Analysis of ground water quality | 1 |
| 11. | Problems on well design | 1 |
| | **Total** | **16** |

## IX. Suggested Reading


- Garg SK. 1987. *Irrigation Engineering and Hydraulic Structures*. Khanna Publisher, Delhi.
- Garg SK. 1987. *Hydrology and Water Resource Engineering.* Khanna Publishers, Delhi.
- Michael AM. 2006. *Irrigation Theory and Practice*. Vikas Publications, New Delhi.
- Sharma RK. 1987. *Hydrology and Water Resources Engineering*. Dhanpat Rai and Sons, New Delhi.
- Subramanian K. 1993. *Engineering Hydrology*. Tata Mc-Graw-Hill Co. New Delhi.

**I. Course Title : Design of Pumps for Irrigation and Drainage**

**II. Course Code : IDE 511**

**III. Credit Hours : 2+0**

**IV. Aim of the course**

To acquaint students about basic hydraulic design of various pumps, energy requirement in pumping, solar photovoltaic system and solar pump including design of pumping station.

**V. Theory**

**Unit I**

Basic hydraulic design of centrifugal pump. Net positive suction head and cavitation, vapour pressure, water hammering problem in centrifugal pump.

**Unit II**

Principles and design of pumping systems for agricultural drainage. Selection and performance of characteristics of vertical turbine pump, submersible pump and axial flow pump.

**Unit III**

Multiple well point system and their design. Energy requirement in groundwater pumping.

**Unit IV**

Non-conventional energy sources for pumping, wind mills, micro turbines, solar pumps. Hydraulic ram: Selection and design criteria. Solar photovoltaic system.

**Unit V**

Design of pumping station. Techno-economic evaluation. Efficient pumping system operation, flow control strategies and conservation measures for pumping systems.

**VI. Learning outcome**

The students will be able to select the pump for desired discharge to be pumped from particular water source by developing pump characteristics curve, able to analyze the flow in different types of pump and also able to design the pumping station for managing the irrigation and drainage system.

**VII. Teaching Schedule**

| S.No. | Topic | No. of Lectures |
|---|---|---|
| 1. | Different types of pumps used under different conditions | 1 |
| 2. | Principal and working of centrifugal pump | 1 |
| 3. | Basic hydraulic design of centrifugal pump | 1 |
| 4. | Net positive suction head and cavitation, vapour pressure, Water hammering problem in centrifugal pump | 3 |
| 5. | Use of pumpsets for agricultural drainage under different conditions. | 1 |
| 6. | Principles and design of pumping systems for agricultural drainage. | 2 |

| | | |
|---|---|---|
| 7. | Selection and performance of characteristics of vertical turbine pump | 2 |
| 8. | Flow pattern in turbine pumps | 1 |
| 9. | Selection and performance of characteristics of vertical submersible pump | 2 |
| 10. | Flow pattern in submersible pumps | 1 |
| 11. | Visit to Pumping Industry | 5 |
| 12. | Use of Multiple well point/skimming well point system under different conditions and its design | 1 |
| 13. | Energy requirement and efficiency for Multiple well point/skimming well point system | 1 |
| 14. | Introduction and use of Non-conventional energy sources for pumping | 1 |
| 15. | Selection and design criteria for Solar photovoltaic system | 2 |
| 16. | Selection and design criteria for wind mills, micro turbines, Solar pumps. Hydraulic ram | 3 |
| 17. | Introduction to pumping station and its components & design | 1 |
| 18. | Techno-economic design evaluation in pumping sets | 1 |
| 19. | Energy conservation measures under different pumping units Under different flow conditions | 2 |
| | **Total** | **32** |

## VIII. Suggested Reading


- Bansal RK. 1990. *A Text Book of Fluid Mechanics and Hydraulic Machines*. Laxmi Publications, New Delhi.
- Church AH and Jagdish Lal. 1973. *Centrifugal Pumps and Blowers*. Metropolitan Book Co.Pvt. Ltd. Delhi.
- Luthin JN. 1966. *Drainage Engineering*. Wiley and Sons. New York, USA.
- Michael AM and Khepar SD. 1989. *Water Wells and Pump Engineering*. Tata McGraw Hill Publishing Co., New Delhi.

**I. Course Title : Crop Environmental Engineering**

**II. Course Code : IDE 512**

**III. Credit Hours : 2+0**

**IV. Aim of the course**

To develop the common understanding aerial and edaphic environments for plant growth, energy and mass transfer which help to maximizing the crop yield. To understand the basic interface of soil and root and its characteristics.

**V. Theory**

**Unit I**

Principles of heat, mass and momentum transport. Transport of radiant energy, radiation environment, micro climatology of radiation. Micrometeorology: Turbulent transfer profiles and fluxes. Interpretation of flux measurement. Laws of electromagnetic radiation, its measurement and estimation.

**Unit II**

Profile balance of heat, mass and momentum in and above crop communities. Climatic changes and plant response to environmental stresses. Measurement and estimation of potential evapotranspiration on point and regional scale.

**Unit III**

Root anatomy, water flow in roots and root density models (microscopic and macroscopic). Stem anatomy and pressure volume curves. Methods of measuring water status in plants. Estimating ET using three temperature model and MODIS algorithm. Soil–Plant–Atmosphere system: Basic properties. Dynamics of watermovement. ET-yield relations.

**Unit IV**

Principles of optimal scheduling of irrigation and seasonal allocation of limiting water supplies using LP and DP. Seasonal and dated production functions. Crop yield modelling and condition assessment. Instrumentation and techniques formonitoring plant environments.

**Unit V**

Design and operation of controlled environment facilities and their instrumentation. Climatic changes and plant response to environmental stresses. Evapotranspirationmodels.

**VI. Learning outcome**

The students will be able to identify climatic changes on plant and how plant responds to environmental stresses and evapotranspiration. The students will be exposed for design and operation of controlled environment facilities and crop yieldmodeling.

**VII. Teaching Schedule**

| S.No. | Topic | No. of lectures |
|---|---|---|
| 1. | Principles of heat, mass and momentum transport | 2 |
| 2. | Transport of radiant energyradiation environment, micro Climatology of radiation | 2 |
| 3. | Micrometeorology: Turbulent transfer profiles and fluxes. | |

| | | |
|---|---|---|
| | Interpretation of flux measurement | 1 |
| 4. | Laws of electromagnetic radiation, its measurement and estimation | 1 |
| 5. | Profile balance of heat, mass and momentum in and different Crop communities | 1 |
| 6. | Climatic changes and plant response to environmental stresses | 1 |
| 7. | Measurement and estimation of potential evapotranspiration on point and regional scale | 1 |
| 8. | Root anatomy, water flow in roots and root density models (microscopic and macroscopic) | 1 |
| 9. | Stem anatomy and pressure volume curves | 1 |
| 10. | Methods of measuring water status in plants | 1 |
| 11. | Estimating ET using three temperature model and MODIS algorithm | 2 |
| 12. | Soil–Plant–Atmosphere system: Basic properties | 1 |
| 13. | Dynamics of water movement | 1 |
| 14. | ET-yield relations | 2 |
| 15. | Principles of optimal scheduling of irrigation | 1 |
| 16. | Seasonal allocation of limiting water supplies using LP and DP | 2 |
| 17. | Seasonal and dated production functions | 2 |
| 18. | Crop yield modelling and condition assessment | 2 |
| 19. | Instrumentation and techniques for monitoring plant environments | 2 |
| 20. | Design and operation of controlled environment facilities and their instrumentation | 2 |
| 21. | Climatic changes and plant response to environmental stresses | 1 |
| 22. | Evapotranspiration models | 2 |
| | **Total** | **32** |

**VIII. Suggested Reading**


- Abtew W and Melese A. 2017. *Evaporation and Evapotranspiration: Measurements and Estimations*. Springer Publications.
- Campbell GS and Norman JM. *An Introduction to Environmental Biophysics*. Springer Publication New York.
- Ghildyal BP and Tripathy RP. 1987. *Fundamental of Soil Physics*. Wiley Eastern.
- Monteith JL and Unsworth MH. *Principles of Environmental Physics*. Elsevier, Amsterdam.
- Slatyor O P 1967. *Plant Water Relationship*. Academic Press.
- Yang Y. *Evapotranspiration over Heterogeneous surfaces: Models and Applications*. Springer Publications.

**I. Course Title : Water Resources Systems Engineering**

**II. Course Code : IDE 513**

**III. Credit Hours : 2+1**

**IV. Aim of the course**

To acquaint students about the concept of optimization and its application in water resources management, mathematical programming techniques and multi objective water resources planning.

**V. Theory**

**Unit I**

Concepts and significance of optimization in water resources management. Model development in water management. Objective functions, deterministic and stochastic inputs. Problem formulation for soil plant atmosphere system

**Unit II**

Mathematical programming techniques: Linear programming: simplex method, integer programming

**Unit III**

Non-linear programming: Quadratic programming, Geometric programming and Dynamic programming. Transportation problem and solution procedures.

**Unit IV**

Soft computing techniques for optimization: Genetic algorithm, optimization of water resources with GA, fuzzy logic

**Unit V**

Application of optimization techniques for water resources planning. Irrigation management for optimum allocation of land and water resources. Optimization of conjunctive use of water resources.

**Unit V**

Multi objective water resources planning. AHP, Compromise and composite programming, Programme evaluation and review techniques. Economic models. Project evaluation and discounting methods.

**VI. Practical**

Assessment of water resources. Problems related to water allocation in agriculture under single and multiple cropping system. Formulation of the objective function and constraints for the optimsation problems related to allocation of land and water resources and other resources in water resources. Use of computer software for linear, integer, dynamic programming and Genetic algorithm. Introduction to the use of other programming methods. Sensitivity analysis of different alternatives of water resources development and allocation. Analysis of water demand and supply. Analysis of Competitive demands for water by various sectors of development. Benefits and cost of water resources development.

**VII. Learning outcome**

The students will be able to identify objective function and components in water resource planning problems and also able to formulate and solve various mathematical programming models of water resource system as well as to develop conjunctive use and crop production function optimization models.

## VIII. Teaching Schedule

| S.No. | Topic | No. of Lectures |
|---|---|---|
| 1. | Concepts and significance of optimization in water resources management | 1 |
| 2. | Model development in water management | 1 |
| 3. | Objective functions, deterministic and stochastic input | 1 |
| 4. | Soil plant atmosphere system. Problem formulation. Mathematical programming techniques | 1 |
| 5. | Linear programming, simplex method | 5 |
| 6. | Non-linear programming, quadratic programming, integer programming | 5 |
| 7. | Transportation problem and solution procedure | 3 |
| 8. | Geometric programming | 3 |
| 9. | Dynamic programming | 4 |
| 10. | Application of optimization techniques for water resources \ planning | 2 |
| 11. | Conjunctive use of water resources | 1 |
| 12. | Crop production functions and irrigation optimization | 2 |
| 13. | Multi objective water resources planning. Critical path method | 2 |
| 14. | Programme evaluation and review technique | 1 |
| 15. | Economic models | 2 |
| 16. | Project evaluation and discounting methods | 1 |
| | **Total** | **35** |

## IX. List of Practicals

| S.No. | Topic | No. of Practicals |
|---|---|---|
| 1. | Assessment of water resources and demands of the region | 1 |
| 2. | Formulation of the optimization problems on land and water resources allocation in agriculture under single and multiple cropping systems | 2 |
| 3. | Familiarization with computer software for linear programming, Integer programming, dynamic programming and GA | 3 |
| 4. | Hands on exercise for linear programming | 2 |
| 5. | Hand on exercise on integer programming | 1 |
| 6. | Hands on exercise for dynamic programming on computer | 1 |
| 7. | Hands on exercise on GA | 2 |
| 8. | Sensitivity analysis of different alternatives of water resources development and allocation | 2 |
| 9. | Analysis of water demand and supply | 1 |
| 10. | Benefits and cost of water resources development | 2 |
| | **Total** | **17** |

**X. Suggested Reading**


- Larry WM. 1996. *Water Resources Handbook.* Mc-Graw-Hill.
- Loucks DP *et al*. 1981. *Water Resources System Planning and Analysis.* Prentice Hall.
- Rao SS. 1978. *Optimization Theory and Application*. Wiley Eastern.
- Wallander WW and Bos M. 1990. *Water Resource System Planning and Management*.
- Hamdi Taha.1971. Operations Research An Introduction. Pearson Education Limited, Essex, England
- https://www.tutorialspoint.com/genetic_algorithms/genetic_algorithms_introduction.html
- https://www.mathworks.com/help/gads/what-is-the-genetic-algorithm.html

**I. Course Title : Irrigation Economics Planning and Management**

**II. Course Code : IDE 514**

**III. Credit Hours : 2+0**

**IV. Aim of the course**

To impart knowledge of various public and government policy on regulation and allocation of irrigation water, cost and benefit analysis including project evaluation, decision making process and risk analysis.

**V. Theory**

**Unit I**

Economic analysis. Problems in project selection. Methods and approaches to water pricing. Criteria for investment and pricing in irrigation projects. Social benefits, problems and causes of under-utilization. Mathematics of economic analysis. Cost allocation, separable and non-separable costs. Discounting factors and techniques. Determination of benefits, cost and benefit analysis. Project evaluation. Limitations of benefit-cost analysis. Dynamics of project analysis.

**Unit II**

Role of financial analysis. Distinctions from economic analysis. Financial feasibility and analysis. Impact of public policies on regulation and allocation of irrigation water. Relative economic efficiency of alternative irrigation water management models. Irrigation system improvement by simulation and optimization to enhance irrigation water use efficiency.

**Unit III**

Indian agriculture, main problems, population, government policies, systems, organizing agriculture production. Farm Management: Definition, importance, scope, relation with other sciences and its characteristics.

**Unit IV**

Socio-economic survey. Importance of such survey in planning, implementation and evaluation of project performance. Planning of socio-economic survey, types of data sets to be collected, preparing the questionnaires form, schedules sampling, editing and scrutinizing of secondary data, classification and analysis of data.

**Unit V**

Role of farm management principles in decision making for irrigated agriculture. Decision making process, assessing risk and uncertainty in planning.

**VI. Learning outcome**

The students will be able to estimate the cost benefit analysis, pricing and investment criteria on irrigation project evaluation and finding their problems.

The students will also be exposed to conduct socio-economic survey and analyse the secondary data.

## VII. Teaching Schedule

| S. No. | Topic | No. of Lectures |
|---|---|---|
| 1. | Economic analysis, problems in project selection | 1 |
| 2. | Methods and approaches to water pricing | 1 |
| 3. | Criteria for investment and pricing in irrigation projects | 1 |
| 4. | Social benefits, problems and causes of under-utilization | 1 |
| 5. | Mathematics of economic analysis | 1 |
| 6. | Cost allocation, separable and non-separable costs | 1 |
| 7. | Discounting factors and techniques | 1 |
| 8. | Determination of benefits and limitations of cost-benefit analysis | 1 |
| 9. | Project evaluation | 1 |
| 10. | Dynamics of project analysis | 1 |
| 11. | Role of financial analysis | 1 |
| 12. | Distinctions from economic analysis | 1 |
| 13. | Financial feasibility and analysis | 1 |
| 14. | Impact of public policies on regulation and allocation of irrigation water | 1 |
| 15. | Relative economic efficiency of alternative irrigation water management models | 2 |
| 16. | Irrigation system improvement by simulation and optimization to enhance irrigation water use efficiency | 2 |
| 17. | Indian agriculture, main problems, population, government policies, systems, organizing agriculture production | 2 |
| 18. | Farm Management: Definition, importance, scope, relation with other sciences and its characteristics | 2 |
| 19. | Socio-economic survey: Importance of survey in planning, implementation and evaluation of project performance | 2 |
| 20. | Planning of socio-economic survey, types of data sets to be collected, preparing the questionnaires form, schedules sampling, editing and scrutinizing of secondary data | 2 |
| 21. | Classification and analysis of data | 1 |
| 22. | Role of farm management principles in decision making for irrigated agriculture | 2 |
| 23. | Decision making process | 1 |
| 24. | Assessing risk and uncertainty in planning | 2 |
| | **Total** | **32** |

**VIII. \Suggested Reading**


- Heady, Early Orel, Hexem R and Roger W. 1978. *Water Production Functions for Irrigated Agriculture*.
- James Douglas and Lee Rober R. 1995. *Economics of Water Resource Planning*. Tata Mcgraw- Hill Publication Company Ltd, Bombay, New Delhi.
- Joshi SS and TR Kapoor. 2001. *Fundamentals of Farm Business Management*. Kalyani Publishers, Ludhiana.
- *Management of Water Project-Decision Making and Investment Appraisal*. Oxford Publication Co.
- Sharma VK. 1985. *Water Resource Planning and Management*. Himalaya Publication House, New Delhi.

**I. Course Title : Sensing and Automation in Irrigation Systems**

**II. Course Code : IDE 515**

**III. Credit Hours : 3+0**

**IV. Aim of the course**

To acquaint students about the concept of sensing and automation in irrigation system, wireless sensor network and digital signal processor. To provide knowledge of surface irrigation automation.

**V. Theory**

**Unit I**

Sensing and sensors. Sensor classifications. Wireless sensor networks. History of wireless sensor networks (WSN). Communication in a WSN. Important design constraints of a WSN like Energy, self management, wireless networking, decentralized management, design constraints, security etc.

**Unit II**

Node architecture. Sensing subsystem. Analog-to-Digital converter. The processor subsystem, architectural overview, microcontroller, digital signal processor, application-specific integrated circuit, field programmable gate array (FPGA).

**Unit III**

Communication interfaces, serial peripheral interface, inter-integrated circuit, the IMote node architecture, The XYZ node architecture, the Hogthrob node architecture.

**Unit -IV**

Applications in surface irrigation automation, automation based on volume, time, fertigation scheduling, water logging, salinity, oxygen diffusion systems, etc.

**VI. Learning outcome**

The students will be able to understand concept of automation in irrigation system which is quite important to enhance water use efficiency and also able to understand Node architecture and other routing protocols.

**VII. Teaching Schedule**

| S.No. | Topics | No. of Lectures |
|---|---|---|
| 1. | Sensing and sensors | 2 |
| 2. | Sensor classifications | 2 |
| 3. | History of wireless sensor networks (WSN) and Wireless sensor networks | 3 |
| 4. | Communication in a WSN | 1 |
| 5. | Important design constraints of a WSN like Energy, self-management, wireless networking, decentralized management, design constraints, security etc | 3 |
| 6. | Node architecture | 1 |
| 7. | Sensing subsystem | 1 |
| 8. | Analog-to-Digital converter | 2 |

| | | |
|---|---|---|
| 9. | The processor subsystem | 1 |
| 10. | Architectural overview | 1 |
| 11. | Microcontroller | 2 |
| 12. | Digital signal processor | 2 |
| 13. | Application-specific integrated circuit | 2 |
| 14. | Field programmable gate array (FPGA) | 2 |
| 15. | Communication interfaces | 2 |
| 16. | Serial peripheral interface | 3 |
| 17. | Inter-integrated circuit | 2 |
| 18. | The IMote node architecture | 2 |
| 19. | The XYZ node architecture | 2 |
| 20. | The Hogthrob node architecture | 2 |
| 21. | Applications in surface irrigation automation | 3 |
| 22. | Automation based on volume, time, fertigation scheduling, water logging, salinity, oxygen diffusion systems, etc | 4 |
| | **Total** | **45** |

**VIII. Suggested Reading**


- Cauligi S Raghavendra, Krishna M Sivalingam and Taieb Znati. *Wireless Sensor Networks*. Springer.
- Edgar H, Callaway Jr. and Edgar H Callaway. *Wireless Sensor Networks: Architectures and Protocols*.
- Holger Karl and Andreas Willig. *Protocols and Architectures for Wireless Sensor Networks*. John Wiley & Sons.
- Waltenegus Dargie and Christian Poellabauer. *Fundamentals of Wireless Sensor Networks:*Theory and Practice. A John Wiley and Sons, Ltd, Publication.

## Course Title with Credit Load
## Ph.D. in Irrigation and Drainage Engineering

**Major Courses (Requirement: 12 Credits)**

| Course Code | Course Title | Credit Hours |
|---|---|---|
| IDE 601* | Recent Developments in Irrigation Engineering | 2+1 |
| IDE 602* | Advances in Drainage Engineering | 2+1 |
| IDE 603 | Hydro-Mechanics and Ground Water Modeling | 3+0 |
| IDE 604 | Soil-Water-Plant-Atmospheric Modeling | 2+1 |
| IDE 605 | Plant Growth Modeling and Simulation | 2+0 |
| IDE 606 | Multi Criteria Decision Making System | 2+0 |
| | **Total** | **13+3** |

*Course has been made compulsory for PhD students.

**Minor Courses (Requirement: 06 Credits)**

**Disciplines for Minor Courses:**

1. Renewable Energy Engineering
2. Farm Machinery and Power Engineering
3. Irrigation and Drainage Engineering
4. Soil and Water Conservation Engineering
5. Civil Engineering
6. Computer Science and Information Technology
7. Basic Sciences

**Suggestive Minor courses**

| Course Code | Course Title | Credit Hours |
|---|---|---|
| SWCE 502 | Applied Watershed Hydrology | 2+1 |
| SWCE 603 | Reservoir Operation and River Basin Modeling | 2+1 |
| SWCE 604 | Modeling Soil Erosion Processes and Sedimentation | 2+1 |
| CSE 503 | Neuro-Fuzzy Application in Engineering | 2+1 |
| CSE 506 | Digital Image Processing | 2+1 |
| FMPE 602 | Advances in Machinery for Precision Agriculture | 2+1 |
| REE 615 | Energy Planning, Management and Economics | 3+0 |
| | Any other course(s) of other department can be taken as per the recommendations of Students Advisory Committee | |

**Supporting Courses (Requirement: 05 Credits)**
**Disciplines for Supporting Courses:**

1. Statistics
2. Computer Science and Information Technology
3. Soil and Water Conservation Engineering
4. Irrigation and Water Management
5. Basic Sciences

Suggestive Supporting Courses

| Course Code | Course Title | Credit Hours |
|---|---|---|
| CPE-RPE 601* | Research and Publication Ethics | 1+1 |
| BSCT 601 | Object Oriented Programming | 2+1 |
| STAT 601 | Operational Research | 1+1 |
| | Courses from subject matter fields (other than Major and Minor) relating to area of special interest and research problem can be taken as per recommendations of the student's advisory committee. | |

**List of other Essential Requirements**

| Course Code | Course Title | Credit Hours |
|---|---|---|
| IDE 691 | Doctoral Seminar-I | 0+1 |
| IDE 692 | Doctoral Seminar-II | 0+1 |
| IDE 699 | Doctoral Research | 0+75 |

# Course Contents and Syllabus of Doctoral Degree

**I. Course Title : Recent Developments in Irrigation Engineering**
**II. Course Code : IDE 601**
**III. Credit Hours : 2+1**

**I. Aim of the course**

To focus the students for the recent designs progressed in surface irrigation systems, surface and subsurface drip irrigation systems and for utilizing good and poor- quality waters for sustaining crop productivity.

**II. Theory**

**Unit I**

Geospatial analysis of hydraulic properties of the soil. One dimensional and two-dimensional zero inertia modelling of border irrigation. Integral equation solutions to surface irrigation and furrow irrigation. Volume balance approach. Design of irrigation runoff recovery systems.

Surge flow irrigation systems and Cablegation: Hydraulics, design and evaluation. Automated supply for surface irrigation surge irrigation and Cabligation.

**Unit II**

Analyzing wind distortion in sprinkler irrigation systems uniformity, micro and mini sprinkler irrigation system, rain-gun, central pivot irrigation system. Solar powered sprinkler irrigation system, LEPA system

**Unit III**

Modeling soil water regimes and solute distribution emanating from surface and sub-surface drip irrigation systems. Analyzing moisture and temperature profiles with time and depth. Effects of emitter variability and plant and soil variability on soil moisture distribution uniformity. Irrigation scheduling through partial root zone irrigation. Low energy drip irrigation systems, sub-surface drip irrigation systems. Recent developments in designs of surface and sub-surface drip irrigation systems. Drip irrigation for poor quality water. Drip irrigation system modification for waste water utilization.

**Unit IV**

Automation 0f irrigation system. Deficit irrigation water management. Fertilizer response function and crop water salinity response function.

**III. Practical**

Designing border irrigation using zero inertia model, volume balance approaches, evaluating surge flow irrigation systems, operation of segmented border irrigation systems for enhancing water use efficiency, geospatial analysis of soil properties, design and planning of surface drip irrigation systems using various designs, design of subsurface drip irrigation, analyzing three dimensional moisture movement under subsurface drip irrigation using simple empirical models, design and planning of surface and subsurface irrigation systems, developing the irrigation schedules using partial root zone irrigation.

**IV. Learning outcome**

The students will be able to design, operate and maintain surface irrigation systems, surface and sub-surface pressurized irrigation systems and managing crop productivity with poor quality of waters without deteriorating soil conditions.

## V. Teaching Schedule

| S.No. | Topic | No. of Lectures |
|---|---|---|
| 1. | Geospatial analysis of hydraulic properties of soil: Geospatial analysis, Spatial interpolation, Data quality assessment, Vegetation analysis, Correlation analysis | 3 |
| 2. | Surge flow: Effect of surging on infiltration and surface flow hydraulics, surge flow systems | 2 |
| 3. | Zero inertia modeling of border irrigation | 2 |
| 4. | Integral equation solutions to surface irrigation: Border and furrow irrigation method | 2 |
| 5. | Design of irrigation runoff recovery systems: Border and furrow irrigation method | 3 |
| 6. | Cablegation: Automated supply for surface irrigation | 2 |
| 7. | Wind effects on sprinkler irrigation performance: Analyzing Wind distortion in sprinkler irrigation system uniformity | 2 |
| 8. | Design of sub-surface drip irrigation systems, Modeling soil water regimes and solute distribution emanating from sub-surface drip irrigation systems | 3 |
| 9. | Effects of emitter variability and plant and soil variability on soil moisture distribution uniformity | 2 |
| 10. | Irrigation scheduling through partial root zone irrigation. | 2 |
| 11. | Low energy drip irrigation systems | 2 |
| 12. | Drip irrigation for poor quality water, Drip automation for time and volume, Drip irrigation system modification for waste water utilization | 2 |
| 13. | Modeling deficit irrigation and crop yield in response to hydraulic variation of the system and distribution uniformity of the soil-crop water fertilizer response function, Crop water salinity response function | 3 |
| 14. | Drip irrigation in command area development | 2 |
| 15. | Mulching and its effect on crop productivity, Analyzing moisture and temperature profiles with time and depth, Effect of shading and mulching on crop productivity, vapour phase movement | 3 |
| | **Total** | **35** |

## VI. List of Practicals

| S.No. | Topic | No. of Practicals |
|---|---|---|
| 1. | Geospatial analysis of hydraulic soil properties | 1 |
| 2. | Design of border and furrow irrigation using zero inertia model | 2 |
| 3. | Design of border and furrow irrigation using volume balance approach | 2 |
| 4. | Design and evaluation of surge flow irrigation system | 1 |
| 5. | Design of irrigation runoff recovery system for border irrigation method | 1 |
| 6. | Design of irrigation runoff recovery system for furrow irrigation method | 1 |
| 7. | Design and planning of cablegation system | 1 |
| 8. | Analysis of wind distortion in sprinkler irrigation system uniformity | 1 |
| 9. | Design and planning of subsurface drip irrigation system | 1 |
| 10. | Analysis of three dimensional moisture movement under Subsurface drip irrigation using simple empirical models | 2 |
| 11. | Development of irrigation schedules using partial root zone irrigation | 1 |
| 12. | Modeling deficit irrigation water management | |
| | **Total** | **15** |

## VII. Suggested Reading


- Cuenca RH. 1989. *Irrigation System Design*: *An Engineering Approach*. Prentice Hall, New York.
- Hoffman GJ, Evans RG, Jensen ME, Martin DL and Elliot RL. (ed). 2007. *Design and Operation of Farm Irrigation Systems*. American Society of Agricultural Engineers St. Joseph Michigan.
- James LG. 1988. *Principles of Farm Irrigation System Design*. John Wiley and Sons, New York, USA.
- Nakayama FS and Bucks DA. 1986. *Trickle Irrigation for Crop production: Design, Operation and Management*. Elsevier Publications, Amsterdam.
- Skogerboe GV and Walkar WR. 2008. *Surface Irrigation Theory and Practice*. Prentice Hall, New York.

**I. Course Title : Advances in Drainage Engineering**

**II. Course Code : IDE 602**

**III. Credit Hours : 2+1**

**IV. Aim of the course**

To provide comprehensive knowledge of advances in land drainage, synthetic materials for drainage systems, linear flow laws and environmental issues related to drainage.

**V. Theory**

**Unit I**

Physics of land drainage. Forces, surface tension and energy effects water. Energy of soil water. Capillary potential.

**Unit II**

Devices to measure capillary potential. Hystersis, Darcy's law. Synthetic materials for drainage systems. Environmental issues related to drainage. Socio-economic impacts of drainage systems.

**Unit III**

Laplace equation its derivation and solution in various forms. Boundary value problems, Liner flow laws.

**Unit IV**

Drainage criteria saturated flow theory, steady flow and non steady flow. Controlled drainage for reducing agricultural non-point pollution. Application of simulation models for drainage systems.

**Unit V**

Flow equations in general and the approach. Flow problem and physical boundary conditions.

**VI. Practical**

Steady state and non steady state flow problems. Measurement of capillary potential. Use of various synthetic materials under the field condition. Use of simulated models for drainage system.

**VII. Learning outcome**

The student will be familiar about energy of soil water, capillary potential, drainage material and various sources of agricultural pollution and also able to develop and apply simulation model for management of drainage system for particular area.

**VIII. Teaching Schedule**

| S.No. | Topic | No. of Lectures |
|---|---|---|
| 1. | Physics of land drainage: Forces acting on movement of water through soil profile, surface tension, capillary forces and energy effects movement of water, Energy of soil water | 5 |
| 2. | Capillary potential: Effect of capillary potential on movement of water through porous media, devices to measure capillary potential. | |
| | Hystersis effect in drainage of soil, Darcy's law | 3 |
| 3. | Synthetic materials for drainage systems: Design of filter | |

| | | |
|---|---|---|
| | and envelop for drainage system with synthetic materials | 2 |
| 4. | Environmental issues related to drainage. Socio-economic impacts of drainage systems | 2 |
| 5. | Drainage Flow Equation: Laplace equation its derivation and solution in various forms, Liner flow laws | 4 |
| 6. | Boundary value problems: Initial and boundary condition and its solution | 3 |
| 7. | Drainage criteria: Drainage criteria for different type of soils and crops, guidelines for design and installation of drainage system | 2 |
| 8. | Saturated flow theory: steady flow and non steady saturated flow | 3 |
| 9. | Controlled drainage for raising crop and reducing agricultural non-point pollution | 2 |
| 10. | Application of simulation models for drainage systems (DRAINMOD, SALTMOD, etc) | 4 |
| 11. | Flow equations: general drainage flow equations and the approach, drainage flow problems and solutions with physical boundary conditions | 3 |
| | **Total** | **34** |

## IX. List of Practicals

| S.No. | Topic | No. of Practicals |
|---|---|---|
| 1. | Steady state drainage flow problems | 3 |
| 2. | Unsteady state drainage flow problems | 3 |
| 3. | Measurement of capillary potential | 2 |
| 4. | Use of various synthetic materials for drainage filter under the field condition | 2 |
| 5. | Design of filter and envelop with synthetic materials | 2 |
| 6. | Use of simulated models for drainage system | 4 |
| | **Total** | **16** |

## X. Suggested Reading


- Chauhan HS. 1999. *Mathematical Modeling of Agricultural Drainage, Ground Water and Seepage*. ICAR Publication New Delhi.
- Kirkham DL and Powers WL. 1972. *Advanced Soil Physics*. Inter Science, New York.
- Lambert K Smedema, Willem FV, Lotman and David Rycroft. 2004. *Modern Land Drainage: Planning, Design and Management of Agricultural Drainage Systems.* CRC Press.
- Ritzema HP. (Ed.). 1994. *Drainage Principles and Applications*. ILRI.
- Skaggs RW and Schilfgaarde Jan Van. 1999. *Agriculture Drainage*. Monograph No. 17. American Society of Agronomy Madison, Wisconsin, USA.

**I. Course Title : Hydro-Mechanics and Groundwater Modeling**

**II. Course Code : IDE 603**

**III. Credit Hours : 3+0**

**IV. Aim of the course**

To acquaint students about the concept of soil aquifer system, unsaturated flow models, numerical modeling of groundwater flow, theory of krigging and movement of groundwater in fractured and swelling porous media.

**V. Theory**

**Unit I**

Concept of soil aquifer system, flow of water in partially saturated soils. Partial differential equation of flow, pressure under curved water films, moisture characteristic functions.

**Unit II**

Physical models, Analog models, Mathematical modelling, Unsaturated flow models, Numerical modelling of groundwater flow, Finite difference equations and solutions.

**Unit III**

Determination of unsaturated hydraulic conductivity and model for its estimation. Diffusivity and its measurement. Infiltration and exfiltration from soils in absence and presence of water table.

**Unit IV**

Fence diagram and aquifer mapping. Movement of groundwater in fractured and swelling porous media. Spatial variability, theory of krigging.

**Unit V**

Data requirements. Conceptual model design: Conceptualization of aquifer system. Parameters, Input-output stresses, Initial and Boundary conditions. Model design and execution: Grid design, Setting boundaries, Time discretization and transient simulation. Model calibration: Steady state and unsteady state. Sensitivity analysis. Model validation and prediction. Uncertainty in the model prediction.

**VI. Learning outcome**

The students will be able to understand complex mechanics movement of water in soil systems and also able to estimate the statistical parameters for better understanding of soil aquifer system, model validation and prediction.

**VII. Teaching Schedule**

| S.No. | Topic | No. of Lectures |
|---|---|---|
| 1. | Concept of soil aquifer system | 1 |
| 2. | Flow of water in partially saturated soils | 1 |
| 3. | Partial differential equation of flow | 1 |
| 4. | pressure under curved water films, moisture characteristic functions | 1 |
| 5. | Different types of Models used in hydrology and Groundwater | 1 |
| 6. | Unsaturated flow models | 1 |

| | | |
|---|---|---|
| 7. | Numerical modelling of groundwater flow | 1 |
| 8. | Finite difference equations and solutions, Finite difference Equations and solutions, Alternating direction implicit procedure | 4 |
| 9. | Crank Nicolson equation. Iterative methods | 2 |
| 10. | Inverse problem. Finite element method | 1 |
| 11. | Determination of unsaturated hydraulic conductivity and model for its estimation | 2 |
| 12. | Diffusivity and its measurement | 1 |
| 13. | Infiltration and exfiltration from soils in absence and presence of water table | 2 |
| 14. | Fence diagram and aquifer mapping | 2 |
| 15. | Movement of groundwater in fractured and swelling porous media, Spatial variability, theory of krigging | 4 |
| 16. | Data requirements. Conceptual model design: Conceptualization of aquifer system. Parameters, Input-output stresses, Initial and Boundary conditions | 4 |
| 17. | Model design and execution: Grid design, Setting boundaries, Time discretization and transient simulation | 4 |
| 18. | Model calibration: Steady state and unsteady state. Sensitivity analysis. Model validation and prediction. Uncertainty in the model prediction | 6 |
| 19. | Course Seminar | 4 |
| | **Total** | **43** |

## VIII. Suggested Reading


- Anderson MP and Woessner WW. 1992. *Applied Groundwater Modelling: Simulation of Flow and Advective Transport.* Academic Press, Inc.
- Elango L and Jayakumar R. 2001. *Modelling in Hydrology*. Allied Publishers Ltd.
- Fetter CW. 1999. *Contaminant Hydrogeology*. Prentice Hall.
- Kirkham and Powers. 1972. *Advanced Soil Physics*. John Wiley & Sons.
- Muskat M. 1937. *The Flow of Homogeneous Fluid through Porous Media.* McGraw Hill.
- Rushton KR. 2003.*Groundwater Hydrology: Conceptual and Computational Models. Wiley,*

**I. Course Title : Soil-Water-Plant-Atmospheric Modeling**

**II. Course Code : IDE 604**

**III. Credit Hours : 2+1**

**IV. Aim of the course**

To impart the knowledge of measurement of radiation within plant cover, thermodynamics of flow through plant cells, heat transfer and radiation exchangeunder plant cover.

**V. Theory**

**Unit I**

Radiation balance of earth's surface. Turbulent transport of heat and momentum. Radiation exchange and heat transfer in a low plant cover.

**Unit II**

Measurement of radiation, leaf and air temperature, humidity and wind profiles within plant cover. Predicting potential evapotranspiration (ET).

**Unit III**

Thermodynamics of flow through plant cells. Dynamics of water movement through soil plant atmosphere system. Stomatal aperture, photosynthesis and actual evapotranspiration relationship.

**Unit IV**

Production functions of evapotranspiration. Evapo-transpiration in mathematical modelling and optimization of design and regulation of irrigation systems and for utilization of limited water resources in agriculture.

**Unit V**

Crop water requirement under protected cultivation and remote sensing-based modeling.

**VI. Practical**

Estimation of potential evapotranspiration. Measurement of ET parameters under open and protected cultivation and development of stochastic and deterministic models of ET. Use of software for estimation of crop water requirement and ET.

**VII. Learning outcome**

The students will be able to understand the measurement of radiation, photosynthesis and actual evapotranspiration relationship along with modeling of evapotranspiration.

**VIII. Teaching Schedule**

| S.No. | Topic | No. of Lectures |
|---|---|---|
| 1. | Radiation balance of earth's surface | 1 |
| 2. | Turbulent transport of heat and momentum | 2 |
| 3. | Radiation exchange and heat transfer in a low plant cover | 2 |
| 4. | Measurement of radiation, leaf and air temperature, humidity and wind profiles within plant cover | 2 |
| 5. | Predicting potential evapotranspiration | 2 |
| 6. | Thermodynamics of flow through plant cells | 2 |

| | | |
|---|---|---|
| 7. | Dynamics of water movement through soil plant atmosphere system | 2 |
| 8. | Stomatal aperture, photosynthesis and actual evapotranspiration relationship | 1 |
| 9. | Production functions of evapotranspiration | 3 |
| 10. | Evapo-transpiration in mathematical modelling and optimization of design and regulation of irrigation systems and for utilization of limited water resources in agriculture | 4 |
| 11. | Crop water requirement under protected cultivation and remote sensing-based modeling | 4 |
| | **Total** | **29** |

## IX. List of Practicals

| S.No. | Topic | No. of Practicals |
|---|---|---|
| 1. | Estimation of potential evapotranspiration using FAO 56 Penman Monteith equation | 1 |
| 2. | Estimation of potential evapotranspiration using FAO Cropwat model | 1 |
| 3. | Estimation of potential evapotranspiration using FAO ETo calculator | 2 |
| 4. | Measurement of ET parameters under open condition | 1 |
| 5. | Measurement of ET parameters under protected cultivation | 1 |
| 6. | Development of stochastic models of ET | 3 |
| 7. | Development of deterministic models of ET | 3 |
| 8. | Use of software for estimation of crop water requirement and ET | 2 |
| | **Total** | **14** |

## X. Suggested Reading


- Allen et al. Irrigation and Drainage Paper No. 56 FAO
- Amarjit Basra. 1994. *Mechanisms of Plant Growth and Improved Productivity*. CRC Press New York.
- Daniel Hillel. *Advances in Irrigation*. All Volumes.
- Nieder AR and Benbi D. 2003. *Handbook of Processes and Modeling in the Soil-Plant System.* CRC Press New York.
- Peter J Gregory. *Plant Roots, their Growth Activity and Interaction with Soils.* Wiley Blackwell New York.

**I. Course Title : Plant Growth Modeling and Simulation**

**II. Course Code : IDE 605**

**III. Credit Hours : 2+0**

**IV. Aim of the course**

To impart the in-depth knowledge of plant growth modeling, type of modeling approach, quantitative analysis of photosynthesis and remote sensing-based modeling.

**V. Theory**

**Unit I**

Introduction to plant growth modeling. Simulation and simulation language. Types of models and modeling approaches.

**Unit II**

Relational diagram of principle process. Structure of a generalized agricultural simulator. Input environment and techniques for monitoring plant environment.

**Unit III**

Process and aspects of growth and development. Input yield models. Quantitative analysis of photosynthesis, respiration, growth, water and nutrient uptake. Yield functions.

**Unit IV**

Remote sensing-based modeling and field variability of growth influencing factors.

**VI. Learning outcome**

The students will be able to know various plant growth models and their application based on input environmental parameters. Student will be acquainted with generalized agricultural simulator.

**VIII. Teaching Schedule**

| S.No. | Topic | No. of Lectures |
|---|---|---|
| 1. | Introduction to plant growth modelling | 4 |
| 2. | Simulation and simulation language | 4 |
| 3. | Types of models and modeling approaches | 4 |
| 4. | Relational diagram of principle process | 2 |
| 5. | Structure of a generalized agricultural simulator | 2 |
| 6. | Input environment and techniques for monitoring plant environment | 4 |
| 7. | Process and aspects of growth and development. Input yield models | 4 |
| 8. | Quantitative analysis of photosynthesis, respiration, growth, water and nutrient uptake. Yield functions | 3 |
| 9. | Remote sensing-based modelling | 3 |
| 10. | Field variability of growth influencing factors | 2 |
| | **Total** | **32** |

**IX. Suggested Reading**


- Charls-Edwards DA. 1981. *The Mathematics of Photosynthesis and Productivity.* Academic Press, London.
- Evans LT. 1963. *Environmental Control of Plant Growth*. Academic Press, New York, USA.
- Goudriaan J and Van Laar HH. 1994. *Modelling Potential Crop Growth Process*. Kluweer Academic Publisher, Dordrecht, The Netherlands.
- Jones JW and Ritchie JT. 1990. *Crop Growth Models*. In: ASAE Monograph on Management of Farm Irrigation.
- Thorwey JHM and Johnson IR. 1990. *Plant and Crop Modelling: A Mathematical Approach to Plant and Crop Physiology*. Clarendon Press, Oxford.
- Kale MU and Supe MS. 2018. Introductory Hydroinformatics. New India Publicizing Agency, New Delhi.

**I. Course Title : Multi Criteria Decision Making Systems**

**II. Course Code : IDE 606**

**III. Credit Hours : 2+0**

**IV. Aim of the course**

To acquaint students about multi criteria decision making system which include multi-attribute decision making and multi-objective decision making.

**V. Theory**

**Unit I**

Introduction: MCDM overview, basic foundations and Pareto optimality elementarydecision analysis. Decision trees and influence diagrams.

**Unit II**

Multi–attribute decision making (MADM): Multi–attribute overview deterministic utility theory, value decomposition, additive value decomposition, Multi–facility location analysis, expected utility theory, single attribute utility functions, two–attribute utility models, multi–attribute assessment.

**Unit III**

Multi-objective decision making (MODM): Vector optimization theory, weighting methods, Analytical Hierarely Process (AHP) weighting example. Compromise and corporate programming

**.Unit IV**

Non interactive and interactive methods, linear goal programming, nonlinear and integer goal programming.

**Unit V**

Interactive trade-off methods: Zionts–Wallenius, Surrogate worth, Group decisionmaking methods.

**VI. Learning outcome**

The students will be able to understand and learn to apply various techniques for the best solutions of real-life command area and other hydrological problems.

**VII. Teaching Schedule**

| S.No. | Topic | No. of Lectures |
|---|---|---|
| 1. | MCDM overview | 1 |
| 2. | Basic foundations and Pareto optimality elementary decision analysis | 2 |
| 3. | Decision trees and influence diagrams | 1 |
| 4. | Multi-attribute decision making (MADM): Deterministic utility theory, value decomposition, additive value decomposition | 2 |
| 5. | Multi-facility location analysis | 1 |
| 6. | Expected utility theory | 1 |
| 7. | Single attribute utility functions | 1 |
| 8. | Multi-attribute overview | 1 |
| 9. | Two-attribute utility models | 1 |

| | | |
|---|---|---|
| 10. | Multi-attribute computer programs and multi–attribute assessment | 2 |
| 11. | Multi-objective decision making (MODM) | 1 |
| 12. | Vector optimization theory | 1 |
| 13. | Weighting methods and examples related with weighting | 2 |
| 14. | Linear vector optimization (LVOP) | 1 |
| 15. | Parametric decomposition | 2 |
| 16. | LVOP algorithm and LVOP example | 2 |
| 17. | Non interactive and interactive methods | 2 |
| 18. | Geoffrion's Bi-criterion method | 1 |
| 19. | Linear goal programming, nonlinear and integer goal programming | 2 |
| 20. | Interactive trade-off methods | 1 |
| 21. | Zionts-Wallenius and Surrogate worth | 2 |
| 22. | Group decision making methods | 2 |
| | **Total** | **32** |

**VIII. Suggested Reading**


- Cohon JL. 2004. *Multi objective Programming and Planning*. Dover Publications.
- Doumpos M and Grigoroudis E. 2013. *Multi criteria Decision Aid and Artificial Intelligence: Links, Theory and Applications*. Wiley-Blackwell.
- Figueira J, Greco S and Ehrgott M 2007. *Multiple Criteria Decision Analysis: State of the Art Surveys*. Springer.
- Tzeng GH and Huang JJ. 2011. *Multiple Attribute Decision Making: Methods and Applications*. Chapman and Hall/CRC.
- Tzeng GH and Huang JJ. 2013. *Fuzzy Multiple Objective Decision Making*. Chapman and Hall/CRC.

## Course Syllabus and content of Minor / Supporting Courses

**I. Course Title : Big Data Analytics**

**II. Course Code : CSE 501**

**III. Credit Hours : 2+1**

**IV. Aim of the course**

To understand principles of analyzing and mining big data and to use simple toolsto extract useful information from big data sets.

**V. Theory**

**Unit I**

Data analysis, data probabilistic view, matrix, attributes. Data: Algebraic and geometric view

**Unit II**

Basics of data mining and CRISP-DM, organizational and data understanding, purposes, Intents and limitations of data mining, database, data warehouse, data mart and data set, types of data, privacy and security, data preparation, collation and data scrubbing.

**Unit III**

Data mining models and methods, correlation, association rules, k-means, clusteringunderstanding of concept, preparation and modelling.

**Unit IV**

Discriminant analysis, linear regression, logistic regression, understanding, preparation and modeling.

**Unit V**

Decision trees, neural networks, understanding, preparation and modeling.

**VI. Practical**

Introduction to Open Office and Rapid Miner in data analytics and mining. Preparing Rapid Miner, Importing data, handling missing data, data reduction, handling Inconsistent data, attribute reduction. Performing different analysis using Rapid Miner or suitable software.

**VII. Learning outcome**

Capability to understand the principles behind analysis of big data and apply the same using simple tools.

**VIII. Teaching Schedule**

| S.No. | Topic | No. of Lectures |
|---|---|---|
| 1. | Data analysis, data matrix attributes | 2 |
| 2. | Algebraic and geometric view, probabilistic view. | 4 |
| 3. | Basics of data mining and CRISP-DM | 2 |
| 4. | Organizational and data understanding | 3 |
| 5. | Intents and limitations of data mining, database, data warehouse, data mart and data set | 4 |
| 6. | Types of data, privacy and security, data preparation, collation and data scrubbing. | 4 |

| | | |
|---|---|---|
| 7. | Data mining models and methods, correlation, association rules | 6 |
| 8. | K-means, clustering understanding of concept, preparation and modelling. | 5 |
| 9. | Discriminant analysis, linear regression, logistic regression, understanding, preparation and modeling. | 5 |
| 10. | Decision trees, neural networks, understanding, preparation and modeling. | 5 |
| | **Total** | **40** |

**IX. List of Practicals**

| S.No. | Topic | No. of Practicals |
|---|---|---|
| 1. | Working of OpenOffice and RapidMiner | 3 |
| 2. | Preparing RapidMiner Dataset | 3 |
| 3. | Handling the inconsistent data, missing data, attribute reduction | 4 |
| 4. | Performing analysis on dataset using RapidMiner | 3 |
| | **Total** | **13** |

**X. Suggested Reading**


- Dr Matthew *North Data Mining for the Masses A Global Text Project Book* ISBN: 0615684378ISBN-13: 978-0615684376.
- Mohammed J Z, Troy and Wagner M Jr. *Data Mining and Analysis: Fundamental Concepts and Algorithms*. Universidade Federal de Minas Gerais, Brazil. Cambridge University Press ISBN 978-0-521-76633-3 Hardback.

**I. Course Title : Artificial Intelligence**

**II. Course Code : CSE 502**

**III. Credit Hours : 2+1**

**IV. Aim of the course**

To introduce students with techniques and capabilities of artificial intelligence (AI) and enable them to do simple exercises.

**V. Theory**

**Unit I**

Definitions of intelligence and artificial intelligence. What is involved in intelligence? Disciplines important to AI. History of development of AI. Different types of AI. Acting humanly, Turing test. AI systems in everyday life. Applications of AI.

**Unit II**

Classical AI, concept of expert system, conflict resolution, multiple rules, forward chaining, backward chaining. Advantages and disadvantages of Fuzzy logic and fuzzy rules. Fuzzy expert systems.

**Unit III**

Problem solving using AI, search techniques, breadth first search, depth first search, depth limited search, bidirectional search, heuristic search, problems and examples. Knowledge representation, frames, methods and demons, correlations, decision trees, fuzzy trees.

**Unit IV**

Philosophy of AI, Penrose's pitfall, weak AI, strong AI, rational AI, brain prosthesis experiment, the Chinese room problem, emergence of consciousness, technological singularity, Turing test.

**Unit V**

Modern AI, biological brain, basic neuron model, perceptrons and learning, self- organizing neural network, N-tuple network, evolutionary computing, genetic algorithms, agent methods, agents for problem solving, software agents, multi agents, hardware agents.

**VI. Practical**

Prolog language, syntax and meaning of Prolog programs, Lists, operators, arithmetic. Using structures: Example programs, controlling backtracking, input and output. more built-in procedures, programming, style and technique, operations on data structures. Advanced tree representations, basic problem-solving strategies, depth-first search strategy, breadth-first search strategy.

**VII. Learning outcome**

Ability to understand and apply principles of AI in solving simple problems to enable them to get insight into working of AI based systems.

**VIII. Teaching Schedule**

| S.No. | Topic | No. of Lectures |
|---|---|---|
| 1. | Definitions of intelligence and artificial intelligence. Disciplines important to AI. History of development of AI. | 2 |
| 2. | Different types of AI. Acting humanly, Turing test. AI | |

| | | |
|---|---|---|
| | systems in everyday life. Applications of AI. | 2 |
| 3. | Classical AI, concept of expert system, conflict resolution, Multiple rules, forward chaining, backward chaining. | 3 |
| 4. | Advantages and disadvantages of expert system. Fuzzy logic and fuzzy rules. Fuzzy expert systems. | 3 |
| 5. | Problem solving using AI, search techniques, breadth first search, depth first search | 4 |
| 6. | Depth limited search, bidirectional search, heuristic search, problems and examples. | 4 |
| 7. | Knowledge representation, frames, methods and demons, correlations, decision trees, fuzzy trees. | 3 |
| 8. | Philosophy of AI, Penrose's pitfall, weak AI, strong AI, rational AI, brain prosthesis experiment, | 2 |
| 9. | Chinese room problem, emergence of consciousness, technological singularity, Turing test. | 3 |
| 10. | Modern AI, biological brain, basic neuron model, perceptrons and learning, self-organizing neural network, | 3 |
| 11. | N-tuple network, evolutionary computing, genetic algorithms, | 2 |
| 12. | Agent methods, agents for problem solving, software agents, | 2 |
| 13. | Multi agents, hardware agents. | 1 |
| | **Total** | **31** |

**IX. List of Practicals**

| S.No. | Topic | No. of Practicals |
|---|---|---|
| 1. | Prolog language, syntax and meaning of Prolog programs, Lists, operators, arithmetic. | 4 |
| 2. | Using structures: Example programs, controlling backtracking, input and output. more built-in procedures, programming, style and technique, operations on data structures. | 5 |
| 3. | Advanced tree representations, basic problem-solving strategies,depth-first search strategy, breadth-first search strategy. | 5 |
| | **Total** | **14** |

**X. Suggested Reading**


- GNU PROLOG *A Native Prolog Compiler with Constraint Solving over Finite Domains*
  Edition 1.44, for GNU Prolog version 1.4.5 July 14, 2018.
- Ivan Bratko, *Prolog Programming for Artificial Intelligence*.
- Warwick K. 2012. *Artificial Intelligence: The Basics* ISBN: 978-0-415-56482-3 (hbk).
- Kale MU and Supe MS. 2018. Introductory Hydroinformatics. New India Publicashing Agency, New Delhi.

**I. Course Title : Neuro-Fuzzy Application in Engineering**
**II. Course Code : CSE 503**
**III. Credit Hours : 2+1**

**IV. Aim of the course**

To learn the basic concept of neural network models and fuzzy logic based models and apply fuzzy reasoning and fuzzy inference to solve various agricultural engineering problems

**V. Theory**

**Unit I**

Basic concepts of neural networks and fuzzy logic, differences between conventional computing and neuro-fuzzy computing, characteristics of neuro-fuzzy computing.

**Unit II**

Fuzzy set theory: Basic definitions, terminology, formulation and parameters of membership functions. Basic operations of fuzzy sets: Complement, intersection, vision, T-norm and T- conorm. Fuzzy reasoning and fuzzy Inference: Relations, rules, reasoning, Inference systems, and modeling. Applications of fuzzy reasoningand modelling in engineering problems.

**Unit III**

Fundamental concepts of artificial neural networks: Model of a neuron, activation functions, neural processing. Network architectures, learning methods. Neural network models: Feed forward neural networks, back propagation algorithm, applications of feed forward networks, recurrent networks, hopfield networks, hebbian learning, self organizing networks, unsupervised learning, competitive learning.

**Unit IV**

Neuro–fuzzy modelling: Neuro-fuzzy inference systems, neuro-fuzzy control.

**Unit V**

Applications of neuro-fuzzy computing: Time series analysis and modelling, remotesensing, environmental modelling.

**VI. Practical**

Training algorithms of artificial neural networks: Basic models, learning rules, single layer and multi-layer feed-forward and feedback networks, supervised and unsupervised methods of training, recurrent networks, modular networks. Fuzzy systems: Fuzzy sets, operations on fuzzy sets, fuzzy relations, measures, fuzzy logic, fuzzy logic controller, integrated hybrid systems. Adaptive neuro-fuzzy inference systems, coactive neuro-fuzzy modelling, classification and regression trees, data clustering algorithms like k-means, fuzzy c-means, mountain and subtractive clustering, rule based structure identification, neuro-fuzzy control, case studies. Use of available software for fuzzy logic and neural networks.

**VII. Learning outcome**

The students will be able to have the basic concept of neural network models and fuzzy logic-based models and will be in a position to apply fuzzy reasoning and fuzzy inference for various problems of agricultural engineering. They will also learn to develop different types of neural network models.

## VIII. Teaching Schedule

| S.No. | Topic | No. of Lectures |
|---|---|---|
| 1. | Basic concepts of neural networks and fuzzy logic, differences between conventional computing and neuro-fuzzy computing, characteristics of neuro-fuzzy computing. | 3 |
| 2. | Fuzzy set theory: Basic definitions, terminology, formulation and parameters of membership functions. | 3 |
| 3. | Basic operations of fuzzy sets: Complement, intersection, vision, T-norm and T- conorm. Fuzzy reasoning and fuzzy Inference: Relations, rules, reasoning, Inference systems, and modeling. | 4 |
| 4. | Applications of fuzzy reasoning and modelling in engineering problems. | 3 |
| 5. | Fundamental concepts of artificial neural networks: Model of a neuron, activation functions, neural processing. Network architectures, learning methods. | 3 |
| 6. | Neural network models: Feed forward neural networks, back propagation algorithm, applications of feed forward networks | 3 |
| 7. | recurrent networks, hopfield networks, hebbian learning, self-organizing networks, unsupervised learning, competitive learning. | 4 |
| 8. | Neuro–fuzzy modelling: Neuro-fuzzy inference systems, neuro-fuzzy control. | 3 |
| 9. | Applications of neuro-fuzzy computing: Time series analysis and modelling, remote sensing, environmental modelling. | 4 |
| | **Total** | **30** |

## IX. List of Practicals

| S.No. | Topic | No. of Practicals |
|---|---|---|
| 1. | Training algorithms of artificial neural networks: Basic models, learning rules, single layer and multi-layer feed-forward and feedback networks, supervised and unsupervised methods of training, recurrent networks, modular networks | 5 |
| 2 | Fuzzy systems: Fuzzy sets, operations on fuzzy sets, fuzzy relations, measures, fuzzy logic, fuzzy logic controller, integrated hybrid systems. Adaptive neuro-fuzzy inference systems, coactive neuro-fuzzy modelling, classification and regression trees, | 5 |
| 3 | Data clustering algorithms like k-means, fuzzy | |

| | |
|---|---|
| c-means, mountain and subtractive clustering, rule based structure identification, neuro-fuzzy control, case studies. Use of available software for fuzzy logic and neural networks | 6 |
| **Total** | **16** |

**X. Suggested Reading**


- Jang, JS R, Sun C Tand Mizutan E 1997. *Neuro-Fuzzy and Soft Computing.* Prentice Hall
- Simon Haykin NJ. 1994. *Neural Networks. A Comprehensive Foundation.* McMillan College Publishing Company.
- Klir George J and Forger TA. 1995. *Fuzzy Sets, Uncertainty and Information.* Prentice Hall of India, Pvt. Ltd, New Delhi.
- Kosko B. 1997. *Neural Networks and Fuzzy Systems.* Prentice Hall of India Pvt. Ltd, New Delhi.
- Rao V and Rao H. 1996. *C++ Neural Networks and Fuzzy Logic*. BPB Publications, New Delhi.
- Lee K.H. 2005. *First Course on Fuzzy Theory and Applications*. Springer.

**I. Course Title : Soft Computing Techniques in Engineering**
**II. Course Code : CSE 504**
**III. Credit Hours : 2+1**

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**IV. Aim of the course**

To learn the basic concepts of soft computing techniques like neural networks, genetic algorithms and fuzzy systems and apply these techniques for real time problem solving.

**V. Theory**

**Unit I**

Introduction to control techniques, need of intelligent control. Architecture for intelligent control. Symbolic reasoning system, rule based systems, the artificial intelligence approach. Knowledge representation and expert systems. Data pre- processing: Scaling, Fourier transformation, principle component analysis and wavelet transformations.

**Unit II**

Concept of artificial neural networks (ANN) and basic mathematical model, network structures, activation function, back propagation, network size and pruning McCulloch-Pitts neuron model, simple perceptron, adaline and madaline neural networks, feed-forward multi-layer perceptron. Learning and training the neural network. Networks: Hopfield network, self-organizing network and recurrent network. Neural network based controller. Case studies: Identification and control of linear and nonlinear dynamic systems.

**Unit III**

Genetic algorithm (GA): Basic concept and detail algorithmic steps, adjustment of free parameters. Solution of typical control problems using GA. Concept of other search techniques like tabu search and ant-colony search for solving optimization problems.

**Unit IV**

Introduction to crisp sets and fuzzy sets, basic fuzzy set operation and approximate reasoning. Introduction to Fuzzy logic modelling and control of a system. Fuzzification, inference and defuzzification. Fuzzy knowledge and rule bases.

**Unit V**

Fuzzy modeling and control schemes for nonlinear systems. Self-organizing fuzzy logic control. Implementation of fuzzy logic controller. Stability analysis of fuzzy control systems. Intelligent control for SISO/MIMO nonlinear systems. Model based multivariable fuzzy controller.

**VI. Practical**

To work on data transformations, brief review on statistical criteria for termination of epochs, deciding the input output and hidden layers and neutrons for ANN problems, working on different algorithms of ANN to different problems in agricultural engineering, working with different fuzzy relations, propositions, implications and inferences, working with defuzzification techniques and fuzzy logic controllers, concept of coding, selection, crossover, mutation and application of genetic programming for global optimization, use of available software for application of soft computing techniques.

**VII. Learning outcome**

To enable students to apply modern engineering techniques which are useful for solving nonlinear and complex functions and to develop application of different soft computing techniques like genetic algorithms, fuzzy logic, neural networks and their combination to real world problems.

**VIII. Teaching Schedule**

| S.No. | Topic | No. of Lectures |
|---|---|---|
| 1. | Introduction to control techniques, need of intelligent control. Architecture for intelligent control. | 3 |
| 2. | Symbolic reasoning system, rule based systems, the artificial intelligence approach. | 3 |
| 3. | Knowledge representation and expert systems. | 2 |
| 4. | Data pre-processing: Scaling, Fourier transformation, principle component analysis and wavelet transformations. | 2 |
| 5. | Concept of artificial neural networks (ANN) and basic mathematical model, network structures, activation function, back propagation, network size and pruning McCulloch-Pitts neuron model | 3 |
| 6. | Simple perceptron, adaline and madaline neural networks, feed-forward multi-layer perceptron. Learning and training the neural network. | 3 |
| 7. | Networks: Hopfield network, self-organizing network and recurrent network. Neural network based controller. Case studies: Identification and control of linear and nonlinear dynamic systems | 3 |
| 8. | Genetic algorithm (GA): Basic concept and detail algorithmic steps, adjustment of free parameters. Solution of typical control problems using GA. | 3 |
| 9. | Concept of other search techniques like tabu search and ant-colony search for solving optimization problems. | 2 |
| 10. | Introduction to crisp sets and fuzzy sets, basic fuzzy set operation and approximate reasoning. | 2 |
| 11. | Introduction to Fuzzy logic modelling and control of a system. Fuzzification, inference and defuzzification. | 2 |
| 12. | Fuzzy knowledge and rule bases. | 2 |
| 13. | Fuzzy modeling and control schemes for nonlinear systems. Self-organizing fuzzy logic control. | 2 |
| 14. | Implementation of fuzzy logic controller. Stability analysis of fuzzy control systems. | 2 |
| 15. | Intelligent control for SISO/MIMO nonlinear systems. Model based multivariable fuzzy controller. | 2 |
| | **Total** | **36** |

## IX. List of Practicals

| S.No. | Topic | No. of Practicals |
|---|---|---|
| 1. | To work on data transformations, brief review on statistical criteria for termination of epochs, deciding the input output and hidden layers and neutrons for ANN problems, | 3 |
| 2. | Working on different algorithms of ANN to different problems in agricultural engineering, working with different fuzzy relations, | 2 |
| 3. | propositions, implications and inferences, working with defuzzification techniques and fuzzy logic controllers, concept of coding, | 3 |
| 4. | Selection, crossover, mutation and application of genetic programming for global optimization, use of available software for application of soft computing techniques. | 4 |
| | **Total** | **12** |

## X. Suggested Reading


- David EG. *Genetic Algorithms*.
- Rajasekaran S and Vijayalakshmi Pai GA. 2017.*Neural Networks, Fuzzy Logic and Genetic Algorithm, Synthesis and Applications*. PHI Learning Pvt. Ltd.
- Ross TJ. 1997. *Fuzzy Logic with Fuzzy Applications*. McGraw Hill Inc.
- Simon H. 2003. *Neural Networks: A Comprehensive Foundation*. Pearson Edition.
- Sivanandam SN and Deepa SN. 2011. *Principles of Soft Computing*. Wiley India Pvt. Ltd., 2nd Edition.
- Sivanandam SN and Deepa SN. 2013. *Principles of Soft Computing*. Wiley India.
- Kale MU and Supe MS. 2018. Introductory Hydroinformatics. New India Publicashing Agency, New Delhi.

**I. Course Title : Digital Image Processing**

**II. Course Code : CSE 506**

**III. Credit Hours : 2+1**

**IV. Aim of the course**

To give an overview of digital image processing including visual perception, image formation, spatial transformations, image enhancement, color image representation and processing, edge detection, image segmentation and morphological image processing.

**V. Theory**

**Unit I**

Digital image fundamentals, elements of visual perception, light and the electromagnetic spectrum, image sensing and acquisition, image sampling and quantization, basic relationships between pixels, linear and nonlinear operations.

**Unit II**

Image enhancement in the spatial domain, basic gray level transformations, histogram processing, basics of spatial filtering, smoothing spatial filters, sharpening spatial filters.

**Unit III**

Color image processing, color fundamentals, color models, pseudo color image processing, basics of full-color image processing, color transformations, smoothing and sharpening, color segmentation.

**Unit IV**

Image segmentation, detection of discontinuities, edge linking and boundary detection, thresholding, region-based segmentation, segmentation by morphological watersheds.

**Unit V**

Morphological image processing, dilation and erosion, opening and closing, extensions to gray-scale images.

**VI. Practical**

To write program to read and display digital image, image processing program using point processing method, program for image arithmetic operations, program for image logical operations, program for histogram calculation and equalization, program for geometric transformation of image, understand various image noise models and to write programs for image restoration and to remove noise using spatial filters. Brief outline of image processing tools.

**VII. Learning outcome**

This course introduces digital image processing. It focuses on the theory and algorithms underlying a range of tasks including acquisition, formation, enhancement, segmentation and representation.

**VIII. Teaching Schedule**

| S.No. | Topic | No. of Lectures |
|---|---|---|
| 1. | Introduction and Fundamentals, Motivation and Perspective, Applications, Components of Image Processing System, | 3 |

| | | |
|---|---|---|
| 2. | Element of Visual Perception, A Simple Image Model | 1 |
| 3. | Sampling and Quantization. | 2 |
| 4. | Light and the electromagnetic spectrum, image sensing and acquisition | 2 |
| 5. | Basic relationships between pixels, linear and nonlinear operations | 2 |
| 6. | Image Enhancement in Spatial Domain | 2 |
| 7. | Introduction; Basic Gray Level Functions | 2 |
| 8. | Histogram Specification | 2 |
| 9. | Basics of spatial filtering, smoothing spatial filters, sharpening spatial filters | 2 |
| 10. | Color image processing, color fundamentals | 1 |
| 11. | Color models, pseudo color image processing | 1 |
| 12. | Color transformations, smoothing and sharpening, color segmentation. | 2 |
| 13. | Image segmentation, detection of discontinuities | 1 |
| 14. | Edge linking and boundary detection, thresholding, region-based segmentation | 2 |
| 15. | Segmentation by morphological watersheds | 1 |
| 16. | Morphological image processing, dilation and erosion | 2 |
| 17. | Opening and closing, extensions to gray-scale images | 2 |
| | **Total** | **30** |

**IX. List of Practical**

| S.No. | Topic | No. of Practicals |
|---|---|---|
| 1. | Display digital image, image processing program using point processing method, program for image arithmetic operations | 3 |
| 2. | Program for image arithmetic operations, image logical operations, histogram calculation and equalization | 4 |
| 3. | Program for geometric transformation of image, understand various image noise models | 4 |
| 4. | Programs for image restoration and to remove noise using spatial filters | 4 |
| 5. | Brief outline of image processing tools | 1 |
| | **Total** | **16** |

**X. Suggested Reading**


- Jayaraman S, Esakkirajan S and Veerakumar T. *Digital Image Processing*. Tata McGraw Hill Publication.
- Rafael CG and Richard EW. *Digital Image Processing*. Third Edition, Pearson Education.
- Sridhar S. *Digital Image Processing*. Oxford University Press.

**I. Course Title : Dimensional Analysis and Similitude**

**II. Course Code : CE 501**

**III. Credit Hours : 2+0**

**IV. Aim of the course**

To acquaint the students with importance of analysis of dimensions and similitude principles in structuring mathematical/simulation models of various processes under different constraint variables.

**V. Theory**

**Unit I**

Introduction, Dimensions, Dimensional homogeneity, Non-dimensional parameter, Methods of dimensional analysis: Rayleigh's method, Buckingham-Pi theorem, Choice of variables, Model analysis, Examples on various applications, Dimensional analysis and Intermediate Asymptotic.

**Unit II**

Model studies, Model classification, Dimensionless numbers: Reynolds model, Froude's model, Euler's Model, Webber's model, Mach model, Scale effects, Distorted models, Model laws.

**Unit III**

Similitude: Types of similarities (geometric-kinematic and dynamic similarity), force ratios, similarity laws. Model analysis: Physical models. Similarity methods for nonlinear problem types of models, Scale effect. Numerical problems on Reynolds'sand Froude's Model.

**Unit IV**

Use and scope of mathematical modeling, Principles of model formulation, Role and importance of steady-state and dynamic simulation, Classification of models, Model building, Modeling difficulties, Degree-of-freedom analysis, Selection of design variables.

**VI. Learning outcome**

The students will be able to analyze complex problems using dimensional analysis and to develop rules for experiments with scale models and provide basis for analyses and calculations, including simplifications and assumptions made, whenformulating mathematical models.

**VII. Teaching Schedule**

| S.No. | Topic | No. of Lectures |
|---|---|---|
| 1. | Introduction, Dimensions, Dimensional homogeneity, Non-dimensional parameter | 2 |
| 2. | Methods of dimensional analysis: Rayleigh's method, Buckingham- Pi theorem, Choice of variables | 3 |
| 3. | Model analysis, Examples on various applications, Dimensional analysis and Intermediate Asymptotic | 2 |
| 4. | Model studies, Model classification, Dimensionless numbers: Reynolds model | 3 |
| 5. | Froude's model, Euler's Model, Webber's model, Mach model, Scale effects | 3 |

| | | |
|---|---|---|
| 6. | Distorted models, Model laws. | 2 |
| 7. | Similitude: Types of similarities (geometric-kinematic and dynamic similarity), force ratios, similarity laws | 3 |
| 8. | Model analysis: Physical models. Similarity methods for nonlinear problem types of models, Scale effect | 3 |
| 9. | Numerical problems on Reynolds's and Froude's Model | 3 |
| 10. | Use and scope of mathematical modeling, Principles of model formulation | 2 |
| 11. | Role and importance of steady-state and dynamic simulation | 2 |
| 12. | Classification of models, Model building, Modeling difficulties | 2 |
| 13. | Degree-of-freedom analysis, Selection of design variables | 2 |
| | **Total** | **32** |

## VIII. Suggested Reading


- Barenblatt GI. 1987. *Dimensional Analysis*. Gordon and Breach Science, New York.
- Langhar HL. 1951. *Dimensional Analysis and the Theory of Models*. Wiley, New York.
- Murphy G. 1950. *Similitude in Engineering*. The Ronald Press Company, New York.
- Zohuri Bahman. *Dimensional Analysis and Self-Similarity Methods for Engineers and Scientists*. Springer Publications, New York.

**I. Course Title : Water Quality and Pollution Control**

**II. Course Code : CE 502**

**III. Credit Hours : 2+1**

**IV. Aim of the course**

To acquire in-depth knowledge of water quality parameters, water quality standards,source of water pollution and multiple use of water.

**V. Theory**

**Unit I**

Physical and chemical properties of water, suspended and dissolved solids, EC and pH, major ions. Water quality (Physical, Chemical and Bacteriological) investigation, Sampling design, Samplers and automatic samplers. Data collection platforms, Field kits, Water quality data storage, analysis and inference, Software packages. Water quality indices. Water quality for irrigation. Salinity and permeability problem, saline water irrigation root zone salinity, interaction of irrigation and drainage.

**Unit II**

Sources and types of pollution, organic and inorganic pollutants. BOD–DO relationships, impacts on water resources. NPS pollution and its control, Eutrophication control. Water treatment technologies, Constructed wetlands.

**Unit III**

Multiple uses of water. Reuse of water in agriculture. Low cost waste water treatment technologies Economic and social dimensions. Packaged treatment units, soil-based water treatment methods, reverse osmosis and desalination in water reclamation.

**Unit IV**

Principles of water quality, water quality classification, water quality standards, water quality indices, TMDL Concepts. Water quality models. Soil crop and other practices for use of poor quality water.

**VI. Practical**

Determination of pH, total solids, dissolved and suspended solids, chlorides, sulphates, turbidity, dissolved oxygen, hardness. Preparation of water quality map of watershed in GIS environment. Visit of water polluted site of nearby area.

**VII. Learning outcome**

The students will be able to understand water quality standards which are quite important for drinking and irrigation purposes. They will also be exposed to source and type of pollution along with multiple uses of water.

**VIII. Teaching Schedule**

| S.No. | Topic | No. of Lectures |
|---|---|---|
| 1. | Physical and chemical properties of water, suspended and dissolved solids, EC and pH, major ions. Water quality (Physical, Chemical and Bacteriological) investigation | 3 |
| 2. | Sampling design, Samplers and automatic samplers. Data collection platforms, Field kits, Water quality data storage, analysis and inference | 3 |

| | | |
|---|---|---|
| 3. | Software packages. Water quality indices. Water quality for irrigation | 2 |
| 4. | Salinity and permeability problem, saline water irrigation root zone salinity, interaction of irrigation and drainage | 3 |
| 5. | Sources and types of pollution, organic and inorganic pollutants. BOD–DO relationships, impacts on water resources | 3 |
| 6. | NPS pollution and its control, Eutrophication control. Water treatment technologies, Constructed wetlands | 3 |
| 7. | Multiple uses of water. Reuse of water in agriculture. Low cost waste water treatment technologies | 3 |
| 8. | Economic and social dimensions. Packaged treatment units, soil-based water treatment methods, reverse osmosis and desalination in water reclamation | 3 |
| 9. | Principles of water quality, water quality classification | 3 |
| 10. | water quality standards, water quality indices | 2 |
| 11. | TMDL Concepts. Water quality models | 2 |
| 12. | Soil crop and other practices for use of poor quality water | 2 |
| | **Total** | **32** |

## IX. List of Practicals

| S.No. | Topic | No. of Practicals |
|---|---|---|
| 1. | Determination of pH, total solids, dissolved and suspended solids | 4 |
| 2. | Determination of chlorides, sulphates, turbidity | 3 |
| 3. | dissolved oxygen, hardness | 4 |
| 4. | Preparation of water quality map of watershed in GIS environment | 4 |
| 5. | Visit of water polluted site of nearby area | 1 |
| | **Total** | **16** |

## X. Suggested Reading


- Abbasi T and Abbasi SA. *Water Quality Indices*. Elsevier Publications, New York.
- Chin and David A. 2006. *Water Quality Engineering in Natural Systems*. Wiley – Interscience.
- Claude E. Boyd. *Water Quality an Introduction*. Springer Publications.
- Eaton AD, Clesceri LS, Rice EW and Greenburg AE (eds). 2005. *Standard Methods for the Examination of Water and Wastewater*. 21st edn. American Public Health Association, Washington, DC.
- Thomann RV and Mueller JA. 1987. *Principles of Surface Water Quality Modelling and Control*. Harper and Row Publishers.
- Wesley W, Wallender PE and Kenneth K. Tanji, Sc.D. *Agricultural Salinity Assessment and Management*. ASCE Press.

**I. Course Title : Experimental Stress Analysis**

**II. Course Code : CE 510**

**III. Credit Hours : 2+1**

**IV. Aim of the course**

To acquaint the students with importance of analysis of stress, analysis of strain, stress-strain relationship under different constraint conditions in 2-D plane as well as 3-D plane.

**V. Theory**

**Unit I**

Strain and stress – strain relationship. Generalized Hook's Law. Strain Gauges- Mechanical, optical, electrical, acoustical and pneumatic etc and their use.

**Unit II**

Different types of electrical resistance strain gauges. Semi-conductor strain gauges. Rosette analysis. Strain gauge circuits. Strain measurements at high temperatures.

**Unit III**

Two dimensional and three dimensional photo-elastic method of strain analysis. Bifringent coatings and scattered light in photo-elasticity.

**Unit IV**

Brittle coating methods. Moiré's method of strain analysis. Grid method of strain analysis. Photo elastic strain gauges.

**VI. Learning outcome**

The students will be able to analyze stress, strain and their interrelationships when they are subjected to different end conditions in two dimensional and three dimensional planes and provide basis for analyses and calculations, including simplifications and assumptions made, when formulating for stress and strain.

**VII.** Teaching **Schedule**

| S.No. | Topic | No. of Lectures |
|---|---|---|
| 1. | Strain and stress – strain relationship. Generalized Hook's Law | 3 |
| 2. | Strain Gauges- Mechanical, optical, electrical, acoustical and pneumatic etc. | 3 |
| 3. | Use of different strain gauges. Types of electrical strain gauges. | 3 |
| 4. | Semi-conductor gauges. Rosette analysis. Strain gauge circuits. | 2 |
| 5. | Strain measurements at high temperatures. | 2 |
| 6. | Two dimensional photo-elastic method of strain analysis. | 3 |
| 7. | Three dimensional photo-elastic method of strain analysis. | 3 |
| 8. | Bifringent coatings and scattered light in photo-elasticity. | 3 |
| 9. | Brittle coating methods | 3 |

| | | |
|---|---|---|
| 10. | Moir's method of strain analysis. | 2 |
| 11. | Grid method of strain analysis. Photo elastic strain gauges. | 2 |
| | **Total** | **32** |

## VIII. List of Practicals

| S.No. | Topic | No. of Practicals |
|---|---|---|
| 1. | Cementing of an electrical resistance strain gage on a Structural member | 1 |
| 2. | To find the gage factor for a resistance type strain gage. | 1 |
| 3. | To measure strain at centre of bream when loaded at greater points by making use of two strain gages one at top surface and 2nd at bottom both along longitudinal direction and fixing both in first and second arm of the bridge. | 3 |
| 4. | To measure the modulus of elasticity of the beam making use of fourstrain gages, two on top and two on bottom, one on longitudinal and one in transversal direction on each face of the beam. | 3 |
| 5. | Deter mine the tension produced in a circular shaft by using strain gages cemented perpendicular to each other. | 1 |
| 6. | Determine the bending moment produced in a circular shaft by using a rectangular shaft. | 1 |
| 7. | To align the circular polariscope. | 1 |
| 8. | Study the plane polariscope and circular polariscope with different light field arrangements. | 1 |
| 9. | Study of Moiré fringe apparatus and its applications in analysis of structures. | 2 |
| 10. | Calibrate the photoelastic material by use of rectangular beam under pure bending. | 2 |
| | **Total** | **16** |

## IX. Suggested Reading


- Srinath LS, Raghavan MR, Lingaiah K, Gargesha G, Pant B and Ramachandra K.Experimental Stress Analysis, McGraw-Hill.
- Dally JW and Riley WF. *Experimental Stress Analysis*, McGraw-Hill.
- Singh S. *Experimental Stress Analysis*, Khanna Publishers.

**I. Course Title : Mechatronics and Robotics in Agriculture**

**II. Course Code : ME 501**

**III. Credit Hours : 2+0**

**IV. Aim of the course**

To introduce the fundamentals of mechatronics and the concepts behind designing mechatronic systems and their subsystems and its application in automation in agriculture.

**V. Theory**

**Unit I**

Introduction to mechatronics: Basic definitions, key elements of mechatronics, historical perspective, the development of the automobile as a mechatronic system. Mechatronic design approach, functions of mechatronic systems, ways of integration, information processing systems, concurrent design procedure for mechatronic systems.

**Unit II**

System interfacing, instrumentation, and control systems.Input/output signals of a mechatronic system, signal conditioning, microprocessor control, microprocessor numerical control, microprocessor input/output control.

**Unit III**

Microprocessor based controllers and microelectronics: Introduction to microelectronics, digital logic, overview of control computers, microprocessors and microcontrollers, programmable logic controllers, digital communications.

**Unit IV**

Technologies of robot: Sub systems, transmission system (Mechanics), power generation and storage system, sensors, electronics, algorithms and software. Servo motor drives types and applications. Stepper motor and its concept. Industrial robots: Classification and sub systems. Defining work space area.

**Unit V**

Application of robots in agriculture: Harvesting and picking, weed control, autonomous mowing, pruning, seeding, spraying and thinning, phenotyping, sorting and packing. Utility platforms. Use of different agrobots in agriculture.

**VI. Learning outcome**

Ability to understand agricultural machinery that is built on concepts of mechatronics and ability to use robotic machinery in agriculture.

**VII.** Teaching **Schedule**

| S.No. | Topic | No. of Lectures |
|---|---|---|
| 1. | Introduction to Mechatronics: Basic definitions, key elements of mechatronics, | 2 |

| | | |
|---|---|---|
| 2. | Historical perspective, the development of the automobile as a mechatronic system | 1 |
| 3. | Mechatronic design approach, functions of mechatronic systems, ways of integration, information processing systems, concurrent design procedure for mechatronic systems. | 3 |
| 4. | System interfacing, Instrumentation, and control systems | 2 |
| 5. | Input/output signals of a mechatronic system, signal conditioning | 2 |
| 6. | Microprocessor control, microprocessor numerical control, microprocessor input/output control | 2 |
| 7. | Microprocessor based controllers and microelectronics | 2 |
| 8. | Introduction to microelectronics, digital logic, overview of control computers | 2 |
| 9. | Microprocessors and microcontrollers, programmable logic controllers, digital communications. | 3 |
| 10. | Technologies of robot: Sub systems, transmission system (Mechanics), power generation and storage system | 2 |
| 11. | sensors, electronics, algorithms and software. Servo motor drives types and applications | 2 |
| 12. | Stepper motor and its concept. Industrial robots: Classification and sub systems. Defining work space area. | 2 |
| 13. | Application of robots in agriculture: Harvesting and picking, weed control | 2 |
| 14. | autonomous mowing, pruning, seeding, spraying and thinning | 2 |
| 15. | phenotyping, sorting and packing. Utility platforms. Use of different agrobots in agriculture. | 3 |
| | **Total** | **32** |

**VIII. Suggested Reading**


- Alciatore DG and Histand MB. 2002. *Introduction to Mechatronics and Measurement System*. McGraw Hill Pvt Limited, New Delhi.
- Robert HB. 2002. *Mechatronic Hand Book*. CRC Press.
- Shakhatreh and Fareed. 2011. *The Basics of Robotics*. Lahti University of Applied Sciences Machine and Production Technology.

**I. Course Title : Refrigeration Systems**

**II. Course Code : ME 502**

**III. Credit Hours : 2+1**

**IV. Aim of the course**

To acquire the skills required to model, analyse and design different refrigeration processes and components.

**V. Theory**

**Unit I**

Reversed Carnot cycle, Carnot, Brayton and aircraft refrigeration systems.

**Unit II**

Vapour compression refrigeration systems: Use of p-h chart, effect of pressure changes on COP, sub cooling of condensate on COP and capacity, super heating, single stage, multi-stage and cascade systems.

**Unit III**

Vapour absorption systems: Theory of mixtures, temperature-concentration and enthalpy concentration diagrams, adiabatic mixing of two systems, diabatic mixing, throttling process, ammonia water and water lithium-bromide systems.

**Unit IV**

Thermoelectric refrigeration systems: Advantages, comparison with vapour compression system. Vortex tube refrigeration system and its thermodynamic analysis. Ultra low temperature refrigeration. Ejection refrigeration. Water refrigeration: Centrifugal and steam jet refrigeration systems, characteristics of steam jet refrigeration system, effect of boiler efficiency on overall COP, actual steam jet system, two-fluid jet refrigeration.

**VI. Practical**

Numerical on air refrigeration cycle, Study of vapour compression refrigeration systems, Determination of the coefficient of performance of the refrigeration system, Study of vapour absorption (electrolux) refrigeration systems, Study and application of P-V, T-s and P-h chart in refrigeration, Study and performance testing of domestic refrigerator, Study of domestic water cooler, Study of actual and theoretical COP of Cascade Refrigeration System, Visit to cold storage plants.

**VII. Learning outcome**

After studying this course, students shall be able to analyse air and vapour compression refrigeration cycle, and perform thermodynamic analysis of absorption, steam jet, thermoelectric and vortex tube refrigeration systems.

**VIII. Teaching Schedule**

| S.No. | Topic | No. of Lectures |
|---|---|---|
| 1. | Reversed Carnot cycle, Carnot cycle | 2 |
| 2. | Brayton refrigeration systems | 2 |
| 3. | Aircraft refrigeration systems | 4 |
| 4. | Vapour compression refrigeration systems, Single stage vapour compression refrigeration, Use of p-h chart | 3 |
| 5. | Effect of pressure changes on COP, sub cooling of | |

| | | |
|---|---|---|
| | condensate on COP and capacity, super heating | 2 |
| 6. | Multi-stage vapour compression refrigeration systems | 3 |
| 7. | Cascade vapour compression refrigeration systems | 2 |
| 8. | Vapour absorption systems: Theory of mixtures, temperature- concentration and enthalpy concentration diagrams, adiabatic mixing of two systems, diabatic mixing, throttling process, | 3 |
| 9. | Ammonia water vapour absorption systems. | 1 |
| 10. | Water lithium-bromide vapour absorption systems. | 1 |
| 11. | Thermoelectric refrigeration systems: Advantages, comparison with vapour compression system. | 1 |
| 12. | Vortex tube refrigeration system and its thermodynamic analysis. | 1 |
| 13. | Ultra low temperature refrigeration. | 3 |
| 14. | Water refrigeration, Centrifugal refrigeration | 1 |
| 15. | Ejection refrigeration, Steam jet refrigeration systems, characteristics of steam jet refrigeration system, effect of boiler efficiency on overall COP, actual steam jet system, two-fluid jet refrigeration. | 3 |
| | **Total** | **32** |

## IX. List of Practicals

| S.No. | Topic | No. of Practicals |
|---|---|---|
| 1. | Numerical on air refrigeration cycle | 2 |
| 2. | Study of vapour compression refrigeration systems | 1 |
| 3. | Determination of the coefficient of performance of the refrigeration system | 1 |
| 4. | Study of vapour absorption (electrolux) refrigeration systems | 2 |
| 5. | Study and application of P-V, T-s and P-h chart in refrigeration | 3 |
| 6. | Study and performance testing of domestic refrigerator, | 2 |
| 7. | Study of domestic water cooler | 1 |
| 8. | Study of actual and theoretical COP of Cascade Refrigeration System | 2 |
| 9. | Visit to cold storage plants. | 2 |
| | **Total** | **16** |

## X. Suggested Reading


- Ahmadul A. *Refrigeration and Air Conditioning*. PHI India.
- Arora CP. *Refrigeration and Air Conditioning*. McGraw-Hill India Publishing Ltd.
- Arora R. *Refrigeration and Air Conditioning*. Prentice Hall of India.

- Crouse and Anglin. *Automobile Air Conditioning*. McGraw Hill Publications.
- Dossat RJ. *Principles of Refrigeration*. Pearson Education.
- Jordon and Prister. *Refrigeration and Air Conditioning*. Prentice Hall of India Pvt. Ltd.
- Prasad M. *Refrigeration and Air Conditioning*. New Age International Publisher.
- Stocker WF and Jones JW. *Refrigeration and Air Conditioning*. McGraw-Hill.

**I. Course Title : Mechanism Analysis and Synthesis**

**II. Course Code : ME 503**

**III. Credit Hours : 2+1**

**IV. Aim of the course**

The objective of the course is to understand the analysis and synthesis of mechanisms and to learn the graphical and analytical techniques commonly usedin the synthesis of mechanisms.

**V. Theory**

**Unit I**

Kinematics of mechanisms, analysis and synthesis, mobility, systematic of mechanisms, deriving other mechanisms from linkages, Relative motion, instantaneous center method, Kennedy's theorem. Graphical and analytical methodsof kinematic analysis.

**Unit II**

Computer - Aided analysis of mechanisms. Synthesis of linkages for path generation, function generation, Graphical techniques. Relative pole method and method of inversion. Analytical kinematics synthesis of linkages, Freudenstein's method, Loop closure equations based on complex variable approach,

**Unit III**

Gears and their motion-Analysis and Synthesis of epicyclic gear trains.

**Unit IV**

Cams-follower system; standard follower motions and combinations, importance of follower acceleration in cam system dynamics, terms related to cam design - their importance. Cam synthesis - graphical cam profile layout for a desired follower motion. Analytical determination of cam profile co-ordinates for disc cam operating common types of follower.

**VI. Practical**

Graphical solutions of mechanisms relating to velocity and acceleration. Problems on computer-aided analysis and synthesis of mechanisms. Analysis and design problems of gear trains, cam profile design.

**VII. Learning outcome**

The Student will be able to design mechanisms for better accuracy and productivity. The student will Get familiar with design process of the mechanisms for functional requirements.

**VIII. Teaching Schedule**

| S.No. | Topics | No. of Lectures |
|---|---|---|
| 1. | Introduction & basic concepts. | 2 |
| 2. | Kinematics of mechanisms, analysis and synthesis, mobility, systematic of mechanisms, deriving other mechanisms from linkages | 3 |
| 3. | Determination of velocity and acceleration using graphical method andanalytical methods (relative velocity and | |

| | | |
|---|---|---|
| | acceleration, instantaneous centers), Kennedy's theorem. Graphical and analytical methods of kinematic analysis | 4 |
| 4. | Computer - Aided analysis of mechanisms. Synthesis of linkages for path generation, function generation, Graphical techniques. Relative pole method and method of inversion | 3 |
| 5. | Analytical kinematics synthesis of linkages, Freudenstein's method, Loop closure equations based on complex variable approach | 5 |
| 6. | Introduction to spur, helical, spiral, bevel and worm gears, law of gearing, nomenclature, velocity of sliding between two teeth in mesh. | 3 |
| 7. | Gears and their motion-Analysis and Synthesis of epicyclic gear trains | 4 |
| 8. | Cams-follower system; standard follower motions and combinations, importance of follower acceleration in cam system dynamics, terms related to cam design | 4 |
| 9. | Cam synthesis - graphical cam profile layout for a desired follower motion. Analytical determination of cam profile co-ordinates for disc cam operating common types of follower. | 4 |
| | **Total** | **32** |

**IX. List of Practicals**

| S.No. | Topic | No. of Practicals |
|---|---|---|
| 1. | Graphical solutions of mechanisms relating to velocity and acceleration (4 different mechanisms to be studied) | 4 |
| 2. | Problems on computer-aided analysis and synthesis of mechanisms | 4 |
| 3. | Analysis and design problems of gear trains | 5 |
| 4. | Cam profile design | 3 |
| | **Total** | **16** |

**X. Suggested Reading**


- Erdman A, Sandor G and Kota S. 2001. *Mechanism Design: Analysis and Synthesis* Pearson India Pvt Ltd, New Delhi.
- Sandor GI, Erdman AG. 1984. *Advanced Mechanism Design: Analysis and Synthesis*Pearson. Facsimile edition.
- Ballaney PL. 2003. *Theory of Machines*. - Khanna Publishers, New Delhi.
- Rattan. SS. 2014. *Theory of Machines*, McGraw Hill Pvt Ltd, New Delhi.
- Khurmi RS and Gupta 2020. *Theory of Machines*. Eurasia Publishing House (P) Ltd, New Delhi.

**I. Course Title : Vibrations**

**II. Course Code : ME 504**

**III. Credit Hours : 3+0**

**IV. Aim of the course**

To enable the students to design vibration control sytem,and balancing of rotating and reciprocating masses.

**V. Theory**

**Unit I**

Vibration motion and its terminology. Undamped free vibrations, equations of motion- natural frequency. Energy method, Rayleigh method; effective mass principle of Virtual work. Equivalent spring stiffness in parallel and in series. Harmonic analysis and Fourier Series

**Unit II**

Damping - viscous, solid, coulomb equivalent dampers. Viscosity damped free vibrations, Logarithmic decrement. Forced vibrations with harmonic excitation and rotating unbalance. Energy dissipated by damping

**Unit III**

Forced vibration with damping, Vibration isolation and force and motion transmissibility. Two degree of freedom systems. Principal modes of vibration, co- ordinate coupling. Vibration absorbers

**Unit IV**

Free vibration equation of motion for multi-degree of freedom systems. Influence coefficients and Maxwell's reciprocal theorem, stiffness coefficients. Numerical methods for finding natural frequencies for multi-degree of freedom systems.

**Unit V**

Vibration of lumped parameter systems and continuous systems. Lagrange equations. Vibration measuring instruments, Vibrometers, velocity pickups, Accelerometer and frequency measuring instruments. Applications of vibrations. Vibration control, balancing of rotating and reciprocating machines, design of vibration isolators.

**VI. Learning outcome**

The student will be able to understand the concept of vibrations, analyze the mathematical modeling of the multidegree freedom systems and able to design vibration isolators.

**VII. Teaching Schedule**

| S.No. | Topic | No. of Lectures |
|---|---|---|
| 1. | Vibration motion and its terminology. | 2 |
| 2. | Undamped free vibrations, equations of motion- natural frequency. | 2 |
| 3. | Energy method, Rayleigh method; effective mass principle of Virtual work. | 2 |
| 4. | Equivalent spring stiffness in parallel and in series. | 1 |
| 5. | Harmonic analysis and Fourier Series. | 2 |
| 6. | Damping - viscous, solid, coulomb equivalent dampers. | 3 |

| | | |
|---|---|---|
| 7. | Viscosity damped free vibrations, Logarithmic decrement | 3 |
| 8. | Forced vibrations with harmonic excitation and rotating unbalance | 2 |
| 9. | Energy dissipated by damping. Forced vibration with damping, | 3 |
| 10. | Vibration isolation and force and motion transmissibility. | 2 |
| 11. | Two degree of freedom systems. Principal modes of vibration co-ordinate coupling | 3 |
| 12. | Vibration absorbers, | 2 |
| 13. | Free vibration equation of motion for multi-degree of freedom systems. | 2 |
| 14. | Influence coefficients and Maxwell's reciprocal theorem, stiffness coefficients. | 3 |
| 15. | Numerical methods for finding natural frequencies for multi-degree of freedom systems. | 3 |
| 16. | Vibration of lumped parameter systems and continuous systems. | 3 |
| 17. | Lagrange equations. Vibration measuring instruments, Vibrometers, velocity pickups | 3 |
| 18. | Accelerometer and frequency measuring instruments. | 2 |
| 19. | Applications of vibrations. Vibration control, balancing of rotating and reciprocating machines | 3 |
| 20. | Design of vibration isolators. | 2 |
| | **Total** | **48** |

**VIII. Suggested Reading**


- V.P. Singh.2014. *Mechanical Vibrations*. Dhanpat Rai and Comopany, New Delhi
- Rao S S. 2010.*Mechanical Vibrations*. Pearson Education, Delhi
- Srinivas P.1983. *Mechanical Vibration Analysis*. Tata McGraw Hill Company
- Limited, New Delhi
- Daniel J Inman.2013. *Engineering Vibration*. Prentice Hall, New Jersey

**I. Course Title : Fatigue Design**

**II. Course Code : ME 507**

**III. Credit Hours : 2+1**

**IV. Aim of the course**

The course provides an understanding on fatigue design considerations of mechanical components. The causes of fatigue in brittle and ductile materials are taught with focus on crack initiation, propagation and fracture.

**V. Theory**

**Unit I**

Theories of failure, maximum normal stress, maximum shear stress and distortion energy theory, failure of ductile materials, failure of brittle materials.

**Unit II**

Stress concentration and its evaluation, stress concentration of ductile and brittle materials under static loading and under dynamic loading, determining geometric stress concentration factors, designing to avoid stress concentration.

**Unit III**

Fatigue of machine components, mechanism of fatigue failure, fatigue failure models and their considerations in design of machine elements, fatigue loads. Fatigue testing and presentation of fatigue data. Influence of stress conditions on fatigue strength/endurance limit of metals. Low and high cycle fatigue

**Unit IV**

Cumulative fatigue damage. Designing for finite and infinite life. Improving fatigue resistance of machine elements. Stress corrosion. Corrosion fatigue.

**VI. Practical**

Fatigue tests on testing machine(s) for specimens of different materials having different discontinuities/stress raisers and various surface conditions. Determination of correlation between fatigue limit and ultimate strength of material. Problems in fatigue design of common machine component.

**VII. Learning outcome**

The students is able to understand technical aspects and principles of fatigue design. The student can design the engineering product having good durability andlong fatigue life

**VIII. Teaching Schedule**

| S.No. | Topic | No. of Lectures |
|---|---|---|
| 1 | Introduction to cyclic loading and Fatigue Design | 1 |
| 2 | Types of Loads and Stresses, Different theories of Failure like maximum normal stress, maximum shear stress and distortion energy theory etc. | 3 |

| | | |
|---|---|---|
| 3 | Determining stress concentration based on geometric stress concentration factors, Design considerations to avoid stress concentration of ductile and brittle materials. | 3 |
| 4 | Mechanical failure. Macroscopic failure modes, Behavior of brittle and ductile materials in fatigue and stress concentration. Fracture in brittle and ductile materials, characteristics of fracture surfaces, inter-granular and intra-granular failure. | 4 |
| 5 | Cleavage and micro-ductility, growth of fatigue cracks, The ductile/brittle fracture transition, temperature for notched and unnotched components. Fracture at elevated temperature. | 3 |
| 6 | Fatigue of machine components, mechanism of fatigue failure. Low and high cycle with examples mean stress R ratio, strain and load control. S-N curves. | 4 |
| 7. | Goodman's rule and Miners rule. Micro-mechanisms of fatigue damage, fatigue limits and initiation and propagation control, leading to a consideration of factors enhancing fatigue resistance. | 3 |
| 8. | Fatigue loads and mathematical models. Fatigue testing and presentation of fatigue data, Influence of stress conditions on fatigue strength/endurance limit of metals. | 3 |
| 9. | Total life and damage tolerant approaches to life prediction. Fatigue failure models and their considerations in design of machine elements. Cumulative fatigue damage and Designing for finite and infinite life | 2 |
| 10. | Methods to improve fatigue resistance of machine elements. Improvement of fatigue strength by chemical/metallurgical processes such as nitriding, flame hardening, case carburizing. Fatigue strength enhancement by mechanical work, cold rolling, peening, shot peening. | 3 |
| 11. | Environmental Assisted Cracking: Stress corrosion cracking, Hydrogen embrittlement, Corrosion fatigue. Creep: Creep curves, Mechanisms of creep, Stress rapture test, Life prediction, High temperature alloys. | 3 |
| | **Total** | **32** |

## IX. List of Practicals

| S.No. | Topic | No. of Practicals |
|---|---|---|
| 1. | Load measurement using Load indicator, Load Cells | 1 |
| 2. | Strain measurement using Strain Gauge | 1 |
| 3. | Stress measurement using strain rosette | 1 |
| 4. | Determination of Fatigue strength measurement of S45C or alike material under same loading condition for different | |

| | | |
|---|---|---|
| | stress concentrations factors (like holes, notches, sharp corners for at least 5 different samples). Comparison to be listed. | 5 |
| 5. | Study to improvement Fatigue Design based on at least 5 different processes like flame hardening, case carburizing, nitriding, shot peening, peening etc or alike processes. | 5 |
| 6. | Determination of correlation between fatigue limit and ultimate strength of commercially available S45C material for three different samples | 3 |
| | **Total** | **16** |

**X. Suggested Reading**


- Lessells, J.M. 1955. *Strength and resistance of metals*. John Wiley & sons, Michigan.
- T.L. Anderson. 2005. *Fracture Mechanics Fundamentals and Applications*. CRC press, Boca Raton.
- Bhandari V.B.2019. *Design of Machine Elements*. Mcgraw Hill Education Pvt Ltd, New Delhi
- Peterson, R.E. 1953 *Stress Concentration Design Factors*. John Wiley & Sons, New York.
- Meguid, S.A.1989 Engineering *Fracture Mechanics*. John Wiley & Sons, New York
- Kare Hellan.1985. *Introduction to Fracture Mechanics*. Mc Graw Hill Book Co, New York.

**I. Course Title : Computer Aided Design**

**II. Course Code : ME 515**

**III. Credit Hours : 2+1**

**IV. Aim of the course**

The **course** provides an understanding on computer aided design. It provides in depth knowledge about 2-d drawing, 3-D Modeling and finite element analysis for optimum product design.

**V. Theory**

**Unit I**

Introduction to computer aided design, scope of computer aided machine design, design process and design environments. Geometric modeling and interactive graphic, engineering analysis, design review and automated drafting, modeling, viewing,

**Unit II**

3-D solid modeling, boundary representation, constructive solid geometry, feature based modeling. Computer aided analysis and synthesis of common mechanical components, a bar, a beam and a shaft, comparison with analytical results.

**Unit III**

Application of numerical methods and optimization techniques to machine design problems, Computer aided selection of standard mechanical components. Introduction to FEM. FEA using two dimensional and three dimensional elements; plain strain and plain stress problems, finite element mesh, automatic meshing techniques, limitations of FEM.

**VI. Practical**

Computer aided design problems for machine components, use of standard software, CAD models for other applications. Development of FEM models for analysis of a bar, beam and a shaft. Practice in using an FEM software on other real life problems like spanners, connecting rods.

**VII. Learning outcome**

The students can design a product having better accuracy, less errors, increased productivity and shorter lead times with the help of CAD.

**VIII. Teaching Schedule**

| S.No. | Topic | No. of Lectures |
|---|---|---|
| 1 | Introduction to Engineering Design, design steps and computer aided design. | 2 |
| 2 | Software and workstation selection for CAD. Design process with and without CAD | 3 |
| 3 | Input and output devices, Display devices; GKS, IGES and STEP; Modeling and viewing, Application areas of CAD. | 3 |
| 4 | Wireframe model, solid modeling, Boundary Representation (B-rep), Constructive Solid Geometry (CSG). | 3 |
| 5 | Mass, volumetric properties calculations; surface modeling, | |

| | | |
|---|---|---|
| | concepts of hidden-line removal and shading: Mechanical Assembly Kinematics analysis and simulation | 3 |
| 6 | Parametric Modeling Technique. Non-parametric and parametric representation of curves. | 2 |
| 7 | Parametric representation of Hermite Cubic, Beizer and B-spline curves; Surface and its analysis. Representation of Analytical and synthetic surfaces. | 2 |
| 8 | Numerical methods and optimization techniques to engineering design problems | 3 |
| 9 | Overview of FEM, Advantages and applications, recent advance in FEM, FEA software Basic principles and general procedure of FEM | 3 |
| 10 | Analyzing simple machine elements and comparing with analytical results of simple machine elements like bar, beam and a shaft. | 4 |
| 11 | Simple Project. Mathematical modelling and design calculations of machines. | 4 |
| | **Total** | **32** |

## IX. List of Practicals

| S.No. | Topic | No. of Practicals |
|---|---|---|
| 1. | Introduction to 2-D drawing. Use of any relevant software | 2 |
| 2. | Study of drawings in First angle and third angle projections | 1 |
| 3. | 2-D assembly drawing and generation of BOM | 1 |
| 4. | 3-D Modeling. GKS, IGES and STEP; Modeling and viewing. Use of relevant software | 3 |
| 5. | Assembly Design | 2 |
| 6. | Introduction to FEA software. Mesh generation (Nodes and elements). Use of any other relevant software for FEA | 3 |
| 7. | Practice on Boundary conditions like loads and constraints. | 2 |
| 8. | Study of static and dynamic loading conditions. Study of Machine elements like bars, beams and shafts or other machine elements. | 2 |
| | **Total** | **16** |

## X. Suggested Reading


a. Mikell P. Groover, Emory W. Zimmers.2000 *CAD/CAM Computer Aided Design and Manufacturing*, PHI,

b. Zeid Ibraham.1991. *CAD/CAM - Theory and Practice*, Tata McGraw Hill, New Delhi

c. Chandandeep Grewal & Kuldeep Sareen.2007. *CAD/CAM Theory and Concepts*. S.Chand, New Delhi

d. P.N Rao.2010. *CAD/CAM*. Tata McGraw Hill, New Delhi

**I. Course Title : Finite Element Methods**

**II. Course Code : MATH 501**

**III. Credit Hours : 2+1**

**IV. Theory**

**Unit I**

Introduction. Historical background, Stress equilibrium, boundary condition,stress strain relation, potential energy and equilibrium. Rayleigh-Ritz method. Galerkin method.

**Unit II**

coordinates and shape functions, potential energy approach,element stiffness matrix,Galerkin approach, assembly of global stiffness matrix. The finite element equation, boundary conditions.

**Unit III**

Trusses: Two dimensional problems, modeling by constant strain triangle, twodimensional iso-parametric elements, the four-node quadrilateral.

**Unit IV**

Scalar field problems, steady state heat transfer, torsion, potential flow, seepageand fluid flow index, dynamic analysis, principles.

**V. Practical**

Use of simple FEM software for FEM software for understanding, principles of FEM. Working out simple problems using LISA or any simple software with understanding of operation. Solving one dimensional problem. Solution to planar and spatial trusses, solving simple two-dimensional problems, Axisymmetric problems, solution of problems with two dimensional iso-parametric elements, solving simple beams and frames, three dimensional problems, solution to heat transfer problems and flow problems.

**VI. Learning outcome**

Ability to formulate problems based on use of FEM and solve them using software tools.

**VII. Teaching Schedule**

| S.No. | Topic | No. of Lectures |
|---|---|---|
| 1. | Introduction. Historical background, Stress equilibrium, boundary condition | 4 |
| 2. | Stress strain relation, potential energy and equilibrium, Rayleigh- Ritz method, Galerkin method. | 4 |
| 3. | coordinates and shape functions, potential energy approach, element stiffness matrix | 3 |
| 4. | Galerkin approach, assembly of global stiffness matrix, The finite element equation, boundary condition | 3 |
| 5. | Trusses: Two dimensional problems, | 3 |
| 6. | Modeling by constant strain triangle | 3 |
| 7. | Two dimensional iso-parametric elements, the four-node quadrilateral. | 3 |

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|---|---|---|
| 8. | Scalar field problems, steady state heat transfer | 3 |
| 9. | Torsion, potential flow, | 3 |
| 10. | Seepage and fluid flow index, dynamic analysis, principles. | 3 |
| | **Total** | **32** |

## VIII. List of Practicals

| S.No. | Topic | No. of Practicals |
|---|---|---|
| 1. | Use of simple FEM software for FEM software for understanding, principles of FEM. | 3 |
| 2. | Working out simple problems using LISA or any simple Software with understanding of operation | 3 |
| 3. | Solving one dimensional problem, Solution to planar and spatial trusses | 2 |
| 4. | Solving simple two-dimensional problems, Axisymmetric problems | 2 |
| 5. | Solution of problems with two dimensional iso-parametric elements | 2 |
| 6. | Solving simple beams and frames | 2 |
| 7. | Three dimensional problems, solution to heat transfer problems and flow problems. | 2 |
| | **Total** | **16** |

## IX. Suggested Reading

a. Tirupathi R, Patla C and Belegundu AD. 1999. *Introduction to Finite Element in Engineering*. Prentice Hall of India Pvt. Ltd, New Delhi

b. Singiresu RaoS. 2001. *The Finite Element Method in Engineering*. Butter worth Heinemann, New Delhi.

c. Rajasekaran S 1999. *Finite Element Analysis in Engineering Design*. Wheeler Publishing, Division of A.h.Wheeler and Co. Ltd, Allahabad.

d. *Tutorials and Reference Guide*, LISA Finite Element Analysis Software Version 8.0.0 2013

I. **Course Title : Numerical Methods for Engineers**

II. **Course Code : MATH 502**

III. **Credit Hours : 2+1**

IV. **Aim of the course**

To expose students to various numerical methods for solving algebraic equations, ordinary and partial differential equations.

V. **Theory**

**Unit I**

Solution of Algebraic Equations: Solution of non-linear and transcendental equations in one or more than one variable using bisection, false position, iteration, Newton Raphson, Secant methods. Solution of linear simultaneous equations: Matrix inversion, Gauss elimination, Gauss Jordan, LU decomposition methods, ill- conditioned systems.

**Unit II**

Solution of Ordinary Differential Equations: Initial Value Problem, Taylor series method, Picard's method, Euler method, Modified Euler method, RK class and predictor corrector class methods. Stiff ODE's and Gear's methods. Boundary Value Problem, Shooting methods, finite difference method. Use of Method of weighted residuals and orthogonal collocation and Galerkin technique to solve BVP in ODEs

**Unit III**

Eigen values and Eigen vectors: Maximum and minimum eigenvalue by Power spectral and Inverse Power Method, all eigenvalues by Fadeev-Leverrier method. Introduction to diagonalization and QR Factorization. Approximation Theory.

**Unit IV**

Finite difference formulae: Forward and backward differences, Richardson's extrapolation, interpolation formulae, polynomial forms, linear interpolation, Lagrange interpolation polynomial, Newton interpolation polynomial.

**Unit V**

Solution of Partial Differential Equations: Classification of PDEs(Parabolic, elliptical and hyperbolic equation), Elliptical equations, standard five points formula, diagonal five-point formula. Solution of Laplace equation by Liebman's iteration method. Poisson's equation and its applications. Solution of parabolic equations by Bender–Schmidt method, Bender-Schmidt recurrence equation, Crank-Nicholson difference method.

VI. **Practical**

Use of EXCEL Sheet and MATLAB: Application of EXCEL Sheet and MATLAB to solve the Engineering problems

VII. **Learning outcome**

Ability to solve algebraic equations, ordinary and partial differential equations coming across in Agricultural Engineering problems using various numerical methods, ability to use latest software's towards numerical problems.

## VIII. Teaching Schedule

| S.No. | Topic | No. of Lectures |
|---|---|---|
| 1. | Solution of Algebraic Equations: Solution of non-linear and transcendental equations in one or more than one variable using bisection method. | 2 |
| 2. | Solution of Algebraic Equations: Solution of non-linear and transcendental equations in one or more than one variable using false position methods. | 1 |
| 3. | Solution of Algebraic Equations: Solution of non-linear and transcendental equations in one or more than one variable using iteration. | 1 |
| 4. | Solution of Algebraic Equations: Solution of non-linear and transcendental equations in one or more than one variable using Newton Raphson, Secant methods. | 1 |
| 5. | Solution of linear simultaneous equations: Matrix inversion, Gauss elimination, Gauss Jordan method. | 2 |
| 6. | Solution of linear simultaneous equations: LU decomposition methods, ill-conditioned systems. | 2 |
| 7. | Solution of Ordinary Differential Equations: Initial Value Problem, Taylor series method, Picard's method, Euler method, Modified Euler method | 2 |
| 8. | Solution of Ordinary Differential Equations: RK class and predictor corrector class methods. Stiff ODE's and Gear's methods. | 1 |
| 9. | Eigen values and Eigen vectors: Maximum and minimum eigenvalue by Power spectral and Inverse Power Method. | 2 |
| 10. | Eigen values and Eigen vectors: all eigenvalues by Fadeev-Leverrier method | 2 |
| 11. | Introduction to diagonalization and QR Factorization. Approximation Theory. | 2 |
| 12. | Finite difference formulae: Forward and backward differences, Richardson's extrapolation, interpolation formulae, polynomial forms. | 2 |
| 13. | Finite difference formulae: linear interpolation, Lagrange interpolation polynomial, Newton interpolation polynomial. | 2 |
| 14. | Solution of Partial Differential Equations: Classification of PDEs (Parabolic, elliptical and hyperbolic equation) | 2 |
| 15. | Elliptical equations, standard five points formula, diagonal five-point formula. | 2 |
| 16. | Solution of Laplace equation by Liebman's iteration method. Poisson's equation and its applications. | 2 |
| 17. | Solution of parabolic equations by Bender–Schmidt method | 2 |
| 18. | Solution of parabolic equations by Bender-Schmidt recurrence equation, Crank-Nicholson difference method. | 2 |
| | **Total** | **32** |

**IX. List of Practicals**

| S.No. | Topic | No. of Practicals |
|---|---|---|
| 1. | Solution of Algebraic Equations: Solution of non- linear and transcendental equations in one or more than one variable using bisection method. | 1 |
| 2. | Solution of Algebraic Equations: Solution of non- linear and transcendental equations in one or more than one variable using false position methods. | 1 |
| 3. | Solution of Algebraic Equations: Solution of non-linear and transcendental equations in one or more than one variable using iteration. | 1 |
| 4. | Solution of Algebraic Equations: Solution of non-linear and transcendental equations in one or more than one variable using Newton Raphson, Secant methods. | 1 |
| 5. | Solution of linear simultaneous equations: Matrix inversion, Gauss elimination, Gauss Jordan method. | 1 |
| 6. | Solution of linear simultaneous equations: LU decomposition methods, ill-conditioned systems. | 1 |
| 7. | Solution of Ordinary Differential Equations: Initial Value Problem, Taylor series method, Picard's method, Euler method, Modified Euler method | 1 |
| 8. | Solution of Ordinary Differential Equations: RK class and predictor corrector class methods. Stiff ODE's and Gear's methods. | 1 |
| 9. | Eigen values and Eigen vectors: Maximum and minimum eigenvalue by Power spectral and Inverse Power Method. | 1 |
| 10. | Eigen values and Eigen vectors: all eigenvalues by Fadeev-Leverrier method | 1 |
| 11. | Introduction to diagonalization and QR Factorization. Approximation Theory. | 1 |
| 12. | Finite difference formulae: Forward and backward differences, Richardson's extrapolation, interpolation formulae, polynomial forms. | 1 |
| 13. | Finite difference formulae: linear interpolation, Lagrange interpolation polynomial, Newton interpolation polynomial. | 1 |
| 14. | Solution of Partial Differential Equations: Classification of PDEs (Parabolic, elliptical and hyperbolic equation), Elliptical equations, standard five points formula, diagonal five-point formula. | 1 |
| 15. | Solution of Laplace equation by Liebman's iteration method. Poisson's equation and its applications. | 1 |
| 16. | Solution of parabolic equations by Bender–Schmidt method, Bender- Schmidt recurrence equation, Crank-Nicholson difference method. | 1 |
| | **Total** | **16** |

**X. Suggested Reading**


- Anderson T W 1958. *An Introduction to Multivariate Statistical Analysis*. John Wiley.
- Dillon W R and Goldstein M. 1984. *Multivariate Analysis - Methods and Applications*. John Wiley.
- Electronic Statistics Text Book: http://www.statsoft.com/textbook/stathome.html
- Goon A M, Gupta M K and Dasgupta B. 1977. *An Outline of Statistical Theory*. Vol. I. The World Press.
- Goon A M, Gupta M K and Dasgupta B. 1983. *Fundamentals of Statistics*. Vol. I. The World Press.
- Hoel P G. 1971. *Introduction to Mathematical Statistics*. John Wiley.
- Hogg R V and Craig T T. 1978. *Introduction to Mathematical Statistics*. Macmillan.
- Montgomery and Runger 2014. *Applied Statistics and Probability for Engineers.* John Wiley
- Morrison D F. 1976. *Multivariate Statistical Methods*. McGraw Hill.
- Siegel S, Johan N and Casellan Jr. 1956. *Non-parametric Tests for Behavior Sciences*. John Wiley.

**I. Course Title : Numerical Analysis**

**II. Course Code : MATH 506**

**III. Credit Hours : 2+1**

**IV. Aim of the course**

To provide understanding and application of basic numerical techniques for evaluation and approximation of roots of polynomials, solution of differential equations, numerical differentiation and integration.

**V. Theory**

**Unit I**

Computational errors, absolute and relative errors, difference operators, divided differences, interpolating polynomials using finite differences, Hermite interpolation, piecewise and spline interpolation, bivariate interpolation.

**Unit II**

Numerical solution of algebraic and transcendental equations by bisection, secant and Newton-Raphson's Methods, solution of polynomial equations by Birge-Vieta's, Bairstow's and Graffe's root squaring methods.

**Unit III**

Numerical differentiation based on interpolation, finite differences and undetermined coefficients. Numerical integration using methods based on interpolation and undetermined coefficients.

**Unit IV**

Numerical solution of ordinary differential equations of first order and first degree by Runge -Kutta method and predictor-corrector methods. Solution of linear system of equations, Gaussian elimination method, pivoting and scaling, factorization method, iterative techniques, inverse of a matrix, computation of eigen values andeigen vectors.

**VI. Practical**

Tutorials on: divided differences, Hermite and spline interpolation, bivariate interpolation, roots of algebraic and transcendental equations by Newton-Raphson's method, bisection method, Birge-Vieta's method, Bairstow's and Graffe's root squaring methods for polynomial equations, numerical evaluation of derivatives and integral, Runge-Kutta and predictor- corrector methods, Gaussian elimination method, factorization method, iterative techniques, inverse of a matrix, eigen values and eigen vectors.

**VII. Learning outcome**

To understand basic numerical methods and apply them to solve higher engineering problems.

**VIII. Teaching Schedule**

| S.No. | Topic | No. of lectures |
|---|---|---|
| 1. | Computational errors, absolute and relative errors | 1 |
| 2. | Difference operators, | 2 |
| 3. | Divided differences | 2 |
| 4. | Interpolating polynomials using finite differences | 2 |
| 5. | Hermite interpolation | 2 |

| | | |
|---|---|---|
| 6. | Piecewise interpolation | 2 |
| 7. | Spline interpolation | 2 |
| 8. | Bivariate interpolation. | 1 |
| 9. | Bisection Method, secant method | 2 |
| 10. | Newton-Raphson's method,Birge-Vieta's, method | 2 |
| 11. | Bairstow's and Graffe's root squaring methods. | 2 |
| 12. | Numerical differentiation based on interpolation, finite differences and undetermined coefficients. | 2 |
| 13. | Numerical integration using methods based on interpolation and undetermined coefficients | 2 |
| 14. | Numerical solution of ordinary differential equations of first order and first degree by Runge -Kutta method | 2 |
| 15. | Predictor-corrector method | 1 |
| 16. | Gaussian elimination method, pivoting and scaling | 1 |
| 17. | Factorization method, iterative techniques | 2 |
| 18. | Inverse of a matrix, computation of eigen values and eigen vectors | 2 |
| | **Total** | **32** |

## IX. List of Practical

| S.No. | Topic | No. of Practicals |
|---|---|---|
| 1. | Divided differences | 1 |
| 2. | Hermite Interpolation | 1 |
| 3. | Spline interpolation | 1 |
| 4. | Bivariate interpolation | 1 |
| 5. | Bisection method | 1 |
| 6. | Bivariate interpolation | 1 |
| 7. | Secant Method | 1 |
| 8. | Newton-Raphson's method | 1 |
| 9. | Birge-Vieta's method | 1 |
| 10. | Bairstow's Method | 1 |
| 11. | Graffe's root squaring methods | 1 |
| 12. | Numerical evaluation of derivatives and integral | 1 |
| 13. | Runge-Kutta method | 1 |
| 14. | Predictor- corrector methods | 1 |
| 15. | Gaussian elimination method, factorization method, | 1 |
| 16. | Iterative techniques, inverse of a matrix, eigen values and eigen vectors | 1 |
| | **Total** | **16** |

## X. Suggested Reading


- Gerald CF and Wheatley PO. 2003. *Applied Numerical Analysis*, Pearson, 7th

Edition,

- Jain MK, Iyengar SRK and Jain RK. 2012. *Numerical Methods for Scientific and Engineering Computation*, New Age International Publishers, 6th edition.
- Chappra SC. 2014. *Numerical Methods for Engineers*, McGraw-Hill Higher Education; 7th edition.
- Mathew JH, *Numerical Methods for Mathematics*, Science and Engineering, Prentice Hall, (1992) 2nd edition,
- Burden RL and Faires JD. 2004. *Numerical Analysis*, Brooks Cole, 8th edition.
- Atkinson K and Han W. 2004. *Elementary Numerical Analysis*, John Willey & Sons, 3rd Edition.

**MCA 513 Mathematics for Applied Sciences 2+0**

Objective

This course is meant for students who do not have sufficient background of Mathematics. The students would be exposed to elementary mathematics that would prepare them to study their main courses that involve knowledge of Mathematics. The students would get an exposure to Linear Algebra, differentiation, integration and differential equations etc.

**Theory**

**UNIT I**

Set theory-set operations, finite and infinite sets, operations of set, function.

**UNIT II**

Vectors and vector spaces, Matrices notations and operations, laws of matrix algebra; transpose and inverse of matrix, Eigen values and Eigen vectors. Determinants - evaluation and properties of determinants, Solutions of Linear Equations.

**UNIT III**

Variables and functions, limits and continuity of specific functions. Differentiation: theorems of differentiation, differentiation of logarithmic, trigonometric, exponential and inverse functions, Differentiation of function of a function, derivatives of higher order, partial derivatives. Application of derivatives, determination of points of inflexion, maxima and minima.

**UNIT IV**

Integration, methods of integration, reduction formulae, definite and indefinite integral, Applications of integration in Agriculture, Differential Equations.

**Suggested Readings**

1. Franz E. Hohn (2013). Elementary Matrix Algebra, 3rdEd., Kindle Edition
2. Harville DA. 1997. Matrix Algebra from a Statistician's Perspective.
3. Springer.
4. Hohn FE. 1973. Elementary Matrix Algebra. Macmillan.
5. Searle SR. 1982. Matrix Algebra Useful for Statistics. John
6. Wiley. Stewart J. 2007. Calculus. Thompson.
7. Thomas GB. Jr. & Finney RL. 1996. Calculus. 9th Ed. Pearson Edu

**I. Course Title : Numerical Methods for Ordinary and PartialDifferential Equations**

**II. Course Code : MATH 507**

**III. Credit Hours : 2+1**

**IV. Aim of the course**

To provide understanding and application of basic numerical techniques for evaluation and approximation of ordinary and partial differential equations.

**V. Theory**

**Unit I**

Interpolation, Approximation, least square and uniform approximation.

**Unit II**

Numerical differentiation and integration, Numerical solution of ordinary differential equations by single step and multi-step methods

**Unit III**

Various difference schemes for solutions of partial differential equations of parabolic, elliptic and hyperbolic types

**Unit IV**

Solution of differential equations by finite element methods

**VI. Practical**

Tutorials on: evaluation of derivatives and integrals by numerical methods, single step and multistep methods for solution of ordinary differential equations, solution of parabolic, hyperbolic and elliptic equations by finite difference methods. Finite element methods

**VII. Learning outcome**

To understand basic numerical techniques and apply them to solve ordinary and partial differential equations.

**VIII. Teaching Schedule**

| S.No. | Topic | No. of Lectures |
|---|---|---|
| 1. | Interpolation | 3 |
| 2. | Approximation | 3 |
| 3. | Least square approximation | 2 |
| 4. | Uniform approximation | 2 |
| 5. | Numerical differentiation | 3 |
| 6. | Numerical integration | 3 |
| 7. | Numerical solution of ordinary differential equations by single step method | 3 |
| 8. | Numerical solution of ordinary differential equations by multi-step method | 3 |
| 9. | Various difference schemes for solutions of partial differential equations of parabolic type | 2 |
| 10. | Various difference schemes for solutions of partial differential equations of elliptic type | 2 |
| 11. | Various difference schemes for solutions of partial differential | |

| | | |
|---|---|---|
| | equations of hyperbolic type | 2 |
| 12. | Solution of differential equations by finite element methods | 4 |
| | **Total** | **32** |

**IX. List of Practical**

| S.No. | Topic | No. of Practicals |
|---|---|---|
| 1. | Evaluation of derivatives by numerical methods | 2 |
| 2. | Evaluation of integrals by numerical methods | 2 |
| 3. | Single step method for solution of ordinary differential equation | 2 |
| 4. | Multistep method for solution of ordinary differential equation | 2 |
| 5. | Solution of parabolic equations by finite difference method | 2 |
| 6. | Solution of hyperbolic equations by finite difference methods | 2 |
| 7. | Solution of elliptic equations by finite difference methods | 2 |
| 8. | Finite Element methods | 2 |
| | **Total** | **16** |

**X. Suggested Reading**


- Gerald CF and Wheatley PO. 2003. *Applied Numerical Analysis*, Pearson, 7th Edition.
- Jain MK, Iyengar SRK and Jain RK. 2012. *Numerical Methods for Scientific and Engineering Computation*, New Age International Publishers, 6th edition.
- Chappra SC. 2014. *Numerical Methods for Engineers*, McGraw-Hill Higher Education; 7th edition.
- Mathew JH. 1992. *Numerical Methods for Mathematics*, Science and Engineering, Prentice Hall, 2nd edition,
- Burden RL and Faires JD. 2004. *Numerical Analysis*, Brooks Cole, 8th edition.
- Atkinson K and Han W. 2004. *Elementary Numerical Analysis*, John Willey & Sons, 3rd Edition.

**I. Course Title : Statistical Methods for Research Workers**

**II. Course Code : STAT 501**

**III. Credit Hours : 2+1**

**IV. Aim of the course**

To expose students to various statistical techniques for analysis of data and interpretation of results.

**V. Theory**

**Unit I**

Probability and probability distributions. Principle of least squares. Linear and non-linear regression. Multiple regression. Correlation analysis. Selection of variables. Validation of models. Sampling techniques. Determination of sample size. Sampling distribution of mean and proportion.

**Unit II**

Hypothesis testing. Concept of p-value. Student's t-test. Large sample tests. Confidence intervals. ANOVA and testing of hypothesis in regression analysis. Analysis of variance for one way and two way classification (with equal cell frequency). Transformation of data.

**Unit III**

Advantages and disadvantages of nonparametric statistical tests. Scales of measurements. Run-test. Sign test. Median test. Wilcoxon-Mann Whitney test. Chi-square test. Kruskal-Walli's one way and Friedman's two way ANOVA by ranks. Kendall's Coefficient of concordance.

**VI. Practical**

Fitting of distributions. Sample and sampling distributions. Correlation analysis. Regression analysis (Multivariate, quadratic, exponential, power function, selection of variables, validation of models, ANOVA and testing of hypothesis). Tests of significance (Z-test, t-test, F-test and Chi-square test). Analysis of variance. Non- parametric tests.

**VII. Learning outcome**

The students will be able to understand different techniques for analyzing the data of their research work.

**VIII. Teaching Schedule**

| S.No. | Topics | No. of Lectures |
|---|---|---|
| 1. | Elementary statistics | |
| 2. | Probability theory | 2 |
| 3. | Probability distributions (Binomial, Poisson and Normal) | 3 |
| 4. | Sampling techniques, Determination of sample size | 2 |
| 5. | Sampling distribution of mean and Proportion | 1 |
| 6. | Hypothesis testing concept of p-value | 1 |
| 7. | Large sample (mean, proportion) | 1 |
| 8. | Student's t-test (Single mean, Difference of mean for independent samples and paired observations) and F-test | 3 |
| 9. | Analysis of variance (one way and two way), | |

| | | |
|---|---|---|
| | Transformation of data | 2 |
| 10. | Correlation analysis and testing (Bivariate, Rank, Intra-class, Partial, Fisher's Z-transformation) | 2 |
| 11. | Multiple linear regression and model validation | 2 |
| 12. | Testing of coefficient of determination and regression coefficient | 2 |
| 13. | Selection of variables in regression (forward substitution method and step-wise regression) | 1 |
| 14. | Non-Linear regression (Quadratic, exponential and Power) | 2 |
| 15. | Introduction to Non-parametric and scales of measurements | 1 |
| 16. | Chi-square test (Goodness of fit, Independence of attributes, homogeneity of variances) | 2 |
| 17. | One Sample test (Sign test, Median test, Run rest,) | 2 |
| 18. | Two sample test (Wilcoxon Sign test, Mann Whitney test, Chi square test for two independent samples) | 1 |
| 19. | K-Sample (Kruskal-Walli's test and Friedman's two way ANOVA) | 2 |
| 20. | Kendall's coefficient of concordance | 1 |
| | **Total** | **33** |

**IX. List of Practicals**

| S.No. | Topics | No. of Practicals |
|---|---|---|
| 1. | Elementary statistics | 1 |
| 2. | Probability distributions (Binomial, Poisson and Normal) | 1 |
| 3. | Sampling techniques, Determination of sample size, Sampling distribution of mean and Proportion | 1 |
| 4. | Large sample (mean, proportion) | 1 |
| 5. | Student's t-test (Single mean, Difference of mean for independent samples and paired observations) and F-test | 1 |
| 6. | Analysis of variance (one way and two way), Transformation of data | 2 |
| 7. | Correlation analysis and testing (Bivariate, Rank, Intra-class, Partial, Fisher's Z-transformation) | 1 |
| 8. | Multiple linear regression and model validation | 1 |
| 9. | Testing of coefficient of determination and regression coefficient | |
| 10. | Selection of variables in regression (Forward substitution method and step-wise regression) | 1 |
| 11. | Non-Linear regression (Quadratic, exponential and Power) | 2 |
| 12. | Introduction to Non-parametric and scales of measurements | |
| 13. | Chi-square test (Goodness of fit, Independence of attributes, homogeneity of variances) | 2 |
| 14. | One Sample test:Sign test, Median test, Run rest, Two sample test: Wilcoxon Sign test, Mann Whitney test, $X^2$ test for two independent samples | 1 |
| 15. | K-Sample: Kruskal-Walli's test and Friedman's two way ANOVA, Kendall's coefficient of concordance | 1 |
| | **Total** | **16** |

**X. Suggested Reading**


- Anderson T W 1958. *An Introduction to Multivariate Statistical Analysis*. John Wiley.
- Dillon W R and Goldstein M. 1984. *Multivariate Analysis - Methods and Applications*. John Wiley.
- Electronic Statistics Text Book: http://www.statsoft.com/textbook/stathome.html
- Goon A M, Gupta M K and Dasgupta B. 1977. *An Outline of Statistical Theory*. Vol. I. The World Press.
- Goon A M, Gupta M K and Dasgupta B. 1983. *Fundamentals of Statistics*. Vol. I. The World Press.
- Hoel P G. 1971. *Introduction to Mathematical Statistics*. John Wiley.
- Hogg R V and Craig T T. 1978. *Introduction to Mathematical Statistics*. Macmillan.
- Montgomery and Runger 2014. *Applied Statistics and Probability for Engineers.* John Wiley
- Morrison D F. 1976. *Multivariate Statistical Methods*. McGraw Hill.
- Siegel S, Johan N and Casellan Jr. 1956. *Non-parametric Tests for Behavior Sciences*. John Wiley.

**I. Course Title : Experimental Designs**
**II. Course Code : STAT 502**
**III. Credit Hours : 1+1**

**IV. Aim of the course**

To acquaint and equip the students with the basic principles of theory of designs and analysis of experiments.

**V. Theory**

**Unit I**

Basic principles of experimental designs. Uniformity trials. Completely randomized design, randomized block design and latin square designs. Multiple comparison tests.

**Unit II**

Missing plot techniques. Analysis of covariance. Factorial experiments:$2^2$, $2^3$and $3^2$. Split plot design. Strip plot design. Factorial in split plot design.

**Unit III**

Crossover designs. Balanced incomplete block design. Response surface designs. Groups of experiments.

**VI. Practical**

Uniformity trials. Completely randomized design. Randomized block and latin square designs. Missing plot and analysis of covariance Split plot designs. Factorial in split plot design. Strip plot designs. Cross over and balanced incomplete block designs. Groups of experiments.

**VII. Learning outcome**

The students will be able to plan and design the experiments for their research. They will also be exposed to statistical software for the analyzing the data pertaining to designs of this course.

**VIII. Teaching Schedule**

| S.No. | Topics | No. of Lectures |
|---|---|---|
| 1. | Basic principles of experimental designs, | 1 |
| 2. | Completely randomized design | 1 |
| 3. | Randomized block design | 1 |
| 4. | Latin square design | 1 |
| 5. | Multiple comparison tests | 1 |
| 6. | Missing plot techniques | 1 |
| 7. | Analysis of covariance | 1 |
| 8. | Factorial experiments | 2 |
| 9. | Split plot design | 1 |
| 10. | Strip plot design | 1 |
| 11. | Factorial in split plot design | 1 |
| 12. | Crossover designs | 1 |
| 13. | Balanced incomplete block design | 1 |

| | | |
|---|---|---|
| 14. | Response surface designs | 1 |
| 15. | Groups of experiments | 1 |
| | **Total** | **16** |

## IX. List of Practicals

| S.No. | Topics | No. of Practical |
|---|---|---|
| 1 | Completely randomized design | 1 |
| 2 | Randomized block design | 1 |
| 3 | Latin square design | 1 |
| 4 | Multiple comparison tests | 1 |
| 5 | Missing plot techniques | 1 |
| 6 | Analysis of covariance | 1 |
| 7 | Factorial experiments | 3 |
| 8 | Split plot design | 1 |
| 9 | Strip plot design | 1 |
| 10 | Factorial in split plot design | 1 |
| 11 | Crossover designs | 1 |
| 12 | Balanced incomplete block design | 1 |
| 13 | Response surface designs | 1 |
| 14 | Groups of experiments | 1 |
| | **Total** | **16** |

## X. Suggested Reading


- Cochran WG and Cox GM 1957. *Experimental Designs*. 2nd Ed. John Wiley.
- Dean AM and Voss D 1999. *Design and Analysis of Experiments*. Springer.
- Design Resources Server: www.iasri.res.in/design.
- *Examination of Theory and Practice*. John Wiley.
- Federer WT 1985. *Experimental Designs*. MacMillan.
- Fisher RA 1953. *Design and Analysis of Experiments*. Oliver & Boyd.
- Montogomery 2013. *Design and analysis of experiments*. John Wiley & Sons.
- Nigam AK and Gupta V K 1979. *Handbook on Analysis of Agricultural Experiments*. IASRI Publ.
- Pearce SC 1983. *The Agricultural Field Experiment: A Statistical Examination of Theory and Practice*. John Wiley & Sons

**RPE 601 Research and Publication Ethics 1+1**

**Aim of the Course:**
This course is mainly focusing on basics of philosophy of science and ethics, research integrity, publication ethics. Hands on sessions are designed to identify research misconduct and predatory publications. Indexing and citation databases, open access publications, research and p metrics and plagiarism tools introduced in the course.

**THEORY**
**Unit 1: Philosophy and Ethics**
1. Introduction to philosophy: definition, nature and scoope, concept, branches
2. Ethics: definitino, moral philosophy, nature of moral judgements and reations.

**Unit 2: Scientific Conduct**
1. Ethics with respcet to science and research
2. Intellectual honest and research integrity
3. Scientific misconducts: falsification, fabrication, and plagiarism.
4. Redundant publications: duplicate and overlapping publications, salami slicing
5. Selective reporting and misrepresentation of data.

**Unit 3: Publication Ethics**
1. Publication ethics: definition, introduction and importance
2. Best practices/standards setting initiatives and guidelines: COPE, WAME, etc.
3. Conflicts of interest
4. Publication misconduct: definition, concept, problems that lead to unethical behavior and vice verse, types
5. Violation of publication ethics, authorship and contributor ship
6. Identification of publication misconduct, complaints and appeals
7. Predatory publishers and journals

**Unit 4: Open Access Publishing**
1. Open access publications and initiatives
2. SHERPA/RoMEO online resourse to check publisher copyright and self-archiving policies.
3. Software tool to identify predatory publications developed by SPPU
4. Journal finder/ journal suggestion tools viz. JANE, Elsevier Journal Finder, Springer Journal Suggester, etc.

**Unit 5: Publication Misconduct**
A. Group Discussions
1. Subject specific ethical issues, FFP, authorship
2. Conflicts of interest
3. Complaints and appeals: examples and fraud from India and abroad

B. Software tools
Use of plagiarism software like Turnitin, Urkund and other open source software tools.

**Unit 6: Databases And Research Metrics**
A Databases
1. Indexing detabeses

2. Citation detabases: Web of Science, Scopus, etc.

B. Research Metrics
Impact Factor of journal as per journal citation report, SNIP, SJR, IPP, Cite Score.
Metrics: h-index, g index, i10 index, altmetrics

**Practicals**

**1. Types of Reaserach**

1. Basic Research:
2. Applied Research:
3. Descriptive Research:
4. Analytical Research:
5. Correlational Research:
6. Qualitative Research:
7. Quantitative Research:
8. Experimental Research:
9. Explanatory Research:
10. Exploratory Research:
11. Selection of Domain/Area of Research:

**2. Formulating a Research Problem and Identification of Keywords:**

1. Literature Survey:
2. Redefining Research Problem, Objectives and Outcomes:
3. Research Proposal:
4. Identifying Variable /Parameters and Research Design:
5. Data Collection and Representation:
6. Testing of Proposed Design on Collected Data/Hypothesis Testing:

**3. Results and Analysis:**

1. Research Report Writing:
2. Features of Good Research Study

**4. Journal Search**

1. Open Access Publishing
2. Impact Factor of journal as per journal citation report, SNIP, SJR, IPP, Cite Score.
Metrics: h-index, g index, i10 index, altmetrics

**Suggested Readings**


- Bird,A. (2006). Philosophy of Sciences. Routledge
- MacIntyre, Alasdair (1967). A Short History of Ethics. London
- P.Chandah. (2018). Ethics in Competitive Research: Do not get Scooped; do not get plagiarized.
- National Academy of Sciences, National Academy of Engineering and Institute of Medicine (2009)., National On being a Scientist: A guide to responsible conduct in Research : third edition, National Academies Press
- Hall GM. Book Farthing MJG. How to Write a Paper. UK Blackwell Publishing; 2008
- NAS-NAE-IOM. Responsible Science: Ensuring the Integrity of the Research Process. Washington, DC: National Academy Press; 1992.
- Alexander M. Novikov & Dmitry A. Novikov, Research Methodology: From Philosophy of Science to Research Design, CRC Press Taylor & Francis Group, (2013).
- C. R. Kothari, Research Methodology: Methods and Techniques, New Age International (P) Ltd., New Delhi (2004).

- David Bridges, Philosophy in Educational Research: Epistemology, Ethics, Politics and Quality, Springer International Publishing AG (2017).
- Deepak Chawla & Neena Sondhi, Research Methodology: Concepts and Cases, VIKAS® Publishing House Pvt Ltd, New Delhi (2015).

- Paul Smeyers & Marc Depaepe, Educational Research: Ethics, Social Justice, and Funding Dynamics, Springer International Publishing AG, (part of Springer Nature) (2018).
- Peter Pruzan, Research Methodology: The Aims, Practices and Ethics of Science, Springer International Publishing Switzerland (2016).
- Ranjit Kumar, Research Methodology: a step-by-step guide for beginners, SAGE Publications India Pvt Ltd, New Delhi (2011).
- Richard Pring, Philosophy of Educational Research, Continuum, London (2000).
- Robyn Brandenburg & Sharon McDonough, Ethics, Self-Study Research Methodology and Teacher Education, Springer Nature Singapore Pte Ltd. (2019).
- S. K. Yadav, Elements of Research Writing, UDH Publishers and Distributers, New Delhi (2015).
- Surbhi Jain, Research Methodology in Arts, Science and Humanities, Society Publishing, Oakville, Canada (2019).
- Vinayak Bairagi and Mousami V. Munot, Research Methodology A Practical and Scientific
- Approach, CRC Press Taylor & Francis Group, New York, NY (2019).

# *E Resources and List of Journals*

- *Advances in Applied Research*
- *Advances in Computational Sciences and Technology [ACST]*
  *Advances in Mechanical Engineering*
  *Advances in Water Resources*
  *Agricultural Engineering*
  *Agricultural Engineering Today*
  *Agricultural Mechanization in Asia, Africa and Latin America*
  *Agricultural Research*
  *Agricultural Reviews*
  *Agricultural Science Digest*
  *Agricultural Water Management*
  *Agronomy Journal (Journal of American Society of Agronomy*
  *American Journal of Food Technology*
  *American Statistician*
  *Annals of Agri Bio Research*
  *Annals of Agricultural Research*
  *Annals of Arid Zone*
  *Annals of Biology*
  *Annals of Horticulture*
  *Annals of Science*
  *Annals of Statistics*
  *Applied Ecology and Environmental Research*
  *Applied Engineering in Agriculture*
  *Applied Ergonomics*
  *Arid Land Research and Management*
  *Asian Journal of Chemistry*
  *Asian Journal of Environmental Science*
  *Atmospheric Research*
  *Australian Journal of Crop Science*
  *Australian Journal of Dairy Technology*
  *Beverage and Food World*
  *CIGR journal*
  *Comptes Rendus Geosciences*
  *Computers and Electronics in Agriculture*
  *Computers & Industrial Engineering*
  *Cotton Research Journal*
  *Current Advances in Agricultural Sciences*
  *Current World Environment*
  *Ecological Engineering*
  *Ecology, Environment and Conservation*
  *Engineering and Technology in India*
  *Environment*
  *Environment and Ecology*
  *Environmental Engineering Science*
  *Environmental Monitoring and Assessment*
  *Environmental Science and Pollution Research*
  *Environmental Science and Technology*

- *Environmental Review*
- *Forage Research*
- *Groundwater*
- *Hydrological Processes*
- *IETE Journal of Research*
- *IETE Journal of Education*
- *Indian Journal of Agricultural Chemistry*
- *Indian Journal of Agricultural Research*
- *Indian Journal of Agricultural Sciences*
- *Indian Journal of Dairy Science*
- *Indian Journal of Extension Education*
- *Indian Journal of Hill Farming*
- *Indian Journal of Radio and Space Physics*
- *Indian Journal of Science and Technology*
- *Indian Journal of Soil Conservation*
- *Indian Research Journal of Extension Education*
- *Institute of Engineers (India)*
- *Journal of Electronics & Tele Communication*
- *International Journal of Agricultural Engineering*
- *International Journal of Agricultural Science and Research*
- *International Journal of Advance Industrial Engineering*
- *International Journal of Advanced Mechanical Engineering [IJAME]*
- *International Journal of Advanced Engineering Technology (IJAET)*
- *International journal of Advanced Research in Engineering & Technology (IJARET)*
- *International Journal of Applied Engineering Research [IJAER]*
- *International Journal of Current Engineering and Technology*
- *International Journal of Design and Manufacturing Technology(IJDMT)*
- *International Journal of Engineering Research and Technology [IJERT]*
- *International Journal of Engineering, Science and Metallurgy*
- *International Journal of Engineering (IJE)*
- *International Journal of Engineering Studies [IJES]*
- *International Journal of Environmental Analytical Chemistry*
- *International Journal of Environmental Research and Public Health*
- *International Journal of Environmental Science and Technology*
- *International Journal of Extension Education*
- *International Journal of Food Engineering*
- *International Journal of Food Microbiology*
- *International Journal of Food Properties*
- *International Journal of Food Science and Nutrition*
- *International Journal of Food Science and Technology*
- *International Journal of Food and Fermentation Technology*
- *International Journal of Innovative Technology and Exploring Engineering (IJITEE)*
- *International Journal of Industrial Engineering & Technology*

*[IJIET]*
*International Journal of Industrial Engineering Research and Development (IJIERD)*
*The International Journal of Industrial Engineering: Theory, Application and Practice (IJIETAP)*

- *International Journal of Engineering and Management Research (IJEMR)*
*International Journal of Engineering Sciences and Management*
*International Journal of Industrial Engineering Computations*
*International Journal of Engineering and Manufacturing Science [IJEMS]*
*International Journal of Research in Chemistry and Environment*
*International Journal of Research In Mechanical Engineering And Technology (IJRMET)*
*International Journal of Thermal Sciences*
*International Journal of Mechanical Engineering and Robotics Research*
*International Journal of Material and Mechanical Engineering*
*International Journal of Mechanical Engineering & Technology(IJMET)*
*International Journal of Mechanical Engineering and Research(IJMER)*
*International Journal of Mechanical Sciences*
*International Journal of Recent Technology and Engineering(TM) Exploring Innovation*
*International Journal of Industrial & Production Engineering & Tech. [IJIPET]*
*International Journal of Industrial and Systems Engineering*
*International Journal of Advanced Materials Science [IJAMS]*
*International Journal of Research in Mechanical Engineering*
*International Journal of Engineering & Technology Research*
*International Review of Applied Engineering Research [IRAER]*
*International Journal of Mechanical and Materials Engineering*
*International Journal of medical, Health, Biomedical, Bioengineering and Pharmaceutical Engineering*
*International Journal of Production Technology and Management (IJPTM)*
*International Journal of Refrigeration*
*International Journal of Remote Sensing*
*International Journal of Thermal Technologies*
*International Journal of Water Resources Development*
*International Journal on Agricultural Sciences*
*International Journal on Environmental Sciences*
*International Journal of Applied Research on Information Technology and Computing*
*International Journal of Mechanical Engineering*
*International Journal of Mechanical and Production Engineering Research and Development*
*International Scholarly Research Notices, ISRN Mechanical Engineering*

*Irrigation Science*
*Irrigation and Drainage (ICID Bulletin)*
*Irrigation and Drainage System*
*Italian Journal of Food Science*
*Journal of Agricultural Engineering (ISAE)*
*Journal of Agriculture Research and Technology*
- *Journal of Agricultural Safety and Health*

*Journal of Applied Ecology*
*Journal of Applied Probability*
*Journal of Applied Statistics*
*Journal of Arid Environments*
*Journal of Cotton Research and Development*
*Journal of Dairy Research*
*Journal of Dairy Science*
*Journal of Ecology*
*Journal of Energy Engineering - ASCE*
*Journal of Engineering*
*Journal of Engineering computers and Applied Sciences*
*Journal of Engineering Research*
*Journal of Ergonomics*
*Journal of Environmental Engineering*
*Journal of Environmental Monitoring*
*Journal of Environmental Protection and Ecology (JEPE)*
*Journal of Environmental Sciences*
*Journal of Environmental Science and Engineering*
*Journal of Environmental Science, Toxicology and Food Technology*
*Journal of Food Biochemistry (Journal of Food Lipids)*
*Journal of Food Composition and Analysis*
*Journal of Food Engineering*
*Journal of Food Legumes*
*Journal of Food Process Engineering*
*Journal of Food Processing and Preservation*
*Journal of Food Quality*
*Journal of Food Safety*
*Journal of Food Science*
*Journal of Food Science and Technology*
*Journal of Food, Agriculture and Environment*
*Journal of Human Ecology*
*Journal of Hydraulic Engineering – ASCE*
*Journal of Hydraulic Research*
*Journal of Hydrologic Engineering*
*Journal of Hydrology*
*Journal of Indian Society of Agricultural Statistics*
*Journal of Indian Water Resources Society*
*Journal of Industrial Engineering International*
*Journal of Irrigation and Drainage Engineering (ASCE)*
*Journal of Mechanical Engineering*
*Journal of Materials in Civil Engineering*
*Journal of Manufacturing Processes*

*Journal of Research, PAU*
*Journal of Soil and Water Conservation*
*Journal of Soil and Water Conservation, India*
*Journal of Statistical Computation and Simulation*
*Journal of Statistical Planning and Inference*
*Journal of Statistical Theory and Practice*
*Journal of Stored Products Research*
*Journal of Sustainable Agriculture*

# Restructured and Revised Syllabi of Post Graduate Programmes

## M.Tech. and Ph. D (Agricultural Engineering)

## in

## Renewable Energy Engineering

**Compiled**
**by**

**Broad Subject Coordinator**
**Associate Dean,**
**Dr. Annasaheb Shinde College of Agricultural Engineering and Technology, MPKV Rahuri**

**Discipline Coordinator**
**Head of Department (Agricultural Engineering)**
**College of Agricultural,**
**Dr. BSKKV, Dapoli**

# CONTENTS

## Preamble

Course curricula and course outlines in Renewable Energy Engineering are designed in view of the fact that courses are offered by students from disciplines of faculties of Farm Machinery and Power Engineering, Irrigation and Drainage Engineering, Process and Food Engineering.

At the post graduate level it becomes more important where they have not only to learn the recent advances in their subjects but have also to be trained in the modern and latest techniques in their disciplines so that they can participate and contribute in the development and advancement in their related fields. Further, the shrinking job opportunities in the National Agricultural Research System (ICAR/SAUs) have put additional pressure on our education system to prepare students in tune with the demands of the private sector.

All courses are designed to cover all basic topics and have been designed by taking into consideration demands of the private sector harnessing commercial aspects, modern research tools and their applications, supplementary skills required, and enhancing the global competitiveness and employability of students. The emphasis has been given on precision irrigation and modeling management and accordingly new courses “Wind energy, solid waste management, new alternate energy system, advances in renewable energy systems and Energy generation from agricultural waste and byproducts” are framed in view of the recent developments in the subject.

The courses have been revised, updated and restructured in view of current developments and emerging trends in Renewable Energy Engineering. The revised courses cover the areas: Energy auditing, conversion and management, Solar photovoltaic system design and analysis, Renewable energy policy, planning and economics, Advances in renewable energy systems, New alternate energy systems, Fuel and combustion, Advances in biogas technology, Solid waste and waste water management, Advanced photovoltaic power generation, Renewable energy for industrial application, Bio-fuel technologies and application and Energy modeling and simulation.

The course content and syllabus upgraded with more of practical orientation and as per ARS Syllabus.

The ICAR recommendations for PG courses have been taken into consideration in framing these courses. It is hoped that these will prove very useful to the future students.

**Committee on Renewable Energy Engineering**

<table>
<tr><th>ICAR-BSMA Broad Subject</th><th>ICAR-BSMA Approved Disciplines</th><th colspan="2">Degree Programmes</th><th>Broad Subject Coordinator (Chairman of all Disciplines' SubCommittees</th><th>Discipline Coordinator (Secretary of respective Discipline Sub-Committee)</th></tr>
<tr><td>M.Tech (Agricultural Engineering)</td><td>Renewable Energy Engineering</td><td>M.Tech. (Agricultural. Engineering)</td><td>Ph.D.</td><td>Dr. D.D. Pawar Associate Dean ASCAET, Rahuri</td><td>Dr. A.G. Mohod Head (Ag. Engg.) College of Agriculture, Dr.BSKKV, Dapoli</td></tr>
<tr><td colspan="6">Members/ Faculties associated for finalization of syllabus</td></tr>
<tr><td colspan="6">1. Prof. and Head, Deptt. Of EOES/FSRE/, CAET, Dapoli/CAET, Akola, CAET, Parbhani and CAET, Rahuri<br>2. Faculty members from four Agricultural Universities involved in teaching of renewable energy courses at UG/PG/PhD level.</td></tr>
</table>

# Organization of Course contents & Credit Requirements

**Minimum Residential Requirement:**

M.Tech : 4 Semesters
Ph.D. : 6 Semesters

**Name of the Departments / Divisions**

Renewable Energy Engineering (REE)

**Nomenclature of Degree Programme**

**1.** PG Degree Nomenclature

**M.Tech. (Agricultural Engineering) in Renewable Energy Engineering**

**2.** PhD Degree Nomenclature

**Ph. D. (Agricultural Engineering) in Renewable Energy Engineering**

**Code Numbers**

- All courses are divided into two series: 500-series courses pertain to Master's level, and 600- series to Doctoral level.
- Credit Seminar for Master's level is designated by code no. 591, and the Two Seminars for Doctoral level are coded as 691 and 692, respectively
- Deficiency courses will be of 400 series.
- Master's research: 599 and Doctoral research: 699

**Course Contents**

The contents of each course have been organized into:

- Objective – to elucidate the basic purpose.
- Theory units – to facilitate uniform coverage of syllabus for paper setting.
- Suggested Readings – to recommend some standard books as reference material. This does not obviously exclude such a reference material that may be recommended according to the advancement and local requirement.
- A list of international and national reputed journals pertaining to the discipline is provided at the end which may be useful as study material for 600/700 series courses as well as research topics.
- Lecture schedule and practical schedule has also be given at the end of each course to facilitate the teacher to complete the course in an effective manner.

## Eligibility for Admission

**Eligibility for admission Master's Degree:**

B.Tech. /B.E. in Agricultural Engineering under 10+2+4 system from Agricultural University with minimum of 5.50/10 or equivalent percentage of marks and based on CET score.

**Eligibility for admission Doctoral Degree:**

Master's degree (Agricultural Engineering) in **EOES/ RES/ REE/BIOENERGY/REEE** OR

M.Tech/ME (Agricultural Engineering) from other streams (Viz: **Farm Machinery and Power Engineering / Processing and Food Engineering)**

Under SAU/ICAR/DU system with minimum of 6.50/10 or equivalent percentage of marks and based on CET score conducted by MAUEB or AIEEA – ICAR.

Students from other streams will have to undergo the Remedial Non Gradial / Deficiency course package of **8-10 credits** pertaining Renewable Energy Engineering courses over and above of PhD course allotment as decided by the Student Advisory Committee.

## Course and Credit Requirements.

| Course Details | Masters Degree | Doctoral Degree |
|---|---|---|
| Major Courses | 20 | 15 |
| Minor Courses | 08 | 06 |
| Supporting / Optional | 06 | 05 |
| Common PGS Courses | 05 | - |
| Seminar | 01 | 02 |
| Research | 30 | 75 |
| **Total** | **70** | **100** |

# Course Layout and Structure of Masters Degree

## Major Courses (Requirement: 20 Credits)

| Course Code | Course Title | Credit Hours |
|---|---|---|
| REE 501* | Renewable Energy Technologies | 2+1 |
| REE 502* | Solar Thermal Energy Conversion Technologies | 2+1 |
| REE 503* | Biomass Energy Conversion Technologies | 2+1 |
| REE 504 | Energy Auditing, Conservation and Management | 2+1 |
| REE 505 | Wind Energy Conversion and Utilization | 2+1 |
| REE 506 | Solar Photovoltaic System Design and Analysis | 1+1 |
| REE 507 | Renewable Energy Policy, Planning and Economics | 3+0 |
| REE 508 | Alternate Fuels and Applications | 2+1 |
| REE 509 | Biogas Technology and Mechanism | 1+1 |
| REE 510 | Energy, Ecology and Environment | 3+0 |
| REE 511 | Design and Analysis of Renewable Energy Conversion Systems | 2+1 |
| REE 512 | Energy Generation from Agricultural Waste and Byproducts | 2+1 |
| REE 513 | Agro Energy Audit and Management | 2+1 |
| REE 514 | Green House Energetic and Passive Architecture | 1+1 |
| REE 515 | Energy Management in Food Processing Industries | 1+1 |
| REE521 | Case study | 0+1 |
| REE522 | Internship | 0+1 |
| | **Total** | **28+15** |

*Compulsory Course

## Minor Courses (Requirement: 08 Credits)

**Minor Disciplines:**

- Farm Machinery and Power Engineering
- Processing and Food Engineering
- Irrigation and Drainage Engineering
- Soil and Water Conservation Engineering
- Farm Structure and Environmental Engineering
- Basic Sciences

Any other course(s) of other department other than courses from major can be taken as per recommendations of the student's advisory committee.

**The indicative courses for minor courses are:**

| Course Code | Course Title | Credit Hours |
|---|---|---|
| FMPE 517 | Machinery for Precision Agriculture | 2+1 |

| | | |
|---|---|---|
| FMPE 518 | Machinery for Horticulture and Protected Agriculture | 2+0 |
| PFE 511 | Application of Engineering Properties in Food Processing | 2+1 |
| PFE 519 | Bioprocess Engineering | 2+1 |
| IDE 511 | Design of Pumps for Irrigation and Drainage | 2+0 |
| CE 501 | Dimensional Analysis and Similitude | 2+0 |
| FMPE 515 | Computer Aided System Design | 0+2 |
| CSE 501 | Big Data Analytics | 2+1 |
| CSE 502 | Artificial Intelligence | 2+1 |
| CSE 504 | Soft Computing Techniques in Engineering | 2+1 |
| MATH 501 | Finite Element Methods | 1+1 |
| MATH 502 | Numerical Methods for Engineers | 2+1 |
| ME 501 | Mechatronics and Robotics in Agriculture | 2+0 |
| Any other course(s) of other department other than course(s) from major can be taken as per recommendations of the student's advisory committee | | |

## Supporting Courses (Requirement: 06 Credits)

**Supporting Discipline:**

- Statistics
- Mathematics
- Computer Sciences and Information Technology
- Mechanical/Civil/Electrical Engineering
- Environmental Science
- 

Courses from subject matter fields (other than Major and Minor) relating to area of special interest and research problems can be taken as per recommendations of the student's advisory committee.

| **Course Code** | **Course Title** | **CreditsHours** |
|---|---|---|
| *STAT 502 | Statistical Methods for Research Works | 2+1 |
| | | |

*Compulsory Course

## Compulsory Common Non-credit PGS Courses (Requirement: 05 Credits)

| **Course code** | **Semester** | **Course Title** | **Credits** |
|---|---|---|---|
| PGS 501 | I | Library and Information Services | 0+1=1 |
| PGS 504 | II | Basic Concepts in Laboratory Techniques | 0+1=1 |
| PGS 502 | I | Technical Writing and Communications Skills | 0+1=1 |
| PGS 503 | II | Intellectual Property and its management in Agriculture | 1+0=1 |

| | | | |
|---|---|---|---|
| PGS 505 | III | Agricultural Research, Research Ethics and Rural Development Programmes | 1+0=1 |
| PGS 506 | III | Disaster Management | 1+0 |

## List of Other Essential Requirements

| Course Code | Course Title | Credits |
|---|---|---|
| REE 591 | Masters Seminar | 0+1 |
| REE 599 | Masters Research | 0+30 |

## Course Layout and Structure of Doctoral Degree

### Major Courses (Requirement: 12 Credits)

| Course Code | Course Title | Credit Hours |
|---|---|---|
| REE 601 | Biochemical Conversion of Biomass | 2+1 |
| *REE 602 | Thermo-Chemical Conversion of Biomass | 2+1 |
| *REE 603 | Advances in Renewable Energy Systems | 2+1 |
| REE 604 | New Alternate Energy Systems | 2+1 |
| REE 605 | Fuels and Combustion | 2+1 |
| REE 606 | Advances in Biogas Technology | 2+1 |
| REE 607 | Solid Waste and Waste Water Management | 2+1 |
| REE 608 | Advanced Photovoltaic Power Generation | 1+1 |
| REE 609 | Energy Planning, Management and Economics | 3+0 |
| REE 610 | Renewable Energy for Industrial Application | 2+1 |
| REE 611 | Biofuel Technologies and Applications | 1+1 |
| REE 612 | Energy Modelling and Simulation | 1+1 |
| REE621 | Case study | 0+1 |
| REE622 | Internship | 0+1 |
| | **Total** | **22+13** |

***** Compulsory Courses

### Minor Courses (Requirement: 06 Credits)

**Minor Disciplines:**

- Farm Machinery and Power Engineering
- Processing and Food Engineering
- Irrigation and Drainage Engineering
- Soil and Water Conservation Engineering
- Farm Structure and Environmental Engineering

Any other course(s) of other department other than courses from major can be taken as per recommendations of the student's advisory committee.

**The indicative courses for minor courses are:**

| Course Code | Course Title | Credit Hours |
|---|---|---|
| FMPE 612 | Farm Machinery Management and System Engineering | 2+1 |
| ME 501 | Mechatronics and Robotics in Agriculture | 2+0 |

| | | |
|---|---|---|
| PFE 614 | Agri- Project Planning and Management | 1+1 |
| Any other course(s) of other department other than course(s) from major can be taken as per recommendations of the student's advisory committee. | | |

## Supporting Courses (Requirement: 05 Credits)

**Supporting Courses from Discipline of**

- Statistics
- Mathematics
- Computer Sciences and Information Technology
- Mechanical/Civil/Electrical Engineering
- Environmental Science

Courses from subject matter fields (other than Major and Minor) relating to area of special interest and research problems can be taken as per recommendations of the student's advisory committee.

**The indicative courses for supporting courses are**

| Course Code | Course Title | Credit Hours |
|---|---|---|
| *CPE-RPE 601 | Research and Publication Ethics | 1+1 |
| Courses from subject matter fields (other than Major and Minor) relating to area of special interest and research problem can be taken as per recommendations of the student's advisory committee. | | |

***** Compulsory Course

## List of other Essential Requirements

| Course Code | Course Title | Credit Hours |
|---|---|---|
| REE 691 | Doctoral Seminar-I | 0+1 |
| REE 692 | Doctoral Seminar-II | 0+1 |
| REE 699 | Doctoral Research | 0+75 |

## Course Syllabus and Contents of Masters Degree

I. **Course Title : Renewable Energy Technologies**

II. **Course Code: REE 501**

III. **Credit Hours : 2+1**

IV. **Aim of the course**

To provide knowledge, understanding and application oriented skills on renewable energy sources and relevant technologies towards their effective utilization for meeting energy demand.

V. **Theory**

**Unit I**

Solar Energy: Heat transfer, estimation and physical conversion, Instruments for measurement. Energy collection and analysis: FPC, ETC, concentrating collectors. Solar energy application: Direct and indirect. Solar photovoltaic technology: conversion, systems components, integrations and applications.

**Unit II**

Energy from biomass and wastes: Production, distribution, characterization, treatments, recycling. Biomass conversion technologies: Thermo-chemical, bio- chemical and agro-chemical technology. Raw materials, process parameters, end products and utilization.

**Unit III**

Wind energy: Resource estimation, technologies, performance curves, power and torque characteristics. Airfoils and rotors: Wind mill parameters, wind farms design and considerations.

**Unit IV**

Alternate Energy Technologies: Ocean Thermal Energy Conversion, Geothermal, Tidal, Hydro. Energy conversion systems: Resources, systems integrations and analysis, applications. Energy storage: Types, materials, characteristics and application.

VI. **Practical**

Analysis of solar collectors. Solar Photovoltaic cell characteristics, analysis of SPV systems. Characterization of biomass. Design and benefit analysis of energy systems. Design and efficiency testing of wind energy conversion devices.

VII. **Learning outcome**

The students are acquainted with the skill to understand technical aspects and principles of renewable energy characteristics of the resource base (solar radiation, wind energy, bio energy, etc.) In a further step an economic analysis of supply technologies.

## VIII. Teaching Schedule

| S.No. | Topic | No. of Lectures |
|---|---|---|
| 1. | Solar energy: Heat transfer, Estimation and conversion, Solar radiations measuring instruments | 1 |
| 2. | Passive Flat plate solar collectors. Passive solar water heaters. Performance of solar water heater. Effect of various parameters on performance | 2 |
| 3. | Solar passive concentrators: Brief introduction to main types of solar concentrators, solar cookers | 1 |
| 4. | Solar passive crop dryers: Description of various types of solar crop dryers, Applications of solar crop dryers | 2 |
| 5. | Solar photovoltaic technology: Conversion, systems components, integrations and applications | 2 |
| 6. | Biomass production, distribution, characterization, treatments, recycling. | 1 |
| 7. | Review of gasifiers basics; Selection criteria for type and capacity of gasifier; Performance parameters for gasifiers e.g. SGR, turn down ratio etc; | 1 |
| 8. | Basic design of small scale Imbert type downdraft gasifier (without use of Tables) and Basic features of throatless and inverted downdraft gasifiers (No designing) | 2 |
| 9. | Baling for densification of biomass and briquetting machines for densification of biomass | 1 |
| 10. | Bio-chemical and agro-chemical technologies for biomass conversion | 2 |
| 11. | Raw materials, process parameters, end products and utilization for bio-chemical and agro-chemical technologies | 2 |
| 12. | Resource estimation of wind energy, technologies and performance curves | 2 |
| 13. | Power and torque characteristics | 2 |
| 14. | Wind mill parameters | 2 |
| 15. | Wind farms design and considerations | 2 |
| 16. | Ocean Thermal Energy Conversion | 2 |
| 17. | Geothermal, Tidal and Hydro Energy conversion systems | 2 |
| 18. | Energy storage: Types, materials, characteristics and application | 4 |
| | **Total** | **32** |

## IX. List of Practical's

| S.No. | Topic | No. of Practical's |
|---|---|---|
| 1. | Analysis of solar collectors<br>1. Flate Plate Collector<br>2. Evacuated Tube Collector<br>3. Concentration .collector | 3 |

| | | |
|---|---|---|
| 2. | Solar Photovoltaic cell characteristics, analysis of SPV systems | 3 |
| 3. | Characterization of biomass<br>i. Proximate analysis<br>ii. Ultimate analysis<br>iii. Calorific Value<br>iv. Thermogravimetric analysis (TGA) | 4 |
| 4. | Design and benefit analysis of energy systems | 3 |
| 5. | Design and efficiency testing of wind energy conversion devices | 3 |
| **Total** | | **16** |

X. **Suggested Reading**


- Culp AW. 1991. *Principles of Energy Conversion.* McGraw-Hill Pub. Co Inc., New york.
- Duffie JA and Beckman WA. 1991. *Solar Engineering of Thermal Processes*. John Wiley, New York.
- Garg HP and Prakash J. 1976. *Solar Energy, Fundamentals and Applications*. Tata McGraw-Hill Pub. Co. Inc., New Delhi.
- Odum HT and Odum EC. 1976. *Energy Basis for Man and Nature*. McGraw-Hill Pub. Co. Inc., New York.
- Sukhatme SP. 1997. *Solar Energy, Principles of Thermal Collection and Storage*. Tata McGraw-Hill. Pub. Co. Ltd, New Delhi.
- Twidell JW and Weir AD. 1986. *Renewable Energy Sources*.E& FN Spon Ltd. London.
- Alain Vertes. *Biomass to biofuel*. A John Wiley and Sons, Ltd. Publications.
- Pradipchakravorty. Bio energy resources. Concept publishing company. New Delhi.
- P.D. Grover. *Biomass briquetting.* FAO publications.
- Tony burtons *et. al. Wind Energy Handbook*. Wilny publication. ND
- Kishor VVN. *Renewable Energy Engineering and Technology- A Knowledge compendium*, TERI press, N.D.

I. **Course Title : Solar Thermal Energy Conversion Technologies**
II. **Course Code : REE 502**
III. **Credit Hours : 2+1**

IV. **Aim of the course**

To provide in-depth knowledge, understanding and application oriented skills on solar thermal conversion technologies and their effective utilization for meeting energy demand.

V. **Theory**

**Unit I**

Characteristics of solar radiation: Attenuation, absorption, scattering and air mass. Solar earth geometry.

**Unit II**

Solar FLUX AND WEATHER DATA. Solar radiation data and estimation: Radiation estimation models and applications. Heat and mass transfer in solar energy utilization: Gray surface, sky radiation, radiation heat transfer coefficient, reflectivity, transitivity, transmittance absorption product. Selective surfaces and materials.

**Unit III**

Solar thermal energy collectors (track and untrack): Heat capacity effect, time constant measurement, design and efficiency calculations, F chart method utility.

**Unit IV**

Techno-economic feasibility of solar thermal energy applications: Cooking, air heating for drying, steam generation, space heating and cooling, refrigeration, architecture, absorption cooling, thermal power generation.

VI. **Practical**

Solar radiation measurement, estimation model and applications, design of collectors, study of materials used in the solar system. Energy balance and efficiency calculation of collectors.

VII. **Learning outcome**

The student is able to understand the detailed knowledge about working and design of various solar thermal devices able to design different solar thermal devices.

VIII. **Teaching Schedule**

| S.No. | Topic | No. of Lectures |
|---|---|---|
| 1. | Introduction to characteristics of solar radiation and solar earth geometry | 2 |
| 2. | Solar flux and weather data measurement and interpretation | 2 |
| 3. | Estimation of Solar radiation data using models and estimation | 2 |
| 4. | Heat and mass transfer in solar energy utilization | 2 |
| 5 | Gray surface, sky radiation, radiation heat transfer coefficient | 2 |
| 6 | Receptivity, Transitivity, Transmittance Absorption | 2 |
| 7 | Selective surfaces and materials as solar energy collectors | 2 |
| 8 | Heat capacity effect, time constant measurement of solar energy | 2 |
| 9 | Design and efficiency calculations of Solar thermal energy collectors | 4 |

| | | |
|---|---|---|
| 10 | F chart method utility for Designing Solar Thermal Water Heating Systems | 2 |
| 11 | Techno-economic feasibility of solar thermal energy in cooking, drying of food products, space heating and cooling. | 4 |
| 12 | Economic feasibility of solar thermal energy in refrigeration, architecture, absorption cooling, thermal power generation. | 4 |
| | **Total** | **30** |

IX. **List of Practical's**

| **S.No.** | **Topic** | **No. of Practical's** |
|---|---|---|
| 1. | Measurement of Solar radiation | 1 |
| 2. | Estimation of solar energy by model applications | 2 |
| 3. | Design of solar energy collectors | 2 |
| 4. | Study of materials used in solar system | 1 |
| 5. | Energy balance in solar energy collectors<br>i. Flat plate collector<br>ii. Concentrating collectors | 2 |
| 6. | Efficiency calculation of collectors | 2 |
| | **Total** | **10** |

X. **Suggested Reading**


- Bansal NK, Kleeman MK and Meliss M. 1990. *Renewable Energy Sources and Conversion Technologies*.Tata McGraw-Hill Pub. Co. Ltd, Delhi.
- Duffie JA and Beckman WA. 2006. *Solar Thermal Engineering Process*. John Wiley & Sons, New Jersey.
- Hsien JS. 2014. *Solar Energy*. Prentice Hall Inc., New Jersey.
- Garg HP. 1990. *Advances in Solar Energy Technology*. Springer Publishing Company, Dordrecht, Netherland.
- Kalogirou SA. 2013. *Solar Energy Engineering*. Academic Press, Cambridge, Massachusetts.
- Kishore VVN. 2008. *Renewable Energy Engineering and Technology–A Knowledge Compendium*. TERI Press, New Delhi, India.
- Pai BR and Ramaprasad MS. 1991. Tata McGraw-Hill Pub. Co., New Delhi. *Power Generation through Renewable Sources of Energy*.
- Sukhatme SP and Nayak J. 2008. *Solar Energy: Principles of Thermal Collection and Storage*. Tata McGraw-Hill Publishing Company Limited, New Delhi, India.

I. **Title : Biomass Energy Conversion Technologies**

II. **Course Code : REE 503**

III. **Credit Hours : 2+1**

IV. **Aim of the course**

To understand the bio-conversion technologies and fuels system, types of biomass derived fuels and energy, thermo-chemical conversion of biomass to heat and power, value adding of agro-residues.

V. **Theory Unit I**

Biomass and its classification. Biomass characterization: Types and resources, sustainability issues, assessment tools and methodologies, biomass fuel characterization, Biomass supply chain concept. Direct use of biomass: Size reduction, baling, pelletization, briquetting technologies.

**Unit II**

Biochemical conversion of biomass: Feedstock, process design, operation, optimized process parameters and utilization for biogas and bioethanol production.

**Unit III**

Biomass combustion: Stoichiometric air requirement, chemistry of combustion, design of combustion system, combustion zones, flame structure, stability, emissions. Co-firing of biomass.

**Unit IV**

Thermo-chemical conversion of biomass: Feedstock, chemistry, reactor design, operation, optimized process parameters and utilization for gasification, carbonization, torrefaction and pyrolysis.

**Unit V**

Cogeneration technologies: Cycles, topping, bottoming, selection, problems, applications. Waste heat recovery: Estimation, systems, design and application.

VI. **Practical**

Biomass characterization. Design of bioreactors. Study of techno-economical feasibility of bio-chemical conversion process. Performance evaluation of combustion gadgets, gasifiers and paralytic converters. Design of waste heat recovery system.

VII. **Learning outcome**

The students is enable to extract the energy from biomass and acquainted the skill to know how to choose the suitable biomass fuels for different industrial applications with design and economics of the system.

Biomass and Its classification, classification of Biomass conversion technologies, choice of technology.

VIII. **Teaching Schedule**

| S.No. | Topic | No. of Lecture's |
|---|---|---|
| 1. | Biomass and its classification, classification of Biomass conversion technologies. choice of technology | 1 |
| 2 | Biomass characterization: Types and resources, sustainability issues, assessment tools and methodologies, biomass fuel characterization, Biomass supply chain concept | 3 |
| 3 | Direct use of biomass | 1 |
| 4 | Size reduction, baling, palletization, briquetting technologies | 2 |
| 5 | Biochemical conversion of biomass | 1 |
| 6 | Feedstock, process design, operation, optimized process parameters. | 1 |
| 7 | Utilization for biogas and bioethanol production. | 1 |
| 8 | Biomass combustion | 1 |
| 9 | Stoichiometric air requirement, chemistry of combustion | 2 |
| 10 | Design of combustion system | 2 |
| 11 | Combustion zones, flame structure, stability, emissions | 2 |
| 12 | Co-firing of biomass | 1 |
| 13 | Thermo-chemical conversion of biomass: Feedstock, chemistry | 2 |
| 14 | Reactor design. | 1 |
| 15 | Operation, optimized process parameters and utilization for gasification carbonization, torrefaction and pyrolysis. | 2 |
| 16 | Cogeneration technologies: Cycles, topping, bottoming, selection. | 2 |
| 17 | Cogeneration Problems and applications. | 2 |
| 18 | Waste heat recovery | 2 |
| 19 | Estimation, systems, design and application. | 2 |
| | **Total** | **32** |

IX. **List of Practical's**

| S.No. | Topics | No. of Practical's |
|---|---|---|
| 1 | Characterization of biomass | 2 |
| 2 | Design of bio-reactors | 1 |
| 3 | Determination of techno-economical feasibility of bio-chemical conversion process. | 2 |
| 4 | Performance evaluation of combustion gadgets | 1 |
| 5 | Performance evaluation of gasifiers | 1 |
| 6 | Performance evaluation of pyrolytic converters | 1 |
| 7 | Design of waste heat recovery system | 2 |
| | **Total** | **10** |

## X. **Suggested Reading**


- Chakravorty A. 1985. *Biogas Technology & other Alternative Technologies*. Oxford & IBH Publication Ltd, Delhi.
- Chaturvedi P. 1995. *Bio-Energy Resources: Planning, Production and Utilization*. Concept Pub. Co., New Delhi.
- Goswami DY. 1986. *Alternative Energy in Agriculture*.Vol. II (Ed), CRC, Press Inc., Florida, USA.
- Stout BA. 1984. *Biomass Energy Profiles*. FAO Agril. Services Bulletin No.54., Elsevier Science Publishers Ltd, England.
- Twidell JW and Weir AD. 2006. *Renewable Energy Sources*. E & F N Spon Ltd, New York.
- Vimal OP. 1984. *Energy from Biomass*. Agrcole Publishing Academy, New Delhi.
- Lamptey. 2011. Biomass conversion Technology. Pergamonpress . New Delhi.

I. **Title : Energy Auditing, Conservation and Management**

II. **Course Code : REE 504**

III. **Credit Hours : 2+1**

IV. **Aim of the course**

To acquaint and equip about the sources of energy, conservation of energy and its management. Study of energy efficiency, energy planning, forecasting and energy economics.

V. **Theory Unit I**

Energy conservation: Concepts, energy classification, Conventional and non conventional form of energy and their use. Heat equivalents and Energy coefficients for different agricultural inputs and products. Direct and indirect energy. scenario, energy pricing, importance. Energy conservation act.

**Unit II**

Energy auditing and economics: Energy management, energy audit strategy, types. Energy performance: output input ratio, benchmarking, fuel substitutions, energy audit instruments, material and energy balance, input and output ratio. Identification of energy efficient machinery systems, Energy losses and their management. Energy conversion: Energy index, Cost index. Financial management.

**Unit III**

Thermal energy audit: Performance evaluation, energy conservation opportunities in boilers, steam system and furnaces, insulation, refractory's and other thermal utilities.

**Unit IV**

Electrical Energy audit: Electrical systems, electricity billing, load management, power factor. Performance evaluation and energy conservation opportunities in motors, compressed air system, HVAC and refrigeration system, fans and blowers, pumps and lighting system.

**Unit V**

Energy auditing and reporting in industries, Energy economics , Energy planning. Replacement of renewable energy technology option, case study in agro-industries. Factors affecting energy economics.

VI. **Practical**

Problems on energy index, cost index. Problems on material balance and energy balance. Financial management. Energy audit and conservation opportunities in thermal and electrical utilities. Case studies on energy audit and conservation.

VII. **Learning outcome**

Able to understand the concept of energy auditing, conservation and management. The in-depth knowledge about the quantification, conservation opportunity and retrofitting of energy efficient system integration is expected from the course.

VIII. **Teaching Schedule**

| S.No. | Topic | No. of Lectures |
|---|---|---|
| 1. | Energy conservation: Introduction, Concepts, Scenario | 2 |
| 2. | Classification of Energy , conventional and unconventional. Direct and indirect | 1 |
| 3. | Energy equivalents, energy pricing, importance. | 2 |
| 4. | Energy conservation act, Energy efficient machinery system | 2 |
| 5. | Introduction to energy management, energy audit strategy and types. | 2 |
| 6. | Energy performance: Benchmarking, fuel substitutions. | 1 |
| 7. | Energy audit instruments, material and energy balance and Energy losses and their management. | 2 |
| 8. | Energy conversion: Energy index, cost index. Financial management. | 2 |
| 9. | Performance evaluation and energy conservation opportunities in boilers. | 1 |
| 10. | Insulation, refractories and other thermal utilities. | 2 |
| 11. | Performance evaluation and energy conservation opportunities in steam system and furnaces. | 2 |
| 12. | Electrical Energy audit: Electrical systems, electricity billing, load management, power factor. | 2 |
| 13. | Performance evaluation and energy conservation opportunities in motors, compressed air system. | 2 |
| 14. | Performance evaluation and energy conservation opportunities in HVAC and refrigeration system. | 2 |
| 15. | Performance evaluation and energy conservation opportunities in fans and blowers, pumps and lighting system. | 2 |
| 16. | Energy auditing and reporting in industries. | 1 |
| 17. | Replacement of renewable energy technology option. | 2 |
| 18. | Case study in agro industries. | 2 |
| | **Total** | **32** |

IX. **List of Practical's**

| S.No. | Topic | No. of Practical's |
|---|---|---|
| 1. | Problems on energy index. | 2 |
| 2. | Problems on cost index. | 2 |
| 3. | Problems on material balance. | 2 |
| 4. | Problems on energy balance. | 2 |
| 5. | Financial management. | 2 |
| 6. | Energy audit and conservation opportunities in thermal utilities. | 2 |
| 7. | Energy audit and conservation opportunities in electrical utilities. | 2 |

| | | |
|---|---|---|
| 8. | Case studies on energy audit and conservation. | 2 |
| | **Total** | **16** |

X. **Suggested Reading**


- *Energy Management*, *Bi-monthly Journal* National Productivity Council, New Delhi.
- Guide Books for *National Certification Examination for Energy Managers and Energy Auditors*, Book 1–4, 2005 Bureau Energy Efficiency, New Delhi.
- Murgai MP and Chandra R. 1990. *Progress in Energy Auditing and Conservation, Boiler Operations.* Wiley Eastern Ltd, New Delhi.
- Murphy WR and McKay G. 1982. *Energy Management*. Butterworth & Co., Publishers Ltd., London.
- Porter R and Roberts T. 1985. *Energy Saving by Waste recycling*. Elsevier applied science publishers, New York, USA.
- Smith CB. 1981. *Energy Management Principles*, *Applications*, *Benefits and Savings*. Pergamon Press Inc., Oxford, England.
- Victor B. 1983. *Ottaviano*, *Energy Management*. An OTIS Publication, Ottaviano Technical Service Inc., Melville, New York.
- Rai G. D. 1998 Nonconventional Sources of Energy khanna publications. New Delhi.
- Twindal J.W. and wier A.D. 1986 Renewable Energy Sources E & F.N. LTD. New York.
- Kennedy w. jr. and Tunnerwc. 1984 Energy management prentice Hall, upper sattle River New Jersey
- Doty S. Turner wc. 2012 Energy management handbook. colorado. The Fairmont press Inc.
- Munasinghe M and Meier P. 1993. Energy policy Analysis and modeling Cambridge Energy and enviro series. Cambridge University press. England.

**I. Course Title : Wind Energy Conversion and Utilization**

**II. Course Code : REE 505**

**III. Credit Hours : 2+1**

**IV. Aim of the course**

To acquire the in-depth knowledge of wind energy conversion systems, wind potential mapping, estimation and analysis of wind data.

**V. Theory**

**Unit I**

Wind mapping and assessment: Wind energy potential, nature of wind, Weibull and Rayleigh analysis, instruments, history and taxonomy of wind mills, wind power laws.

**Unit II**

Wind turbine aerodynamics: Momentum theories, basic aerodynamics, air foils and their characteristics. Horizontal Axis Wind Turbine (HAWT): Blade element theory, wake analysis. Vertical Axis Wind Turbine (VAWT): Aerodynamics, rotor design, power regulation, yaw system.

**Unit III**

Selection of site. Mechanical and electrical applications. Wind farms: Interfacing, maintenance. Management of power generated by wind mill: Instruments and controls. Stand alone and grid connected systems. Wind energy storage. Wheeling and banking. Cost economics. Testing and certification procedures.

**Unit IV**

Wind turbine loads: wind power equipment such as pumps generators, storage of wind energy, wind measuring instruments and controls, Different systems of measuring and recording wind velocity wind turbulence, static. Wind energy control system (WECS). Synchronous and asynchronous generators. Annual Energy Output (AEO). Testing of WECS.

**VI. Practical**

Visit to the meteorological observatory. Wind velocity mapping and curve analysis. Wind energy instruments and resource assessment. Design of wind mills, water pumping windmills. Performance evaluation of wind aero-generator. Wind turbine loads. Economics of wind energy systems.

**VII. Learning outcome**

The students will acquire knowledge regarding mechanisms of wind energy and different types of wind machines available to harness wind power and also be able to design wind turbines for irrigation as well as for power generation.

**VIII. Teaching Schedule**

| S.No. | Topic | No. of lectures |
|---|---|---|
| 1 | Mapping of Wind energy and its assessment, nature of wind, Wind energy potential | 2 |
| 2 | Weibull and Rayleigh analysis | 2 |

| | | |
|---|---|---|
| 3 | Instruments, history and taxonomy of wind mills, wind power laws | 2 |
| 4 | Aerodynamics of Wind turbine, Momentum theories, airfoils and their characteristics | 3 |
| 5 | Elemental theory of Horizontal and Vertical Axis Wind Turbine (HAWT) | 2 |
| 6 | Aerodynamics of wind turbines, rotor design, power regulation, yaw system | 2 |
| 7 | Selection of site for wind mill installation, Mechanical and electrical applications of wind mills | 2 |
| 8 | Wind farms: Interfacing and maintenance, instruments and controls for management of power generated by wind mill | 3 |
| 9 | Stand alone and grid connected systems, Wind energy storage, Wheeling and banking. | 2 |
| 10 | Economics of wind mills | 2 |
| 11 | Testing and certification procedures for wind mills | 3 |
| 12 | Wind turbine Aerodynamic loads in steady operation, wind turbulence, static. | 2 |
| 13 | Wind energy control system (WECS), Synchronous and asynchronous generators | 2 |
| 14 | Annual Energy Output (AEO), Testing of Wind energy control system | 3 |
| | **Total** | **32** |

## IX. List of Practical's

| S.No. | Topic | No. of Practical's |
|---|---|---|
| 1 | Visit to meteorological observatory | 1 |
| 2 | Wind velocity | 1 |
| 3 | mapping and curve analysis | 2 |
| 4 | Wind energy | 1 |
| 5 | instruments and resource assessment | 1 |
| 6 | Design of wind mills | 1 |
| 7 | Water pumping windmills | 1 |
| 8 | Performance evaluation of wind aero-generator | 1 |
| 9 | Study of Wind turbine loads | 2 |
| 10 | Economics of wind energy systems. | 1 |
| | **Total** | **12** |

## X. Suggested Reading


- Cheremision NP. 1978. *Fundamental of Wind Energy*: Ann Arbor Science, Pub. Inc., Michigan.
- Eldridge FR. 1980. *Wind Machines*. Van Nostr and Reinhold Co., New York.
- More HG and Maheshwari RC. *Wind Energy Utilization in India*, Technical Bulletin No. CIAE/82/38, CIAE, Bhopal.

- Lipman NH, Muggrove PJ and Pontin GW. 1982. *Wind Energy for the Eighties*. Peter Peregrinus Ltd. Stenvenage, New York.
- Lysen EH. 1983. *Introduction to Wind Energy*. Consultancy Services Wind Energy Developing Countries, Netherlands.
- Manwell JF, McGswan JG and Rogers AL. 2012. *Wind Energy Explained–Theory Design and Application*. John Wiley and Sons, New Jersey.
- Powar AG and Mohod AG. 2010. *Wind Energy Technologies*. Jain Publication, New Delhi.
- Robert. Gasch, JochenTweleDelho. Wind power plants, fundamental design, construction. Springer Inc
- sathyajeeth Mathew. Wind Energy, fundamental Resource analysis and Economics. Springer publication.
- Ziyadsalameh. Renewable Energy system design. Academic press Elsewier.
- G.D. Rai. 1998. Non conventional Energy sources,  khanna publisher. ND

I. **Course Title : Solar Photovoltaic System Design and Analysis**
II. **Course Code : REE 506**
III. **Credit Hours : 1+1**

IV. **Aim of the course**

To provide detailed knowledge about working and design of various solar photovoltaic systems for power generation.

V. **Theory Unit I**

Fundamentals of semiconductor, pn junction diode, bond theory, Physics of solar cells: Crystal structure, band theory, semiconductor, p-n junctions, absorption of radiation, generation, recombination and carrier separation. Standard solar cell structure: I,V characteristics, conversion efficiency, losses in solar cell, impact of radiation and temperature.

**Unit II**

Solar PV module technologies, First generation: Silicon wafer based technology, Second generation: Thin film technologies, Third generation/emerging PV technologies: Organic PV, Dye sensitized PV, Quantum-dot, Hot-carrier, up conversion and down conversion. Latest benchmark efficiencies: Laboratory and manufacturing. Fabrication technologies.

**Unit III**

Solar PV systems: solar photovoltaic modules Balance of System (BoS), SPV system design guideline and methodologies, introduction to PVSyst, designing of standalone/grid connected PV systems for domestic/commercial use. Introduction to Rooftop business models: CAPEX and RESCO, canal top, floating PV system design.

**Unit IV**

Materials and devices for energy storage: Batteries, Carbon Nano-Tubes (CNT), fabrication of CNTs, CNT-polymer composites, ultra-capacitors etc.

VI. **Practical**

Solar cell efficiency testing. SPV fabrication technologies. System integration and BoS matching studies. PV software's operation and utilization. Design and estimation of SPV systems components for agro based industrial applications. Battery performance testing.

VII. **Learning outcome**

Students are able to design different solar photovoltaic systems for power generation with system integration and economic analysis.

VIII. **Teaching Schedule**

| **S.No.** | **Topic** | **No. of Lectures** |
|---|---|---|
| 1. | Fundamentals of Semiconductor, pn junction diode, band theory, physics of solar cells: crystal structure. | 1 |
| 2. | Absorption of radiation, generation, recombination and carrier separation. | 2 |
| 3. | Standard solar cell structure: I-V characteristics, conversion efficiency, losses in solar cell, impact of radiation and temperature. | 2 |
| 4. | Solar PV module technologies, First generation: Silicon wafer based technology, Second generation: Thin film technologies. | 1 |

| | | |
|---|---|---|
| 5. | Third generation/emerging PV technologies: Organic PV, Dye sensitized PV, Quantum-dot, Hot-carrier, up conversion and down conversion. | 1 |
| 6. | Latest benchmark efficiencies: Laboratory and manufacturing. Fabrication technologies. | 2 |
| 7. | Solar PV systems: solar photovoltaic modules Balance of System (BoS), SPV system design guideline and methodologies, | 1 |
| 8. | Introduction to PVSyst, designing of standalone/grid connected PV systems for domestic/commercial use. | 2 |
| 9. | Introduction to Rooftop business models: CAPEX and RESCO, canal top, floating PV system design. | 2 |
| 10. | Materials and devices for energy storage: Batteries, Carbon Nano-Tubes (CNT), Fabrication of CNTs, CNT-polymer composites, ultra-capacitors. | 2 |
| | **Total** | **16** |

IX. **List of Practical's**

| **S.No.** | **Topic** | **No. of Practical's** |
|---|---|---|
| 1 | To demonstrate the I-V and P-V characteristics of a PV module with varying radiation and temperature level and efficiency determination. | 1 |
| 2 | To demonstrate the I-V and P-V characteristics of series combination of PV modules and efficiency determination | 1 |
| 3 | To demonstrate the I-V and P-V characteristics of parallel combination of PV modules and efficiency determination | 1 |
| 4 | To show the effect of variation in tilt angle on PV module power | 1 |
| 5 | To demonstrate the effect of shading on module output power and efficiency determination. | 1 |
| 6 | Study on SPV fabrication technologies. | 1 |
| 7 | Study on system integration and BoS matching. | 1 |
| 8 | PV software's operation and utilization | 1 |
| 9 | Design and estimation of SPV systems components for agro based industrial applications. | 1 |
| 10 | Battery performance testing | 1 |
| | **Total** | **10** |

X. **Suggested Reading**


- Garg HP. 1990. *Advances in Solar Energy Technology*. D. Publishing Company, Tokyo.
- Duffie JA and Beckman WA. 1991. *Solar Engineering of Thermal Processes*. John Wiley, New Jersey.
- Green MA. 1981. *Solar Cells Operating Principles, Technology, and System Applications.* Prentice Hall, Upper Saddle River, New Jersey.
- Kreith F and Kreider JF. 1978. *Principles of Solar Engineering*. McGraw-Hill, New York.

- Luque A and Hegedus S. 2011. *Handbook of Photovoltaic Science and Engineering Education*. John Wiley & Sons, New Jersey.
- Solanki CS. 2011. *Solar Photovoltaic: Fundamentals, Technologies and Applications*. PHI Learning Private Ltd, Delhi.
- Sze SM and Kwok K Ng. 2007. *Physics of Semiconductor Devices*. 3rd Edn. John Wiley & Sons, New Jersey.
- Veziroglu TN. 1977. *Alternative Energy Sources*. Vol.5. McGraw-Hill, New York.
- Solanki CS. 2013. Solar photovoltaic Technology and systems. PHI Learning private LTD.
- Rai GD. 2012 solar Energy utilization, khanna publications, New Delhi.
- Hongye. F.. 2013. Renewable Energy systems. Advanced conversion Technologies and Applications New York CRC press.
- Bauer T. 2011. Thermo photovoltaic Basic Principles and critical aspects of system design. ENGG publisher : Springer, Delhi.
- Augustin M. markvatt, castoner L. 2006 practical handbook of photovoltaic fundamentals and Applications. Enggpublisher : Elsevier. New York.

**I. Course Title : Renewable Energy Policy, Planning and Economics**

**II. Course Code : REE 507**

**III. Credit Hours : 3+0**

**IV. Aim of the course**

To provide the in-depth knowledge about the current energy policy and planning, environmental economics, policy and ecology.

**V. Theory**

**Unit I**

Introduction to policy parameters, regulatory bodies. Introduction to overall policy environment on energy sector, policy formulation parameters. Entities: Consumers and their tariffs, generator, DISCOM, Regulators: CERC and SERC, Statutory bodies. Typical issues of Indian power sector.

**Unit II**

Indian energy Policy: Introduction, Electricity Act, National Policy on Tariff, Climate Change, RE, Solar Missions, Wind Power and Regulatory Commissions. Concept of Grid Code, Green Corridor, Solar and Hybrid Parks. Electricity Trading: Open Access, RPO Distributed Generation Regional Grid Region. International Energy Policies and Treaties.

**Unit III**

Policy and planning: Energy, environment interaction, clean development mechanism, financing of energy systems, software for energy planning, socio- economical approach. Project management in energy: Cost economics-sensitivity and risk analysis.

**UNIT IV**

Energy economics: economic evaluation of renewable energy systems, life cycle costing, components of energy investment and risk and uncertainties in energy investment.

**VI. Learning outcome**

A student is able to develop an interdisciplinary knowledge base that will enable them to understand and solve contemporary energy policy, planning and environmental problems.

**VII. Teaching Schedule**

| S.No. | Topic | No. of Lectures |
|---|---|---|
| 1. | Introduction to policy parameters and regulatory bodies in Energy | 2 |
| 2. | Introduction to overall policy environment on energy sector, policy formulation parameters | 3 |
| 3. | Entities: Consumers and their tariffs | 2 |
| 4. | Generator, DISCOM, Regulators: CERC and SERC, Statutory bodies. | 3 |
| 5. | Typical issues of Indian power sector. | 2 |
| 6. | Introduction to Indian energy Policy and Electricity Act | 3 |

| | | |
|---|---|---|
| 7. | National Policy on Tariff | 2 |
| 8. | Climate Change, RE, Solar Missions, Wind Power and Regulatory Commissions | 3 |
| 9. | Concept of Grid Code, Green Corridor, Solar and Hybrid Parks. | 3 |
| 10. | Clean development mechanism, nancing of energy systems | 3 |
| 11. | Policy and planning in Energy, environment interaction | 2 |
| 12. | Electricity Trading: Open Access, RPO Distributed Generation Regional Grid Region. International Energy Policies and Treaties. | 4 |
| 13. | Software for energy planning, socio-economical approach. | 3 |
| 14. | Project management in energy: Cost economics-sensitivity and risk analysis. | 4 |
| 15. | Energy economics: economic evaluation of renewable energy systems | 3 |
| 16. | Life cycle costing, components of energy investment | 3 |
| 17. | Risk and uncertainties in energy investment | 3 |
| | **Total** | **48** |

## VIII. Suggested Reading


- BEE Reference book: no.1/2/3/4.
- Bhattacharyya SC. 2011. *Energy Economics*. Springer, New York City, USA.
- Brown CE. 2002. *World Energy Resources*. Springer, New York City, USA.
- Conti J. 2016. *International Energy Outlook*. US Energy Information Administration (*EIA*), Washington.
- Culp AW. 1991. *Principles of Energy Conversion*. McGraw-Hill Int. edition, New York.
- Krithika PR and Mahajan S. 2014. *Governance of Renewable Energy in India: Issues and Challenges*. TERI, New Delhi.
- Parikh JK. 1981. *Modeling Approach to Long Term Demand and Energy Policy Implication for India*. IIASA, Laxenburg, Austria.
- Reddy AKN, Williams RH, Goldenberg J and Johansson TB. 1987. *Energy for a Sustainable World*. Wiley-Eastern Ltd, New Delhi, India.
- TEDDY Year Book Published by Tata Energy Research Institute (TERI).

I. **Course Title : Alternate Fuels and Applications**

II. **Course Code : REE 508**

III. **Credit Hours : 2+1**

IV. **Aim of the course**

To get acquainted with various alternate fuels, their applications and also to learn safety factors of alternate fuel, efficiency, economics and commercial considerations.

V. **Theory**

**Unit I**

Introduction to alternate fuels: Methanol, ethanol, biogas, producer gas, hydrogen and fuel cell. Production composition and properties, combustion characteristics, comparison with conventional fuels, potential, possibilities and problems.

**Unit II**

Fuel cell: Principle, classification, system efficiency. Life cycle assessment of fuel cell systems.

**Unit III**

Hydrogen fuel: Production, gas cleanup, challenges and opportunities. Hydrogen storage and energy economy.

**Unit IV**

Utilization: Thermal and mechanical applications. Environmental impact and safety factors of alternate fuel, efficiency, economics and commercial considerations.

VI. **Practical**

Performance of I.C. engines on alternate fuels, measurement of flue gas parameters, thermal applications of alternate fuels. Hydrogen production. Biomass based fuel cell. Integrated biomass based gasifier for power generation.

VII. **Learning outcome**

Students will understand various properties of alternate fuels like methanol, ethanol, fuel cells, hydrogen fuel for energy efficient utilization.

VIII. **Lecture Schedule**

| S.No. | Topic | No. of Lectures |
|---|---|---|
| 1 | Introduction to alternate fuels: methanol, ethanol, biogas, producer gas, and hydrogen fuel cell. | 3 |
| 2 | Alternate fuels: potential, possibilities and problems. | 2 |
| 3 | Production, composition and properties of methanol. | 2 |
| 4 | Production, composition and properties of ethanol. | 2 |
| 5 | Production, composition and properties of biogas | 2 |
| 6 | Production, composition and properties of producer gas | 2 |
| 7 | Production and properties of hydrogen fuel cell. | 2 |
| 8 | Combustion characteristics of alternate fuels, comparison of with conventional fuels. | 3 |
| 9 | Fuel cell: Principle, classification, system efficiency | 2 |
| 10 | Life cycle assessment of fuel cell systems. | 2 |
| 11 | Hydrogen fuel: gas cleanup. | |

| | | |
|---|---|---|
| 12 | Hydrogen fuel: challenges and opportunities | 2 |
| 13 | Hydrogen storage and energy economy. | 1 |
| 14 | Thermal and mechanical applications alternate fuel. | 2 |
| 15 | Environmental impact and safety factors of alternate fuels, efficiency, economics and commercial considerations | 3 |
| | **Total** | **32** |

IX. **List of Practical's**

| S.No. | Topic | No. of Practical's |
|---|---|---|
| 1. | Performance of I.C. engines on alternate fuels (biogas, producer gas and biodiesel) | 3 |
| 2. | Measurement of flue gas parameters. | 1 |
| 3. | Thermal applications of alternate fuels (biogas, producer gas and biodiesel) | 3 |
| 4. | Hydrogen production. | 1 |
| 5. | Biomass based fuel cell. | 1 |
| 6. | Integrated biomass-based gasifier for power generation. | 1 |
| | **Total** | **10** |

X. **Suggested Reading**


- Babu MKG and Subramanian KA. 2013. *Alternative Transportation Fuels: Utilization in Combustion Engines*. CRC Press, Florida.
- Bungay HR. 1981. *Energy, the Biomass Options*. John Willey & Sons, New York.
- Dahiya A. 2014. *Bioenergy: Biomass to Biofuels*. *Engines*. Springer, New York City, New York.
- Demirbas A. 2010. *Biodiesel: A Realistic Fuel Alternative for Diesel Chemicals*. Academic Press, Cambridge, England.
- Klass DL. 1998. *Biomass for Renewable Energy, Fuels, and Chemicals*. Academic Press, Cambridge, England.
- Mukunda HS. 2011. *Understanding Clean Energy and Fuels from Biomass*. Wiley India.
- San PA. 1980. *Biochemical and Photosynthetic: Aspects of Energy Production*. Academic Press. London.
- Speight JG and Loyalka SK. 2007. *Handbook of Alternative Fuel Technologies*. CRC Press.Florida.
- Twidell JW and Weir AD. 1986. *Renewable Energy Sources*. E & FN Spon Ltd, New York.
- Brownstein A.M. Renewable Motor Fuel- the past, the present and uncertain future, Newyork Elsevier 2015.
- Devi V.N, Prasand P.M. Fuels and Biofuels, ENGG publisher India agrobios 2007.
- Gregor Hoogers. Fuel cell technology handbook. New york CRE press 2013.

I. **Course Title : Biogas Technology and Mechanism**
II. **Course Code : REE 509**
III. **Credit Hours : 1+1**

IV. **Aim of the course**

To provide in-depth knowledge about biogas technology and its mechanism in detail to use the biogas as domestic as well as commercial fuel.

V. **Theory**

**Unit I**

Biogas Technology: Potential and status, chemistry, physical conditions and utilization of alternate feedstock materials.

**UNIT II**

Types of reactors: Single phase, two phase processes. High rate biomethanation process, selection of model and size, construction technique, material requirement. Design concept of night soil, kitchen waste, solid state cold condition biogas plants.

**Unit III**

Biogas distribution and utilization: Properties and uses of biogas, design of gas distribution system. Biogas utilization devices: Biogas scrubbing and compressing, dual fuel engines and its limitations, generation of power. Testing of biogas appliances.

**Unit IV**

Effluent: Handling of effluent biogas plant, effluent treatment and management, BDS applications and enrichment. Cost and financial viability of biogas plants. Repair and maintenance of biogas plants.

VI. **Practical**

Design of biogas plant for solid and liquid wastes, cost estimation, analysis of biogas, purification of biogas. Performance evaluation of biogas appliances. Testing of biogas burners for heat transfer, thermal and cooking efficiency. Bio digested slurry analysis, use of biogas spent slurry. Carbon credits.

VII. **Learning outcome**

Students are able to design, select, estimate and analyze the biogas technology, chemical and physical conditions and get acquainted with various biogas appliances.

VIII. **Lecture Schedule**

| S.No. | Topic | No. of Lectures |
|---|---|---|
| 1 | Biogas Technology potential and status | 1 |
| 2 | Chemistry, physical conditions and utilization of alternate feedstock materials Biogas plant :- Types and Classification | 1 |
| 3 | Types of reactors: Single phase, two phase processes | 2 |
| 4 | High rate bio-methanation process, selection of model and size, construction technique, material requirement | 1 |
| 5 | Design of Biogas plants based on animal waste and organic were Design concept of night soil, kitchen waste, solid state cold condition biogas plants. | 1 |
| 6 | Properties and uses of biogas, design of gas distribution system | 1 |
| 7 | Biogas scrubbing and compressing, dual fuel engines and its limitations, generation of power | 2 |

| | | |
|---|---|---|
| 8 | Testing of biogas appliances | 2 |
| 9 | Handling of biogas plant effluents, effluent treatment and management | 1 |
| 10 | Bio digested Slurry applications and enrichment | 2 |
| 11 | Cost and financial viability of biogas plants | 1 |
| 12 | Repair and maintenance of biogas plants | 1 |
| | **Total** | **16** |

IX. **List of Practical's**

| **S.No.** | **Topic** | **No. of Lectures** |
|---|---|---|
| 1 | Design of biogas plant for solid and liquid wastes | 1 |
| 2 | Cost estimation of different biogas plants: KVIC, Janta, Deenbandhu | 2 |
| 3. | Analysis of biogas | 1 |
| 4. | Experiment on purification of biogas | 1 |
| 5. | Performance evaluation of biogas appliances | 1 |
| 6. | Testing of biogas burner for heat transfer, thermal and cooking efficiency | 2 |
| 7. | Analysis of Bio-digested slurry | 2 |
| 8. | Study on use of biogas spent slurry | 1 |
| 9 | Study and analysis of Carbon credits. | 1 |
| | **Total** | 12 |

X. **Suggested Reading**


- Abbasi SA and Nipaney PC. 1993. *Modeling and Simulation of Biogas System Economies*. Ashish Pub. House, New Delhi.
- Chawala OP. 1986. *Advances in Biogas Technology*. ICAR, New Delhi.
- Khandelwal KC and Mahdi SS. 1986. *Biogas Technology*. A Practical Hand Book, Vol.I, Tata McGraw-Hill Pub. Co. Ltd, New Delhi.
- Mittal KM. 1996. *Biogas Systems: Principles and Applications*. New Age international **(**P) Ltd, New Delhi.
- Rohlich GA, Walbot V, Connar LJ, Golueke CG, Hinesly TD, Jones PH, Lapp HM, Loehr RC, LueiHing C, Pfeffer JT, Prakasam TBS and Brown NL. 1977. *Methane Generation from Human Animals and Agril Wastes*. National Academy of Sciences, Washington.
- Tasneem A, Tauseef SM and Abbasi SA. 2012. *Biogas Energy*. Springer Publications, Springer Science and Business Media, New York, USA.
- Van BA. 1981. *Chinese Biogas Manual*. Intermediate Technology Publications, London.
- Srivastava and shukla. 1993 A technology and applications of Biogas. Jain Brothers, New Delhi.
- Nijaguna. 2002. Biogas Technology. New Age International Publication. ISBN : 81-224.
- Vijay V.K. and 2012. Biogas Production, upgradation and slurry management, Narosa publishing House, New Delhi.

I. **Course Title : Energy, Ecology and Environment**
II. **Course Code : REE 510**
III. **Credit Hours : 3+0**

IV. **Aim of the course**

To provide detailed knowledge of carbon cycle, ecosystem, climate change and global environmental change and inter linkages of renewable energy sources.

V. **Theory**

**Unit I**

Global carbon cycle. Carbon reservoirs flow and human interventions. Global warming and climate change. Energy efficient technology: Efficiency hierarchy, energy dependent activities, energy policies, linkage between energy use and economic growth and environment. Layers of Atmosphere.

**Unit II**

Ecosystem: Kinds, transfection, components of ecosystem, ecosystem development of evaluation, major ecosystem of the world, physical environment and metrology.

**Unit III**

Climate change: Impact and models. Energy for sustainable development: Development indices, pillars, subsystems, principles and dimensions. Low carbon technologies: Energy efficiency projects, carbon trading. Renewable and non-renewable energy sources.

**Unit IV**

Environment, Environmental degradation: Thermal and chemical pollution, primary and secondary pollutant, air pollution, water pollution, unclear energy hazard, radioactive hazards, mining hazards, land use, oil spills and gas leaks.

**Unit V**

Global environmental changes: United Nations Framework Convention on Climate Change (UNFCC), Kyoto protocol and clean development mechanism: Overview, administration, participation, institutions, procedures, project design and formulation. Soil and noise pollution, acid rain, solid waste management sources, causes and effect, Role of individuals in prevention of pollution.

VI. **Learning outcome**

Students will be able to understand the relationship between carbon cycle, energy policies, energy use and economic growth and factors affecting the environment.

VII. **Teaching Schedule**

| S.No. | Topic | No. of Lectures |
|---|---|---|
| 1. | Global carbon cycle. | 1 |
| 2. | Carbon reservoirs flow and human interventions. | 2 |
| 3. | Global warming and climate change. | 2 |
| 4. | Energy efficient technology: Efficiency hierarchy, energy dependent activities, energy policies, linkage between energy use and economic growth and environment. Layers of Atmosphere | 4 |

| | | |
|---|---|---|
| 4. | Ecosystem: Kinds, transfection, components of ecosystem, | 3 |
| 5. | Ecosystem development of evaluation, major ecosystem of the world, physical environment and metrology. | 3 |
| 6. | Climate change: Impact and models. | 3 |
| | Energy for sustainable development: Development indices, pillars, subsystems, principles and dimensions. renewable and non renewable energy sources. | 2 |
| 7. | Low carbon technologies: Energy efficiency projects, carbon trading. | 3 |
| 8. | Environment, Environmental degradation | 1 |
| 9. | Thermal and chemical pollution, primary and secondary pollutant, air pollution, | 3 |
| 10. | Water pollution | 1 |
| 11. | unclear energy hazard | 1 |
| 12. | Radioactive hazards, mining hazards, land use, oil spills and gas leaks. | 3 |
| 13. | Global environmental changes: United Nations Framework Convention on Climate Change (UNFCC) Soil and noir pollution, Acid rain. | 4 |
| 14. | Kyoto protocol and clean development mechanism: Overview, administration, participation, institutions, procedures, project design and formulation. Solid water management sources cause effect role of individuals in prevention of pollution. | 4 |
| | **Total** | **40** |

VIII. **Suggested Reading**


- Canter LC. 1979. *Environmental Impact Assessment*. McGraw Hill Pub. Co., New York.
- Coley D. 2008. *Energy and Climate Change*. John Wiley & Sons, Ltd., New Jersey.
- Dessler A. 2011. *Introduction to Modern Climate Change*. Cambridge University Press, Cambridge, England.
- Essam E and Hinnami EI. 1991. *Environmental Impact of Production and Use of Energy*. Tycooly Press Ltd, Dublin.
- Fowler JM. 1984. *Energy and the Environment, Second Edition*. McGraw-Hill, New York.
- Kaushika ND and Kaushik K. 2004. *Energy, Ecology and Environment: A Technological Approach.* Capital Publishing, New Delhi.
- Mathur AN, Rathore NS and Vijay VK. 1995. *Environmental Awareness*, Himanshu Pub., Udaipur.
- Puppy HG. *Energy and Environment, Mankind and Energy Needs*. Elsevier Pub. Co., New York.
- Rathore NS and Kurchania AK. 2001. *Climatic Changes and their Remedial Measures*. Shubhi Publications, Gurgaon.
- Thomdike EH. 1978. *Energy and Environment: A Premier for Scientists and Engineers*. Adson, Wesley Pub. Co., Boston, US.

- Wilson R and Jones WJ. 1974. *Energy, Ecology and the Environment*. Academic Press Inc., Cambridge, Massachusetts, US.
- C. manoharo chary, p. jayarams Reddy. Principles of Environmental studies (Ecology, Economics management and law) , B S publications Hyderabad.
- RituBir. Environmental studies , Vayu. Eduction of India.
- V. K. Ahliwalissanitamalhotra. Environmental science. Ane Books PVT. LTD. 2009.
- DurgaNathDhar, TrilokiVaishShalinkumar. Environmental Science and ethics, , Vayu Education of India New Delhi 2009.
- R. Rajagopalan. Environmental Studies from crisis to cure Second edition, Oxford university press.

I. **Course Title : Design and Analysis of Renewable Energy Conversion Systems**

II. **Course Code : REE 511**

III. **Credit Hours : 2+1**

IV. **Aim of the course**

To design and analyze renewable energy conversion systems, thermodynamics involved in it and performance of renewable energy systems.

V. **Theory**

**Unit I**

Energy cycle of the earth. Estimation and assessment of renewable energy sources: Water flow and storage, ocean currents and tides, biomass energy, solar energy, wind energy and other renewable energy sources.

**Unit II**

Thermodynamics of renewable energy conversion: Energy and exergy analysis of renewable energy power systems. Principle of design of RECS. Optimum design of hybrid renewable energy systems: Concept, considerations and methodologies.

**Unit III**

Design of renewable energy systems: Design concept, operational parameters, consideration and rational values for agro industrial applications and domestic applications.

**Unit IV**

Performance analysis of renewable energy systems: Standards and test codes, optimum performance records, evaluation and maintenance aspects, uses of HOMER (Hybrid Optimization Model for Electric Renewable) software.

VI. **Practical**

Estimation and assessment of renewable energy sources in India. Thermodynamic principles of energy conversion. Design and operational parameters of renewable energy systems. Study on standards and test codes of renewable energy systems.

VII. **Learning outcome**

Students will be able to design various energy conversion systems, standards and test codes of renewable energy systems and their performance analysis.

VIII. **Teaching Schedule**

| **S.No.** | **Topic** | **No. of Lectures** |
|---|---|---|
| 1 | Energy cycle of the earth | 1 |
| 2 | Estimation and assessment of renewable energy sources: Water flow and storage, ocean currents and tides | 2 |
| 3 | Estimation and assessment of renewable energy sources: biomass energy, solar energy, wind energy | 3 |
| 4. | Estimation and assessment of renewable energy sources: other renewable energy sources. | 2 |
| 5. | Thermodynamics of renewable energy conversion: Energy and energy analysis of renewable energy power systems. | 4 |
| 6. | Optimum design of hybrid renewable energy systems: Concept, considerations and methodologies. | 4 |
| 7. | Design of renewable energy systems: Design concept, operational parameters, | 4 |
| 8. | Design of renewable energy systems: Consideration and rational values for agro industrial applications. | 4 |
| 9. | Performance analysis of renewable energy systems: Standards and test codes, optimum performance records | 3 |
| 10. | Performance analysis of renewable energy systems: Evaluation and maintenance aspects | 3 |
| 11. | Uses of HOMER (Hybrid Optimization Model for Electric Renewable) software. | 2 |
| | **Total** | **32** |

IX. **List of Practical's**

| **S.No.** | **Topic** | **No. of Practicals** |
|---|---|---|
| 1. | Estimation and assessment of renewable energy sources in India | 1 |
| 2. | Thermodynamic principles of energy conversion | 2 |
| 3. | Design and operational parameters of biogas plant | 2 |
| 4. | Design of a updraft gasifier using solid biomass | 2 |
| 5. | Design of solar photovoltaic plant for a hostel/and residential buildings. | 2 |
| 6 | Life cycle assessment and financial assessment of a photovoltaic plant for a hostel/building | 1 |

| | | |
|---|---|---|
| 7. | Study on standards of renewable energy systems | 1 |
| 8. | Study on test codes of renewable energy systems | 2 |
| | **Total** | **13** |

X. **Suggested Reading**


- Boyle G. 1996. *Renewable Energy: Power for a Sustainable Future*. Oxford Univ. Press, England.
- Culp AW. 1991. *Principles of Energy Conservation*. Tata McGraw-Hill, New Delhi.
- Duffle JA and Beckman WA. 1991. *Solar Engineering of Thermal Processes*. John Wiley, Hoboken, North America.
- Garg HP and Prakash J. 1997. *Solar Energy: Fundamental and Application*. Tata McGraw-Hill, New Delhi.
- Grewal NS, Ahluwalia S, Singh S and Singh G. 1997. *Hand Book of Biogas Technology*. TMH New Delhi.
- Lambert T and Lilienthal P 2004. *Homer: The Micro-Power Optimization Model*. National Renewable Energy Lab., Philippines.
- Manwell JF, McGowan JG and Rogers AL. 2003. *Wind Energy Explained*. John Wiley, Hoboken, North America.
- Mittal KM. 1985. *Biomass Systems: Principles and Applications*. New Age International, New Delhi.
- Patel MK. 1999. *Wind and Solar Power Systems*. CRC Press, Florida.
- Kishor VVN. Renewable Energy Engineering and Technology Acknowledge compendium, TERI press. ND.
- Manwell J.F. and Mangowan J.G. Wind Energy Theory, design and application. ENGG publisher N.D.

I. **Course Title : Energy Generation from Agricultural Waste and Byproducts**
II. **Course Code : REE 512**
III. **Credit Hours : 2+1**

IV. **Aim of the course**

To focus on agricultural wastes and by products for its utilization for energy generation.

V. **Theory**

**Unit I**

By Products: Generation, estimation and utilization. Agricultural and agro industrial by-products/wastes: Properties, characterization, on site handling, storage and processing. Concept, scope and maintenance of waste management and effluent treatment

**Unit II**

Waste as fuel: Utilization pattern, pretreatments, secondary treatments, Agricultural waste fired furnaces: mechanism, construction, efficiency. suitability of waste as fuel.

**Unit III**

Utilization of agro based industrial wastes for paper production, production of particle board, fertilizer through vermi-composting and fuel.

**Unit IV**

Thermo-chemical and biochemical conversion of agricultural waste and byproducts: Densification, combustion, gasification, extraction, pyrolysis, carbonization, torrefaction, liquefaction, anaerobic digestion and fermentation process.

VI. **Practical**

Estimation and characterization of agricultural waste and byproducts, production of fuel from agricultural wastes and by products, techno-economic feasibility of waste to fuel systems.

VII. **Learning outcome**

Student will be able to understand the estimation, characterization, storage and handling of agricultural wastes and by products to generate the energy.

VIII. **Teaching Schedule**

| **S. No.** | **Topic** | **No. of Lectures** |
|---|---|---|
| 1 | Introduction to Agricultural and agro industrial by-products/ wastes:. | 1 |
| 2 | Generation, estimation and utilization of Agricultural and agro-industrial by-products/wastes | 2 |
| 3 | Properties, characterization, of Agricultural and agro industrial by-products/wastes | 1 |
| 4 | On site handling, storage and processing Agricultural and agro industrial by-products/wastes | 2 |
| 5 | Concept, scope and maintenance of waste management and effluent treatment | 2 |
| 6 | Introduction to Waste as fuel:. Utilization pattern of waste as Fuel in India and world | 2 |

| | | |
|---|---|---|
| 7 | Pre treatments and secondary treatments for waste for conversion to Fuel | 2 |
| 8 | Agricultural waste fired furnaces. | |
| 9 | Suitability of waste as fuel. | |
| 10 | Mechanism, construction, efficiency and suitability of treatments | 2 |
| 11 | Utilization of agro based industrial wastes for paper production | 2 |
| 12 | Production of particle board, | 1 |
| 13 | Fertilizer through vermi-composting and fuel | 1 |
| 14 | Introduction to Thermo-chemical conversion of agricultural waste and by-products | 1 |
| 15 | Introduction to biochemical conversion of agricultural waste and by-products | 1 |
| 16 | Densification | 1 |
| 17 | Combustion | 1 |
| 18 | Gasification | 1 |
| 19 | Extraction | 1 |
| 20 | Pyrolysis | 1 |
| 21 | Carbonization | 1 |
| 22 | Torrefaction | 1 |
| 23 | Liquefaction | 1 |
| 24 | Anaerobic digestion | 2 |
| 25 | Fermentation process | 2 |
| | **Total** | **32** |

IX. **List of Practical's**

| **S.No.** | **Topic** | **No. of Practical's** |
|---|---|---|
| 1. | Estimation of agricultural waste by remote sensing and field Method | 2 |
| 2. | Characterization of agricultural waste and by products | 1 |
| 3. | Determination of moisture content ,V.S., F.C. and ash content | 1 |
| 4. | Estimation of calorific value of biomass | 1 |
| 5. | Estimation of calorific value of biogas | 1 |
| 6. | Estimation of calorific value of producer gas | 1 |
| 7. | Estimation of calorific value of Liquid fuel. | 1 |
| 8. | Determination of Lignin ,Cellulose, and hemicellulose in biomass | 1 |
| 9. | Production of fuel from agricultural wastes and by products, | 1 |
| 10. | Production of Biogas, Producer gas and Biodiesel from Agricultural waste | 1 |
| 11. | Production of producer gas from Agricultural wastes | 1 |

| | | |
|---|---|---|
| 12. | Production of Biodiesel from Agricultural wastes. | 2 |
| 13. | Techno-economic feasibility of waste to fuel systems | 2 |
| **Total** | | **16** |

X. **Suggested Reading**


- Anonymous. 1984. *Manure Production and Characteristics.* ASAE Standards, America.
- Chahal DS. 1991. *Food, Feed and Fuel from Biomass.* Oxford & IBH, New Delhi.
- David C Wilson. 1981. *Waste Management, Planning, Evaluation, Technologies*. Clarendon Press, Oxford, England, UK.
- Klass DL and George EH. 1981. *Fuels from Biomass and Wastes*. Ann. Arbor. Science Publ., New York.
- Luh BS. 1991. *Rice: Production and Utilization*. AVI Publ. Company Inc., Westport, Connecticut.
- Srivastava PK, Maheswari RC and Ohja TP. 1995. *Biomass Briquetting and Utilization.* Jain Bros. Publications, New Delhi.
- Methane Generation from Human, Animal and Agricultural wastes:- ENGG publisher. Delhi. National Academy 1977.
- Wise D.L. 1981 Fuel Gas Production from Biomass Vol. 1 and Vol. 2

I. **Course Title : Agro Energy Audit and Management**

II. **Course Code : REE 513**

III. **Credit Hours : 2+1**

IV. **Aim of the course**

To emphasize the energy audit and its management in agriculture production system and agro based industries.

V. **Theory**

**Unit I**

Energy resources on the farm: Conventional and non-conventional forms of energy and their use. Heat equivalents and energy coefficients for different agricultural inputs and products. Pattern of energy consumption and their constraints in production of agriculture.

**Unit II**

Direct and indirect energy, energy audit of production agriculture, rural living and scope of conservation.

**Unit III**

Energy requirement in different agro-based industries: Energy analysis, energy ratio and specific energy value. Identification of energy efficient machinery systems: energy losses and their management.

**Unit IV**

Energy analysis techniques and methods: Energy balance, output and input ratio, resource utilization, conservation of energy sources. Energy conservation planning and practices.

VI. **Practical**

Study of energy audit techniques, energy use pattern and management strategies in various agro-industries, assessment of overall energy consumption, production and its cost in selected agro- industries. Estimation of energy requirement in different agriculture production system, study of energy input/output ratio of different agriculture production system.

VII. **Learning outcome**

Students will learn detailed energy audit, energy balance techniques, energy management strategies, energy conservation planning and practices in agriculture production system.

VIII. **Lecture Schedule**

| S.No. | Topic | No. of Lectures |
|---|---|---|
| 1 | Energy resources on the farm. | 2 |
| 2 | Conventional and non-conventional forms of energy and their use. | 2 |
| 3 | Heat equivalents and energy coefficients for different agricultural inputs and products. | 3 |
| 4 | Pattern of energy consumption and their constraints in production of agriculture. | 3 |
| 5 | Direct and indirect energy | 2 |
| 6 | Energy audit of production agriculture, rural living and scope of conservation. | 3 |
| 7 | Energy requirement in different agro-based industries. | 2 |

| | | |
|---|---|---|
| 8 | Energy analysis, energy ratio and specific energy value. | 2 |
| 9 | Identification of energy efficient machinery systems. | 2 |
| 10 | Energy losses and their management. | 2 |
| 11 | Energy analysis techniques and methods. | 2 |
| 12 | Energy conservation planning and practices. | 2 |
| 13 | Energy balance, output and input ratio, resource utilization. | 3 |
| 14 | Conservation of energy sources. | 2 |
| | **Total** | **32** |

IX. **List of Practical's**

| **S.No.** | **Topic** | **No. of Practical's** |
|---|---|---|
| 1 | Study of energy audit techniques. | 2 |
| 2 | Energy use pattern and management strategies in various agro-industries. | 2 |
| 3 | Assessment of overall energy consumption, production and its cost inselected agro-industries. | 2 |
| 4 | Estimation of energy requirement in different agriculture production system | 2 |
| 5 | Study of energy input/output ratio of different agriculture production system. | 2 |
| | **Total** | 10 |

X. **Suggested Reading**


- Fluck RC and Baird CD. 1984. *Agricultural Energetics*. AVI Publ. Company, Inc., Westport, Connecticut.
- Kennedy WJ Jr and Turner WC. 1984. *Energy Management.* Prentice Hall, Upper Saddle River, New Jersey.
- Pimental D. 1980. *Handbook of Energy Utilization in Agriculture*. CRC Press, Florida.
- Rai GD. 1998. *Nonconventional Sources of Energy*. Khanna Publ., New Delhi.
- Singh CP. 1978. *Energy Requirement of Important Farm Operations for Existing Cropping System in Punjab.* PAU, Ludhiana.
- Twindal JW and Wier AD. 1986. *Renewable Energy Sources*. E & F.N. Spon Ltd, New York.
- Verma SR, Mittal JP and Singh S. 1994. *Energy Management and Conservation in Agricultural Production and Food Processing.* USG Publ. &Dist, Ludhiana.
- S. Singh, R.S.Singh. 2014. Energy for production Agriculture DIPA- ICAR, New Delhi.
- Doty S. turner N.C. 2012 Energy management handbook colon do the fairmount press inc.

I. **Course Title : Greenhouse Energetic and Passive Architecture**

II. **Course Code : REE 514**

III. **Credit Hours : 1+1**

IV. **Aim of the course**

To provide in-depth knowledge about greenhouse design, energetics, production technique, passive heating concept and evaporative cooling etc.

V. **Theory**

**Unit I**

Green House: Environmental requirement, analysis of thermal energy flows, analysis of a greenhouse as solar collector. Instrumentation and control in green house.Passive concepts and components: Passive heating concepts, direct gain, indirect grain, isolated gains and sunspace passive cooling concepts,

**Unit III**

Evaporative cooling: Evaporative air and water coolers, application of wind, water and earth for cooling, use of isolation, shading, paint sand cavity walls for cooling.

**Unit IV**

Passive heating and cooling: Concepts, roof pond/sky therm, roof radiation trap, vary thermo wall, earth sheltered or earth based structures and earth air tunnels, ventilation, components, windows and thermal storage.

VI. **Practical**

Design of passive structures for animals, rural housing, study of evaporative cooling, air and light flows in house, survey of green houses, greenhouse energetic.

VII. **Learning outcome**

Students get knowledge of thermal energy flows, analysis of greenhouse, instrumentation and control in greenhouse.

VIII. **Teaching Schedule**

| **S.No.** | **Topic** | **Lectures** |
|---|---|---|
| 1. | Green House: Environmental requirement, analysis of thermal energy flows, analysis of a greenhouse as solar collector. | 3 |
| 2. | Instrumentation and control in green house. | 2 |
| 3. | Passive concepts and components | 1 |
| 4. | Passive heating concepts | 1 |
| 5. | Direct gain, indirect grain, isolated gains and sunspace passive cooling concepts | 3 |
| 6. | Evaporative cooling: Evaporative air and water coolers, application of wind, water and earth for cooling | 2 |
| 7. | Use of isolation, shading, paint, sand cavity walls for cooling. | 1 |
| 8. | Passive heating and cooling | 1 |

| | | |
|---|---|---|
| 9. | Concepts, roof pond/sky theorem, roof radiation trap, varying thermo wall, earth sheltered or earth based structures and earth air tunnels, ventilation, components, windows and thermal storage. | 2 |
| | **Total** | **16** |

IX. **List of Practical's**

| S.No. | Topic | No. of Practical's |
|---|---|---|
| 1. | Design of passive structures for animals. | 2 |
| 2. | Design of passive structures for rural housing | 2 |
| 3. | Study of evaporative cooling | 1 |
| 4. | Study of air and light flows in house | 1 |
| 5. | Survey of green houses | 8 |
| 6. | Green house energetic | 2 |
| | **Total** | **16** |

X. **Suggested Reading**


- Parkar BE. 1991. *Solar Energy in Agriculture*. Elsevier, Amsterdam.
- Pattern AR. 1975. *Solar Energy for Heating and Cooling of Building*. Noyal Date Corporation (NDC), Park Ridge, New Jersey, USA.
- Paul JK. 1975. *Passive Solar Energy Design and Materials*. Noyel Data Corporation, Park Ridge, New Jersey, USA.
- Radhamanohar K and Igathinathane C. 2000. *Green House Technology and Management*. B.S. Publication. 4309 Sultan Basar, Hyderabad.
- Sodha MS, Bansal NK, Kumar PKA and Malik MAS. 1986. *Solar Passive: Building Science and Design*. Pergamon Press, New York.
- Esmay ML and Dixaon JE. 1986 Environmental control per Agricultural Buildings the AVI corp.
- Tiwari GN and Goyal RK. Green house Technology Fundamental Design, modeling and Applications. Narosa publishing house. New Delhi.
- Nelson pv. 2011 Greenhouse operation and management prentice hall pub.
- Tiwari GN. 2012 Greenhouse Technology of controlled Environment. Narosa publishing house New Delhi.

I. **Course Title : Energy Management in Food Processing Industries**

II. **Course Code : REE 515**

III. **Credit Hours : 1+1**

IV. **Aim of the course**

To acquaint and equip the students with different energy management techniques including energy auditing of food industries.

V. **Theory**

**Unit I**

Energy forms and units, energy perspective, norms and scenario, energy auditing, data collection and analysis for energy conservation in food processing industries.

**Unit II**

Sources of energy, its audit and management in various operational units of the agro-processing units, passive heating, passive cooling, sun drying and use of solar energy, biomass energy and other non-conventional energy sources in agro-processing industries.

**Unit III**

Reuse and calculation of used steam, hot water, chimney gases and cascading of energy sources. Energy accounting methods, measurement of energy, design of computer-based energy management systems, economics of energy use.

VI. **Practical**

Study of energy use pattern in various processing units i.e., rice mills, sugar mills, dal mills, oil mills, cotton-ginning units, milk plants, food industries etc. Energy audit study and management strategies in food processing plants. Identification of energy efficient processing machines. Assessment of overall energy consumption, production and its cost in food processing plants, visit to related food processing industry.

VII. **Learning outcome**

Student's capability to understand energy sources, analyze energy requirement in food processing operations and to economize it in food industries.

VIII. **Teaching Schedule**

| S.No. | Topic | No. of Lectures |
|---|---|---|
| 1. | Energy forms and units, energy perspective, norms and scenario | 2 |
| 2. | Energy auditing: definition, types of energy audit, planning | 2 |
| 3. | Data collection and analysis for energy conservation in food processing industries. | 2 |
| 4. | Sources of energy, its audit and management in various operational units of the agro-processing units | 2 |
| 5. | Passive heating, passive cooling, sun drying and use of solar energy in agro-processing industries. | 1 |

| | | |
|---|---|---|
| 6. | Use of biomass energy and other non-conventional energy sources in agro-processing industries. | 2 |
| 7. | Reuse and calculation of used steam, hot water, chimney gases and cascading of energy sources. | 2 |
| 8. | Energy accounting methods, measurement of energy | 1 |
| 9. | Design of computer-based energy management systems, economics of energy use. | 2 |
| | **Total** | **16** |

IX. **List of Practical's**

| S.No. | Topic | No. of Practical's |
|---|---|---|
| 1. | Study of energy use pattern in rice mill | 1 |
| 2. | Study of energy use pattern in sugar mill | 1 |
| 3. | Study of energy use pattern in dal mill | 1 |
| 4. | Study of energy use pattern in oil mill | 1 |
| 5. | Study of energy use pattern in cotton-ginning unit | 1 |
| 6. | Study of energy use pattern in milk plant | 1 |
| 7. | Energy management strategies in rice mill | 1 |
| 8. | Energy management strategies in sugar mill | 1 |
| 9. | Energy management strategies in oil mill | 1 |
| 10. | Energy management strategies in milk plant | 1 |
| 11. | Identification of energy efficient processing machines | 2 |
| 12. | Assessment of overall energy consumption, production and its cost in food processing plants | 2 |
| 13. | Visit to related food processing industry | 2 |
| | **Total** | **16** |

X. **Suggested Reading**


- Pimental D. 1980. *Handbook of Energy Utilization in Agriculture*. CRC Press.
- Rai GD. 1998. *Non-conventional Sources of Energy*. Khanna Publisher.
- Twindal JW and Wier AD. 1986. *Renewable Energy Sources*. E & F. N. Spon Ltd.
- Verma SR, Mittal JP and Singh S. 1994. *Energy Management and Conservation in Agricultural Production and Food Processing*. USG Publisher and Distributors, Ludhiana.
- Surendrasingh, R.S. Singh. 2014. Energy for Production Agriculture, DIPA, ICAR, New Delhi.
- Bureau of Energy efficiency. Guide books Vol. 1 , 2 and 3. BEE, New Delhi.

# Course Syllabus and Contents of Doctoral Degree

I. **Course Title : Biochemical Conversion of Biomass**

II. **Course Code : REE 601**

III. **Credit Hours : 2+1**

IV. **Aim of the course**

To impart the advanced knowledge about biochemical conversion technologies of biomass, engineering design and kinetic of bio-energy systems.

V. **Theory**

**Unit I**

Biomass formation: Energy recovery and recycling. Biochemical conversion of organic wastes: Methane production, vertical through digesters, high solid digestion, sludge treatment.

**Unit II**

Lagoons: Composting, contact and filter digestion, reactors, physical and chemical removal of dissolved materials. Activated sludge and other suspended culture process parameters. Waste waters, biological film flow processes, sanitation land fill, predigestion of waste.

**Unit III**

Engineering design of biogas units: Biogas boosters, structural behaviour, alternate construction materials, multi-criteria optimization, immobilization, modular biogas for tropical areas, kinetic models.

**Unit IV**

Bioconversion of biomass to alcohol: Types and pre-treatment of biomass, production process. Fermenter design and process parameters. Economics of bio-alcohol production, reaction kinetics, gasohol. Bio-hydrogen from algae/biomass.

VI. **Practical**

Lagoons and compositing. Biogas plant: Analysis of biogas system. Determination of methane production rate and parameters, biogas storage, purification, utilization and kinetic equations. Alcohol production, optimization of process parameters, fermenter designing and evaluation. Economic calculations of biogas and alcohol.

VII. **Learning outcome**

The student will able to design, analyze and evaluate the various biomass conversion technologies and parameters related to biomass for utilization of it for fuel extraction.

IX **Teaching Schedule**

| S.No. | Topic | No. of Lectures |
|---|---|---|
| 1. | Biomass formation, Biomass, Classification | 1 |
| 2. | Energy recovery and recycling. | 1 |
| 3. | Biochemical conversion of organic wastes. | 1 |
| 4. | Methane production, vertical through digesters, high solid digestion. | 2 |
| 5. | Sludge treatment. | 1 |
| 6. | Lagoons: Composting, contact and filter digestion, reactors. | 2 |
| 7. | Physical and chemical removal of dissolved materials. | 2 |

| | | |
|---|---|---|
| 8. | Activated sludge and other suspended culture process parameters. | 2 |
| 9. | Waste waters | 1 |
| 10 | Biological film flow processes, sanitation land fill, pre-digestion of waste. | 2 |
| 11 | Engineering design of biogas units | 2 |
| 12. | Biogas boosters, structural behaviour. | 1 |
| 13. | Alternate construction materials. | 1 |
| 14. | Multi-criteria optimization, immobilization. | 2 |
| 15. | Modular biogas for tropical areas. Kinetic models | 2 |
| 16. | Bioconversion of biomass to alcohol | 1 |
| 17. | Types and pre-treatment of biomass production process. | 2 |
| 18. | Fermenter design and process parameters. | 2 |
| 19. | Economics of bio-alcohol production. | 1 |
| 20. | Reaction kinetics, Gasohol. | 1 |
| 21. | Bio-hydrogen from algae/biomass. | 2 |
| | **Total** | **32** |

X**. List of Practical's**

| S.No. | Topic | No. of Practical's |
|---|---|---|
| 1. | Lagoons and compositing. | 1 |
| 2. | Analysis of biogas systems. | 2 |
| 3. | Determination of methane production rate and parameters. | 1 |
| 4. | Biogas storage, purification. | 1 |
| 5. | Biogas storage utilization and kinetic equations. | 1 |
| 6. | Alcohol production, optimization of process parameters. | 1 |
| 7. | Fermenter designing and evaluation. | 1 |
| 8. | Economic calculations of biogas and alcohol. | 2 |
| | **Total** | **10** |

**X. Suggested Reading**


- Culp AW. 1979. *Principles of Energy Conversion*. McGraw Hill Book Company, New York, USA.
- Kiang YH. 1981. *Waste Energy Utilization Technology*. Marcel Dekkar, New York, USA.
- Klan E. 1985. *Energy from Biomass and Wastes.* Institute of Gas Technology, Chicago.
- Wilson DG and Reinhold VN. 1977. *Hand Book of Solid Waste Management.* McGraw Hill Book Company, New York, USA.
- Hongzhangchen and Lan wang Technologies for Biochemical conversion of Biomass Elsevier. Science publishing.

I. **Course Title : Thermo-Chemical Conversion of Biomass**
II. **Course Code : REE 602**
III. **Credit Hours : 2+1**

IV. **Aim of the course**

V. To help students to understand in depth knowledge of thermo-chemical conversion of organic waste, combustion chemistry and different heat based conversion technologies for fuel and power generation.

VI. **Theory**

**Unit I**

Biomass: Characterization, resources and energy recovery. Thermo-chemical conversion of organic wastes. Chemical thermodynamics, stoichiometry and thermodynamics.

**Unit -II**

VII. Combustion of fuels: Solid fuels, stoker, types, fluidised bed. Liquid fuels: Atomization, vapour concentration, combustion phenomena. Gaseous fuel: Flame characteristics, infiammability limits, submerged combustion, combustion with explosion flame, pulsating combustion.

**Unit III**

Biomass Gasification: Gasifier configurations, classification, entrained flow, fluidized bed, moving bed, plasma gasification. Coal gasification technologies. Syngas characteristics. Tar and particulates in gasification. Integrated coal gasification. Gas turbine technologies.

**Unit IV**

Pyrolysis: Models, regimes, kinetics and effect of process parameters. Radiant heat flux, heterogeneous reactions, wall heat transfer. Fluidised bed reactors: Heat transfer circulating beds, moving bed reactor.

**Unit V**

Torrefaction and charcoal production: Carbonization parameters, temperature zone, input output, energy density ratios and characterization of finished products.

VIII. **Practical**

Combustion thermodynamics and phenomenon in solid, liquid and gaseous fuels. TGA studies. Liquid and gaseous burners, flame studies, flue gas, heat budgeting. Kinetic study on gasifiers. Producer gas based power generation systems. Kinetic and model studies for torrefaction, char coal and bio oil production.

IX. **Learning outcome**

Students will enable to critical analysis of combustion of fuel and system design for thermos chemical conversion technologies for domestic and industrial applications.

X. **Teaching Schedule**

| **S.No.** | **Topic** | **No. of Lectures** |
|---|---|---|
| 1. | Biomass: Characterization, resources and energy recovery | 2 |
| 2. | Thermo-chemical conversion of organic wastes | 1 |
| 3. | Chemical thermodynamics and stoichiometry | 3 |

| | | |
|---|---|---|
| 4. | Combustion of solid fuels: stoker, types, fluidized bed | 2 |
| 5. | Combustion of liquid fuels: Atomization, vapour concentration, combustion phenomena. | 2 |
| 6. | Combustion of gaseous fuel: Flame characteristics, infammability limits, submerged combustion, combustion with explosion flame pulsating combustion. | 2 |
| 7. | Biomass Gasification: Gasifier configurations , classification, entrained Flow, guided bed, moving bed, plasma gasification | 3 |
| 8. | Coal gasification technologies, Integrated coal gasification | 2 |
| 9. | Syngas characteristics, Tar and particulates in gasification. | 2 |
| 10. | Gas turbine technologies. | 2 |
| 11. | Pyrolysis: Models, regimes, kinetics and effect of process parameters | 2 |
| 12. | Radiant heat fix, heterogeneous reactions, wall heat transfer. | 2 |
| 13. | Fluidized bed reactors: Heat transfer circulating beds, moving bed reactor | 2 |
| 14. | Torrefaction and charcoal production: Carbonization parameters, temperature zone, input output | 2 |
| 15. | Energy density ratios and characterization of finished products. | 2 |
| | **Total** | **31** |

IX. **List of Practical’s**

| **S.No.** | **Topic** | **No. of Practical’s** |
|---|---|---|
| 1. | Combustion thermodynamics and phenomenon in solid, liquid and gaseous fuels | 2 |
| 2. | Determination of efficiency of improved chulha through water boiling test procedure. | 1 |
| 3. | Thermo-gravimetric analysis of biomass sample | 1 |
| 4. | Study of liquid burners | 1 |
| 5. | Study of gaseous burners | 1 |
| 6. | Flame studies and flue gases | 1 |
| 7. | Study on heat budgeting | 1 |
| 8. | Study on kinetics of fluidized bed gasifier | 1 |
| 9. | Producer gas based power generation systems | 1 |
| 10. | Kinetic and model studies for Torrefaction | 2 |
| 11. | Kinetic and model studies for charcoal production. | 2 |
| 12. | Kinetic and model studies for bio oil production. | 2 |
| | **Total** | **16** |

X. **Suggested Reading**


- Culp AW. 1979. *Principles of Energy Conversion*. McGraw Hill Book Company, New York, USA.
- Glassman I. 1987. *Combustion*. Academic Press Inc. Orlando, Florida, USA.
- Klan E. 1985. *Energy from Biomass and Wastes*. Institute of Gas Technology, Chicago.
- Kiang YH. 1981. *Waste Energy Utilization Technology*. Marcel Dekkar, New York, USA.
- Rezaiyan J and Cheeremisinoff NP. 2005. *Gasification Technologies–A Primer for Engineers and Scientists.* CRC Press, Taylor and Francis group, New York, USA.
- Tchobanoglous G and Elliassen HTR. 1978. *Solid Wastes*. McGraw Hill Book Company, New York, USA.
- Wilson DG and Reinhold VN. 1977. *Hand Book of Solid Waste Management*. Van Nostrand Reinhold Company, New York.
- Non-conventional Energy sources by-Rathore N.S Kuchania A.K. New Delhi. Himanshu Publications 2018, ISBN : 8179061660
- Renewable Energy theory and practice by- Rathore N.S. panwaz. N.L. and Kazhania A.K. Delhi Himanshu Publications 2018, ISBN : 978-81-7906-131-2
- Biomass Gasification pyzolysinTozzefaction by-Basu.p Delhi Elsevice-2008

**I. Course Title : Advances in Renewable Energy Systems**
**II. Course Code : REE 603**
**III. Credit Hours : 2+1**

**IV. Aim of the course**

To provide in depth knowledge, understanding and application oriented skills on advanced renewable energy systems and relevant technologies towards their effective utilization for meeting energy demand.

**V. Theory**

**Unit I**

Solar thermal energy systems: Kinetics and heat transfer analysis, modelling studies. Design and performance of solar thermal systems, mathematical models, power plants, design and performance.

**Unit II**

Photovoltaics: Thermodynamic limitations of photocells. Semiconductors: P-n and n-p junctions, module design, sizing, power control and storage, space charge control, low pressure diode, cesium converter. Photo electro chemical cells, photo electrolysis cell.

**Unit III**

Wind power: Rotor design procedure, betz limit, ideal horizontal axis wind turbine, wake rotation, momentum theory and blade element theory, blade shape for ideal rotor without wake rotation, performance prediction wind turbine rotor dynamics and dynamic models.

**Unit IV**

Designing of water pumping wind mills: Electric power, power transformers, electrical machines, ancillary electrical equipment, wind power to consumer/grid. Wind turbine: Sitting, installation and operation issues, offshore wind farms, operation in severe climates.

**VI. Practical**

Design parameters of air collectors. Thermal analysis and heat loss, regularity models of heliostatic fields, power plant design. Photovoltaic cells characteristic curves. Water pumping.Power control system, grid control devices.Design of wind mills, rotor design procedure, momentum theory and blade element theory. Wind mill installation and operation issues.

**VII. Learning outcome**

The student is able to design and analyzed the renewable energy systems and relevant technologies critically with economic feasibility.

**VIII. Teaching Schedule**

| S.No. | Topic | No. of Lectures |
|---|---|---|
| 1 | Solar thermal energy systems | 1 |
| 2 | Kinetics and heat transfer analy sis, modelling studies. | 3 |
| 3 | Design and performance of solar thermal systems | 2 |
| 4 | Mathematical models, power plants, design and performance | 2 |
| 5 | Solar thermal energy systems: Kinetics and heat transfer analysis, modelling studies. | 2 |

| | | |
|---|---|---|
| 6 | Design and performance of solar thermal systems, mathematical models, power plants, design and performance | 3 |
| 7 | Photo-voltaic | 1 |
| 8 | Thermodynamic limitations of photocells. | 2 |
| 9 | Semiconductors: P-n and n-p junctions, module design, sizing, power control and storage, space charge control, low pressure diode, cesium converter. | 2 |
| 10 | Photo electro chemical cells, photo electrolysis cell | 1 |
| 11 | Wind power | 1 |
| 12 | Design procedure of rotor, betz limit, ideal horizontal axis wind turbine, wake rotation, momentum theory and blade element theory, blade shape for ideal rotor without wake rotation | 3 |
| 13 | Performance prediction wind turbine rotor dynamics and dynamic models. | 1 |
| 14 | Designing of water pumping wind mills. | 1 |
| 15 | Electric power, power transformers. | 1 |
| 16 | Electrical machines, ancillary electrical equipment, wind power to consumer/grid | 2 |
| 17 | Wind turbine: Sitting, installation and operation issues | 2 |
| 18 | Offshore wind farms, operation in severe climates | 2 |
| | **Total** | **32** |

IX. **List of Practical's**

| **S.No.** | **Topic** | **No. of Practical's** |
|---|---|---|
| 1. | Design parameters of solar air collectors. | 1 |
| 2. | Thermal analysis and heat loss analysis of solar collector | 1 |
| 3. | Regularity models of heliostatic fields | 1 |
| 4. | Design of solar thermal power plant. | 2 |
| 5. | Photovoltaic cells characteristic curves. | 1 |
| 6. | Analysis of water pumping with photovoltaic cells. | 1 |
| 7. | Power control systems for wind turbines | 1 |
| 8. | Grid control devices for wind power plants | 1 |
| 9. | Design of wind mills. | 2 |
| 10. | Rotor design procedure for wind turbine | 1 |
| 11. | Momentum theory and blade element theory | 2 |
| 12. | Installation of wind mill. | 1 |
| 13. | Wind mill operation issues. | 1 |
| | **Total** | **16** |

## X. Suggested Reading


- Anderson EE. 1983. *Fundamentals of Solar Energy Conversion*. Addision Wesley publication Company, Boston, United State.
- Kishore VVN. 2008. *Renewable Energy Engineering and Technology–A Knowledge Compendium*. TERI Press, New Delhi, India.
- More HG and Maheshwari RC. *Wind Energy Utilization in India*. Technical Bulletin No.CIAE/82/38,CIAE, Bhopal.
- Powar AG and Mohod AG. 2010. *Wind Energy Technology*. Jain Publication, New Delhi, India.
- Rai GD. 1994. *Nonconventional Sources of Energy*. Khanna Publishers, New Delhi, India.
- Rao S and Parulekar BB. 1994. *Energy Technology Nonconventional, Renewable and Conventional*. Khanna Publishers, New Delhi, India.
- Sitharthan R and Geethanjali M. 2014. *Wind Energy Utilization in India: A Review*. MiddleEast Journal of Scienti□c Research, Pakistan.
- Solanki CS. 2011. *Solar Photovoltaics: Fundamentals, Technologies and Applications*. PHI Learning Private Limited, New Delhi, India.
- Sukhatme SP and Nayak J. 2008. *Solar Energy: Principles of Thermal Collection and Storage*.Tata McGraw Hill Publishing Company Limited, New Delhi, India.
- MattewBuresh photovoltaic energy systems. Tata.McGraw Hill Publication. N.D.
- Rathore N.S. panwar N.L. Renewable Energy sources for sus. Development. New India Pub, ND.
- Bala B. K. Renewable Energy , ENG Publisher, ND.
- Narsesian I.R. Energy for 21st centuary. ENG Publisher N.D.

I. **Course Title : New Alternate Energy Systems**
II. **Course Code : REE 604**
III. **Credit Hours : 2+1**

IV. **Aim of the course**

To get acquainted with various recent and emerging alternate fuels and their various applications for power generation.

V. **Theory**

**Unit I**

Hydrogen production: Water splitting, electrolytic methods, chemical cycle, photo splitting, photo galvanic, photo chemical. Hydrogen storage and utilization. Fuel cells: Reactions, types, design, applications, conversion and problems. Thermoelectric convertor and thermionic convertors. Magneto hydra dynamic system (MHD). Electro gas dynamics (EGD): Principles, types.

**Unit II**

Tidal energy: Operating mode, energy content. Estimation of wave power, tidal power sites and ocean thermal energy cycle (OTEC): Baseline design, heat design, power cycle design, plant working wave Energy conversion technologies.

**Unit III**

Geo-thermal energy system: Geo pressured Resources, Hot dry rock resources, magma resources Classification, binary cycle conversion, water fed heat pumps, Prime marers for geothermal energy conversion electric generation, steam generation, steam field. Heat mining, Darcy's law, volcano related heat resources, sedimentary basins.

**Unit IV**

Power generation through alternative sources. Environmental pollution: Measurements and control methods, instrumentation, pollution standards, social cost estimates, $CO_2$ reduction potential, $CO_2$ sequestration.

VI. **Practical**

Testing of electrolysis plant, photo electric plant, photo plant, design criteria of fuel cell. Design considerations for alternative energy systems.

VII. **Learning outcome**

Students are able to understand the various recent and emerging alternate energy sources and their utilization for meeting the increasing energy demand.

VIII. **Teaching Schedule**

| **S.No.** | **Topic** | **No. of lectures** |
|---|---|---|
| 1 | Hydrogen production: Water splitting, electrolytic methods, chemical cycle, photo splitting, photo galvanic, photo chemical. | 2 |
| 2 | Hydrogen storage and utilization. | 1 |
| 3 | Fuel cells: Reactions, types, design, applications, conversion and problems. | 2 |
| 4 | Thermoelectric convertor and thermionic convertors | 2 |

| | | |
|---|---|---|
| 5 | Magneto hydra dynamic system (MHD). Electro gas dynamics (EGD): Principles, types. | 2 |
| 6 | Tidal energy: Operating mode, energy content. | 1 |
| 7 | Estimation of wave power, tidal power sites and ocean thermal energy cycle (OTEC) | 2 |
| 8 | Baseline design, heat design, power cycle design, plant working. | 3 |
| 9 | Geo-thermal energy system | 1 |
| 10 | Classification, binary cycle conversion, waterfed heat pumps, electric generation, steam generation, steam field. | 4 |
| 11 | Heat mining, Darcy's law, volcano related heat resources, sedimentary basins, hot dry rocks. | 3 |
| 12 | Power generation through alternative sources. | 1 |
| 13 | Environmental pollution | 1 |
| 14 | Measurements and control methods for environmental pollution. | 1 |
| 15 | Instrumentation, pollution standards, | 2 |
| 16 | Social cost estimates. | 1 |
| 17 | $CO_2$ reduction potential, $CO_2$ sequestration | 2 |
| | **Total** | **32** |

IX. **List of Practical's**

| S.No. | Topic | No. of Practical's |
|---|---|---|
| 1. | Design parameters of air collectors. | 1 |
| 2. | Thermal analysis and heat loss, | 1 |
| 3. | Regularity models of heliostatic fields | 1 |
| 4. | Testing of electrolysis plant | 2 |
| 5. | Testing of photo electric plant | 2 |
| 6. | Testing of photo plant. | 2 |
| 7. | Design criteria of fuel cell | 2 |
| 8. | Design considerations for alternative energy systems | 2 |
| | **Total** | **10** |

X. **Suggested Reading**


- Culp JA. 1979. *Principles of Energy Conversion*. McGraw-Hill Book Company, London.
- Appleby A C 1987. *Fuel Cells: Trends in Research and Application*. Hemisphere, Washington.
- Blomen LJMJ and Mugerwa MN. 1993. *Fuel Cell System.* Plenum Press, New York, USA.

- Thielhein KD. 1977. *Alternate Energy Sources*. International compendium, Hemi sphere publishing company, London.
- Rai G.  2011 Non-conventional Energy sources, khanna publishers, New Delhi.
- Gorg HP and prakash J. 1976. Solar Energy, fundamentals and Applications. Tata Mc Grow –Hill Publication Co. INC. New Delhi.
- TwindellIw and weir AD. 1986. Renewable Energy sources E and FN spon Ltd. Londan.

I. **Course Title : Fuel and Combustion**

II. **Course Code : REE 605**

III. **Credit Hours : 2+1**

IV. **Aim of the course**

To get acquainted with in depth knowledge about solid, liquid and gaseous fuels and their combustion kinematics. Understand of different combustion technologies.

V. **Theory**

**Unit I**

Solid and liquid fuels: Type and availability, oxidation, hydrogenation of solid fuel and processing of solid fuels. Liquid Fuels: Processing, properties testing of liquid fuels and reining. Liquid fuels from other sources: Preparation and storage. Production technologies for solid and liquid fuel.

**Unit II**

Gaseous Fuels: Types, processing and testing of gaseous fuels, gases from biomass refinery gases, LPG, oil gasification, cleaning and purification of gaseous fuels. Gaseous fuel production technologies.

**Unit III**

Combustion Stoichiometry: Thermodynamics and kinetics, solid, liquid and gaseous fuels. Combustion of solid fuels. Biomass combustion, stages of wood combustion, industrial biomass combustion concepts, types of combustion system.

**Unit IV**

Combustion of liquid fuels: Atomization, vapour concentration, droplet and ignition. Liquid fuel burners: Atomizing air burners, pressure jet atomizing burners, thin fluid burners, rotary atomizing burners.

**Unit V**

Combustion of gaseous fuel: Character, shape and size of the flame. Flame stabilization of bluff bodies. Effect of equivalence on reaction rate and extinction velocity, submerged combustion, combustion with explosion flame, pulsating combustion.

VI. **Practical**

Determination of fuel properties of solid, liquid and gaseous fuels. Determination of efficiency of combustion system using solid, liquid and gaseous fuel. Standard testing of burners for thermal efficiency for solid, liquid and gaseous fuel.

VII. **Learning outcome**

Students will able to design, estimate and critical analysis of various combustion techniques for efficient utilization of fuels.

VIII. **Teaching Schedule**

| **S.No.** | **Topic** | **No. of Lectures** |
|---|---|---|
| 1 | Type and availability of solid and liquid fuels | 1 |
| 2 | Oxidation and hydrogenation of solid fuel. | 1 |

| | | |
|---|---|---|
| 3 | Processing of solid fuels | 1 |
| 4 | Processing of liquid fuel, properties and testing of liquid fuels. | 2 |
| 5 | Refining of liquid fuel. | 1 |
| 6 | Liquid fuels from other sources: Preparation and storage. | 1 |
| 7 | Production technologies for solid and liquid fuel. | 2 |
| 8 | Gaseous fuel production technologies. | 1 |
| 9 | Gases from biomass, refinery gases and LPG | 2 |
| 10 | Oil gasification. | 1 |
| 11 | Types, processing and testing of gaseous fuels | 2 |
| 12 | Cleaning and purification of gaseous fuels. | 1 |
| 13 | Combustion Stoichiometry: thermodynamics and kinetics. | 2 |
| 14 | Solid, liquid and gaseous fuels | 2 |
| 15 | Combustion of solid fuels, biomass combustion, stages of wood combustion. | 2 |
| 16 | Industrial biomass combustion concepts | 1 |
| 17 | Types of combustion systems. | 1 |
| 18 | Combustion of liquid fuels: Atomization, vapor concentration, droplet and ignition | 2 |
| 19 | Liquid fuel burners: Atomizing air burners, pressure jet atomizing burners, thin fluid burners, rotary atomizing burners. | 2 |
| 20 | Combustion of gaseous fuel: Character, shape and size of the flame. | 2 |
| 21 | Flame stabilization of bluff bodies | 1 |
| 22 | Effect of equivalence on reaction rate and extinction velocity | 1 |
| 23 | Submerged combustion, Combustion with explosion flame, Pulsating combustion. | 1 |
| | **Total** | **32** |

IX. **List of Practical's**

| **S.No** | **Topic** | **No. of Practical's** |
|---|---|---|
| 1. | Determination of fuel properties of solid fuels. | 2 |
| 2. | Determination of fuel properties of liquid fuels. | 2 |
| 3. | Determination of fuel properties of gaseous fuels. | 2 |
| 4. | Determination of efficiency of combustion system using solid fuels. | 2 |
| 5. | Determination of efficiency of combustion system using liquid fuels. | 2 |
| 6. | Determination of efficiency of combustion system using gaseous fuels. | 2 |
| 7. | Standard testing of burners for thermal efficiency for solid. | 2 |

| | | |
|---|---|---|
| 8. | Standard testing of burners for thermal efficiency for liquid fuel. | 2 |
| 9. | Standard testing of burners for thermal efficiency for gaseous fuel. | 1 |
| | **Total** | **16** |

## X. Suggested Reading


- Babu MKG and Subramanian KA. 2013. *Alternative Transportation Fuels: Utilization in Combustion Engines*. CRC Press, Boca Raton, Florida.
- Glassman I. 1987. *Combustion*. Academic Press Inc. Orlando, Florida, USA.
- Mukunda HS. 2011. *Understanding Clean Energy and Fuels from Biomass*. Wiley India Publication, New Delhi, India.
- Sarkar S. 1990. *Fuels and Combustion*. Orient Longmans, Bombay.
- Speight JG and Loyalka SK. 2007. *Handbook of Alternative Fuel Technologies*. CRC Press, Boca Raton, Florida.
- Babu V. 1998 Biofuels Production. Wiley publisher Delhi
- Gupta V.K. 2013 Biofuel Technologies. Springe New Delhi.
- V.N. Prasad P. M. 2007 . Fuel and Biofuels. Eng. Publisher : India Agro bios.

I. **Course Title : Advances in Biogas Technology**

II. **Course Code : REE 606**

III. **Credit Hours : 2+1**

IV. **Aim of the course**

The students will understand advances in biogas technology and its mechanism in detail. To analyze the case studies for understanding success and failures. To facilitate the students in developing skills in the decision making process.

V. **Theory**

**Unit I**

Worldwide review of anaerobic digesters, realistic potential- of biogas, analysis of biogas system and proposed means for their prospects. Engineering design of biogas units for biogas production from solid and liquid wastes.

**Unit II**

Design parameters: Affecting and failure of biogas systems, structural behaviour

and conditions of fixed dome digesters, alternate construction- materials, gas holders for gas production in colder regions, heating, stirring etc.

**Unit III**

Multi-criteria optimization design of fermentation systems, immobilization, modular biogas for tropical rural areas. Toxicity effect of pesticides herbicides on the anaerobic digestion process. Kinetic models, design equations, contact and anaerobic filter digesters, high rate digesters.

**Unit IV**

Scrubbing, purification and compression of biogas. Scaling-up and standardization of biogas plant for power generation and heating. Advanced bio fuels: Bio-CNG/ renewable natural gas (RNG) as vehicle fuel. Liquefaction of biogas.

VI. **Practical**

Engineering design and analysis of biogas system. Development of kinetic equations. Biogas purification, compression and liquefaction. Industrial applications of biogas.

VII. **Learning outcome**

The student is able to analyse the various aspects of biogas energy management systems, Carry out techno-economic feasibility for biogas plant, to apply the knowledge in planning and operations of biogas energy system.

VIII. **Teaching Schedule**

| S.No. | Topic | No. of Lectures |
|---|---|---|
| 1. | Review of anaerobic digesters | 1 |
| 2. | Realistic potential- of biogas | 1 |
| 3. | Analysis of biogas system | 2 |
| 4. | Proposed means for prospects of biogas systems | 1 |
| 5. | Engineering design of biogas units for biogas production from solid and liquid wastes | 3 |

| | | |
|---|---|---|
| 6. | Design parameters: Affecting and failure of biogas systems | 2 |
| 7. | Structural behaviour and conditions of fixed dome digesters | 2 |
| 8. | Alternate construction- materials for biogas plants | 1 |
| 9. | Design of biogas plants for colder regions | 1 |
| 10. | Heating and stirring systems for biogas plants | 2 |
| 11. | Multi-criteria optimization design of fermentation systems contact and anaerobic filter digesters, high rate digesters | 2 |
| 12. | Immobilization, modular biogas for tropical rural areas | 2 |
| 13. | Toxicity effect of pesticides herbicides on the anaerobic digestion process | 1 |
| 14. | Chemical kinetics and mathematical modelling of bio-methanation process | 2 |
| 15. | Contact and anaerobic filter digesters, high rate digesters | 1 |
| 16. | Scrubbing, purification and compression of biogas. | 2 |
| 17. | Scaling-up and standardization of biogas plant for power generation and heating | 2 |
| 18. | Bio-CNG/renewable natural gas (RNG) as vehicle fuel | 2 |
| 19. | Liquefaction of biogas | 2 |
| | **Total** | **32** |

IX. **List of Practical's**

| **S.No.** | **Topic** | **No. of Practical's** |
|---|---|---|
| 1. | Engineering design and analysis of biogas system | 3 |
| 2. | Development of kinetic equations | 3 |
| 3. | Biogas purification, compression and liquefaction | 3 |
| 4. | Industrial applications of biogas | 3 |
| 5. | Preparation of Detailed Project Reports for commercial biogas projects | 4 |
| | **Total** | **16** |

X. **Suggested Reading**


- Abbasi SA and Nipaney PC. 1993. *Modeling and Simulation of Biogas System Economies*. Ashish Publication House, New Delhi.
- Abbasi T, Tauseef SM and Abbasi SA. 2012. *Biogas Energy*. Springer publications, New York, USA.
- Chawala OP. 1986. *Advances in Biogas Technology*. ICAR, New Delhi.
- Mittal KM. 1996. *Biogas Systems: Principles and Applications*. New Age international Publication Limited, New Delhi.
- Rohlich GA, Walbot V, Connar LJ, Golueke CG, Hinesly TD, Jones PH, Lapp HM, Loehr RC, LueiHing C, Pfeffer JT, Prakasam TBS and Brown NL. 1977. *Methane Generation from Human Animals and Agril Wastes.* National Academy of Sciences, Washington.

I. **Course Title : Solid Waste and Waste Water Management**
II. **Course Code : REE 607**
III. **Credit Hours : 2+1**

IV. **Aim of the course**

To provide in depth knowledge, understanding and application oriented skills on sources, quality, classification and characteristics of solid waste along with municipal and compost treatment and remote sensing technologies for waste management.

V. **Theory**

**Unit I**

Solid waste: Sources, quality, classification and characteristics, collection and reduction at source, handling, storage, transportation and disposal methods composting, vermicomposting Thermal process incineration.

**Unit II**

Reactor for anaerobic digestion: Contact and filter digestion, homogenous and nonhomogeneous reactors. Energetic and kinetics of anaerobic treatment.

**Unit III**

Gas transfer, mass models, bubble aeration, film flow oxygen transfer, stripping, solids removal. Activated sludge and other suspended culture processes parameters. Biosorption of contact stabilization.

**Unit IV**

Sanitation land fill, municipal and compost treatment. Predigestion of waste. Sensors, ICT and remote sensing technologies for waste management.

VI. **Practical**

Design principles in waste treatment, equipment specifica-tion and instrumentation.

Mathematical modelling of BOD and COD reduction rate, recovery by batch distillation.

VII. **Learning outcome**

The student is able to estimate, characterize and design of solid waste conversion system and also able to understand the energetic and kinetics of anaerobic treatment, sanitation land fill, pre-digestion of waste etc.

VIII. **Teaching Schedule**

| **S.No.** | **Topic** | **No. of Lectures** |
|---|---|---|
| 1. | Introduction to Solid waste | 1 |
| 2. | Sources, classification and characteristic and quality | 2 |
| 3. | Collection and handling and Transportation | 2 |
| 4. | Disposal methods, reduction at source compostion, vermicomposting Thermal Process incineration. | 3 |
| 5. | Reactor for anaerobic digestion | 2 |
| 6. | Contact and filter digestion | 2 |

| | | |
|---|---|---|
| 7. | homogenous and non-homogeneous reactors | 2 |
| 8. | Energetic and kinetics of anaerobic treatment. | 2 |
| 9. | Gas transfer, mass models | 3 |
| 10. | Bubble aeration, film flow oxygen transfer, stripping, solids removal. | 2 |
| 11. | Activated sludge and other suspended culture processes parameters. | 2 |
| 12. | Biosorption of contact stabilization | 1 |
| 13. | Sanitation land fill | 2 |
| 14. | Municipal and compost treatment | 2 |
| 15. | Predigestion of waste. | 1 |
| 16. | Sensors, ICT and remote sensing technologies for waste management | 3 |
| | **Total** | **32** |

IX. **List of Practical's**

| S.No. | Topic | No. of Practical's |
|---|---|---|
| 1. | Design principles in waste treatment | 3 |
| 2. | Specification of equipment for waste treatment | 2 |
| 3. | Instrumentation for waste treatment | 2 |
| 4. | Mathematical modelling of BOD and COD reduction rate | 3 |
| 5. | Development of computer code for Mathematical modelling of BOD and COD reduction rate | 3 |
| 6. | Recovery by batch distillation. | 3 |
| | **Total** | **16** |

X. **Suggested Reading**


- Bridgwater AV and Mum-ford CJ. 1979. *Waste Recycling and Pollution Control Handbook*. Van Nostrand Reinhold Company, New York.
- Kreith F and Tchobanoglous G. 2002. *Handbook of Solid Waste Management*. McGraw Hill Book Company, New York.
- Ramachandra TV. 2006. *Management of Municipal Solid Waste*. Capital Publication Company, New Delhi.
- Tchobanoglous G, Theisenand H and Elliassen R. 1978. *Solid Wastes*. McGraw Hill Book Company, New York.
- Environmental Engineering (Vol.II) Sewage Disposal and Air pollution Engineering, S.K. gargkhanna publishers.
- Klaste water Treatment for pollution control second edition Arceival soil I. Tata me Graw Hill publications company Ltd. New Delhi 1998.

I. **Course Title : Advanced Photovoltaic Power Generation**

II. **Course Code : REE 608**

III. **Credit Hours : 1+1**

IV. **Aim of the course**

To develop a comprehensive technological understanding in solar PV system components. To provide in depth understanding of design parameters to help design and simulate the performance of a solar PV power plant. To pertain knowledge about planning, project implementation and operation of solar PV power generation.

V. **Theory**

**Unit I**

Semiconductors: Transport properties, junctions, dark and illumination characteristics. Single junction and multi junction films. Solar PV concentrator cells and systems. Thin Film solar cells: Nano, micro, and polycrystalline solar cells.

**Unit II**

Systems for remote applications and large solar PV power plants: System integrations, roof top system, sizing methodology, power control, storage, tracking and control. PCID simulation of industrial solar cell structure, software's in solar cell simulation.

**Unit III**

Space charge control, low pressure diode, MMPT, cesium converter, system considerations. Photo electro chemical cells and materials. Photo galvanic cells: Recent development. Installation, Troubleshooting and safety of PV systems.

**Unit IV**

Conjunctive use of photo conversion systems: Photo-agriculture system, components, integration and economics. Software's for PV system integration and designing. PV system for ground mounted and rooftop plants with shadow analysis.

VI. **Practical**

PV systems for typical applications, water pumping, solar PV tracking and mechanical clock tracking. Testing of power control system for output regulation, charging and discharging characteristics of storage by PV panels.

VII. **Learning outcome**

Student will able to design different solar photovoltaic system for power generation. Design and simulate a PV power plant using software tool, Plan, project implementation, operation and maintenance. Carry out techno-economic environmental performance evaluation of a solar PV power plant.

VIII. **Teaching Schedule**

| **S.No.** | **Topic** | **No. of Lectures** |
|---|---|---|
| 1 | Semiconductors: Transport properties, junctions, dark and illumination characteristics. | 1 |
| 2 | Single junction and multi junction films, Solar PV concentrator cells and systems. | 1 |

| | | |
|---|---|---|
| 3 | Thin film solar cells: Nano, micro, and polycrystalline solar cells | 1 |
| 4 | Systems for remote applications, Large solar Photovoltaic power plants System integrations, roof top system and sizing methodology | 2 |
| 5 | Power control, storage, tracking and control in Photovoltaic power plants | 1 |
| 6 | PCID simulation of industrial solar cell structure, software's in solar cell simulation | 2 |
| 7 | System considerations for Space charge control, low pressure diode, MMPT and cesium converter | 2 |
| 8 | Photo electro chemical cells and materials | 1 |
| 9 | Recent development in Photo galvanic cells | 1 |
| 10 | Conjunctive use of photo conversion systems: Photo-agriculture system, components, integration and economics | 1 |
| 11 | Software's for PV system integration and designing. | 2 |
| 12 | PV system for ground mounted and rooftop plants with shadow analysis | 1 |
| | **Total** | **16** |

IX. **List of Practical's**

| S.No. | Topic | No. of Practical's |
|---|---|---|
| 1. | Typical applications of Photovoltaic (PV) systems | 1 |
| 2. | Applications of Photovoltaic systems in water pumping | 2 |
| 3. | Study of Solar PV tracking and mechanical clock tracking | 2 |
| 4. | Testing of power control system for output regulation | 3 |
| 5. | Charging and discharging characteristics of storage by PV panels. | 2 |
| | **Total** | **10** |

X. **Suggested Reading**


- Duffie JA and Beckman WA. 1991. *Solar Engineering of Thermal Processes*. John Wiley, New Jersey.
- Fonash SJ. 1982. *Solar Cell Device Physics*. Academic Press, Cambridge, England.
- Garg HP. 1990. *Advances in Solar Energy Technology*. Springer Publishing Company, Dordrecht, Netherland.
- Green MA. 1981. *Solar Cells Operating Principles, Technology, and System Applications*. Prentice Hall, New Jersey.
- Kreith F and Kreider JF. 1978. *Principles of Solar Engineering*. McGraw Hill, New York.
- Luque A and Hegedus S. 2011. *Handbook of Photovoltaic Science and Engineering Education*. John Wiley and Sons, New Jersey.
- Solanki CS. 2011. *Solar Photovoltaic: Fundamentals, Technologies and Applications*. PHI Learning Private Limited, Delhi.

- Sze SM and Kwok KN. 2007. *Physics of Semiconductor Devices*. John Wiley & Sons, New Jersey.
- Veziroglu TN. 1977. *Alternative Energy Sources*. McGraw Hill, New York.
- Solanki CS. 2013. Solar photovoltaic Technology and systems. PHI Learning Private Ltd, Delhi.
- Hung lef. 2013. Renewable Energy systems. Advanced conversion Technologies and Applications. New york CRC press.
- Bauer T. 2011. Thermophotovoltaic : Basic principles and critical Aspects of system Design. Engg. Publisher : Springer, Delhi.

I. **Course Title : Energy Planning, Management and Economics**
II. **Course Code : REE 609**
III. **Credit Hours : 3+0**

IV. **Aim of the course**

To acquaint and equip with energy planning, management and economical evaluation for agricultural production system.

V. **Theory**

**Unit I**

Energy resources on the farm: Conventional and non-conventional forms of energy and their use. Heat equivalents and energy coefficients for different agricultural inputs and products. Pattern of energy consumption and their constraints in production of agriculture. Direct and indirect energy.

**Unit II**

Energy audit of production agriculture and rural living and scope of conservation. Identification of energy efficient machinery systems, energy losses and their management.

**Unit III**

Energy analysis techniques and methods: Energy balance, output and input ratio, resource utilization, conservation of energy sources. Energy conservation planning and practices.

**Unit IV**

Energy forecasting, energy economics, energy pricing and incentives for energy conservation, factors effecting energy economics. Techno-economic evaluation of RET's, computation of programme for efficient energy management.

VI. **Learning outcome**

The student will be able to quantify, analyze and forecast the demand and supply of different energy for agriculture production system.

4. Role of energy in economic development and Social transformation.

12. Energy policy : Global Energy Issues, Energy security, Energy vision, Energy pricing and Impact of Global Variations. Energy productivity (National and Sector wise Productivity.)

16. Energy conservation : Act 2001 and its features, Electricity Act- 2003 and its features –Energy crisis, future Energy options- need for use for New and Renewable energy sources- Energy for sustainable Development.

VII. **Teaching Schedule**

| **S.No.** | **Topic** | **No. of Lectures** |
|---|---|---|
| 1. | Energy resources on the farm: Conventional and non-conventional forms of energy and their use. | 3 |
| 2. | Heat equivalents and energy coefficients for different agricultural inputs and products. | 3 |
| 3. | Pattern of energy consumption and their constraints in production agriculture. Direct and indirect energy. | 3 |

| | | |
|---|---|---|
| 4. | Techno-economic evaluation of RET's | 4 |
| 5. | Energy audit of production agriculture and rural living and scope of conservation. | 4 |
| 6. | Identification of energy efficient machinery systems | 3 |
| 7. | Energy losses and their management. | 4 |
| 8. | Energy analysis techniques and methods: Energy balance, output and input ratio, resource utilization, conservation of energy sources. | 4 |
| 9. | Energy conservation planning and practices. | 4 |
| 10. | Energy forecasting | 3 |
| 11. | Energy pricing and incentives for energy conservation, | 3 |
| 12. | Energy economics and factors affecting energy economics | 4 |
| 13. | Computation of programme for efficient energy management. | 3 |
| | **Total** | **45** |

VIII. **Suggested Reading**


- Fluck RC and Baird CD. 1984. *Agricultural Energetics*. AVI Publication, United State.
- Kennedy WJ and Turner WC. 1984. *Energy Management.* Prentice Hall, New Jersey.
- Pimental D. 1980. *Handbook of Energy Utilization in Agriculture*. CRC Press, Florida.
- Rai GD. 1998. *Nonconventional Sources of Energy*. Khanna Publication, New Delhi.
- Twindal JW and Wier AD. 1986. *Renewable Energy Sources*. E & F N Spon, New York.
- Verma SR, Mittal JP and Singh S. 1994. *Energy Management and Conservation in Agricultural Production and Food Processing*. USG Publication, Chicago.
- Bureau of Energy efficiency 2012 Vol.1 and 2 BEE, New Delhi.

**I. Course Title : Renewable Energy for Industrial Application**

II. **Course Code : REE 610**

III. **Credit Hours : 2+1**

IV. **Aim of the course**

To provide the knowledge regarding the energy consumption pattern in agro based industries, quantification techniques and identification of opportunities for renewable energy sources.

V. **Theory**

**Unit I**

Elucidation of unit operations in industry. Energy quantification techniques, system boundary, estimation of productivity, plant capacity utilization, energy density ratio and energy consumption pattern. Energy flow diagram conservation opportunities identification.

**Unit II**

Solar energy for industrial application: Solar water heating, steam solar cooking system, industrial solar dryer and solar process heat, solar cooling system (refrigeration, air conditioning and solar architecture technology), solar furnace and solar green house technology for high-tech cultivation. Solar photovoltaic technology for industrial power.

**Unit III**

Bio energy for industrial application: Quantification of industrial bio-waste, characterization, power generation through bio-methanation, gasification and dendro thermal power plant.

**Unit IV**

Wind energy: Aero generator of new era and national and international state of art in wind power generation. Other renewable energy sources: Magneto hydro dynamics, fuel cells technology and micro-hydro energy technology.

VI. **Practical**

Elucidation and energy consumption for unit operations in industry. Study of energy quantification and identification of opportunities for RET's. Design of solar dryers. Design of solar photovoltaic system. Design of gasifiers for thermal energy and power generation. Design of combustor (gasifier stove). Study of solar greenhouse. Study of biogas engine generator set. Case study of agro-industrial energy estimation and visit to RSE power generation site.

VII. **Learning outcome**

Students will be acquainted with energy quantification techniques, design of system, economic evaluation and utilization of renewable energy sources for agro-industrial applications.

VIII. **Teaching Schedule**

| S.No. | Topic | No. of Lectures |
|---|---|---|
| 1. | Elucidation of unit operations in industry. | 1 |

| | | |
|---|---|---|
| 2. | Energy quantification techniques, system boundary, | 2 |
| 3. | Estimation of productivity, plant capacity utilization, | 2 |
| 4. | Energy density ratio and energy consumption pattern. | 2 |
| 5. | Energy flow diagram conservation opportunities identification. | 1 |
| 6. | Solar energy for industrial application. | 1 |
| 7. | Solar water heating. | 1 |
| 8. | Steam solar cooking system. | 1 |
| 9. | Industrial solar dryer and solar process heat. | 2 |
| 10. | Solar cooling system (refrigeration, air conditioning and solar architecture technology). | 2 |
| 11. | Solar furnace. | 1 |
| 12. | Solar greenhouse technology for high-tech cultivation. | 2 |
| 13. | Solar photovoltaic technology for industrial power. | 1 |
| 14. | Bio energy for industrial application | 1 |
| 15. | Quantification of industrial bio-waste, its characterization | 2 |
| 16. | Power generation through bio-methanation, | 2 |
| 17. | Gasification and dendro thermal power plant. | 2 |
| 18. | Wind energy: Aero generator of new era. | 1 |
| 19. | National and international state of art in wind power generation. | 2 |
| 20. | Other renewable energy sources: Magneto hydro dynamics, fuel cells technology and micro-hydro energy technology. | 3 |
| | **Total** | **32** |

IX. **List of Practical's**

| **S.No.** | **Topic** | **No. Of Practical's** |
|---|---|---|
| 1 | Elucidation and energy consumption for unit operations in industry | 1 |
| 2 | Study of energy quantification and identification of opportunities for RET's | 1 |
| 3 | Design of solar dryers. | 2 |
| 4 | Design of solar photovoltaic system. | 2 |
| 5 | Design of gasifiers for thermal energy and power generation. | 2 |
| 6 | Design of combustor (gasifier stove). | 2 |
| 7 | Study of solar greenhouse. | 1 |
| 8 | Study of biogas engine generator set. | 1 |
| 9 | Case study of agro-industrial energy estimation | 2 |

| | | |
|---|---|---|
| 10 | Visit to RSE power generation site | 1 |
| | **Total** | **15** |

X. **Suggested Reading**


- Duffie JA and Beakman WA. 2006. *Solar Energy Thermal Process*. John Wiley and Sons, New York.
- Kumar S. 2011. *Energy Conservation Building User Code Guide.* Bureau of Energy Efficiency, New Delhi.
- Rathore NS, Kurchania AK and Panwar NL. 2007. *Non Conventional Energy Sources*. Himanshu Publications, Udaipur, Rajasthan.
- Sayigh AAM. 2012. *Solar Energy Engineering*. Academic Press, New York.
- Singh P, Kurchania AK, Rathore NS and Mathur AN. 2005. *Sustainable Development through Renewable Energy Sources*. Yash Publications, Bikaner, Rajasthan.
- Bureau of Energy efficiency 2012 Vol.1 and 2 BEE, New Delhi.

I. **Course Title : Biofuel Technologies and Applications**
II. **Course Code : REE 611**
III. **Credit Hours : 1+1**

IV. **Aim of the course**

To get acquainted with recent biofuel production technologies and their applications. To perform financial estimations of the biofuel projects. To get insight of the various biofuel technologies.

V. **Theory**

**Unit I**

Liquid biofuels: Non-edible oilseeds, oil extraction, pre-processing, characterization. World scenario: Liquid fuel challenges and some solutions. Liquid bio-fuel applications.

**Unit II**

Bioethanol: First and second generation ethanol production technologies. Production of syngas from biomass, production of methanol from syngas, production of ethanol from lingo-cellulosic biomass. Syngas and poly-generation, chemical conversion of syngas to methanol and ethanol and some advanced fuels like bio butanol, biopropanol.

**Unit III**

BioCNG: Biogas to green vehicle fuel, anaerobic digestion. Bio gas opportunities: Landfill gas, agricultural and industrial wastewater and additional sources of methane.

**Unit IV**

Biodiesel: Feedstock for biodiesel, manufacturing processes for biodiesel, value addition by utilization of by-products, environmental impacts of biodiesel, biodiesel from algae, biodiesel engines.

**Unit V**

Pyrolysis oil: Fast pyrolysis technologies, composition and issues of bio oil. Bio oil upgradation technologies.

VI. **Practical**

Evaluation of liquid fuel system for heat and power generation and characterization of liquid fuel, transesterification process. Engine performance on biodiesel. Biogas engine system for transport vehicle. Bio oil production by pyrolysis.

VII. **Learning outcome**

Student will able to understand the bio-fuel production technologies with financial viability and applications of bio-fuel in different sector of development.

VIII. **Lecture Schedule**

| S.No. | Topic | No. of Lectures |
|---|---|---|
| 1 | Liquid biofuels: Non-edible oilseeds, oil extraction, pre-processing, Characterization. | 1 |
| 2 | World scenario: Liquid fuel challenges and some solutions. Liquid bio-fuel applications. | 1 |
| 3 | Bioethanol: First- and second-generation ethanol production technologies. | 1 |

| | | |
|---|---|---|
| 4 | Production of syngas from biomass. | 1 |
| 5 | Production of methanol from syngas. | 1 |
| 6 | Production of ethanol from lingo-cellulosic biomass. | 1 |
| 7 | Syngas and poly-generation. | 1 |
| 8 | Chemical conversion of syngas to methanol and ethanol, some advanced fuels like bio butanol, bio-propanol. | 1 |
| 9 | Bio CNG: Biogas to green vehicle fuel, anaerobic digestion. | 1 |
| 10 | Bio gas opportunities: Landill gas, agricultural and industrial wastewater and additional sources of methane. | 1 |
| 11 | Biodiesel: Feedstock for biodiesel, manufacturing processes for biodiesel, value addition by utilization of by-products, environmental impacts of biodiesel. | 2 |
| 12 | Biodiesel from algae, biodiesel engines | 1 |
| 13 | Pyrolysis oil: Fast pyrolysis technologies. | 1 |
| 14 | Composition and issues of bio oil | 1 |
| 15 | Bio oil up-gradation technologies. | 1 |
| | **Total** | **16** |

IX. **List of Practical's**

| **S. No.** | **Topic** | **No. of Lectures** |
|---|---|---|
| 1. | Evaluation of liquid fuel system for heat and power generation. | 2 |
| 2. | Characterization of liquid fuel. | 1 |
| 3. | Transesterification process. | 2 |
| 4. | Engine performance on biodiesel. | 1 |
| 5. | Biogas-engine system for transport vehicle. | 1 |
| 6. | Bio oil production by pyrolysis. | 1 |
| **Total** | | **08** |

X. **Suggested Reading**


- Boyle G. 2008. *Renewable Energy*. Atlantic Publishing Company, New Delhi.
- Gonsalves JB. 2006. *An Assessment of the Biofuels Industry in* John *India*. Wiley & Sons, New Delhi.
- Kishore VVN. 2008. *Renewable Energy Engineering and Technology–A Knowledge Compendium. Education*. TERI Press, Delhi.
- Klass D. 1998. *Biomass for Renewable Energy, Fuels, and Chemicals*. Entech International, Barrington, Illinois, USA.
- Mitzlaff KV. 1988. *Engines for Biogas–Theory, Modification, Economic Operation*. Deutsches Zentrumfür Entwicklungs technologien–GATE, Germany.

- Biofuel potential and challenges by- pandey A.K. ENG publisher Delhi Scientific zoll, ISBN : 978-81-7233-696-7
- Fuels and biofuel by- Devi V.N. Prasad P.M. ENG Publisher India agzobios 2007, ISBN : 81-7754-315-6
- Alternate souzces of Energy by –singh B.P, ENG Publisher Kanpur Bhasker publication 2011 ISBN: 978-93- 80348-39-1
- Biofuel –A New Revlution By- Tiwari S.K. ENG Publisher Delhi pearl Books 2010 ISBN: 978-93-80191-40-9
- Handbook of Bio energy and Biofuels ByMutha. V.K. ENG Publisher, Delho SBS Publcaiton 2010
- Biofuels Production by- Babu. V. Delhi Wiley 1998 ISBN : 978-1-118-63450-9

I. **Course Title : Energy Modelling and Simulation**

II. **Course Code : REE 612**

III. **Credit Hours : 1+1**

IV. **Aim of the course**

The objective of this course is to provide in depth knowledge about various mathematical models, interdependence of energy, ecology and environment, energy modelling in the context of climate change.

V. **Theory**

**Unit I**

Model: Basics, system, boundary, interaction, types of models, physical, analogy models and applications. Mathematical models: Concepts, input, output model, stochastic, deterministic, empirical models, linear, non-linear models, interdependence of energy, economy, environment, modelling concept and application.

**Unit II**

Energy Modelling: Review of various energy sector models, energy demand analysis and forecasting, energy supply assessment and evaluation, energy demand, supply balancing, energy modelling in the context of climate change.

**Unit III**

Model studies in gasification, pyrolysis, biogas, fermentation, biodiesel, solar, wind technologies and heat transfer applications. Moving boundary models.

**Unit -IV**

Energy economics of energy sources: Investment and cost management in various energy technologies. Economics of energy generation, energy conservation economics, financial analysis, sensitivity and risk analysis.

VI. **Practical**

Formulating dimensionless numbers, applications, types of models, mathematical model formulation and types, Software's and model evaluation. Development of models in thermo-chemical and biochemical conversion processes. Studies on model development in solar and wind technologies, economics of energy generation and conservation, financial analysis.

VII. **Learning outcome**

Students will get thorough knowledge about energy modelling of gasification, pyrolysis, biogas system, fermentation, biodiesel production system, solar and wind technologies etc.

VIII. **Teaching Schedule**

| S.No. | Topic | No. of Lectures |
|---|---|---|
| 1 | Introduction to Model | 1 |
| 2 | Basics, system, boundary, interaction, types of models, physical, analogy models. | 2 |
| 3 | Model applications. | 1 |
| 4 | Mathematical models: Concepts, input, output model, stochastic, | 3 |

| | | |
|---|---|---|
| | deterministic, empirical models, linear, non-linear models, interdependence of energy, economy, environment. | |
| 5 | Modelling concept and application. | 1 |
| 6 | Energy Modelling | 1 |
| 7 | Review of various energy sector models | 1 |
| 8 | Energy demand analysis and forecasting | 1 |
| 9 | Energy supply assessment and evaluation | 1 |
| 10 | Energy demand, supply balancing. | 2 |
| 11 | Energy modelling in the context of climate change. | 2 |
| 12 | Model studies in gasification, pyrolysis. | 2 |
| 13 | Model studies in biogas, fermentation. | 1 |
| 14 | Model studies in biodiesel. | 1 |
| 15 | Model studies in solar | 1 |
| 16 | Model studies in wind technologies. | 1 |
| 17 | Heat transfer applications. | 1 |
| 18 | Moving boundary models. | 1 |
| 19 | Energy economics of energy sources | 1 |
| 20 | Investment and cost management in various energy technologies. | 2 |
| 21 | Economics of energy generation. | 1 |
| 22 | Energy conservation economics, financial analysis. | 2 |
| 23 | Energy conservation sensitivity and risk analysis | 2 |
| | **Total** | **32** |

IX. **List of Practical's**

| Sr.No. | Topic | No. of Practical's |
|---|---|---|
| 1. | Formulating dimensionless numbers. | 1 |
| 2. | Applications of dimensionless numbers. | 1 |
| 3. | Types of models for dimensionless numbers. | 1 |
| 4. | Mathematical model formulation and types. | 2 |
| 5. | Software's and model evaluation. | 2 |
| 6. | Development of models in thermo-chemical | 1 |
| 7. | Development of models in biochemical conversion processes. | 1 |
| 8. | Studies on model development in solar technologies. | 1 |
| 9. | Studies on model development in wind technologies | 1 |
| 10. | Economics of energy generation and conservation | 2 |
| 11. | Financial analysis. | 1 |
| | **Total** | **14** |

X. **Suggested Reading**


- Desai A V 1990. *Energy Planning and Economics.* New Age International Publication Limited, New Delhi.
- Munasinghe M and Meier P 1993. *Energy Policy Analysis and Modelling* (*Cambridge Energy and Environment Series*). Cambridge University Press, England.
- Modeling and optimization of Renewable energy system by A.S. sahin, Springer.
- Energy for production Agriculture Surendra sing, redbeyshyamsingh.
- Modelling and simulation of hybrid Renewable Energy system by Akella Ashok Kumar, Lambert academic publisher.
- Simulation of prwer system with renewable by pal Bikash, Elsvire J. edition Energy modelling Art science practice by Milton f. searl.

**RPE 601 Research and Publication Ethics 1+1**

**Aim of the Course:**
This course is mainly focusing on basics of philosophy of science and ethics, research integrity, publication ethics. Hands on sessions are designed to identify research misconduct and predatory publications. Indexing and citation databases, open access publications, research and p metrics and plagiarism tools introduced in the course.

**THEORY**
**Unit 1: Philosophy and Ethics**
1. Introduction to philosophy: definition, nature and scoope, concept, branches
2. Ethics: definitino, moral philosophy, nature of moral judgements and reations.

**Unit 2: Scientific Conduct**
1. Ethics with respect to science and research
2. Intellectual honest and research integrity
3. Scientific misconducts: falsification, fabrication, and plagiarism.
4. Redundant publications: duplicate and overlapping publications, salami slicing
5. Selective reporting and misrepresentation of data.

**Unit 3: Publication Ethics**
1. Publication ethics: definition, introduction and importance
2. Best practices/standards setting initiatives and guidelines: COPE, WAME, etc.
3. Conflicts of interest
4. Publication misconduct: definition, concept, problems that lead to unethical behavior and vice verse, types
5. Violation of publication ethics, authorship and contributor ship
6. Identification of publication misconduct, complaints and appeals
7. Predatory publishers and journals

**Unit 4: Open Access Publishing**
1. Open access publications and initiatives
2. SHERPA/RoMEO online resource to check publisher copyright and self-archiving policies.
3. Software tool to identify predatory publications developed by SPPU
4. Journal finder/ journal suggestion tools viz. JANE, Elsevier Journal Finder, Springer Journal Suggester, etc.

**Unit 5: Publication Misconduct**
A. Group Discussions
1. Subject specific ethical issues, FFP, authorship
2. Conflicts of interest
3. Complaints and appeals: examples and fraud from India and abroad

B. Software tools
Use of plagiarism software like Turnitin, Urkund and other open source software tools.

**Unit 6: Databases And Research Metrics**
A Databases
1. Indexing detabeses

2. Citation databases: Web of Science, Scopus, etc.

B. Research Metrics
Impact Factor of journal as per journal citation report, SNIP, SJR, IPP, Cite Score.
Metrics: h-index, g index, i10 index, altmetrics

**Practicals**

**1. Types of Research**

1. Basic Research:
2. Applied Research:
3. Descriptive Research:
4. Analytical Research:
5. Correlational Research:
6. Qualitative Research:
7. Quantitative Research:
8. Experimental Research:
9. Explanatory Research:
10. Exploratory Research:
11. Selection of Domain/Area of Research:

**2. Formulating a Research Problem and Identification of Keywords:**

1. Literature Survey:
2. Redefining Research Problem, Objectives and Outcomes:
3. Research Proposal:
4. Identifying Variable /Parameters and Research Design:
5. Data Collection and Representation:
6. Testing of Proposed Design on Collected Data/Hypothesis Testing:

**3. Results and Analysis:**

1. Research Report Writing:
2. Features of Good Research Study

**4. Journal Search**

1. Open Access Publishing
2. Impact Factor of journal as per journal citation report, SNIP, SJR, IPP, Cite Score.
   Metrics: h-index, g index, i10 index, altmetrics

**Suggested Readings**


- Bird,A. (2006). Philosophy of Sciences. Routledge
- MacIntyre, Alasdair (1967). A Short History of Ethics. London
- P.Chandah. (2018). Ethics in Competitive Research: Do not get Scooped; do not get plagiarized.
- National Academy of Sciences, National Academy of Engineering and Institute of Medicine (2009)., National On being a Scientist: A guide to responsible conduct in Research : third edition, National Academies Press
- Hall GM. Book Farthing MJG. How to Write a Paper. UK Blackwell Publishing; 2008
- NAS-NAE-IOM. Responsible Science: Ensuring the Integrity of the Research Process. Washington, DC: National Academy Press; 1992.
- Alexander M. Novikov & Dmitry A. Novikov, Research Methodology: From Philosophy of Science to Research Design, CRC Press Taylor & Francis Group, (2013).

- C. R. Kothari, Research Methodology: Methods and Techniques, New Age International (P) Ltd., New Delhi (2004).
- David Bridges, Philosophy in Educational Research: Epistemology, Ethics, Politics and Quality, Springer International Publishing AG (2017).
- Deepak Chawla & Neena Sondhi, Research Methodology: Concepts and Cases, VIKAS® Publishing House Pvt Ltd, New Delhi (2015).

- Paul Smeyers & Marc Depaepe, Educational Research: Ethics, Social Justice, and Funding Dynamics, Springer International Publishing AG, (part of Springer Nature) (2018).
- Peter Pruzan, Research Methodology: The Aims, Practices and Ethics of Science, Springer International Publishing Switzerland (2016).
- Ranjit Kumar, Research Methodology: a step-by-step guide for beginners, SAGE Publications India Pvt Ltd, New Delhi (2011).
- Richard Pring, Philosophy of Educational Research, Continuum, London (2000).
- Robyn Brandenburg & Sharon McDonough, Ethics, Self-Study Research Methodology and Teacher Education, Springer Nature Singapore Pte Ltd. (2019).
- S. K. Yadav, Elements of Research Writing, UDH Publishers and Distributers, New Delhi (2015).
- Surbhi Jain, Research Methodology in Arts, Science and Humanities, Society Publishing, Oakville, Canada (2019).
- Vinayak Bairagi and Mousami V. Munot, Research Methodology A Practical and Scientific
- Approach, CRC Press Taylor & Francis Group, New York, NY (2019).

## E Resources and List of Journals

- *Journal of Fundamentals of Renewable Energy and Application*
- Energy and Environmental Science
- Progress in Energy and Combustion Science
- Advanced Energy Materials
- Annual Review of Chemical and Biomolecular Engineering
- IEEE Transactions on Sustainable Energy
- Nano Energy Progress in Photovoltaics: Research and Applications
- Applied Energy
- IEEE Transactions on Power Systems
- Renewable and Sustainable Energy Reviews
- ChemSusChem Energy Economics Energy
- IEEE Transactions on Energy Conversion
- International Journal of Sustainable Transportation
- Journal of Materials Chemistry A Biotechnology for Biofuels GCB Bioenergy
- Solar Energy Materials and Solar Cells
- Energy Policy
- IEEE Transactions on Power Delivery
- Solar Energy Renewable Energy
- International Journal of Greenhouse Gas Control
- Environmental Research Letters
- Journal of Physical Chemistry C
- Energy Conversion and Management
- ShiyouKantan Yu Kaifa/Petroleum Exploration and Development
- Journal of Power Sources Polymer Reviews
- Biomass and Bioenergy
- Probabilistic Engineering
- Mechanics
- Geothermics
- Biofuels
- Bioproducts and Biorefining
- IEEE Power and Energy Magazine
- Journal of Cleaner Production
- International Journal of Electrical Power and Energy Systems
- IET Renewable Power Generation
- Fuel Processing Technology
- Fuel
- Applied Thermal Engineering
- Experimental Thermal and Fluid Science
- Geophysics
- Environmental Innovation and Societal Transitions SPE
- Journal SAE International
- Journal of Engines
- International Journal of Coal Geology

- AAPG Bulletin Electric Power Systems Research
- Bioenergy Research

# Restructured and Revised Syllabi of Post Graduate Programmes

## M.Tech. and Ph. D (Agricultural Engineering)

## in

## Soil and Water Conservation Engineering


**Compiled**

**by**

**Broad Subject Coordinator**
**Associate Dean,**
**Dr. Annasaheb Shinde College of Agricultural Engineering**
**and Technology, MPKV, Rahuri**

**Discipline Coordinator**
**Professor and Head (SWCE)**
**Dr. Annasaheb Shinde College of Agricultural Engineering**
**and Technology, MPKV, Rahuri**

## CONTENTS

## Preamble

Course curricula and course outlines in Soil and Water Conservation Engineering are designed in view of the fact that courses are offered by students from disciplines of faculties of Soil Science, Agronomy and Agricultural Meteorology.

At the post graduate level it becomes more important where they have not only to learn the recent advances in their subjects but have also to be trained in the modern and latest techniques in their disciplines so that they can participate and contribute in the development and advancement in their related fields. Further, the shrinking job opportunities in the National Agricultural Research System (ICAR/SAUs) have put additional pressure on our education system to prepare students in tune with the demands of the private sector. All courses are designed to cover all basic topics and have been designed by taking into consideration demands of private sector harnessing commercial aspects, modern research tools and their applications, supplementary skills required, and enhancing the global competitiveness and employability of students. The emphasis has been given on advanced watershed hydrology and modeling management and accordingly new courses "Stochastic hydrology, Climate change and water resources, Waste water treatment and utilization, Multi criteria decision making system" are framed in view of the recent developments in the subject.

The courses have been revised, updated and restructured in view of current developments and emerging trends in Soil and Water Conservation Engineering. The revised courses cover the areas: Advanced Soil and Water Conservation Engineering, Applied Watershed Hydrology, Soil and Water Conservation Structures, Watershed Management and Modeling, Flow Through Porous Media, Remote sensing and GIS for land and water resource management, Dryland Water Management Technologies, Minor irrigation, Design of Drip and Sprinkler Irrigation Systems, Groundwater engineering, Water Resources Systems Engineering, Advances in Hydrology, Soil and Water Systems Simulation and Modeling, Reservoir Operation and River Basin Modeling, Modeling Soil Erosion Processes and Sedimentation.
The course content and syllabus upgraded with more of practical orientation and as per ARS Syllabus.

The committee was constituted by the Deans Coordination Committee for the formulation of Course content and the syllabus for the SAUs of Maharashtra State. The series of meetings were held for their finalization of the syllabus. The ICAR recommendations for PG courses have been taken into consideration in framing these courses. It is hoped that these will prove very useful to the future students.

## Committee on Soil and Water Conservation Engineering

| ICAR-BSMA Broad Subject | ICAR-BSMA Approved Disciplines | Degree Programmes | | Broad Subject Coordinator (Chairman of all Disciplines' Sub Committees | Discipline Coordinator (Secretary of respective Discipline Sub-Committee) |
|---|---|---|---|---|---|
| Agricultural Engineering and Technology | **Soil and Water Conservation Engineering** | M. Tech. (Agril. Engg.) in Soil & Water Conservation Engineering | Ph.D. (Agril. Engg.) in Soil & Water Conservation Engineering | Dr. D. D. Pawar, Associate Dean, CoAE, MPKV, Rahuri | Dr. S. B. Nandgude, Head, Dept. of SWCE, MPKV, Rahuri |

**Contributing Faculty members for discipline subcommittee:**

| S. N | Name of the Faculty | Designation |
|---|---|---|
| 1 | Dr. S. B. Nandgude | Chairman &Head, Dept. of SWCE, MPKV, Rahuri |
| 2 | Dr. G. U. Satpute | Head, Dept. of SWCE, Dr. PDKV, Akola |
| 3 | Dr. B. L. Ayare | Head, Dept. of SWCE, Dr. BSKKV, Dapoli |
| 4 | Prof. B.W. Bhuibhar | Head, Dept. of SWCE, VNMKV, Parbhani |
| 5 | Dr. A. A. Atre | Professor of SWCE, Dept. of SWCE, MPKV, Rahuri |
| 6 | Dr. V. N. Barai | Professor of SWCE, Dept. of SWCE, MPKV, Rahuri |
| 7 | Dr. B.K. Gavit | Associate Professor of SWCE, Dept. of SWCE, MPKV, Rahuri |
| 8 | Dr. K. D. Gharde | Associate Professor, Dept. of SWCE, Dr. PDKV, Akola |
| 9 | Dr. S. D. Payal | Assistant Professor, Dept. of SWCE, VNMKV, Parbhani |
| 10 | Dr. H. N. Bhange | Assistant Professor, Dept. of SWCE, Dr. BSKKV, Dapoli |
| 11 | Prof. M.R.More | Assistant Professor, Dept. of SWCE, VNMKV, Parbhani |
| 12 | Dr. Yamesh Bisen | Assistant Professor, Dept. of SWCE, Dr. PDKV, Akola |
| 13 | Dr. M. S. Supe | Assistant Professor, Dept. of SWCE, Dr. PDKV, Akola |

**Implementation of New Curriculum**

The universities offering PG programmes in Soil and Water Conservation Engineering need to be supported for establishing specialized laboratories equipped with state-of-the art equipment's for conducting practical classes especially, Soil Mechanics, Advanced Hydrology, RS and GIS, Soil & Water Conservation, Hydro informatics and Field laboratories.

One-time catch-up grant should be awarded to each SAU, offering PG programmes in SWCE for meeting expenditure for upgrading the course requirements.

Faculty training and retraining should be an integral component. For imparting total quality management, a minimum of two faculty in each department under an SAU should be given on job training in reputed national and international institutes. To execute the new PG and Ph.D. programmes in Soil & water Conservation in effective manner, special funds from ICAR would be required for outsourcing of faculty from Indian/Foreign Universities for some initial years.

The already existing M. Tech. (Agril. Engg.) and Ph.D. (Agril. Engg.) Programmes in Soil and Water Conservation Engineering will be considered at par with the recommended M. Tech. & Ph.D. programme by V$^{th}$ Deans Committee for admission and employment.

**Expected Outcome**

- Revamping of post graduate programme in whole of Soil and Water Conservation Engineering throughout the country.
- Imparting quality education.
- Development of technical manpower to cater the need of governments, corporate sector and research organization in India and abroad.
- Exposure to the faculty in the latest technical knowhow.
- Skill development for entrepreneurship

## Organization of Course Contents & Credit Requirements

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**Minimum Residential Requirement:**

**M. Tech.: 4 Semesters**

**Ph.D.: 6 Semesters**

**Name of the Departments / Divisions**

Soil and Water Conservation Engineering (SWCE)

**Nomenclature of Degree Programme**

**(a) M. Tech. Programme**

M. Tech. (Agricultural Engineering) in Soil and Water Conservation Engineering

**(b) Ph.D. Programme**

Ph.D (Agricultural Engineering) in Soil & Water Conservation Engineering

**Code Numbers**

- All courses are divided into two series: 500-series courses pertain to Master's level, and 600- series to Doctoral level.
- Credit Seminar for Master's level is designated by code No. 591, and the Two Seminars for Doctoral level are coded as 691 and 692, respectively
- Special Problem credit course for Master's level is designated by codeNo.521 and for Doctoral level is designated by code No. 621
- Internship credit course for Master's level is designated by code No.522 and for Doctoral level is designated by code No. 622
- Deficiency courses will be of 400 series.
- Master's research: 599 and Doctoral research: 699

**Course Contents**

The contents of each course have been organized into:

- Objective – to elucidate the basic purpose.
- Theory units – to facilitate uniform coverage of syllabus for paper setting.
- Suggested Readings – to recommend some standard books as reference material. This does not obviously exclude such a reference material that may be recommended according to the advancement and local requirement.
- A list of international and national reputed journals pertaining to the discipline is provided at the end which may be useful as study material as well as research topics.
- Lecture schedule and practical schedule has also been given at the end of each course to facilitate the teacher to complete the course in an effective manner.

## Eligibility for Admission

- <u>**Master's Degree Programme**</u>

  (i) **B.Tech. (Agril. Engg.) (4 - year programme)/ B. E. (Agril. Engg.) (4 - year programme) with** four years duration of agriculture related Universities and having the Common Entrance Test in Agril. Engineering conducted by competent authority.

- **Doctoral Degree Programme:**

  (j) Master Degree in any of the following Disciplines with under graduate in B.Tech. (Agril. Engg.) and appearing the Common Entrance Test of SWCE subject conducted by competent authority.

| Sr. No | Name of Department | Specialization in Ph.D.(SWCE) | Eligibility criteria |
|---|---|---|---|
| 1. | Department of Soil & Water Conservation Engineering | Ph.D. (Soil & Water Conservation Engineering) | M. Tech. (Agril. Engg.) in Soil & Water Conservation Engineering/Soil & Water Engineering /Land & Water resource Engineering / Soil Water management /Water Resources Development and Management / M. Tech. (Civil Engg.) * / M.E. (Civil Engg.)* in Hydrology / Water Resources / M. Tech. (Remote sensing & GIS)* in Water Resources |

* Candidates with PG degree in Civil Engineering or Remote Sensing & GIS must have completed UG in B.Tech.(Agril. Engg.)

****** Candidates of other than Agril. Engineering discipline have to complete 6-10 credits as deficiency courses as recommended by SAC.

## Course and Credit Credit Requirements

| Course Details | Masters Degree | Doctoral Degree |
|---|---|---|
| Major Courses | 20 | 12 |
| Minor Courses | 08 | 06 |
| Supporting / Optional | 06 | 05 |
| Common PGS Courses | 05 | - |
| Seminar | 01 | 02 |
| Research | 30 | 75 |
| **Total** | **70** | **100** |

# Course Layout and Structure of Masters Degree

## LIST OF CORE COURSES/ DEPARTMENT WISE SPECIALIZATION/ COMPULSORY/SUPPORTING COURSES

### MAJOR COURSES (Requirement: 20 Credits)

| S.No. | Course Title | Course Code | Credits |
|---|---|---|---|
| 1 | Advanced Soil and Water Conservation Engineering | *SWCE 501 | 2+1 |
| 2 | Applied Watershed Hydrology | *SWCE 502 | 2+1 |
| 3 | Soil and Water Conservation Structures | SWCE 503 | 2+1 |
| 4 | Stochastic Hydrology | SWCE 504 | 2+1 |
| 5 | Watershed Management and Modeling | *SWCE 505 | 2+1 |
| 6 | Flow Through Porous Media | SWCE 506 | 2+0 |
| 7 | Remote Sensing and GIS for Land and Water Resource Management | SWCE 507/ IDE 507 | 2+1 |
| 8 | Climate Change and Water Resources | SWCE 508 | 3+0 |
| 9 | Numerical Methods in Hydrology | SWCE 509 | 2+0 |
| 10 | Dryland Water Management Technologies | SWCE 510 | 2+0 |
| 11 | Special problem | SWCE 521 | 0+1 |
| 12 | Internship | SWCE 522 | 0+1 |
| **Total** | | | **21+8** |

* Compulsory course

### MINOR COURSES (Requirement: 08 Credits)

**Disciplines for Minor courses**

1. Irrigation and Drainage Engineering
2. Farm Machinery and Power Engineering
3. Renewable Energy Engineering
4. Computer Sciences and Information Technology
5. Mechanical/Civil/Electrical Engineering
6. Basic Sciences

**Suggestive List of Minor courses**

| S.No. | Course Title | Course Code | Credits |
|---|---|---|---|
| 1 | Design of Drip and Sprinkler Irrigation Systems | IDE505 | 2+1 |
| 2 | Groundwater Engineering | IDE506 | 2+1 |
| 3 | Minor Irrigation | IDE510 | 2+1 |
| 4 | Water Resources Systems Engineering | IDE513 | 2+1 |
| 5 | Dimensional Analysis and Similitude | CE501 | 2+0 |
| 6 | Water Quality and Pollution Control | CE502 | 2+1 |
| 7 | Machinery for Precision Agriculture | FMPE517 | 2+1 |
| 8 | Energy, Ecology and Environment | REE513 | 3+0 |
| 9 | Big Data Analytics | CSE501 | 2+0 |
| 10 | Artificial Intelligence | CSE502 | 2+0 |
| 11 | Soft Computing Techniques in Engineering | CSE504 | 2+1 |

| | | | |
|---|---|---|---|
| 12 | Finite Element Methods | MATH501 | 2+0 |
| 13 | Numerical Methods for Engineers | MATH502 | 2+0 |
| 14 | Mechatronics and Robotics in Agriculture | ME501 | 2+0 |
| 15 | Any other course(s) of other department can be taken as per recommendations of the student's advisory committee. | | |

**SUPPORTING COURSES (Requirement: 06 Credits):**

**Disciplines for Supporting courses**

One or two courses under supporting courses will be selected relating to area of special interest and research problem as per recommendations of the student's advisory committee from following disciplines.

1. Irrigation & Drainage Engineering
2. Farm Machinery & Power Engineering
3. Farm Structure & Rural Electrification
4. Renewable energy Engineering
5. Agronomy
6. Soil Science and Agricultural Chemistry
7. Irrigation and Water Management
8. Computer Science
9. Forestry

**Suggestive List of courses as Supporting Courses**

| S.No. | Course Title | Course Code | Credits |
|---|---|---|---|
| 1 | Statistical Methods for Research Works | *STAT 501 | 2+1 |
| 2 | Courses from subject matter fields (other than Major and Minor) relating to area of special interest and research problem can be taken as per recommendations of the student's advisory committee. | | |

*Compulsory Course

**COMPULSORY COMMON NON CREDIT PGS COURSES (Requirement: 05 Credits)**

| Course code | Semester | Course Title | Credits |
|---|---|---|---|
| PGS 501 | I | Library and Information Services | 0+1=1 |
| PGS 504 | II | Basic Concepts in Laboratory Techniques | 0+1=1 |
| PGS 502 | I | Technical Writing and Communications Skills | 0+1=1 |
| PGS 503 | II | Intellectual Property and its management in Agriculture | 1+0=1 |
| PGS 505 | III | Agricultural Research, Research Ethics and Rural Development Programmes | 1+0=1 |
| PGS 506 | III | Disaster Management | 1+0 |

**List of other Essential Requirements**

| S.No. | Course title | Course Code | Credits |
|---|---|---|---|
| 1 | Masters Seminar | SWCE591 | 0+1 |
| 2 | Masters  Research | SWCE599 | 0+30 |

## Course Layout and Structure of Doctoral Degree

### MAJOR COURSES (Requirement: 12 Credits)

| S.No. | Course Title | Course Code | Credits |
|---|---|---|---|
| 1 | Advances in Hydrology | *SWCE601 | 2+1 |
| 2 | Soil and Water Systems Simulation and Modeling | *SWCE602 | 2+1 |
| 3 | Reservoir Operation and River Basin Modeling | SWCE603 | 2+1 |
| 4 | Modeling Soil Erosion Processes and Sedimentation | SWCE604 | 2+1 |
| 5 | Waste Water Treatment and Utilization | SWCE605 | 3+0 |
| 6 | Hydro-Chemical Modeling | SWCE606 | 2+0 |
| 7 | Drone and Google Earth Engine for NRM | SWCE - 607 | 2+1 |
| 8 | Special problem | SWCE 621 | 0+1 |
| 9 | Internship | SWCE 622 | 0+1 |
| **Total** | | | **15+7** |

*Compulsory course

### MINOR COURSES (Requirement: 06 Credits)

**Disciplines for Minor courses**

1. Irrigation and Drainage Engineering
2. Farm Machinery and Power Engineering
3. Renewable Energy Engineering
4. Computer Sciences and Information Technology
5. Mechanical/Civil/Electrical Engineering
6. Basic Sciences

**Suggestive list of Minor courses**

| S.No. | Course Title | Course Code | Credits |
|---|---|---|---|
| 1 | Hydro-Mechanics and Ground Water Modeling | IDE 603 | 3+0 |
| 2 | Soil-Water-Plant-Atmospheric Modeling | IDE 604 | 2+1 |
| 3 | Multi Criteria Decision Making System | IDE 606 | 2+0 |
| 4 | Neuro-Fuzzy Application in Engineering | CSE 503 | 2+1 |
| 5 | Digital Image Processing | CSE 506 | 2+1 |
| 6 | Courses from subject matter fields (other than Major and Minor) relating to area of special interest and research problem can be taken as per recommendations of the student's advisory committee. | | |

## SUPPORTING COURSES (Requirement: 05 Credits)

### Disciplines for Supporting courses

1. Irrigation & Drainage Engineering
2. Farm Machinery & Power Engineering
3. Farm Structure & Rural Electrification
4. Renewable energy Engineering
5. Agronomy
6. Soil Science and Agricultural Chemistry
7. Irrigation and Water Management
8. Computer Science

### Suggestive List of Supporting Courses

| S.No. | Course Title | Course Code | Credits |
|---|---|---|---|
| 1 | Research and Publication Ethics | *CPE-RPE 601 | 1+1 |
| 2 | Courses from subject matter fields (other than Major and Minor) relating to area of special interest and research problem can be taken as per recommendations of the student's advisory committee. | | |

* Course compulsory

### List of other Essential Requirements

| S.No. | Course title | Course Code | Credits |
|---|---|---|---|
| 1 | Doctoral Seminar-I | SWCE 691 | 0+1 |
| 2 | Doctoral Seminar-II | SWCE 692 | 0+1 |
| 3 | Doctoral Research | SWCE 699 | 0+75 |

# Course Syllabus and Contents of Masters Degree

## SWCE 501 Advanced Soil and Water Conservation Engineering 2+1

**Objectives:**
To acquaint and equip students with the advances in soil and water conservation measures, use of RS and GIS and Software's for design of soil and water conservation structures.

**Unit-I**
Concept of probability in design of soil and water conservation structures. Probability and continuous frequency distribution. Fitting empirical distributions.

**Unit-II**
Relevance of soil and water conservation in agriculture and in the river valley projects. Layout and planning of soil and water conservation measures.

**Unit-III**
Soil loss estimation models: MUSLE, RUSLE Productivity loss due to soil erosion. Water stress and water excess. Types and mechanics of soil erosion. Software's for soil loss estimation, WEAP, EPIC.

**Unit-IV**
Theories of sediment transport. Control of runoff and sediment loss. Sediment deposition process. Estimation of sediment load.

**Unit-V**
Design of soil and water conservation structures: Check dams, gully plugs, gabion structures, earth dams, silt detention dams, farm ponds, etc., and the alternate use of the stored water for agriculture. Software's for design of conservation structures. Application of Remote Sensing and GIS in Soil and Water Conservation.

**Practical:**
Assessment of erosive status of a watershed through field measurement or analysis of morphometric properties. Estimation of erosivity index of rainfall. Determination of soil physical properties: Texture, grain size distribution, Atterberg's limits, various moisture percentages. Locating best possiblesites of soil and water conservation structures on the basis of map features and erosivity status. Estimation of costs of soil and water conservation measures.

**Course Outcome:**
The students will able to plan and design soil and water conservation measures in particular watershed using RS and GIS techniques. They can estimate the sedimentation and capacity losses, design of gully control structures and earthen dams using softwares.

**Teaching Schedule**

| S.No. | Topic | No. of Lectures |
|---|---|---|
| 1 | Concept of probability in design of soil and water conservation structures | 2 |
| 2 | Probability and continuous frequency distribution | 2 |
| | Fitting empirical distributions | 2 |
| 3 | Relevance of soil and water conservation in agriculture and in the river valley projects | 2 |
| 4 | Layout and planning of soil and water conservation measures | 2 |

| | | |
|---|---|---|
| 5 | Software's for design of conservation structures | 1 |
| 6 | Productivity loss due to soil erosion | 1 |
| 7 | Water stress and water excess | 1 |
| 8 | Types and mechanics of soil erosion | 1 |
| 9 | Software's for soil loss estimation, WEAP, EPIC | 3 |
| 10 | Theories of sediment transport | 2 |
| 11 | Control of runoff and sediment loss | 1 |
| 12 | Sediment deposition process and estimation of sediment load | 2 |
| 13 | Design of soil and water conservation structures: Check dams, gully plugs, gabion structures, earth dams, silt detention dams, farm ponds, etc., and the alternate use of the stored water for agriculture | 6 |
| 14 | Application of Remote Sensing and GIS in Soil and Water Conservation | 3 |
| | **Total** | **31** |

**List of Practicals**

| S.No. | Topic | No. of Practicals |
|---|---|---|
| 1 | Assessment of erosive status of a watershed through field measurement | 2 |
| 2 | Morphometric analysis of a watershed | 2 |
| 3 | Estimation of erosivity index of rainfall | 1 |
| 4 | Determination of Soil erodibility factor "K' | 1 |
| 5-8 | Design of Check dams, gully plugs, gabion structures, earth dams, silt detention dams and farm ponds | 4 |
| 9 | Locating best possible sites of soil and water conservation structures on the basis of map features and erosivity status | 2 |
| 10 | Use of Software for soil loss estimate | 1 |
| **11** | Use of Software for design of conservation measures | 2 |
| 12 | Estimation of costs of soil and water conservation measures | 2 |
| | **Total** | **17** |

**References:**


1. Suresh R 2016.*SoilandWaterConservationEngineering*. Standard Publishers and Distributors, Delhi.
2. Garg SK 1987. *Irrigation Engineering and Hydraulic Structures*. Khanna Publishers, New Delhi
3. Kirkby MJ and Morgan PPC (eds). 1980. *Soil Erosion*. John Wiley and Sons. New York, USA.
4. Rajkumar Patel.2012. Watershed Management Planning Using Remote Sensing and GIS. Lambert Academic Publishing.
5. Soil and Water Conservation Structures. http://ecoursesonline.iasri.res.in/
6. Nandgude S.B. and Others 2011.Development of Software for Design of Soil and Water Conservation Structures in Watershed. International Journal of Computer Applications (0975 – 8887) Volume 14– No.5, January 2011
7. Yuriko Osakabe and others .2014.Response of plants to water stress. Front. Plant Sci., 13 March 2014.
8. WEAP: Water Evaluation And Planning System. https://www.weap21.org .
9. The EPIC Crop Growth Model.
10. Williams J. R, and others. The EPIC Crop Growth Model. TRANSACTIONS of the ASAE,PP497-511

## SWCE 502 Applied Watershed Hydrology 2+1

**Objectives:**
To provide in depth knowledge of surface and sub-surface hydrology of watershed including stream flow measurement and computer simulation of hydrological processes in small watersheds.

**Unit-I**
Hydrology in water resources planning, rainfall, surface run off and sub-surface run off as components of hydrologic cycle. Run off phenomena, relationship between precipitation and run off. Stream flow measurement and analysis of data in detail.

**Unit-II**
Synthetic unit hydrograph. Recent advances in analysis of hydrologic data and flow from small watersheds. Methods of run off estimation from small watersheds. Use of IUH and various methods of estimation. Run off estimation models: SCS, CN software.

**Unit-III**
Microclimate, estimation methods of evaporation. Advances and improvements in rational approach. SCS approach criticism and improvements.

**Unit-IV**
Hydrological hazard functions. Methods of estimation of hydrologic parameters. Data transformation. Flood routing, Reservoir sedimentation process.

**Unit-V**
Calibration and evaluation of hydrologic models. Computer simulation of hydrological process in small watersheds.

**Practical:**
Delineation of watershed and study of watershed characteristics. Measurement of rainfall and runoff in a watershed and data analysis. Estimation of infiltration and runoff from a watershed. Analysis and derivation of various types of hydrographs. Flood routing. Reservoir sedimentation. Watershed model components. Visit to a watershed.

**Course Outcome:**
The students will be able to understand and analyse the process and the effect of various climatic parameters on rainfall-runoff relationship. They can also be able to develop the competency for calibration and evaluation of hydrologic models and computer simulation.

**Teaching Schedule**

| S.No. | Topic | No. of Lectures |
|---|---|---|
| 1 | Hydrology in water resources planning, rainfall, surface runoff and sub-surface runoff as components of hydrologic cycle | 2 |
| 2 | Basics of watershed hydrology and processes, global and watershed perspectives | 2 |
| 3 | Runoff phenomena, relationship between precipitation and runoff | 1 |
| 4 | Synthetic unit hydrograph, Unit hydrograph and its derivation including for complex storm, | 3 |
| 5 | S-hydrograph and derivation, Use of IUH and various methods of estimation. | 3 |

| | | |
|---|---|---|
| 6 | Runoff estimation models: SCS, CN software | 3 |
| 7 | Flood routing principles | 2 |
| 8 | Recent advances in analysis of hydrologic data and flow from small watersheds. Methods of runoff estimation from small watersheds. | 3 |
| 9 | Microclimate, estimation methods of evaporation. Advances and improvements in rational approach. SCS approach criticism and improvements | 3 |
| 10 | Process of sedimentation of reservoirs | 2 |
| 11 | Hydrological hazard functions, Methods of estimation of hydrologic parameters, Data transformation, | 3 |
| 12 | Hydrologic modeling approaches, component conceptualization, Types of watershed hydrologic models and choice of model. | 3 |
| 13 | Calibration and evaluation of hydrologic models. Computer simulation of hydrological process in small watersheds | 2 |
| | **Total** | **32** |

**List of Practical**

| S.No. | Topic | No. of Practicals |
|---|---|---|
| 1 | Delineation of watershed and study of watershed characteristics | 1 |
| 2 | Measurement of rainfall and runoff in a watershed | 1 |
| 3 | Analysis of hydrologic data and flow from small watersheds | 1 |
| 4 | Estimation of infiltration and runoff from a watershed | 1 |
| 5 | Measurement and analysis of stream flow data | 1 |
| 6 | Analysis of synthetic unit hydrograph for complex storm | 1 |
| 7 | Analysis of S-hydrograph for complex storm | 1 |
| 8 | Use of runoff estimation models: SCS, CN software | 2 |
| 9 | Study of different types of flood routing methods | 2 |
| 10 | Computer simulation of hydrological process in small watersheds | 1 |
| 11 | Study of reservoir sedimentation | 1 |
| 12 | Study of watershed model components | 1 |
| 13 | Visit to a watershed | 1 |
| | **Total** | **16** |

**Suggested Readings :**

1. Singh V P 2010. Rainfall-Runoff Modeling (Vol.I) Prentice Hall, New York.
2. Singh V P 2010. Environmental Hydrology, Springer, New York.
3. Haan C T. Hydrologic Modeling of Small Watershed.
4. Mutreja K N Applied Hydrology Tata Mc Grow Hill publishing company Limited, New York.
5. Subramanya K. Engineering Hydrology. Tata Mc Grow-Hill Publishing company Limited, Second edition.
6. Suresh, R. Soil and Water Conservation Engineering. Standard publishers distributors, 5th edition,

7. Ven Te chow, David R Mauldment, Larry w Mays (2010). Applied Hydrology TATA Mc Grow Hill edition.
8. Gayathri K Devi, Ganasri B P, Dwarakish G S. 2015 A Review on Hydrological Models. International Conference On Water Resources, Coastal And Ocean engineering (ICWRCOE 2015)
9. Tommaso Caloiero. 2018. Hydrological Hazard: Analysis and Prevention. National Research Council—Institute for Agricultural and Forest Systems in Mediterranean (CNR-ISAFOM)
10. Müsteyde Baduna Koçyiğit ,Hüseyin Akay, Ali Melih Yanmaz.2017. Estimation of Hydrologic Parameters of Kocanaz Watershed by a Hydrologic Model, International Journal of Engineering & Applied Sciences (IJEAS),Vol.9, Issue 4 (2017) 42-50,
11. Hoshin Vijai Gupta and Soroosh Sorooshian. 1998. Toward improved calibration of hydrologic models: Multiple and non commensurable measures of information. Water Resources Research, VOL. 34, NO. 4, PAGES 751–763,

**SWCE 503 Soil and Water Conservation Structures 2+1**

**Objectives:**
To acquaint students with the planning and design of soil and water conservation structures, their stability checks and mechanized soil conservation techniques.

**Unit-I**
Design, planning and layout of soil and water conservation structures. Criteria of selection of appropriate structures as per soil, land use and climatic conditions.
**Unit-II**
Design and construction of earthen dam, stability analysis of land slopes and soil mass including landslides.
**Unit-III**
Hydrological and structural design including stress analysis. Hydraulic jump and energy dissipaters for soil conservation structures.
**Unit-IV**
Seepage through dams, flownet and determination of uplift pressure in drop structures, design of energy dissipaters.
**Unit-V**
Design of water harvesting structures, construction, maintenance and utilization of stored water. Mechanized construction techniques for soil and water conservation structures.
**Practical:**
Stability analysis and structural design of masonry water harvesting structures.Design of earthen dams and other energy dissipating structures. Cost analysis of water harvesting structures. Field visit to already constructed water harvesting structures in the nearby area/ watershed.
**Course Outcome:**
The student will be able to design the soil and water conservation structures as well as permanent gully control structures and water harvesting structures. They can have understanding of mechanized construction of soil and water conservation structures.

**Teaching Schedule**

| S.No. | Topic | No. of Lectures |
|---|---|---|
| 1 | Introduction and need of Soil and Water Conservation in agricultural watershed | 1 |
| 2 | Runoff process and factors affecting it and estimation of runoff Using various methods | 3 |
| 3 | Analysis of rainfall data, Probability concepts in the design of structures | 3 |
| 4 | Introduction, classification and functional requirement of soil and Water conservation structures-Straight Drop spillway, chute spillway and drop inlet spillway | 1 |
| 5 | Specific energy and specific force | 2 |
| 6 | Hydraulic jump and its application, type of hydraulic jump, energy dissipation due to jump, jump efficiency, relative loss of energy | 2 |

| | | |
|---|---|---|
| 7 | Straight drop spillway- Components and their functions, hydrologic, hydraulic and structural design | 4 |
| 8 | Drop inlet spillway-Components and their functions, hydrologic, hydraulic and structural design | 2 |
| 9 | Chute Spillway-Components and their functions, hydrologic, Hydraulic and structural design | 3 |
| 10 | Criteria of selection of appropriate structures as per soil, land use and climatic conditions | 1 |
| 11 | Design of energy dissipaters in soil and water conservation structures | 1 |
| 12 | Introduction, types, design, criteria and construction of earthen dam, causes of failure of earthen dam, retaining wall and its design | 3 |
| 13 | Stability analysis of land slopes and soil mass including landslides, seepage control in earthen dams, flow net in earthen dams | 2 |
| 14 | Water harvesting: principles, importance and issues. Water harvesting techniques: classification based on source, storage and use. Runoff harvesting: short-term and long-term harvesting techniques, purpose and design criteria. | 3 |
| 15 | Mechanized construction techniques for soil and water conservation structures | 1 |
| | **Total** | **32** |

**List of Practicals**

| S.No. | Topic | No. of Practicals |
|---|---|---|
| 1 | Construction of specific energy and specific force diagram | 1 |
| 2 | Measurement of hydraulic jump parameters and amount of energy dissipation | 2 |
| 3 | Hydrologic and hydraulic design of a straight drop spillway | 1 |
| 4 | Determination of uplift force and construction of uplift pressure Diagram | 1 |
| 5 | Determination of loads on head wall and construction of triangular Load diagram | 1 |
| 6 | Stability analysis of a straight drop spillway | 1 |
| 7 | Hydraulic design of a chute spillway | 1 |
| 8 | Design of drop inlet spillway | 1 |
| 9 | Design of energy dissipating structures | 1 |
| 10 | Design of earthen dam | 1 |
| 11 | Seepage analysis in earthen embankment | 1 |
| 12 | Design of water harvesting structures | 1 |
| 13 | Economic analysis of water harvesting structures | 1 |
| 14 | Field visit to already constructed water harvesting structures in the nearby area/ watershed. | 1 |
| | **Total** | **15** |

**Suggested Reading :**


1. Murty VVN 1988. *Land and Water Management Engineering.* Second Edition Kalyani Publishers, New Delhi.
2. Singh Gurmel C, Venkataraman G, Sastriand B.P. Joshi 1991. *Manual of Soil & Water conservation Practices*. Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi.
3. Singh PK 2000. *Watershed Management (Design and Practice)*.e-media publications, Udaipur.
4. Suresh R 2006. *Soil and Water Conservation Engineering*. Fourth Edition Standard Publishers and Distributors, Delhi.
5. Singh Raj Vir. 2003. *Watershed Management*. Second Edition, Yash Publishing, Bikaner.
6. Mahnot, SC Singh PK and Chaplot PC 2011.*Soil and Water Conservation and Watershed Management*. APEX publishing house,Udaipur.
7. Mutreja K. N. Applied Hydrology, Tata McGraw Hill Publication

**SWCE 504 Stochastic Hydrology 2+1**

**Objectives:**
To acquaint students about the stochastic processes in hydrology including statistical characteristics of hydrological time series data, modelling hydrologic uncertainty and analysis of multi variate hydrologic series,

**Unit-I**
Hydrologic cycle, Systems concept, Hydrologic systems model. Classification of hydrologic models, Statistical, stochastic and deterministic approaches. Statistical characteristics of hydrological data, probability distribution of hydrologic variables. Deterministic and stochastic hydrology, Cause and effect analysis. Hydrologic time series analysis– nature, stationarity and ergodicity, components of time series, trend, periodicity and stochastic parts, para meter estimation of probability distributions. Analysis of hydrologic extremes.

**Unit-II**
Multi variate regression analysis, correlation analysis, correlation coefficient and its significance in regional analysis. Developing prediction equation by simple and multiple linear regression. Reliability of the Model.

**Unit-III**
Stochastic Process: Classification, stationary process. Time series: Classification, component of time series. Methods of investigation: Auto correlation coefficient, moving average process, auto regressive process, auto regressive moving average process, auto regressive integrated moving average process. Spectral analysis, analysis of multi variate hydrologic series.

**Unit-IV**
Thomas Fiering model, Box Jenkins model. Model formulation: Parameter estimation, calibration and validation. Application to hydrologic data. Generation and forecasting. Regional flood frequency analysis. Transformations, Hypothesis testing.

**Unit-V**
Modeling hydrologic uncertainty. First order Markov process, Markov chain, Data generation, Hydrologic time series analysis, Modelling of hydrologic time series.

**Practical:**
To estimate various statistical parameters of the hydrologic variables, estimating missing data in historical series, various parameter estimation methods like method of moments, method of maximum likelihood, method of mixed moments, probability of weighted moments fitting discrete and continuous distribution functions to variables, application of transformation techniques to historical data for estimating variables at different return periods, determining correlation and regression coefficients, analyzing multivariate regression, auto correlation coefficient for independent and correlated events, fitting ARMA models, fitting Markov models of first and second order, regional frequency analysis, time series analysis of the historical data, estimating and fitting Thomas Fiering Model.

**Course Outcome:**
The students are enabled to understand the stochastic process of hydrology including statistical based analysis of hydrological time series data. They are exposed to stochastic and deterministic modelling of small watersheds.

**Teaching Schedule**

| S.No. | Topic | No. of lectures |
|---|---|---|
| 1 | Hydrologic cycle, Systems concept, Hydrologic systems model | 1 |
| 2 | Hydrological models, processes and systems - Physical Characterization of watersheds; Rainfall measurements | 1 |
| 3 | Classification of hydrologic models, Statistical, stochastic and deterministic approaches | 1 |
| 4 | Statistics and probabilities in hydrology– Basic concepts– Experiment, Sample space, element, event, complement, intersection, disjoint, union, statistical parameters; Uncertainty in hydrological event; Statistical homogeneity, Permutation, combination, probability, conditional probability; Independent events, random variables, discrete and continuous sample space, Probability and Return period | 3 |
| 5 | Statistics and probabilities in hydrology- Frequency Analysis– Mean, Median, Mode, Variance, Frequency Analysis-Standard deviation, Coefficient of Variance, Skewness, Kurtosis Theoremson Probability; Total probability theorem and Baye's theorem | 3 |
| 5 | Statistics and probabilities in hydrology-Discrete and Continuous probability-Random Variable and Variate; Probability Distribution of hydrological variables; Co-relation and regression analysis. | 3 |
| 6 | Introduction and examples of stochastic processes; Specification of Stochastic process-nature, stationarity and ergodicity, components of time series, | 2 |
| 7 | Hydrologic time series analysis–trend, periodicity | 1 |
| 8 | Stochastic time series analysis-Methods of analysis-Auto correlation coefficient, | 1 |
| 9 | Stochastic time series analysis- moving average process, auto Regressive process, | 2 |
| 10 | Stochastic time series analysis-auto regressive moving average process, | 2 |
| 10 | Stochastic time series analysis-auto regressive integrated moving average process. | 2 |
| 11 | Spectral analysis, analysis of multivariate hydrologic series | 2 |
| 12 | Thomas Fiering model, Box Jenkins model | 2 |
| 13 | Model formulation: Parameter estimation, calibration and validation. | 2 |
| 14 | Application to hydrologic data | 2 |
| 15 | Generation and forecasting-Regional flood frequency analysis Transformations, | 1 |
| 16 | Hypothesis testing | 1 |
| | **Total** | **32** |

**List of Practicals**

| S.No. | Topic | No. of Practicals |
|---|---|---|
| 1 | Development of regression models | 1 |

| | | |
|---|---|---|
| 2 | Estimation of missing data in historical series | 1 |
| 3 | Parameter estimation- Method of Moments | 1 |
| 4 | Parameter estimation- method of maximum likelihood | 1 |
| 5 | Parameter estimation-method of mixed moments, Probability of weighted moments | 1 |
| 6 | Fitting discrete and continuous distribution functions to variables | 1 |
| 7 | Transformation techniques to historical data for estimating variables at different return periods | 1 |
| 8 | Regression analysis, Correlation analysis, | 1 |
| 9 | Analyzing multivariate regression, | 1 |
| 10 | Auto correlation coefficient for independent and correlated events, | 1 |
| 11 | Fitting ARMA models to rainfall runoff data | 1 |
| 12 | Fitting Markov models of first and second order, | 1 |
| 13 | Regional frequency analysis, | 1 |
| 14 | Estimating parameters of Thomas Fiering Model | 1 |
| 15 | Fitting of Thomas Fiering Model | 1 |
| | **Total** | **15** |

**Suggested Readings:**


1. Clarke RT *Mathematical Models in Hydrology*. FAO Publication.
2. Haan CT *Statistical Methods in Hydrology*. Iowa State Press2002.
3. Kotteguda, NT1982. *Stochastic Water Resources Technology*. The Macmillan Press,New York.
4. Yevjevich V *Stochastic Processes in Hydrology*. Water Resources Publications, Colorado.
5. McCuen RH and Snyder WM *Hydrological Modelling–Statistical Methods and Applications*. Prentice Hall Inc.New York.
6. Handbook on Hydrology, ICAR Publication
7. Applied Modelling of Hydrologic Time Series by J D Salas, W. Delleur, V. Yevjevich and W. L. Lave, Water Resource Publication

**SWCE 505 Watershed Management and Modeling 2+1**

**Objectives:**
To acquaint students with watershed management concept and its benefit for sustainable rural development through participatory approach, including environmental impact as well as policy frame work.

**Unit-I**
Concept of watershed, its hydrological and geo-morphological characteristics. Status of watershed management programs in India. Problems of desertification and degradation.

**Unit-II**
Concept of watershed management and sustainability, participatory approach and operational watershed. Surveys, monitoring, reclamation and conservation of agricultural and forest watersheds, hill slopes and ravines.

**Unit-III**
Watershed management research instrumentation and measurement, problem identification, simulation and synthesis. Rainfed farming and drought management. Modeling of flood and drought phenomenon.

**Unit-IV**
Use of Remote Sensing and GIS in watershed management and modeling. Watershed modelling approaches.

**Unit-V**
Environmental impact assessment of watersheds. Quantitative evaluation of management techniques. National land use policy, legal and social aspects. Case studies of watershed management.

**Practical:**
Selection and delineation of a watershed. Benchmark surveys. Preparation of watershed land use map. Preparation of watershed development proposal. Preparation of watershed evaluation and impact assessment report. Application of watershed models for evaluation of conservation treatments. Use of Remote Sensing and GIS in watershed management and modeling.

**Course Outcome:**
The students will be able to understand different conservation practices and their effect on watershed behavior. They can also estimate the geomorphologic parameters of particular watershed which is quite useful for watershed planning and development of watershed models.

**Teaching Schedule**

| S.No. | Topic | No. of Lectures |
|---|---|---|
| 1 | Concept of watershed, its hydrological and geo-morphological characteristics | 2 |
| 2 | Status of watershed management programs in India | 2 |
| 3 | Problems of desertification and degradation | 2 |
| 4 | Concept of watershed management and sustainability, participatory approach and operational watershed | 3 |

| | | |
|---|---|---|
| 5 | Surveys, monitoring, reclamation and conservation of agricultural and forest watersheds, hill slopes and ravines | 3 |
| 6 | Watershed management research instrumentation and measurement, Problem identification, simulation and synthesis | 3 |
| 7 | Rainfed farming and drought management | 2 |
| 8 | Modeling of flood and drought phenomenon | 2 |
| 9 | Use of Remote Sensing and GIS in watershed management and modeling | 2 |
| 10 | Environmental impact assessment of watersheds | 3 |
| 11 | Quantitative evaluation of management techniques | 2 |
| 12 | National land use policy, legal and social aspects | 3 |
| 13 | Case studies of watershed management | 3 |
| | **Total** | **32** |

**List of Practical**

| S.No. | Topic | No of Practical |
|---|---|---|
| 1 | Selection and delineation of a watershed | 3 |
| 2 | Bench mark surveys | 2 |
| 3 | Preparation of watershed land use map | 2 |
| 4 | Preparation of watershed development proposal | 3 |
| 5 | Preparation of watershed evaluation and impact assessment report | 2 |
| 6 | Application of watershed models for evaluation of conservation treatments | 2 |
| 7 | Use of Remote Sensing and GIS in watershed management and modelling | 2 |
| | **Total** | **16** |

**Suggested Readings**

1. Tideman EM 1999. *Watershed Management (Guidelines for Indian Conditions)*. Omega Scientific Publishers, New Delhi.
2. Dhruvanarayana VV, Sastry G and Patnaik US. *Watershed Management*. Publ. and Inf. Div., ICAR, Krishi Anusandhan Bhavan, New Delhi.
3. Singh RV 2000. *Watershed Planning and Management* .Second Edition Yash Publishing House, Bikaner.
4. Dhaliwal GS Hansra BS and Ladhar SS1993. *Wetlands, their Conservation and Management*. Punjab Agricultural University, Ludhiana.
5. Suresh R2017. *Watershed Planning and Management*. Standard Publication and Distribution, Delhi
6. Integrated Watershed Management, Principles and Practices by Isobel W. Heathcoate

**SWCE 506 Flow Through Porous Media 2+0**

**Objectives:**
To provide comprehensive knowledge to the students in aquifer and fluid properties, unsaturated flow theory and movement of ground water in fractured and swelling porous media.

**Unit-I**
Aquifer and fluid properties, forces holding water in soils, hydrodynamics in porous media and limitations of governing laws.

**Unit-II**
Differential equations of saturated flow, initial and boundary conditions. Dupuit and Business approximations and linearization techniques.

**Unit-III**
Stream functions, potential functions and flow net theory. Analysis of seepage from canal sand ditches.

**Unit-IV**
Unsaturated flow theory, Infiltration and capillary rise flux dynamics. Movement of groundwater in fractured and swelling porous media.

**Unit-V**
Hydro-dynamic dispersion in soil- aquifer system. Velocity hydrograph, flow characteristics at singular points, examples of velocity hydrograph, solution by complex velocity, solution of triangular dam, drainage in retaining structures, influence of seepage on stability of slopes, drainage methods for stability of slopes.

**Course Outcome:**
The students will be able to understand physical properties of flow through porous media. Competence on various laws governing dynamics of flow through porous media. Understanding of hydrodynamics in porous media, governing laws and boundary conditions.

**Teaching Schedule**

| S.No. | Topic | No. of Lectures |
|---|---|---|
| 1 | Aquifer and its classification, properties of aquifers and fluids | 1 |
| 2 | Forces responsible for holding water in soil and movement, hydro static pressure distribution | 1 |
| 3 | Porosity, permeability and hydraulic conductivity: its importance in Fluids flow | 1 |
| 4 | Hydro dynamics in porous media: Continuum approach to porous media, Representative Elementary Volume (REV), linear and aerial porosity, velocity and specific discharge relationship in porous medium | 3 |
| 5 | Generalization of Darcy Law in isotropic and an isotropic layered porous medium, deviation from Darcy Law and limitations of governing laws in flow through porous media | 3 |
| 6 | Saturated flow: Differential equations for flow through saturated medium, initial and boundary conditions, types of boundary conditions, boundary and initial value problems | 3 |

| | | |
|---|---|---|
| 7 | Dupuit and Boussinesq approximations and linearization: Dupuit assumption and equation, Boussinesq linearization Techniques ands olutions | 3 |
| 8 | Unsaturated flow theory: Continuity and conservation equations for a homogeneous fluid in non-deforming medium and deforming medium, Continuity equation for compressible fluid and moveable solid matrix | 6 |
| 9 | Infiltration and capillary rise flux dynamics, movement of ground water in fractured and swelling porous media | 2 |
| 10. | Stream and potential functions: Stream functions in two and three Dimensional flow, potential functions and flow net theory | 3 |
| 11 | Analysis of seepage from canals and ditches | 2 |
| 12 | Hydro-dynamic dispersion in soil-aquifer system: Hydro-dynamic dispersion, derivation of dispersion and diffusion equation | 3 |
| 13 | Velocity hydrograph: Flow characteristics at singular points, examples of velocity hydrograph, solution by complex velocity, solution of triangular dam, drainage in retaining structures, influence of see page on stability of slopes, drainage methods for stability of slopes | 3 |
| | **Total** | **34** |

**Suggested Reading:**


1. Helmut K Soil Physics, pp7-79
2. Core A T Flow in Porous Media.
3. Collins R E 1961. Flow of Fluids through Porous Materials. Reinhold publishing cooperation, New York.
4. De Wiest Roger J M 1969. Flow through Porous Media. Academic press, New York.
5. Verruijt A 1982 Theory of Groundwater Flow. 2$^{nd}$Edn., Macmillan, London
6. Bear J and Arnold V Modeling Groundwater Flow and pollution D Reidel Publishing Company.
7. Bears J 1972 Dynamics of Fluids in Porous Media, American Elsevier Publishing Co. Inc New York.
8. David keith Todd 1980. Groundwater Hydrology, Second edition
9. Amrakh: J Mamedov. 2014. Soil water retention and Structure Stability as affected by water quality. Eurasion Journal of Soil science. Pp 89-94
10. Heineman, Z. E. 2003 Fluid flow in porous media, Text book series, Vol.I
11. Ahad zarghami, Chiara Bisearin, sauro succi and stefana. 2014. Hydrodynamics in porous media Journal of scientific computing pp 81-104
12. Kutilek and Nielsem 2001 Saturated and unsaturated flow, college on soil physics Elsevier soil and tillage Research Journal.
13. Chandesris, M, Jamet, D. Boundary conditions at a fluid–porous interface: An a priori estimation of the stress jump coefficients. International Journal of Heat and Mass Transfer, Elsevier, 2006, 49 (13-14), pp.2137-2150.
14. Ying-Hsin Wu, Takahiro Sayama, Eiichi Nakakita, 2018. Appropriate Boundary Condition for Dupuit-Boussinesq Theory on the Steady Groundwater Flow in an Unconfined Sloping Aquifer With Uniform Recharge, Water Resources Research.

15. Siddique,J. I, D. M. Anderson,and Andrei Bondarev. 2009. Capillary rise of a liquid into a deformable porous material, Physich of Fluid. DOI:10.1063/1.3068194
16. Harish Gopalan, Alex Povitsky. 2009. Stream function-potential function coordinates for aeroacoustics and unsteady aerodynamics. International Journal of Computational Fluid Dynamics, 285-290
17. Dale M. Lancaster, 1952. MEASUREMENT OF SEEPAGE LOSSES FROM IRRIGATION CANALS, A paper for the Summer Convention, ASCE,, Denver, Colorado.
18. Haga, D., Niibori, Y., Chida, T. 1999. Hydrodynamic dispersion and mass transfer in unsaturated flow, WATER RESOURCES RESEARCH, VOL. 35, NO. 4, PAGES 1065-1077.
19. Mohsen Safarian, Hadi Norouzi& Jalal Bazargan. 2021. Study of hydraulic gradient and velocity changes of unsteady flow through coarse porous media. International Journal of River Basin Management.

**SWCE 507 / IDE507 GIS and Remote Sensing for Land and Water Resource Management 2+1**

**Objectives:**
To acquaint students with recent technology of RS and GIS including satellite data analysis, digital image processing and thematic mapping of landuse, surface and groundwater.

**Unit-I**
Physics of remote sensing, electro magnetic radiation (EMR), interaction of EMR with atmosphere, earth surface, soil, water and vegetation. Remote sensing platform, monitoring atmosphere, land and water resources: LANDSAT, SPOT, ERS, IKONOS, SENTINEL and others, Indian Space Programme.

**Unit-II**
Satellite Data analysis: Visual interpretation, digital image processing, image pre-processing, image enhancement, image classification and data merging.

**Unit-III**
Definition: Basic components of GIS, map projections and co-ordinate system, spatial data structure-raster, vector, spatial relationship, topology, geo-data base models, hierarchical network, relational, object-oriented models, integrated GIS database-common sources of error–data quality: Macro, micro and usage level components, meta data, Spatial data transfer standards.

**Unit-IV**
Thematic mapping, measurements in GIS: Length, perimeter and areas. Query analysis, reclassification: Buffering, neighbourhood functions, map overlay: Vector and raster overlay: Interpolation, network analysis, digital elevation modelling.

**Unit-V**
Spatial data sources: 4 MGIS approach water resources system, Thematic maps, rainfall runoff modelling, ground water modeling, Analytical Hierarchy Process, Object oriented GIS–AM/FM/GIS, Web Based GIS. Site selection for artificial recharge, reservoir sedimentation.

**Practical:**
Familiarization with the Remote sensing instruments and satellite imagery. Aerial Photograph and scale determination with stereoscope. Interpretation of satellite imageries and aerial photographs. Determination of Parallaxes in images. Introduction to digital image processing software and GIS software and their working principles. Generation of digital elevation model (DEM) for land and water resource management. Case studies on mapping, monitoring and management of natural resources using remote sensing and GIS.

**Course Outcome:**
Students will be able to use satellite remote sensing to perform image analysis and classification for developing thematic maps. Able to integrate satellite data with GIS to undertaker course mapping and planning studies.

**Teaching Schedule**

| S.No. | Topic | No. of Lectures |
|---|---|---|
| 1 | Introduction and brief history of RS and GIS, applications of RS And GIS | 1 |

| | | |
|---|---|---|
| 2 | Physics of remote sensing. Electro Magnetic radiation (EMR), interaction of EMR with atmosphere, earth surface, soil, water and vegetation | 2 |
| 3 | Remote sensing platforms: Monitoring atmosphere, land and water resources: LANDSAT, SPOT, ERS, IKONOS, SENTINEL and others Indian Space Programme | 2 |
| 4 | Satellite data analysis. Visual interpretation. | 2 |
| 5 | Digital image processing- Image pre-processing, Image enhancement, Image classification, data merging. | 3 |
| 6 | Basic components of GIS- Map projections and co-ordinate system. | 2 |
| 7 | Spatial data sources, Thematic maps | 1 |
| 8 | Spatial data structure: Raster, vectordata, Spatial relationship-Topology | 2 |
| 9 | Geodata base models: Hierarchical, network, relational, object-oriented models. Integrated GIS database | 3 |
| 10 | Data quality, Common sources of error, Macro, micro and Usage Level components, Metadata and Spatial data transfer standards | 2 |
| 11 | Measurement in GIS- Length, perimeter and areas | 1 |
| 12 | Query analysis. Reclassification, Buffering and Neighborhood functions | 1 |
| 13 | Map overlay: Vector and raster overlay | 1 |
| 14 | Interpolation and network analysis | 1 |
| 15 | Digital elevation modelling. Analytical Hierarchy Process. Object oriented GIS, AM /FM/GIS and Web Based GIS | 3 |
| 16 | GIS approach to Rainfall runoff modeling | 2 |
| 17 | GIS approach to Ground water modeling | 2 |
| 18 | Site selection for artificial recharge. Reservoir sedimentation | 1 |
| | **Total** | **32** |

**List of Practical**

| S.No. | Topic | No. of Practical |
|---|---|---|
| 1 | Familiarization with the remote sensing instruments and satellite imagery | 1 |
| 2 | Methods of establishing ground truth survey and Comparison between ground truth and remotely sensed data | 2 |
| 3 | Aerial Photograph and scale determination with stereoscope | 1 |
| 4 | Interpretation of satellite imagery and aerial photograph | 1 |
| 5 | Determination of Parallaxes in images | 1 |
| 6 | Demonstration on GPS; Provision of Ground Control by GPS in different mode | 1 |
| 7 | Introduction to digital image processing software | 1 |
| 8 | Introduction to GIS software | 1 |
| 9 | Data input; Data editing and Topology creation-Digitization of point, line & polygon features | |
| 10 | SRTM & CARTODEM download from web and Georeferencing of an image | 1 |

| | | |
|---|---|---|
| 11 | Delineation of Watershed, DEM generation: slope, Aspect, flow direction, Flow accumulation, Drainage, network & morphometric analysis | 2 |
| 12 | LULC by supervised classification and LULC by unsupervised classification | 1 |
| 13 | Determination of NDVI and SAVI | 2 |
| 14 | Temporal satellite data analysis for vegetation condition, crop water requirement calculation | 1 |
| 15 | Erosion mapping using aerial and satellite Data | 1 |
| | **Total** | **17** |

**References:**

1. Ian H. S. Cornelius and Steve C. 2002. An Introduction to Geographical Information Systems. Pearson Education, New Delhi
2. James B. C. and Randolph H. W. 2011 Introduction to Remote Sensing The Guilford Press
3. Lilles T. M. and Kiefer R. W. 2008 Remote Sensing and Image Interpretation John Wiley and Sons
4. Rees W, W, 2001 Physical Principles of Remote Sensing. Cambridge University Press
5. Paul Curran P. J. 1985 Principle of Remote sensing ELBS Publication
6. Fundamental of Remote sensing George Joseph and C. Jeganathar
7. Principles of RS and Principles of GIS, ITC, Netherland PUBL.
8. Principle of GIS, ITC Netherland Publication
9. Introduction to GIS by Kangtsang Chary hill pub.

**SWCE 508 Climate Change and Water Resources 3+0**

**Objectives:**
To acquaint students about the concept of climate change and its impact on surface and ground water resources. To understand adaptation and mitigation strategy under climate change scenario.

**Unit-I**
The climate system: Definitions, climate, climate system, climate change. Drivers of climate change, characteristics of climate system components: Greenhouse effect, carbon cycle, wind systems. Trade winds and the Hadley Cell, ozone hole in the stratosphere, El Nino, La Nina–ENSO, teleconnections.

**Unit-II**
Impacts of climate change: Observed and projected**,** global and Indian scenario, observed changes and projected changes of IPCC: Impacts on water resources, NATCOM Report, impacts on sectoral vulnerabilities, SRES, different scenarios, climate change impacts on ET and irrigation demand.

**Unit-III**
Tools for vulnerability assessment: Need for vulnerability assessment, steps for assessment, approaches for assessment. Models: Quantitative models, Economic models, impact matrix approach, Box models, Zero-dimensional models, Radioactive-convective models, Higher-dimension models, EMICs (Earth-system models of intermediate complexity), GCMs (global climate models or general circulation models), Sectoral models.

**Unit-IV**
Adaptation and mitigate on water: Related adaptation to climate change in the fields of ecosystems and biodiversity, agriculture and food security, landuse and forestry, soil and water resources and economy, Adaptation, vulnerability and sustainable development.

**Unit-V**
Sector specific mitigation: Carbon-dioxide capture and storage (CCS), bio-energy crops, land-use change and management, crop land management, afforestation and reforestation. Potential water resource conflicts between adaptation and mitigation. Implications for policy and sustainable development.

**Case studies:** Water resources assessment case studies: Regional River valley project. Adaptation strategies in assessment of water resources. Hydrological design practices and dam safety, operation policies for water resources projects. Flood management strategies, drought management strategies, temporal and spatial assessment of water for irrigation, land use and cropping pattern, coastal zone management strategies.

**Course Outcome:**
The students will be able to understand climate change concept particularly on surface and ground water. Students can have indepth knowledge about adaptation and mitigation strategies in respect of climate change.

**Teaching Schedule**

| S.No. | Topic | No. of Lectures |
|---|---|---|
| 1 | Definitions-climate, climate system, climate change; Drivers of Climate change | 3 |
| 2 | Climate system and its components; wind systems, carbon cycle, Greenhouse effect, Trade winds and the Hadley Cell, ozone hole in the stratosphere, El Nino, La Nina–ENSO, tele connections | 3 |
| 3 | Climate scenarios- SRES, RCP, Scenario based observed and Projected climate changes in Indian and global context | 3 |
| 4 | IPCC projected climate change impacts on water resources, NATCOM Report-impacts on ET and irrigation demand | 3 |
| 5 | Vulnerability assessment: Need, steps for assessment, approaches for assessment | 2 |
| 6 | Models: Quantitative models, Economic models, impact matrix approach, Box models, Zero-dimensional models, Radioactive-convective models, Higher-dimension models, EMICs (Earth-system models of intermediate complexity), GCMs (global climate models or general circulation models), Sectoral models | 4 |
| 7 | Adaptation to climate change in the fields of ecosystems and biodiversity, agriculture and food security, landuse and forestry, And economy. | 4 |
| 8 | Sector specific mitigation: Carbon-dioxide capture and storage (CCS) | 2 |
| 9 | Sector specific mitigation: bio-energy crops, Soil conservation measures. | 2 |
| 10 | Sector specific mitigation: land-use change and management, Crop land management, afforestation and reforestation | 2 |
| 11 | Potential water resource conflicts between adaptation and mitigation | 2 |
| 12 | Implications for policy and sustainable development. | 2 |
| 13 | Case studies-Regional river valley project | 5 |
| 14 | Adaptation strategies in assessment of water resources-Temporal and spatial assessment of water for irrigation, land use and cropping pattern | 2 |
| 15 | Adaptation strategies in assessment of water resources- | 3 |
| | Hydrological design practices and dam safety, operation policies for water resources projects | |
| 16 | Flood management strategies, coastal zone management strategies. | 3 |
| | **Total** | **45** |

**Suggested Readings:**

1. Srinivasa R K and Nagesh K D Impact of climate change on water resources with Modelling Techniques and case studies. Springer publications, New York.
2. Rao Y S, Zhang T C Ojha, Gurjar B R, Tyagi R D, Kao CM (eds) Climate change Modellinng, Mitigation and Adaption. American Society of civil Engineers.
3. Tamim Y and Caitlin A G. Climate Change and Water Resources. Springer Publication.

4. Majumdar P P and Nagesh K D. Floosa in a Changing Climate: Hydrological Modelling. Cambridge University Press, New York.
5. Pathak H, Agarwal, P K and Singh, S. D. Mitigation in Agriculture: Methodology for assessment and Application. Division of Environmental Sciences, IARI New Delhi.
6. Climate smart Agriculture (Concept, Challenges and Opportunity) by Pratap Bhattacharya, Himanshu Pathak, Sharmishta Pal, Springer Pub., Singapore
7. Klein, R.J.T., S. Huq, F. Denton, T.E. Downing, R.G. Richels, J.B. Robinson, F.L. Toth, 2007: Inter-relationships between adaptation and mitigation. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.
8. Sen, D. (2010). Flood Hazards in India and Management Strategies. In: Jha, M.K. (eds) Natural and Anthropogenic Disasters. Springer, Dordrecht. https://doi.org/10.1007/978-90-481-2498-5_7

**SWCE 509 Numerical Methods in Hydrology 2+0**

**Objectives:**
To acquaint students about the concept of linear space, triangular and quadrilateral shape functions, isoparametric elements and transformation of coordinates.

**Unit-I**
Review of finite difference operators. Concept of linear space and basis functions. Approximating from finite dimensional subspaces.

**Unit-II**
Variational and weighted residual methods. Lang range polynomials. Triangular and quadrilateral shape functions.

**Unit-III**
Isoparametric elements and transformation of coordinates. Basis functions in three dimensions.

**Unit-IV**
Galerk infinite element solution of Laplace, diffusion and dispersion- convection equations.

**Unit-V**
Method of collocation, application in surface and sub surface hydrology.

**Course Outcome:**
The students are able to understand numerical methods in hydrology by having in-depth knowledge of linear space and finite element solution in surface and sub-surface hydrology.

**Teaching Schedule**

| S.No. | Topic | No. of Lectures |
|---|---|---|
| 1 | Review of finite difference operators | 2 |
| 2 | Concept of linear space and basis functions | 3 |
| 3 | Approximating from finite dimensional subspaces | 3 |
| 4 | Variational and weighted residual methods | 2 |
| 5 | Langrange polynomials | 2 |
| 6 | Triangular and quadrilateral shape functions | 3 |
| 7 | Isopara metric elements and transformation of coordinates. | 3 |
| 8 | Basis functions in three dimensions | 3 |
| 9 | Galerkin finite element solution of Laplace | 3 |
| 10 | Diffusion and dispersion- convection equations | 3 |
| 11 | Method of collocation | 2 |
| 12 | Application in surface and subsurface hydrology | 3 |
| | **Total** | **32** |

**Suggested Readings**


1. George H and Patricia W2000. Numerical Methods in the Hydrological Sciences. American Geophysical Union, Florida Avenue, N.W
2. Bear J and Verruijt A1987. Modeling Ground water Flow and Pollution. 414pp. Dordrecht, Boston.
3. Carr JR 1995.Numerical Analysis for the Geological Sciences.592pp.Prentice-Hall, Englewood Cliffs NJ.

4. Middleton GV 2000. Data Analysis in the Earth Sciences using MATLAB 260pp., Prentice Hall, Saddle River NJ.
5. Wang HF and Anderson MP1982. Introduction to Ground water Modeling: Finite Difference and Finite Element Methods.237pp.,W.H. Freeman and Co., San Francisco.
6. Gerald CF and Wheatley PO1999. Applied Numerical Analysis. 6$^{th}$ ed., 768pp., Addison-Wesley, Reading, MA.

**SWCE 510 Dryland Water Management Technologies 2+0**

**Objectives:**
To provide detail knowledge about analysis of severity of drought assessment and various dryland water management technologies suitable for conservation, harvesting and enhancing productivity of rainfed areas.

**Unit-I**
Drought severity assessment: Meteorological, hydrological and agricultural methods. Drought indices. GIS based drought information system, drought vulnerability assessment and mapping using GIS. DPAP programme, IWDP, State Water Conservation programmes (PMKY, Jalyukt Shivar etc.), drought monitoring constraints, limiting crop production in dry land areas. Types of drought, characterization of environment for water availability, crop planning for erratic and aberrant weather conditions.

**Unit-II**
Drought management strategies. Preparation of appropriate crop plans for dry land areas. Mid contingent plan for aberrant weather conditions.

**Unit-III**
Land shaping and land development for soil moisture conservation. Improvement of tillage and soil management by implements and engineering practices. Soil and moisture conservation for rainfed lands through improved implements and engineering practices. Gel technology. Ex-situ measures: Water harvesting-micro catchments. Design of small water harvesting structures: Farm Ponds, percolation tanks their types and design, recycling of runoff water for crop productivity.

**Unit-IV**
Crops and cropping practices related to soil and moisture conservation. Fertility management in dryland farming. Planning and development of watersheds from engineering view point. Case studies.

**Unit-V**
Application of RS in surveys and planning of watersheds for rainfed agriculture.
Watershed Evaluation & Monitoring: Use of indices

**Course Outcome:**
The students will be able to under stand drought severity assessment techniques along with new and appropriate methods of rainwater conservation and harvesting technologies for rainfed areas.

**Teaching Schedule**

| S.No. | Topic | No. of Lectures |
|---|---|---|
| 1 | Drought severity assessment: Meteorological, hydrological and Agricultural methods | 2 |
| 2 | Drought indices | 1 |
| 3 | GIS based drought information system, drought vulnerability assessment and mapping using GIS | 2 |
| 4 | DPAP programme, IWDP and State programme drought monitoring constraints,limiting crop production in dry land areas | 3 |
| 5 | Types of drought: characterization of environment for water availability | 1 |
| 6 | Types of drought: crop planning for erratic and aberrant weather | 1 |

| | | |
|---|---|---|
| | conditions | |
| 7 | Drought management strategies | 1 |
| 8 | Preparation of appropriate crop plans for dry land areas | 2 |
| 9 | Mid-contingent plan for aberrant weather conditions | 1 |
| 10 | Land shaping and land development for soil moisture conservation | 1 |
| 11 | Improvementoftillageandsoilmanagementbyimplementsandengine eringpractices | 2 |
| 12 | Soil and moisture conservation for rainfed lands through improved Implements and engineering practices | 2 |
| 13 | Introduction of Gel technology for conservation measures | 1 |
| 14 | Ex-situ measures: Water harvesting-micro catchments | 1 |
| 15 | Design of small water harvesting structures: Farm Ponds | 1 |
| 16 | Design of small water harvesting structures: percolation tanks their types and design | 2 |
| 17 | Recycling of runoff water for crop productivity | 1 |
| 18 | Crops and cropping practices related to soil and moisture conservation | 1 |
| 19 | Fertility management in dryland farming | 1 |
| 20 | Planning and development of watersheds from engineering view point | 2 |
| 21 | Planning and development of watersheds- Case studies | 1 |
| 22 | Application of RS in surveys and planning of watersheds for rainfed agriculture | 1 |
| 23 | Use of Remote Sensing in soil moisture estimation | 1 |
| | **Total** | **32** |

**Suggested Readings**


1. Singh RV 2003. *Watershed Planning and Management*. Second Edition. Yash Publishing House, Bikaner.
2. Das NR 2007. *Tillage and Crop Production*. Scientific Publishers.
3. Dhopte, AM 2002. *Agro Technology for Dryland Farming*. Scientific Publ.
4. Gupta, US 1995. *Production and Improvements of Crops for Drylands* .Oxford & IBH
5. Singh, RP 1988. *Improved Agronomic Practices for Dryland Crops*. CRIDA.
6. Singh, RP2005. *Sustainable Development of Dryland Agriculture in India*. Scientific Publ.
7. Singh, SD1998. *Arid Land Irrigation and Ecological Management*. Scientfic Publisher
8. Hand book of Applied Hydrology-G Mail Book
9. Soil Conservation and Land Management-S.K. Datta
10. Map Projection –A Working Manual, G mail Book
11. Soil and Water Conservation Engineering –Prof. R. Suresh
12. Hydrology -H. M. Raghunath

# Course Syllabus and Contents of Doctoral Degree

## SWCE 601 Advances in Hydrology 2+1

**Objectives:**
To provide comprehensive knowledge to the students about hydrologic models, flood frequency analysis and formulation of statistical models.

**Unit-I**
Hydrologic models, processes and systems. Uncertainty in hydrological events. Statistical homogeneity.

**Unit-II**
Probabilistic concept. Frequency analysis. Probability distribution of hydrological variables. Confidence intervals and hypothesis testing.

**Unit-III**
Simple and multiple linear regressions, correlation, statistical optimization and reliability of linear regression models. Analysis of hydrologic time series and modeling. Auto–correlation, correlogram and cross-correlation analysis.

**Unit-IV**
Markov processes, stochastic hydrologic models including Markov chain models. Generation of random variates. Hydrology of climate extremes. Area-duration-frequency curves. Regional flood frequency analysis.

**Unit-V**
Formulation of various steps involved in formulation of statistical models and their application in hydrology.

**Practical:**
Parametric and non-parametric test of time series data. Development of probabilistic and deterministic models for time series data of rainfall and runoff. Development of hydrologic models and frequency analysis for specified data set using SPSS and other software used in hydrologic modelling.

**Course outcome:** The students will be able to develop the hydrologic modelling and find out their trend as well as periodic component. To develop the stochastic and deterministic models for forecasting precipitation for prediction of floods and droughts.

**Teaching Schedule**

| S.No. | Topic | No. of Lectures |
|---|---|---|
| 1 | Hydrologic models, processes and systems | 1 |
| 2 | Uncertainty in hydrologic events risks, uncertainty | 1 |
| 3 | Statistical homogeneity in hydrologic processes | 1 |
| 4 | Probability, total probability theorem, Bayes theorem | 2 |
| 5 | Moment generating function, statistical parameters | 1 |
| 6 | Probability distribution of hydrologic variables | 2 |
| 7 | Confidence interval one sided, two sided, Hypothesis testing test statistics | 2 |
| 8 | Regression analysis, simple regression, confidence interval on regression coefficient, regression line, inference on regression | 3 |
| 9 | Multiple linear regression | 2 |

| | | |
|---|---|---|
| 10 | Optimization of regression coefficients, Statistical optimization and reliability of linear regression models | 3 |
| 11 | Time series analysis, components, stationarity, Auto correlation, correlograms, Cross correlation analysis | 3 |
| 12 | Generating processes, Mark ovprocess- first order, higher order | 2 |
| 13 | Statistical principles and techniques for time series modeling | 2 |
| 14 | Markov chain models, Examples of Markov chain models in hydrology | 2 |
| 15 | Autoregressive models, Autoregressive modeling of annual time series, Examples of auto regressive modeling | 3 |
| 16 | Hydrology of climate extremes. Area-duration-frequency curves. Regional flood frequency analysis | 2 |
| 17 | Formulation of various steps involved in formulation of statistical models and their application in hydrology | 2 |
| | **Total** | **34** |

**List of Practical**

| S.No. | Topic | No .of Practical |
|---|---|---|
| 1 | Study of parametric and nonparametric test of time series data | 4 |
| 2 | Development of probabilistic models for time series data of rainfall and runoff | 2 |
| 3 | Development of deterministic models for time series data of rainfall and runoff | 2 |
| 4 | Development of hydrologic models for specified data set using SPSS and other software used in hydrologic modeling | 2 |
| 5 | Development of frequency analysis for specified dataset using SPSS and other software used in hydrologic modeling | 2 |
| 6 | Development of the stochastic models for forecasting precipitation for prediction of floods and droughts | 2 |
| 7 | Development of deterministic models for forecasting precipitation for prediction of floods and droughts | 2 |
| | **Total** | **16** |

**Suggested Readings:**


1. Garg SK1987. *Hydrology and Water Resources Engineering*. Khanna Publications.
2. Hann CT. *Advanced Hydrology*. Oxford Publications House.
3. Linseley RK Jr, Kohler MA and Paulhus JLH 1975. *Applied Hydrology*. McGraw Hill.
4. Mutreja KN1986. *Applied Hydrology*. Tata McGraw Hill.
5. Singh VP 2010. *Hydrological Modelling*. Springer, New York.
6. Applied Hydrology, Ven T. Chow, David R Maidman, Mays, L. W, Mac Graw hill, Indian edition
7. Statistical Methods in Hydrology, by C.T. Hann (1978)

**SWCE 602 Soil and Water Systems Simulation and Modeling 2+1**

**Objectives:**
To acquaint students about the rainfall-runoff models, sediment model, over land and channel flow simulation and decision support systems using simulation models.

**Unit-I**
Models and their classification, simulation procedure. Rainfall-runoff models. Infiltration models, evapo-transpiration models, structure of a water balance model.

**Unit-II**
Over land and channel flow simulation. Modelling approaches and parameters. Stream flow statistics. Surface water storage requirements.

**Unit-III**
Flood control storage capacity and total reservoir capacity. Surface water allocations. Palaeo-channels. Ground water models.

**Unit-IV**
Design of nodal network. General systems frame work. Description of the model. Irregular boundaries. Decision support system using simulation models. Monte-Carlo approach to water management.

**Unit-V**
Stanford watershed model and input data requirements of various hydrologic modelling systems. Soil water assessment tool (SWAT). Ground water modelling and solute transport.

**Practical:**
Rainfall-runoff models. Infiltration models. Stanford watershed model (SWM). Channel flow simulation problems. Stream flow statistics. Model parameters and input data requirements of various software's of surface hydrology and groundwater. Hydrologic modelling system. Soil water management model. Soil water assessment tool (SWAT). Catchments simulation hydrology model. Stream flow model and use of dimension less unit hydrograph. Generalized ground water models.

**Course outcome:**
The students will be able to develop the model for overland and channel flow simulation, which can be used for watershed management and planning and also able to simulate the ground water and surface water by developing the ground water model and runoff models.

**Teaching Schedule**

| S.No. | Topic | No. of Lectures |
|---|---|---|
| 1 | Models and their classification, simulation procedure | 2 |
| 2 | Rainfall-runoff models | 3 |
| 3 | Infiltration models, evapo-transpiration models, structure of a water balance model | 2 |
| 4 | Overland and channel flow simulation | 2 |
| 5 | Modeling approaches and parameters. Stream flow statistics | 2 |
| 6 | Surface water storage requirements | 1 |
| 7 | Flood control storage capacity and total reservoir capacity | 2 |
| 8 | Surface water allocations | 1 |
| 9 | Palaeo-channels | 1 |

| | | |
|---|---|---|
| 10 | Ground water models | 2 |
| 11 | Design of nodal network | 1 |
| 12 | General systems framework | 1 |
| 13 | Description of the model | 1 |
| 14 | Irregular boundaries | 1 |
| 15 | Decision support system using simulation models | 2 |
| 16 | Monte-Carlo approach to water management | 2 |
| 17 | Stanford watershed model and input data requirements of various hydrologic modeling systems | 2 |
| 18 | Soil water assessment tool (SWAT) | 2 |
| 19 | Ground water modeling and solute transport | 2 |
| | **Total** | **32** |

**List of Practical**

| S.No. | Topic | No. of Practical |
|---|---|---|
| 1 | Rainfall-runoff models | 2 |
| 2 | Infiltration models | 1 |
| 3 | Stanford watershed model (SWM) | 1 |
| 4 | Channel flow simulation problems | 1 |
| 5 | Stream flow statistics | 2 |
| 6 | Model parameters and input data requirements of various software's of surface hydrology and ground water | 2 |
| 7 | Hydrologic modeling system. Soil water management model | 2 |
| 8 | Soil water assessment tool (SWAT). Catchments simulation Hydrology model | 2 |
| 9 | Stream flow model and use of dimensionless unit hydrograph | 1 |
| 10 | Generalized ground water models | 2 |
| | **Total** | **16** |

**Suggested Readings**


1. Biswas A K 1976, Systems Approach to Water Management McGraw Hill.
2. Cox, D R and Mille, H D 1965. The Theory of Stochastic Processes. John Wiley and Sons.
3. Eagleson, P. S. 1970, Dynamic Hydrology. Mc Graw Hil.
4. Himmel Blau D M and Bischoff K B 1968, Process Analysis and Simulation Deterministic Systems John Willey and Sons.
5. Linsley R K., Kohler M A. and Paulhus J L H 1949, Applied Hydrology Me Graw Hill
6. Schwar R S and Friedl and B 1965, Linear System Me Graw Hill.
7. Ven Te Chow, David R Maidment and Mays L W 1998. Applied Hydrology Me Graw Hill.
8. Vijay P. Singh, Donald K. Frevert (2010) Watershed Models https://doi.org/10.1201/9781420037432 (eBook)
9. Soil water assessment tool (SWAT) user manual 2002 S.L. Neitsch, J.G. Arnold, J.R. Kiniry, R. Srinivasan, J.R. Williams Grassland, Soil And Water Research Laboratory Agricultural Research Service 808 East Blackland Road. Temple, Texas 76502

10. Jeffrey G. Arnold, Daniel N. Moriasi, Philip W. Gassman, Karim C. Abbaspour, Michael J. White, Raghavan Srinivasan, Chinnasamy Santhi, Daren Harmel, Ann van Griensven, Michael W. Van Liew, Narayanan Kannan, and Manoj K. Jha 2012 SWAT: Model use, calibration, and validation
11. Soil water assessment tool (SWAT) 2009 S.L. Neitsch, J.G. Arnold, J.R. Kiniry, J.R. Williams Grassland, Soil And Water Research Laboratory Agricultural Research Service 808 East Blackland Road. Temple, Texas 76502
12. Demetris Koutsoyiannis 2011 A Monte Carlo approach to water management Department of Water Resources and Environmental Engineering Faculty of Civil Engineering National Technical University of Athens, Greece
13. Rainfall-Runoff Modelling 2012 The Primer SECOND EDITION Keith Beven Lancaster University, UK
14. Lu Zhang, Walker, G.R. and Dawes, W.R. 2002. Water balance modelling: concepts and applications. In: McVicar, T.R., Li Rui, Walker, J., Fitzpatrick, R.W. and Liu Changming (eds), Regional Water and Soil Assessment for Managing Sustainable Agriculture in China and Australia, ACIAR Monograph No. 84, 31–47
15. DREAM: a distributed model for runoff, evapotranspiration, and antecedent soil moisture simulation 2005 Advances in Geosciences, 2, 31–39,
16. Developments in physically-based overland flow modelling 1998Modelling Soil Erosion, Sediment Transport and Closely Related Hydrological Processes. IAHS Publ. No. 249,.
17. Palaeochannels Of North West Iindiia:: Review And Assessment 2016 Report Of The Expert Committee To Review Available Information On Palaeochannels
18. C. P. Kumar Introduction To Groundwater Modelling

**SWCE 603 Reservoir Operation and River Basin Modeling 2+1**

**Objectives:**
To provide comprehensive knowledge to the students about water management plans, Demand analysis and water resources planning in river basins including stochastic and deterministic modeling.

**Unit-I**
Water resources system analysis: Techniques, concept, objectives and applications.

**Unit-II**
Identification and evaluation of water management plans. Demand analysis, policy formulation. Water resources planning objectives. Water resources planning underun certainty.

**Unit-III**
Definition of terminologies and basic concepts. Theories and principles of IRBM processes/ phases in integrated river basin management. River basins, river functions. Human interventions and impacts. River basins in India, related case studies. Water resources planning in river basins. Operational management, tools and methods. Monitoring, acquisition and processing of water resource data.

**Unit-IV**
Statistical methods. Decision support systems. Deterministic river basin modeling. Stream flow estimation, estimating reservoir storage, mass diagram analysis, sequent peak analysis, single and multi-reservoir operation models. Economics and finance.

**Unit-V**
Stochastic river basin modeling: Single reservoir design and operation, multisite river basin models, stochastic linear programming operation models.

**Practical:**
Development of regression models, stochastic models and deterministic models for river basin based on stream flow data. Estimation of reservoir storage and preparation of operation models.

**Course outcome:**
The students will be able to develop the model for effective water resources planning for river basins, identification and evaluation of water management plans as well as in-depth knowledge of stochastic and deterministic modeling.

**Teaching Schedule**

| S.No. | Topic | No. of lectures |
|---|---|---|
| 1 | Introduction–Concepts of Systems and Systems Analysis; Techniques, objectives and applications | 2 |
| | Applications of Water resources system analysis | 1 |
| 2 | Identification and evaluation of water management plans–water demand analysis, Water resources planning objectives | 2 |
| 3 | Water resource planning and management approaches-Top-Down Planning and Management; Bottom-Up Planning and Management Integrated Water Resources Management | 1 |
| 4 | Water resource management policy formulation, Water resources planning under uncertainty | 1 |
| 5 | River basins, river functions, Theories and principles of IRBM processes/ phases in integrate driver basin management | 1 |

| | | |
|---|---|---|
| 6 | Human interventions and impacts in integrate driver basin management | 1 |
| 7 | River basins in India-related case studies | 1 |
| 8 | Water resources planning in river basins- Operational management, tools and methods | 2 |
| 9 | Water resources planning in river basins-Monitoring, acquisition and processing of water resource data | 2 |
| 10 | Economic Considerations in Water Resources Planning | 1 |
| 10 | Deterministic river basin modeling-Stream flow estimation, estimating reservoir storage, mass diagram analysis, sequent peak analysis | 2 |
| 11 | Deterministic river basin modeling- Reservoir Sizing; Reservoir Operation – standard operating policy, optimal operating policy; multi-reservoir systems, | 6 |
| 12 | Concept of Reliability | 1 |
| 13 | Stochastic river basin modeling: Basic probability theory, | 2 |
| 14 | Single reservoir design and operation-Chances on strained Linear Programming for reservoir operation and design | 3 |
| 15 | Stochastic river basin modeling: multisite river basin models, | 1 |
| | Model Formulations and Case Studies-Conjunctive use of ground and surface water; Crop yield optimization, Multi-basin and multi-reservoir systems | 3 |
| | **Total** | **33** |

**List of Practical**

| S.No. | Topic | No. of Practical |
|---|---|---|
| 1 | Development of regression models | 1 |
| 2 | Regression analysis | 1 |
| 3 | Correlation analysis | 1 |
| 4 | Simple Linear Regression and coefficient of determination | 1 |
| 5 | Discrete and Continuous probability- Random Variable and Variate | 1 |
| 6 | Deterministic models for river basin based on stream flow data | 1 |
| 7 | Stochastic models for river basin based on stream flow data | 1 |
| 8 | Stochastic river basin modeling | 1 |
| 9 | Stochastic linear programming operation models | 1 |
| 10 | Single and multi- reservoir operation models | 1 |
| 11 | Evaluation of water management plans | 1 |
| 12 | Evaluation of demand analysis | 1 |
| 13 | Stream flow estimation | 1 |
| 14 | Estimation of reservoir storage | 1 |
| 15 | Preparation of operation models | 1 |
| 16 | Deterministic river basin planning model | 1 |
| | **Total** | **16** |

**Suggested Readings**:

1. Loucks D P *et al.* 1980. Water Resources System Planning and Analysis, Prentice Hall, NJ.
2. Chaturvedi M C 1984. System Approach to Water Resources Planning and Management.
3. Major D. C. and Lenton R L 1979. Applied Water Resources System Planning. Prentice Hall Inc. New Jersey.
4. Larry W. Mays, 1996. Water Resources Handbook M C Grow Hill
5. Singh, V P 1994. Elementary Hydrology, Prentice Hall of India
6. Sharma R K, and T. K. Sharma, 2000. A Text book of Hydrology and Water Resource Engineering.

**SWCE 604 Modeling Soil Erosion Processes and Sedimentation 2+1**

**Objectives:**
To acquaint students about the concept of modelling upland erosion, reservoir sedimentation and sediment yield models for estimation of soil erosion.

**Unit-I**
Mechanics of soil erosion. Erosion- sedimentation systems of small watersheds. Overland flow theory and simulation. Basic theory of particle and sediment transport. Sediment deposition processes.

**Unit-II**
Modeling upland erosion and component processes. Modes of transport and transport capacity concept and computation. Channel erosion. Erosion and sediment yield measurement and estimates.

**Unit-III**
Reservoir sedimentation surveys and computation. Classification of models, structure and mathematical bases of sediment yield models. Nature and properties of sediment: Individual and group of particles. Critical tractive force, lift and drag forces. Shield's analysis.

**Unit-IV**
Calibration and testing of models. Universal soil loss equation, its modification and revisions. Stochastic and dynamic sediment yield models.

**Unit-V**
Evaluation of erosion control measures. Computer models used for hydrologic and/ or watershed modelling.

**Practical**:
Computation of soil erosion index. Estimation of soil erodibility factor. Design of erosion control structures. Computation of suspended load and sediment load using empirical formulae. Application of sediment yield models. Prediction of sediment loss. Computation of reservoir sedimentation, sounding method.

**Course outcome:**
The students will be able to estimate the sediment from the particular watershed by using various instruments. Development of the common understanding of mechanics of sediment transportation process and remedies to reduce sedimentation of watersheds.

**Teaching Schedule**

| S.No. | Topic | No. of Lectures |
|---|---|---|
| 1 | Mechanics of soil erosion | 1 |
| 2 | Erosion-sedimentation systems of small watersheds | 1 |
| 3 | Over land flow theory and simulation | 2 |
| 4 | Basic theory of particle and sediment transport. Sediment deposition processes | 2 |
| 5 | Modeling upland erosion and component processes | 2 |
| 6 | Modes of transport and transport capacity concept and computation | 2 |
| 7 | Channel erosion | 1 |
| 8 | Erosion and sediment yield measurement and estimates | 1 |
| 9 | Reservoir sedimentation surveys and computation | 2 |

| | | |
|---|---|---|
| 10 | Classification of models, structure and mathematical bases of sediment yield models | 2 |
| 11 | Nature and properties of sediment: Individual and group of particles | 2 |
| 12 | Critical tractive force, lift and drag forces | 2 |
| 13 | Shield's analysis | 2 |
| 14 | Calibration and testing of models | 2 |
| 15 | Universal soil loss equation, its modification and revisions | 2 |
| 16 | Stochastic and dynamic sediment yield models | 2 |
| 17 | Evaluation of erosion control measures | 2 |
| 18 | Computer models used for hydrologic and/or watershed modeling | 2 |
| | **Total** | **32** |

**List of Practical**

| S.No. | Topic | No of Practical |
|---|---|---|
| 1 | Computation of soil erosion index | 2 |
| 2 | Estimation of soil erodibility factor | 2 |
| 3 | Design of erosion control structures | 4 |
| 4 | Computation of suspended load and sediment load using empirical formulae | 2 |
| 5 | Application of sediment yield models | 2 |
| 6 | Prediction of sediment loss | 2 |
| 7 | Computation of reservoir sedimentation, sounding method | 2 |
| | **Total** | **16** |

**Suggested Readings:**


1. Garde RJ And Ranga Raju KG1977. *Mechanics of Sediment Transport and Alluvial Stream Problems*. Wiley Eastern Ltd.
2. Morgan RPC (Ed. DA Davison)1986. *Soil Erosion and Conservation*. ELBS.
3. Longman USDA1969. *A Manual on Conservation of Soil and Water*. Oxford & IBH.
4. Tripathi RP and Singh HP1993. *Soil Erosion and Conservation*. Publisher- New Age International New Delhi.
5. Predicting Rainfall erosion losses (Guide to Conservation Planning) USDA Agriculture Handbook, No.537
6. Soil & water conservation Engineering by R. Suresh, Std. Pub. Distributors, Delhi
7. Applied Hydrology by K. N. Mutreja, Tata Mc graw Hill Pub. Co., New Delhi

**SWCE 605 Waste Water Treatment and Utilization 3+0**

**Objectives:**

To acquaint students about types of waste water and the various treatment measures along with the utilization of waste water in agriculture and other sectors.

**Unit-I**

Types of waste water, causes of pollution, analysis of pollutants in the waste effluents, Biological waste water treatment, biological sludge treatment. Biological systems: Fundamentals of microbiology and biochemistry, bioenergetics and metabolism, kinetics of biological growth. Process analysis: Reaction rates, effect of temperature on reaction rate, enzyme reaction and kinetics, effect of temperature on reaction rate. Reactor analysis, residence time distribution.

**Unit-II**

Sewerage system: Domestic waste water characteristics, flow equalization, population equivalent, treatment flow chart. Primary, secondary and tertiary treatment of domestic wastewater. Downstream waste water treatment for reuse and recycle. Need for downstream processing. Guidelines for wastewater recycling. Small and package plants for waste water treatment.

**Unit-III**

Activated sludge process: Substrate utilization and biomass growth, Monod's kinetics, estimation of kinetic parameters. Process Description and its Modification, Process design, process performance evaluation, trouble shooting. Nitrogen removal-Biological nitrification and denitrification.

**Unit-IV**

Activated sludge process design for nutrient removal. Process operation: (F/M), mean cell residence time, oxygen requirement. Biological and chemical phosphorus removal, Sedimentation of activated sludge. Advanced activated sludge process-Sequencing Batch reactor, Oxidation ditch and membrane bioreactors.

**Unit-V**

Bio film process: Trickling filter, bio tower, rotational biological contactor, integrated activated sludge and biofilm processes. Stabilization ponds and aerated lagoons: Types and their description, design, operation and maintenance. Anaerobic processes: Process description, process design, operation and maintenance, sludge digestion. Sludge treatment-thickening, dewatering-mechanical and sludge drying beds. Utilization of waste water in agriculture and other sectors.

**Course outcome:**

Students will be able to have in-depth knowledge about waste water treatment methods, sewerage system, activated sludge process, biofilm process. The student will also expose to use of wastewater in agriculture and other sectors.

**Teaching Schedule**

| S.No. | Topic | No. of Lectures |
|---|---|---|
| 1 | Status of wastewater in India, Sources of contamination and characterization of urban and rural wastewater for irrigation | 2 |
| 2 | Water quality: Physical, chemical and biological parameters of wastewater | 2 |

| | | |
|---|---|---|
| 3 | Wastewater quality requirement: Potable water standards, waste water effluent standards, water quality indices. Irrigation water quality standards both national and global and guidelines for their restricted and unrestricted uses. | 2 |
| 4 | Different types of waste water, pollutants and contaminants. | 1 |
| 5 | Impact of waste water on ecosystem, eutrophication, biomagnification, water borne diseases. | 2 |
| 6 | Key drivers of wastewater use in agriculture and existing approaches for regulating waste water reuse in agriculture | 2 |
| 7 | Selection of appropriate forestry trees, fruits, vegetables, oilseeds and food grain crop for wastewater utilization and practices used for Irrigation | 3 |
| 8 | Health Risks Associated with the Use of Wastewater for Irrigation | 1 |
| 9 | Waste water treatment methods: Physical, chemical and biological. | 3 |
| 10 | Choice of (Cost-Effective) Wastewater Treatment Systems for Irrigation | 2 |
| 11 | General water treatments: Wastewater recycling, constructed wetlands, reed bed system. | 2 |
| 12 | Carbon foot prints of wastewater reuse. Environmental standards. | 2 |
| 13 | Management of health and environmental risks of wastewater irrigation | 1 |
| 14 | Regulation and environmental impact assessment (EIA): Environmental standards-CPCB Norms for discharging industrial effluents to public sewers. Valuation of environmental impacts. | 3 |
| 15 | Impact on ground water resources and soil health, EIA process, Stages of IA-monitoring and auditing. Environmental clearance procedure in India | 3 |
| 16 | Economics of wastewater irrigation | 1 |
| | **Total** | **32** |

**List of Practical**

| S.No. | Topic | No. of Practical |
|---|---|---|
| 1. | Study on physical, chemical and biological parameters of wastewater | 1 |
| 2. | Determination of EC and pH of wastewater | 1 |
| 3. | Determination of BOD of wastewater | 1 |
| 4. | Determination of COD of wastewater | 1 |
| 5. | Determination of TSS and TDS of wastewater | 1 |
| 6. | Determination RSC of wastewater | 1 |
| 7. | Determination of e-coli in the wastewater | 1 |
| 8. | On field demonstration of wastewater use for the irrigation | 1 |
| 9. | Determination of nutrient (N, P and K) concentration in wastewater | 2 |
| 10. | Field demonstration of impact of wastewater on eco-system and human health. | 1 |
| 11. | Study on various wastewater treatment methods | 2 |

| | | |
|---|---|---|
| 12. | Study on effect of wastewater on contamination of ground water | 1 |
| 13. | Visit of village pond treatment nearby area | 1 |
| 14. | Visit of sewerage treatment plant nearby area | 1 |
| | **Total** | **16** |

**Suggested Readings:**


1. Metcalf and Eddy2003. *Wastewater Engineering*, 4thEd.,McGraw Hill.
2. Droste RL1997. *Theory and Practice of Water and Wastewater Treatment*. John Wiley.
3. Qasim SR1999. *Wastewater Treatment Plants–Planning, Design and Operation*. CRC Press, Florida.
4. Ramalho RS. *Wastewater Treatment*. Wiley.
5. Duncan Mara, 1978, Sewage Treatment in Hot Climates, ELBS & John Wiley & Sons, Chichester.
6. S P Gautam , Guide Manual: Water and Waste Water Analysis, , Central Pollution Control Board,
7. Soli J Arceivala and Shyam R Asolekar 2005, Wastewater Treatment for Pollution Control and Reuse, Tata McGraw-Hill Publishing Company Limited NEW DELHI
8. Rai S N, 2003, Ground Water Pollution in India: An Overview, Proceedings of International Conference on Water and Environment, Bhopal, Allied Publisher Pvt Limited, New Delhi.
9. James Waterhouse, 1982, Water Engineering for Agriculture, Batsford Academic & Educational Limited, London.

**SWCE 606 Hydro-Chemical Modeling 2+0**

**Objectives:**
To provide comprehensive knowledge to the students about hydro dynamics of flow through porous media and development of analytical, statistical and numerical models.

**Unit-I**
Review of hydro dynamics in flow through porous media. Miscible displacement, physical processes.

**Unit-II**
Break through curves and mathematical models for miscible displacement. Hydro dynamic dispersion convection equations and its solutions.

**Unit-III**
Statistical models for dispersion .Gaseous ($CO_2$ and $O_2$) diffusion equation.

**Unit-IV**
Heat flow through soil by conduction. Concept of adsorption in solute transport.

**Unit-V**
Analytical and numerical models of contaminant transport in unsaturated soil profile and ground water aquifers.

**Course outcome:**
Students will be able to demonstrate understanding of hydrodynamics of fluid transport through modeling and will be able to do water quality analysis of lakes and reservoir based physical and chemical characteristics. Develop water reclamation and water reuse plans for irrigation and industries.

**Teaching Schedule**

| S.No. | Topic | No. of Lectures |
|---|---|---|
| 1 | Review of hydrodynamics in flow through porous media | 7 |
| 2 | Miscible displacement, physical processes, break through curves | 2 |
| 3 | Mathematical models for miscible displacement | 5 |
| 4 | Hydrodynamic dispersion convection equation and its solutions | 4 |
| 5 | Heat flow through soil by conduction | 2 |
| 6 | Concept of adsorption in solute transport | 2 |
| 7 | Analytical and numerical models of contaminant transport in unsaturated soil profile and ground water aquifers. | 6 |
| 8 | Statistical models for dispersion | 3 |
| 9 | Gaseous ($CO_2$ and $O_2$) diffusion equation. | 3 |
| | **Total** | **34** |

**Suggested Readings:**

1. Larry,W Mays1996. Water Resources Handbook. McGraw Hill.
2. Metcalf and Eddey 4th Ed., 2003 Wastewater Engineering: Treatment and Reuse, Metcalf and Eddy Inc.
3.Droste, RL 1997. Theory and Practice of Water and Wastewater Treatment. John Wiley.
4. Qasim, SR 1999. Wastewater Treatment Plants– Planning, Design and Operation. CRC Press, Florida.
5. Ramalho, RS. Wastewater Treatment. Wiley.

6. Bear Jacob, 1972, Dynamics of fluids in porous media, Am Elsevier Publishing Co., New York.
7. Iavandel, I, Doughty C, Tsang, C F, 1984, Groundwater Transport: Handbook of Mathematical Models, American Geophysical Union Water Resources Monogram10.
8. Konikow, L. F and Grove, D B, 1977, Derivation of equations describing solute transport in groundwater, US Geological Survey Water Resources Investigations, 77-19.
9. Jacob Bear and Alexander Cheng, 2019, Modeling Groundwater Flow and Contaminant Transport, Springer
10. Daniel Hillel, Environmental Soil Physics, Academic Press, San Diego / London.

**SWCE 607 Drone and Google Earth Engine for NRM 2+1**

| Lecture No. | Topics | Book No | Page No. |
|---|---|---|---|
| 1-2 | Drones and UAVs, Basics, definitions, concepts, Classification of drones, Component of drones | 1,<br>2,<br><br>3 | 1-50<br>5-40, 83-90, 577-610<br>3-30 |
| 3-4 | Basic Principles of Flight, Regulations of DGCA | 2,3,4 | |
| 5 | Google Earth Engine Applications, theory | 5 | 1-4 |
| 6-7 | Google Earth Engine Applications Since Inception: Usage, Trends, and Potential | 5 | 5-19 |
| 8-9 | Global Estimation of Biophysical Variables from Google Earth Engine Platform | 5 | 20-36 |
| 10-11 | An Operational Before-After-Control-Impact (BACI) Designed Platform for Vegetation Monitoring at Planetary Scale | 5 | 37-49 |
| 12-13 | Mapping Vegetation and Land Use Types Using Google Earth Engine | 5 | 50-63 |
| 14-15 | A Dynamic Landsat Derived Normalized Difference Vegetation Index (NDVI) Product | 5 | 64-77 |
| 16-17 | High Spatial Resolution Visual Band Imagery Outperforms Medium Resolution Spectral Imagery for Ecosystem Assessment in the Semi-Arid Zone | 5 | 78-103 |
| 18-19 | Sharpening Resolution and Improving Accuracy of Land-Use/Land-Cover Classifications in Google Earth Engine | 5 | 132-152 |
| 20-21 | Regional Crop Gross Primary Productivity and Yield Estimation Using Fused Landsat-MODIS Data | 5 | 174-194 |
| 22-23 | A Cloud-Based Multi-Temporal Ensemble Classifier to Map Smallholder Farming Systems | 5 | 222-239 |
| 24-25 | Flood Prevention and Emergency Response System Powered by Google Earth Engine | 5 | 282-301 |
| 26-27 | Leveraging the Google Earth Engine for Drought Assessment Using Global Soil Moisture Data | 5 | 302-324 |
| 28-30 | Multitemporal Cloud Masking in the Google Earth Engine, satellite data uses | 5 | 325-342 |
| 31-32 | Estimating Satellite-Derived Bathymetry (SDB) with the Google Earth Engine and Sentinel-2 | 5 | 376-393 |

**Practical**

| Sr. No. | Topic Name |
|---|---|
| 1. | Introduction to the Earth Engine JavaScript API |
| 2. | Visualizing Images and Image Bands |
| 3. | Computations using Images |
| 4. | Image Collections |
| 5. | Compositing, Masking and Mosaicking |
| 6. | NDVI, Mapping a Function over a Collection, Quality Mosaicking |
| 7. | Exporting Charts and Images |
| 8. | Study About UAV Flight Planning |
| 9. | Establish Ground Control Points. |
| 10. | Boundary setting and Data Collection by using Flight Mapping. |
| 11. | Measure UAV Data Processing Orthomosaic Maps using 3D Point Cloud |
| 12. | Calculate Aerial Mapping using Drones |
| 13. | Calculate Topography Mapping Using Drones |

**Suggested Readings:**

1. Agricultural Drones A Peaceful Pursuit: K. R. Krishna. CRS Press Taylors and Francis Group (1-50)
2. Handbook of Unmanned Aerial Vehicles. Editors Kimon P. Valavanis, George J. Vachtsevanos. Springer Publication.
3. Drone 101: A Must-Have Guide for Any Drone. Myin Uddin. Enthusiast Book · August 2020.
4. Drones The Complete Manual. The essential handbook for drone enthusiasts. Imagine Publishing Ltd, Richmond House 33 Richmond Hill Bournemouth. IP imagine Publishing. First Edition 2016.
5. Google Earth Engine Applications. Special Issue Editors Lalit Kumar and Onisimo Mutanga. Printed Edition of the Special Issue Published in *Remote Sensing*. www.mdpi.com/journal/remotesensing.
6. UAV Based Remote Sensing Volume 2. Special Issue Editors Felipe Gonzalez Toro Antonios Tsourdos. (http://www.mdpi.com/journal/sensors ).
7. Quad copters and Drones A Beginner's Guide to Successfully Flying and Choosing the Right Drone By Mark Smith.
8. https://developers.google.com/earth-engine/tutorials/edu

## Course Syllabus and Content of Supporting and Minor Courses

**CE 501 Dimensional Analysis and Similitude 2+0**

**Objectives:**

To acquaint the students with importance of analysis of dimensions and similitude principles in structuring mathematical/simulation models of various processes under different constraint variables.

**Unit-I**

Introduction, Dimensions, Dimensional homogeneity, Non-dimensional parameter, Methods of dimensional analysis: Rayleigh's method, Buckingham-Pi theorem, Choice of variables, Model analysis, Examples on various applications, Dimensional analysis and Intermediate Asymptotic.

**Unit-II**

Model studies, Model classification, Dimensionless numbers: Reynolds model, Froude's model, Euler's Model, Webber's model, Mach model, Scale effects, Distorted models, Model laws.

**Unit-III**

Similitude: Types of similarities (geometric-kinematic and dynamic similarity), force ratios, similarity laws. Model analysis: Physical models. Similarity methods for nonlinear problem types of models, Scale effect. Numerical problems on Reynolds's and Froude's Model.

**Unit-IV**

Use and scope of mathematical modeling, Principles of model formulation, Role and importance of steady-state and dynamic simulation, Classification of models, Model building, Modeling difficulties, Degree-of-freedom analysis, Selection of design variables.

**Course Outcome**:

The students will be able to analyze complex problems using dimensional analysis and to develop rules for experiments with scale models and provide basis for analyses and calculations, including simplifications and assumptions made, when formulating mathematical models.

**Teaching Schedule**

| S. No. | Topic | No. of Lectures |
|---|---|---|
| 1 | Introduction, Dimensions, Dimensional homogeneity, Non-dimensional Parameter | 2 |
| 2 | Methods of dimensional analysis: Rayleigh's method, Buckingham-Pitheorem, Choice of variables | 3 |
| 3 | Model analysis, Examples on various applications, | 2 |

| | | |
|---|---|---|
| | Dimensional analysis and Intermediate Asymptotic | |
| 4 | Model studies, Model classification, Dimensionless numbers: Reynolds Model | 3 |
| 5 | Froude's model, Euler's Model, Webber's model, Mach model, Scaleeffects | 3 |
| 6 | Distorted models, Model laws. | 2 |
| 7 | Similitude: Types of similarities (geometric-kinematic and dynamicsimilarity), force ratios, similarity laws | 3 |
| 8 | Model analysis: Physical models. Similarity methods for nonlinear problem types of models, Scale effect | 3 |
| 9 | Numerical problems on Reynolds's and Froude's Model | 3 |
| 10 | Use and scope of mathematical modeling, Principles of model formulation | 2 |
| 11 | Role and importance of steady-state and dynamic simulation | 2 |
| 12 | Classification of models, Model building, Modeling difficulties | 2 |
| 13 | Degree-of-freedom analysis, Selection of design variables | 2 |
| | **Total** | **32** |

**Suggested Reading:**


1. Barenblatt G I 1987. *Dimensional Analysis*. Gordon and Breach Science, New York
2. Langhar HL 1951. *Dimensional Analysis and the Theory of Models*. Wiley, New York.
3. Murphy G 1950.*Similitude in Engineering*. The Ronald Press Company, New York.
4. Zohuri Bahman. *Dimensional Analysis and Self-Similarity Methods for Engineers andScientists*. Springer Publications, New York.

**CE 502 Water Quality and Pollution Control 2+1**

**Objective**

To acquire in-depth knowledge of water quality parameters, water quality standards, source of water pollution and multiple use of water.

**Unit I**

Physical and chemical properties of water, suspended and dissolved solids, EC and pH, major ions. Water quality (Physical, Chemical and Bacteriological) investigation, Sampling design, Samplers and automatic samplers. Data collection platforms, Field kits, Water quality data storage, analysis and inference, Software packages. Water quality indices. Water quality for irrigation. Salinity and permeability problem, saline water irrigation root zone salinity, interaction of irrigation and drainage.

**Unit II**

Sources and types of pollution, organic and inorganic pollutants. BOD–DO relationships, impacts on water resources. NPS pollution and its control, Eutrophication control. Water treatment technologies, Constructed wetlands.

**Unit III**

Multiple uses of water. Reuse of water in agriculture. Low cost waste water treatment technologies Economic and social dimensions. Packaged treatment units, soil-based water treatment methods, reverse osmosis and desalination in water reclamation.

**Unit IV**

Principles of water quality, water quality classification, water quality standards, water quality indices, TMDL Concepts. Water quality models. Soil crop and other practices for use of poor quality water.

**Practical**

Determination of pH, total solids, dissolved and suspended solids, chlorides, sulphates, turbidity, dissolved oxygen, hardness. Preparation of water quality map of watershed in GIS environment. Visit of water polluted site of nearby area.

**Course outcome**

The students will be able to understand water quality standards which are quite important for drinking and irrigation purposes. They will also be exposed to source and type of pollution along with multiple uses of water.

**Teaching Schedule**

| S.No. | Topic | No. of Lectures |
|---|---|---|
| 1. | Physical and chemical properties of water, suspended and dissolved solids, EC and pH, major ions. Water quality \ (Physical, Chemical and Bacteriological) investigation | 3 |
| 2. | Sampling design, Samplers and automatic samplers. Data collection platforms, Field kits, Water quality data storage, analysis and inference | 3 |
| 3. | Software packages. Water quality indices. Water quality for irrigation | 2 |
| 4. | Salinity and permeability problem, saline water irrigation root Zone salinity, interaction of irrigation and drainage | 3 |
| 5. | Sources and types of pollution, organic and inorganic pollutants. BOD–DO relationships, impacts on water resources | 3 |

| | | |
|---|---|---|
| 5. | NPS pollution and its control, Eutrophication control. Water treatment technologies, Constructed wetlands | 3 |
| 6. | Multiple uses of water. Reuse of water in agriculture. Low cost wastewater treatment technologies | 3 |
| 7. | Economic and social dimensions. Packaged treatment units, soil-based water treatment methods, reverse osmosis and desalination in water reclamation | 3 |
| 8. | Principles of water quality, water quality classification | 3 |
| 9. | Water quality standards, water quality indices | 2 |
| 10. | TMDL Concepts. Water quality models | 2 |
| 11. | Soil crop and other practices for use of poor quality water | 2 |
| | **Total** | **32** |

**List of Practicals**

| S.No. | Topic | No. of Practicals |
|---|---|---|
| 1. | Determination of pH, total solids, dissolved and suspended solids | 4 |
| 2. | Determination of chlorides, sulphates, turbidity | 3 |
| 3. | Determination of dissolved oxygen, hardness | 4 |
| 4. | Preparation of water quality map of watershed in GIS environment | 4 |
| 5. | Visit of water polluted site of nearby area | 1 |
| | **Total** | **16** |

**Suggested Reading**


1. Abbasi T and Abbasi SA. Water Quality Indices. Elsevier Publications, New York.
2. Chin and David A. 2006. Water Quality Engineering in Natural Systems. Wiley – Interscience.
3. Claude E. Boyd. Water Quality an Introduction. Springer Publications.
4. Eaton AD, Clesceri LS, Rice EW and Greenburg AE (eds). 2005. Standard Methods for the Examination of Water and Wastewater. 21st edn. American Public Health Association, Washington, DC.
5. Thomann RV and Mueller JA. 1987. Principles of Surface Water Quality Modelling and Control. Harper and Row Publishers.
6. Wesley W, Wallender PE and Kenneth K. Tanji, Sc.D. Agricultural Salinity Assessment and Management. ASCE Press.

**STAT 501 Statistical Methods for Research Works 2+1**

**Objective**

To expose students to various statistical techniques for analysis of data and interpretation of results.

**Unit I**

Probability and probability distributions. Principle of least squares. Linear and non-linear regression. Multiple regression. Correlation analysis. Selection of variables. Validation of models. Sampling techniques. Determination of sample size. Sampling distribution of mean and proportion.

**Unit II**

Hypothesis testing. Concept of p-value. Student's t-test. Large sample tests. Confidence intervals. ANOVA and testing of hypothesis in regression analysis. Analysis of variance for one way and two way classification (with equal cell frequency). Transformation of data.

**Unit III**

Advantages and disadvantages of nonparametric statistical tests. Scales of measurements. Run-test. Sign test. Median test. Wilcoxon-Mann Whitney test. Chi-square test. Kruskal-Walli's one way and Friedman's two way ANOVA by ranks. Kendall's Coefficient of concordance.

**Practical**

Fitting of distributions. Sample and sampling distributions. Correlation analysis. Regression analysis (Multivariate, quadratic, exponential, power function, selection of variables, validation of models, ANOVA and testing of hypothesis). Tests of significance (Z-test, t-test, F-test and Chi-square test). Analysis of variance. Non- parametric tests.

**Course outcome**

The students will be able to understand different techniques for analyzing the data of their research work.

**Teaching Schedule**

| S.No. | Topics | No. of Lectures |
|---|---|---|
| 1. | Elementary statistics | |
| 2. | Probability theory | 2 |
| 3. | Probability distributions (Binomial, Poisson and Normal) | 3 |
| 4. | Sampling techniques, Determination of sample size | 2 |
| 5. | Sampling distribution of mean and Proportion | 1 |
| 6. | Hypothesis testing concept of p-value | 1 |
| 7. | Large sample (mean, proportion) | 1 |
| 8. | Student's t-test (Single mean, Difference of mean for independent samples and paired observations) and F-test | 3 |
| 9. | Analysis of variance (one way and two way), Transformation of data | 2 |
| 10. | Correlation analysis and testing (Bivariate, Rank, Intra-class, Partial, Fisher's Z-transformation) | 2 |
| 11. | Multiple linear regression and model validation | 2 |

| | | |
|---|---|---|
| 12. | Testing of coefficient of determination and regression coefficient | 2 |
| 13. | Selection of variables in regression (forward substitution method and step-wise regression) | 1 |
| 14. | Non-Linear regression (Quadratic, exponential and Power) | 2 |
| 15. | Introduction to Non-parametric and scales of measurements | 1 |
| 16. | Chi-square test (Goodness of fit, Independence of attributes, homogeneity of variances) | 2 |
| 17. | One Sample test (Sign test, Median test, Run rest,) | 2 |
| 18. | Two sample test (Wilcoxon Sign test, Mann Whitney test, Chi square test for two independent samples) | 1 |
| 19. | K-Sample (Kruskal-Walli's test and Friedman's two way ANOVA) | 2 |
| 20. | Kendall's coefficient of concordance | 1 |
| | **Total** | **33** |

**List of Practicals**

| S.No. | Topics | No. of Practicals |
|---|---|---|
| 1. | Elementary statistics | 1 |
| 2. | Probability distributions (Binomial, Poisson and Normal) | 1 |
| 3. | Sampling techniques, Determination of sample size, Sampling distribution of mean and Proportion | 1 |
| 4. | Large sample (mean, proportion) | 1 |
| 5. | Student's t-test (Single mean, Difference of mean for independent samples and paired observations) and F-test | 1 |
| 6. | Analysis of variance (one way and two way), Transformation of data | 2 |
| 7. | Correlation analysis and testing (Bivariate, Rank, Intra-class, Partial, Fisher's Z-transformation) | 1 |
| 8. | Multiple linear regression and model validation | 1 |
| 9. | Testing of coefficient of determination and regression coefficient | |
| 10. | Selection of variables in regression (Forward substitution method and step-wise regression) | 1 |
| 11. | Non-Linear regression (Quadratic, exponential and Power) | 2 |
| 12. | Introduction to Non-parametric and scales of measurements | |
| 13. | Chi-square test (Goodness of fit, Independence of attributes, homogeneity of variances) | 2 |
| 14. | One Sample test:Sign test, Median test, Run rest, Two sample test: Wilcoxon Sign test, Mann Whitney test, $X^2$ test for two independent samples | 1 |
| 15. | K-Sample: Kruskal-Walli's test and Friedman's two way ANOVA, Kendall's coefficient of concordance | 1 |
| | **Total** | **16** |

**Suggested Reading**


- Anderson T W 1958. *An Introduction to Multivariate Statistical Analysis*. John Wiley.

- Dillon W R and Goldstein M. 1984. *Multivariate Analysis - Methods and Applications*. John Wiley.
- Electronic Statistics Text Book: http://www.statsoft.com/textbook/stathome.html
- Goon A M, Gupta M K and Dasgupta B. 1977. *An Outline of Statistical Theory*. Vol. I. The World Press.
- Goon A M, Gupta M K and Dasgupta B. 1983. *Fundamentals of Statistics*. Vol. I. The World Press.
- Hoel P G. 1971. *Introduction to Mathematical Statistics*. John Wiley.
- Hogg R V and Craig T T. 1978. *Introduction to Mathematical Statistics*. Macmillan.
- Montgomery and Runger 2014. *Applied Statistics and Probability for Engineers.* John Wiley
- Morrison D F. 1976. *Multivariate Statistical Methods*. McGraw Hill.
- Siegel S, Johan N and Casellan Jr. 1956. *Non-parametric Tests for Behavior Sciences*. John Wiley.

**RPE 601 Research and Publication Ethics 1+1**

**Aim of the Course:**
This course is mainly focusing on basics of philosophy of science and ethics, research integrity, publication ethics. Hands on sessions are designed to identify research misconduct and predatory publications. Indexing and citation databases, open access publications, research and p metrics and plagiarism tools introduced in the course.

**THEORY**
**Unit 1: Philosophy and Ethics**
1. Introduction to philosophy: definition, nature and scoope, concept, branches
2. Ethics: definition, moral philosophy, nature of moral judgments and reactions.

**Unit 2: Scientific Conduct**
1. Ethics with respect to science and research
2. Intellectual honest and research integrity
3. Scientific misconducts: falsification, fabrication, and plagiarism.
4. Redundant publications: duplicate and overlapping publications, salami slicing
5. Selective reporting and misrepresentation of data.

**Unit 3: Publication Ethics**
1. Publication ethics: definition, introduction and importance
2. Best practices/standards setting initiatives and guidelines: COPE, WAME, etc.
3. Conflicts of interest
4. Publication misconduct: definition, concept, problems that lead to unethical behavior and vice verse, types
5. Violation of publication ethics, authorship and contributor ship
6. Identification of publication misconduct, complaints and appeals
7. Predatory publishers and journals

**Unit 4: Open Access Publishing**
1. Open access publications and initiatives
2. SHERPA/RoMEO online resource to check publisher copyright and self-archiving policies.
3. Software tool to identify predatory publications developed by SPPU
4. Journal finder/ journal suggestion tools viz. JANE, Elsevier Journal Finder, Springer Journal Suggester, etc.

**Unit 5: Publication Misconduct**
A. Group Discussions
1. Subject specific ethical issues, FFP, authorship
2. Conflicts of interest
3. Complaints and appeals: examples and fraud from India and abroad

B. Software tools
Use of plagiarism software like Turnitin, Urkund and other open source software tools.

**Unit 6: Databases And Research Metrics**
A Databases
1. Indexing databases

2. Citation databases: Web of Science, Scopus, etc.

B. Research Metrics
Impact Factor of journal as per journal citation report, SNIP, SJR, IPP, Cite Score.
Metrics: h-index, g index, i10 index, altmetrics

**Practicals**

**1. Types of Research**

1. Basic Research:
2. Applied Research:
3. Descriptive Research:
4. Analytical Research:
5. Correlation Research:
6. Qualitative Research:
7. Quantitative Research:
8. Experimental Research:
9. Explanatory Research:
10. Exploratory Research:
11. Selection of Domain/Area of Research:

**2. Formulating a Research Problem and Identification of Keywords:**

1. Literature Survey:
2. Redefining Research Problem, Objectives and Outcomes:
3. Research Proposal:
4. Identifying Variable /Parameters and Research Design:
5. Data Collection and Representation:
6. Testing of Proposed Design on Collected Data/Hypothesis Testing:

**3. Results and Analysis:**

1. Research Report Writing:
2. Features of Good Research Study

**4. Journal Search**

1. Open Access Publishing
2. Impact Factor of journal as per journal citation report, SNIP, SJR, IPP, Cite Score.
   Metrics: h-index, g index, i10 index, altmetrics

**Suggested Readings**


- Bird,A. (2006). Philosophy of Sciences. Routledge
- MacIntyre, Alasdair (1967). A Short History of Ethics. London
- P.Chandah. (2018). Ethics in Competitive Research: Do not get Scooped; do not get plagiarized.
- National Academy of Sciences, National Academy of Engineering and Institute of Medicine (2009)., National On being a Scientist: A guide to responsible conduct in Research : third edition, National Academies Press
- Hall GM. Book Farthing MJG. How to Write a Paper. UK Blackwell Publishing; 2008
- NAS-NAE-IOM. Responsible Science: Ensuring the Integrity of the Research Process. Washington, DC: National Academy Press; 1992.
- Alexander M. Novikov & Dmitry A. Novikov, Research Methodology: From Philosophy of Science to Research Design, CRC Press Taylor & Francis Group, (2013).

- C. R. Kothari, Research Methodology: Methods and Techniques, New Age International (P) Ltd., New Delhi (2004).
- David Bridges, Philosophy in Educational Research: Epistemology, Ethics, Politics and Quality, Springer International Publishing AG (2017).
- Deepak Chawla & Neena Sondhi, Research Methodology: Concepts and Cases, VIKAS® Publishing House Pvt Ltd, New Delhi (2015).
- Paul Smeyers & Marc Depaepe, Educational Research: Ethics, Social Justice, and Funding Dynamics, Springer International Publishing AG, (part of Springer Nature) (2018).
- Peter Pruzan, Research Methodology: The Aims, Practices and Ethics of Science, Springer International Publishing Switzerland (2016).
- Ranjit Kumar, Research Methodology: a step-by-step guide for beginners, SAGE Publications India Pvt Ltd, New Delhi (2011).
- Richard Pring, Philosophy of Educational Research, Continuum, London (2000).
- Robyn Brandenburg & Sharon McDonough, Ethics, Self-Study Research Methodology and Teacher Education, Springer Nature Singapore Pte Ltd. (2019).
- S. K. Yadav, Elements of Research Writing, UDH Publishers and Distributers, New Delhi (2015).
- Surbhi Jain, Research Methodology in Arts, Science and Humanities, Society Publishing, Oakville, Canada (2019).
- Vinayak Bairagi and Mousami V. Munot, Research Methodology A Practical and Scientific
- Approach, CRC Press Taylor & Francis Group, New York, NY (2019).

**E Resources and List of Journals**

- *Advances in Applied Research*
- *Advances in Computational Sciences and Technology [ACST]*
  *Advances in Mechanical Engineering*
  *Advances in Water Resources*
  *Agricultural Engineering*
  *Agricultural Engineering Today*
  *Agricultural Mechanization in Asia, Africa and Latin America*
  *Agricultural Research*
  *Agricultural Reviews*
  *Agricultural Science Digest*
  *Agricultural Water Management*
  *Agronomy Journal (Journal of American Society of Agronomy*
  *American Journal of Food Technology*
  *American Statistician*
  *Annals of Agri Bio Research*
  *Annals of Agricultural Research*
  *Annals of Arid Zone*
  *Annals of Biology*
  *Annals of Horticulture*
  *Annals of Science*
  *Annals of Statistics*
  *Applied Ecology and Environmental Research*
  *Applied Engineering in Agriculture*
  *Applied Ergonomics*
  *Arid Land Research and Management*
  *Asian Journal of Chemistry*
  *Asian Journal of Environmental Science*
  *Atmospheric Research*
  *Australian Journal of Crop Science*
  *Australian Journal of Dairy Technology*
  *Beverage and Food World*
  *CIGR journal*
  *Comptes Rendus Geosciences*
  *Computers and Electronics in Agriculture*
  *Computers & Industrial Engineering*
  *Cotton Research Journal*
  *Current Advances in Agricultural Sciences*
  *Current World Environment*
  *Ecological Engineering*
  *Ecology, Environment and Conservation*
  *Engineering and Technology in India*
  *Environment*
  *Environment and Ecology*
  *Environmental Engineering Science*
  *Environmental Monitoring and Assessment*
  *Environmental Science and Pollution Research*
  *Environmental Science and Technology*

*Environmental Review*
*Forage Research*

- *Groundwater*

*Hydrological Processes*
*IETE Journal of Research*
*IETE Journal of Education*
*Indian Journal of Agricultural Chemistry*
*Indian Journal of Agricultural Research*
*Indian Journal of Agricultural Sciences*
*Indian Journal of Dairy Science*
*Indian Journal of Extension Education*
*Indian Journal of Hill Farming*
*Indian Journal of Radio and Space Physics*
*Indian Journal of Science and Technology*
*Indian Journal of Soil Conservation*
*Indian Research Journal of Extension Education*
*Institute of Engineers (India)*
*Journal of Electronics & Tele Communication*
*International Journal of Agricultural Engineering*
*International Journal of Agricultural Science and Research*
*International Journal of Advance Industrial Engineering*
*International Journal of Advanced Mechanical Engineering [IJAME]*
*International Journal of Advanced Engineering Technology (IJAET)*
*International journal of Advanced Research in Engineering & Technology (IJARET)*
*International Journal of Applied Engineering Research [IJAER]*
*International Journal of Current Engineering and Technology*
*International Journal of Design and Manufacturing Technology(IJDMT)*
*International Journal of Engineering Research and Technology [IJERT]*
*International Journal of Engineering, Science and Metallurgy*
*International Journal of Engineering (IJE)*
*International Journal of Engineering Studies [IJES]*
*International Journal of Environmental Analytical Chemistry*
*International Journal of Environmental Research and Public Health*
*International Journal of Environmental Science and Technology*
*International Journal of Extension Education*
*International Journal of Food Engineering*
*International Journal of Food Microbiology*
*International Journal of Food Properties*
*International Journal of Food Science and Nutrition*
*International Journal of Food Science and Technology*
*International Journal of Food and Fermentation Technology*
*International Journal of Innovative Technology and Exploring Engineering (IJITEE)*
*International Journal of Industrial Engineering & Technology*

*[IJIET]*
*International Journal of Industrial Engineering Research and Development (IJIERD)*
*The International Journal of Industrial Engineering: Theory,*
- *Application and Practice (IJIETAP)*

*International Journal of Engineering and Management Research (IJEMR)*
*International Journal of Engineering Sciences and Management*
*International Journal of Industrial Engineering Computations*
*International Journal of Engineering and Manufacturing Science [IJEMS]*
*International Journal of Research in Chemistry and Environment*
*International Journal of Research In Mechanical Engineering And Technology (IJRMET)*
*International Journal of Thermal Sciences*
*International Journal of Mechanical Engineering and Robotics Research*
*International Journal of Material and Mechanical Engineering*
*International Journal of Mechanical Engineering & Technology(IJMET)*
*International Journal of Mechanical Engineering and Research(IJMER)*
*International Journal of Mechanical Sciences*
*International Journal of Recent Technology and Engineering(TM) Exploring Innovation*
*International Journal of Industrial & Production Engineering & Tech. [IJIPET]*
*International Journal of Industrial and Systems Engineering*
*International Journal of Advanced Materials Science [IJAMS]*
*International Journal of Research in Mechanical Engineering*
*International Journal of Engineering & Technology Research*
*International Review of Applied Engineering Research [IRAER]*
*International Journal of Mechanical and Materials Engineering*
*International Journal of medical, Health, Biomedical, Bioengineering and Pharmaceutical Engineering*
*International Journal of Production Technology and Management (IJPTM)*
*International Journal of Refrigeration*
*International Journal of Remote Sensing*
*International Journal of Thermal Technologies*
*International Journal of Water Resources Development*
*International Journal on Agricultural Sciences*
*International Journal on Environmental Sciences*
*International Journal of Applied Research on Information Technology and Computing*
*International Journal of Mechanical Engineering*
*International Journal of Mechanical and Production Engineering Research and Development*
*International Scholarly Research Notices, ISRN Mechanical Engineering*

*Irrigation Science*
*Irrigation and Drainage (ICID Bulletin)*
*Irrigation and Drainage System*
*Italian Journal of Food Science*
*Journal of Agricultural Engineering (ISAE)*
*Journal of Agriculture Research and Technology*

- *Journal of Agricultural Safety and Health*

*Journal of Applied Ecology*
*Journal of Applied Probability*
*Journal of Applied Statistics*
*Journal of Arid Environments*
*Journal of Cotton Research and Development*
*Journal of Dairy Research*
*Journal of Dairy Science*
*Journal of Ecology*
*Journal of Energy Engineering - ASCE*
*Journal of Engineering*
*Journal of Engineering computers and Applied Sciences*
*Journal of Engineering Research*
*Journal of Ergonomics*
*Journal of Environmental Engineering*
*Journal of Environmental Monitoring*
*Journal of Environmental Protection and Ecology (JEPE)*
*Journal of Environmental Sciences*
*Journal of Environmental Science and Engineering*
*Journal of Environmental Science, Toxicology and Food Technology*
*Journal of Food Biochemistry (Journal of Food Lipids)*
*Journal of Food Composition and Analysis*
*Journal of Food Engineering*
*Journal of Food Legumes*
*Journal of Food Process Engineering*
*Journal of Food Processing and Preservation*
*Journal of Food Quality*
*Journal of Food Safety*
*Journal of Food Science*
*Journal of Food Science and Technology*
*Journal of Food, Agriculture and Environment*
*Journal of Human Ecology*
*Journal of Hydraulic Engineering – ASCE*
*Journal of Hydraulic Research*
*Journal of Hydrologic Engineering*
*Journal of Hydrology*
*Journal of Indian Society of Agricultural Statistics*
*Journal of Indian Water Resources Society*
*Journal of Industrial Engineering International*
*Journal of Irrigation and Drainage Engineering (ASCE)*
*Journal of Mechanical Engineering*
*Journal of Materials in Civil Engineering*
*Journal of Manufacturing Processes*

*Journal of Research, PAU*
*Journal of Soil and Water Conservation*
*Journal of Soil and Water Conservation, India*
*Journal of Statistical Computation and Simulation*
*Journal of Statistical Planning and Inference*
*Journal of Statistical Theory and Practice*
*Journal of Stored Products Research*
*Journal of Sustainable Agriculture*

# Restructured and Revised Syllabi of Post Graduate Programmes

# M. Tech. (Agriculture Engineering)

# in

# Agriculture Structures and Environment Management

**Compiled by**

**Broad Subject Co-ordinator**
**Associate Dean,**
**Dr. Annasaheb Shinde College of Agricultural Engineering and Technology, MPKV, Rahuri**

**Discipline Coordinator**
**Professor and Head (FS)**
**College of Agricultural Engineering and Technology, Dr. PDKV, Akola**

CONTENTS

## Preamble

Farm structures or Agricultural Structures are one of the branches of agricultural Engineering that deals with planning, design and construction of farm buildings and other structures in the farm and outside the farm environment. Farm structure involves both shelter and non-shelter, while farm buildings involve only shelter for accommodation of man, livestock and crops. Examples of non-shelter of farm structures are roads, bridges and fences. There are some structures which may not be found within the farm premises and environment respectively but have functions related with agricultural activities could also be classified as farm structures. Examples of this type of structures are green house, polyhouse, vertical farming structures, hydroponic structures, warehouse, processing centers, machinery workshops, fruits and vegetables storage structures.

Farm structures have contributed significantly to agriculture in providing better housing, improvement in transportation and communication respectively, provision of modern conveniences and recreational facilities for good standard of living and working conditions of the farmers. Also, farm structure has brought improvement in productivity of livestock and reduction in post-harvest loss through improvement in animal houses and adequate storage facilities respectively. There are some structures and facilities which are for other non-agricultural purposes, but were converted or remodelled for agricultural uses, for example, old residential buildings that are converted to crop storage structures or poultry buildings.

Farm structures are classified based on utilization or materials of construction. Construction materials of farm structures are concrete, earth, timber and steel. Although, steel is not a common material in farm building, because of its high cost that may be beyond the purchasing power of most farmers. The definition of farm structures shows the necessity of farm structures in our nation, hence it is indispensable. It shows that **no farm structures means no agricultural development**, hence, no nation building.

The emerging trends in research, need for human resources for teaching and application of research for crop improvement, shrinking job opportunities in the public sector etc would warrant students to possess the technical knowledge and skills in coupled with good practical and management skills, to be competitive for both public and private sectors. Hence a thorough restructuring of course curriculum and delivery system is needed.

Hence, the course curriculum of M. Tech. (Agril. Engg.) in Agril. Structures and Environment Management has been revised as per the need of the hour.

**Committee on Agricultural Engineering**

| ICAR-BSMA Broad Subject | ICAR-BSMA Approved Disciplines | Degree Programmes | | Broad Subject Coordinator (Chairman of all Disciplines' Sub Committees | Discipline Coordinator (Secretary of respective Discipline Sub-Committee) |
|---|---|---|---|---|---|
| Agriculture Engineering and Technology | Agriculture Structures and Environment Management | M.Tech. | - | Dr. D.D. Pawar, CoAE, MPKV, Rahuri | Dr. Suchita V. Gupta, Head, Deptt. of Farm Structures, Dr. PDKV, Akola |

## Implementation of New Curriculum

**Expected Outcome**

- Revamping of post graduate programme in whole of Agricultural Engineering throughout the country.
- Imparting quality education.
- Development of technical manpower to cater the need of governments, corporate sector and research organization in India and abroad.
- Exposure to the faculty in the latest technical knowhow.

## Organization of Course Contents & Credit Requirements

**Minimum Residential Requirement:**
**M. Tech.: 4 Semesters**

**Name of the Departments / Divisions**

- Department of Farm Structures

**Nomenclature of Degree Programme**

**(a) M. Tech. Programme**

i) M. Tech. (Agril. Engg.) in Agriculture Structures and Environment Management

**Code Numbers**

- All courses are divided into series: 500-series courses pertain to Master's level
- Credit Seminar for Master's level is designated by code no. 591
- Deficiency courses will be of 400 series.
- Master's research is designated by code no. 599

**Course Contents**

The contents of each course have been organized into:

- Objective – to elucidate the basic purpose.
- Theory units – to facilitate uniform coverage of syllabus for paper setting.
- Suggested Readings – to recommend some standard books as reference material. This does not obviously exclude such a reference material that may be recommended according to the advancement and local requirement.
- A list of international and national reputed journals pertaining to the discipline is provided at the end which may be useful as study material for 600/700 series courses as well as research topics.
- Lecture schedule and practical schedule has also been given at the end of each course to facilitate the teacher to complete the course in an effective manner.

**Eligibility for Admission**

- **Master's Degree Programme**
  - B. Tech./B.E. (Agril. Engg.), having appeared for common entrance test for M.Tech. (Agril. Engg.) conducted by competent authority.
  - If needed, students have to offer 6-10 credits deficiency courses as recommended by the Student Advisory Committee.

**Course and Credit Requirements**

| **Course Details** | **Masters Degree** |
|---|---|
| Major Courses | 20 |
| Minor Courses | 08 |
| Supporting / Optional | 06 |
| Common PGS Courses | 05 |
| Seminar | 01 |
| Research | 30 |
| **Total** | **70** |

## Course Layout and Structure

**LIST OF CORE COURSES/ DEPARTMENT WISE SPECIALIZATION/ COMPULSORY/SUPPORTING COURSES**

**1. M. Tech. Agricultural Engineering (Agriculture Structures and Environment Management)**

**Major courses ( 12+8 credits):**

| Course Code | Semester | Course Title | Credit Hrs. |
|---|---|---|---|
| FS 501* | - | Advance Structural Engineering | 3 (2+1) |
| FS 502* | - | Environmental and Pollution Control in Agriculture | 3 (2+1) |
| FS 503* | - | Agriculture Structures and Animal Housing | 3 (2+1) |
| FS 504* | - | Design of Structures for Agricultural Production | 3 (2+1) |
| FS 505 | - | Environmental Science and Engineering | 3 (2+1) |
| FS 506 | - | Rural Planning and Safety | 3 (2+1) |
| FS 507 | - | Environmental Management | 3 (2+1) |
| FS 508 | - | Costing, Estimating and Contracting | 3 (2+1) |
| FS 509 | - | Engineering Materials for Agricultural Structures | 3 (2+1) |
| FS 510 | - | Design of Storage Structures | 3 (2+1) |
| FS 511 | - | Farm Structures and Environmental Control | 2 (2+0) |
| FS 512 | - | Handling, Packaging and Transportation | 3 (2+1) |
| FS 513 | - | Greenhouse Technology | 3 (2+1) |
| FS 514 | - | Residue Effluent Waste Management | 3 (2+1) |
| FS 515 | - | Environmental Impact Assessment | 3 (2+1) |
| **Other Essential Courses** | | | |
| FS 591* | | Seminar | 0+1 |
| FS 599* | | Thesis Research | 0+30 |

***Core and Compulsory Courses**

**Minor Courses (8 Credits)**

**Minor Disciplines:**

1. Farm Machinery and Power Engineering
2. Processing and Food Engineering
3. Irrigation and Drainage Engineering
4. Renewable Energy Engineering
5. Soil and Water Conservation Engineering
6. Biotechnology and Bioinformatics
7. Dairy Science and Technology

**Suggestive minor courses:**

Followings are the list of some of the suggestive minor courses. Students will be required to complete minor courses (8 credits) from the below courses from minor disciplines related to the major discipline in which student admitted and as decided by the Student Advisory Committee.

| Sr. No | Course No. | Course Title | Credit |
|---|---|---|---|
| 1. | PFE 505 | Storage Engineering and Handling of Agricultural Produce | 3 (2+1) |
| 2. | PFE 506 | Food Package Engineering | 2 (1+1) |
| 3. | PFE 509 | Food Quality and Safety | 3 (2+1) |
| 4. | PFE 514 | Farm Structures and Environmental Control | 3 (2+1) |
| 5. | PFE 517 | Design of Aquacultural Structures | 3 (2+1) |
| 6. | REE 510 | Energy, Ecology and Environment | 3 (3+0) |
| 7. | REE 512 | Energy Generation from Agricultural Waste and By-products | 3 (2+1) |
| 8. | FMPE 517 | Machinery for Precision Agriculture | 3 (2+1) |
| 9. | FMPE 518 | Machinery for Horticulture and Protected Agriculture | 2 (2+0) |
| 10. | SWCE 503 | Soil and Water Conservation Structures | 3 (2+1) |
| 11. | SWCE 508 | Climate Change and Water Resources | 3 (3+0) |
| 12. | CSE-501 | Big Data Analysis | 3 (2+1) |
| 13. | CSE-502 | Artificial Intelligence | 3 (2+1) |
| 14. | CSE-504 | Soft Computing Techniques in Engineering | 3 (2+1) |
| 15. | MATH 501 | Finite Element Methods | 2 (1+1) |
| 16. | MATH 502 | Numerical Methods for Engineers | 3 (2+1) |
| 17. | MATH 506 | Numerical Analysis | 3 (2+1) |
| 18. | ME 501 | Mechatronics and Robotics in Agriculture | 2 (2+0) |
| 19. | ME 502 | Refrigeration Systems | 3 (2+1) |

| | | | |
|---|---|---|---|
| 20. | CE 502 | Water Quality and Polluting Control | 3 (2+1) |
| 21. | CE 510 | Experimental Stress Analysis | 3 (2+1) |

**Supporting Courses Disciplines (6 credits):**

1. Renewable Energy Engineering
2. Soil and Water Conservation Engineering
3. Basic Sciences and Engineering.
4. Dairy Science and Technology
5. Computer Science and Information Technology

**Suggestive Optional Courses :**

| Course Code | Semester | Course Title | Credit Hrs. |
|---|---|---|---|
| FS 521 | - | Special Problem | 0+1 |
| FS 522 | - | Internship | 0+1 |

Supporting courses could be Courses from Subject Matter Fields (Other than Major and Minor) as per recommendation of Student Advisory Committee

**Common Compulsory Non Credit PGS Courses: ((5 credits Non Credit)**

| Course code | Semester | Course Title | Credits |
|---|---|---|---|
| PGS 501 | I | Library and Information Services | 0+1 |
| PGS 502 | I | Technical Writing and Communications Skills | 0+1 |
| PGS 503 | II | Intellectual Property and its management in Agriculture | 1+0 |
| PGS 504 | II | Basic Concepts in Laboratory Techniques | 0+1 |
| PGS 505 | III | Agricultural Research, Research Ethics and Rural Development Programmes | 1+0 |
| PGS 506 | III | Disaster Management | 1+0 |

**Compulsory Non Credit Deficiency Courses**

The students other than Agricultural Engineering , if needed, will have to complete the Non credit deficiency courses (6 to 10 credits ) related to the discipline in which admitted and as decided by the Student Advisory committee.

| No. | Course No. | Title | Credits |
|---|---|---|---|
| 1 | FS 111 | Engineering Mechanics | 2+1 |
| 2 | FS 122 | Strength of Materials | 1+1 |
| 3 | FS 233 | Theory of Structures | 1+1 |
| 4 | FS 244 | Building Construction and Cost Estimation | 1+1 |
| 5 | FS 355 | Agricultural Structures, Storage Engineering and Environmental Control | 2+1 |

# Course Syllabus and Contents

**FS-501 Advance Structural Engineering 3 (2+1)**

**Objective**
To understand knowledge regarding the design of Steel structures, RCC structures, construction and manufacturing materials.

**Theory**
**Unit I:** Reinforced concrete, structural elements, Loads on structure, Design of trusses, Ductility versus brittleness, Derivation of formulae for balanced design, constituents of concrete, Types of cement, Negi LS (2012),Design of steel structures, Tata Mc Graw, Hill Station, P, Storing of cement, Aggregate, specific gravity, bulk density.

**Unit II:** Types of Footings, General Design considerations, Transfer of load at the base of columns, isolated footings, Axially loaded pad footing, Axially loaded sloped footing.

**Unit III:** Columns Introductory, Definition and General Requirements Reinforcement requirements, axially loaded columns, short columns, and Long columns eccentrically loaded columns.

**Unit IV:** BIS code for structural design.

Check dam structural design, stress-strain analysis, aeroponics, hydroponics, layout, design principles of water conservation structures, earthen dam, etc.

**Practicals :**
1. Design of Single storey building.
2. Design of Truss King post and queen post Truss.
3. Design of Slab One way and Two way.
4. Design of Footing and its reinforcement details.
5.Test for setting time of cement.
6. Test for fineness and consistency of cement.
7.Test for compressive strength of cement.

**Recommended Books:**
1. Reinforced Concrete Vol-I by H.J. Shah, Charotar publishing House, Anand.
2. Elementary Reinforced Concrete-S.B. Junnarkar and H.J. Shah, Charotar publishing House, Anand.
3. BIS codes,IS-875(Part 1 to 5)- 1987, JS 1893 (Part I: 2002,Bureau of Indian Std. New Delhi.
4. Negi LS(2012)Design of steel structures Tata Mc Graw Hill Education Pvt. Ltd. New Delhi.
5. Khurmi RS (2003), Strength of Material (Mechanics of Solids). S. Chand and Co. Ltd., New Delhi.

**FS-502* Environmental and Pollution Control In Agriculture 3 (2+1)**

**Objective**

To get the knowledge regarding sources of environmental pollution and their control measures.

**Theory**

**Unit I:** Air pollution: Definition, natural and man-made sources of air pollution, stationary and mobile sources, classification of pollution Sources, Classification of Air pollutants, and Effects of air pollution. Primary and secondary pollutants transport and diffusion of pollutants in air, Control devices-Gravitational Settling Chamber, Cyclone separators, Fabric filters, Electrostatic precipitator, Wet collectors, spray tower. Pollution due to agro processing Industry, Dairy barn and agricultural structures.

Emission and ambient standards, vehicular pollution and urban air quality. Air pollutants: Sulfur oxides (SOX);nitrogen oxides (NOx), carbon monoxide, total suspended particulate matter, respirable particulates, photo-chemical Oxidants, specific pollutants Pollution due to Agro processing Industry, Dairy barn and Agril. Structures.

**Unit II:** Water Pollution: Introduction water quality standards, water pollution, sources of water pollution, classification of water pollutants, Effects of water pollution on colour, Taste and odour, Temperature, Turbidity, Hardness, pH ,Quality of potable water. Pollution due to irrigation practices in agriculture.

**Unit III:** Noise pollution: Introduction, sources of noise pollution, Industrial sources, household, Agricultural machine, Defence equipments. Effect of noise Physical effects, physiological effects, psychological effects, Controls of Noise pollution.

Environmental Legislation, water pollution act, air pollution act, wild life protection act, Indian forest act, environment protection act,

**Practicals**

1 To find pH of water and Sewage sample.
2. To Determine Turbidity of waste water.
3. To find Total Solids and Dissolved solid of waste water.
4. To find exact coagulant dose for removal of dissolved suspended solids.
5. Visit to Agro processing industry.
6. Visit to Dairy barn.

**Recommended Books:**

1. Environmental Engineering and Management-By Suresh K. Dhameja S.K Kataria& Sons publishers and Distributors.

2. R. K. Trivedi & P. K. Goel, an Introduction to Air Pollution, Techno Science Publications, Jaipur (1995)

3. C.S.Rao, Environmental Pollution Control Engineering, New Age International Publication New.

**FS-503* Agricultural Structures and Animal Housing 3 (2+1)**

**Objective**

To get the knowledge about design and development of agricultural structures and arrangement for comfortable zone for animals.

**Theory**

**Unit I:** Animal physiology, Physiological reactions of animals to ambient temperature and humidity, homoeothermic mechanisms, effect on moisture evaporation and respiration.

**Unit II :**Cattle housing Manager, dung channel, passages, calving sheds, Isolation sheds, sheep and goat housing, poultry housing, bull pen, sheep pen.

**Unit III:** Poultry equipment, dairy barn equipment

**UNIT IV:** Animal environment requirement, comfort indices, light ammonia gas, air requirement, sound, stocking density, use of plant materials, sprinkler system, mechanical ventilations fogging, evaporative cooling system, heating system, use of zeolite, computer controlled system

**Practical**

Flooring of comfort mats, rubber mats, sawdust, roof points, atomization in operation in operation floggers, coolers, lights, ventilations, study of equipment used in housing. Temperature and humidity effects on animal behaviour. Design values for livestock fallout shellers, floor and suspended loads on agricultural structures

**Suggested Books**


1. Vasavada A.A.(1994) Farm Structure in India, Indian Council-of Agricultural Research, New Delhi.
2. Woolley John C.(2011)Planning farm Building;3rd Edition, Biotech Books, Delhi
3. Horold E, Gray(1995)Farm service Building; Mc Graw Bok CO. Inc
4. Lindley James A. and Whitakar James H.(1996) Agricultural Buildings and structures,
5. ASAE, The Society for Engineers in Agriculture, Food and Biological System, USA.
6. Barre HJ and Sammet LL (1998) Farm Structure; John Willey and sons, New York.
7. Rai GD (2000)Non Conventional Energy Sources; Khanna publishers, New Delhi
8. JamesH. Whiotakar James (1979) Agricultural Buildings and structures, Publishing House; Virginia Reston
9. Mishra R.P., Ahuja S.D. Poultry structures, Division of Technology Transfer, Central Avian Research Institute, Izatnagar

**FS-504* Design of Structure for Agricultural Production 3 (2+1)**

**Objective**

To gain knowledge about design and development of agricultural structures for protected cultivation and environment control.

**Theory**

**UNIT I:** Greenhouses and greenhouse effect, Plant-environment interactions, historical developments, Types of Green houses, Design of greenhouses, Environmental control, Operation and maintenance, Economics of greenhouse production

**UNIT II:** Attributes of greenhouse technology, design criterion-isolation, structure, cover, Uniform building codes ,NGMA(National Greenhouse manufacture Association) Standard, Relationship greenhouse span, pit spacing and pit diameter.

**UNIT III :** Glazing properties of covers-traditional, optical, physical, degradation Practical Design of greenhouses, cooling, heating, ventilation system for greenhouse, fan pad system, role of co2,control of light, components of greenhouse, specification of farm fences construction, operation of greenhouses, Estimating quantity of foggers, specification for lightening protection. study of side and roof curtains for environment control.

**Practicals**

Design of Green house structures for 500, 1000, 2000, 4000 sq m, Load calculations, soil parameters, shadenet specifications, Visit to polyhouses /shadenet houses/bamboo house structures

**Suggested Books**

1. Tiwari GN and Goyal RK(2000) Greenhouse Technology fundamentals, design, modeling, and application, Naro publishing House New Delhi.

2. Nelson PV (2013) Greenhouse house operation management, Prentice Hall, New Jersey, Fifth Edition

3. Salokhe VM and Sharma AK(2006) Greenhouse technology and applications, Agrotech Publishing Academy, Udaypur.

4. Radha Manohar K.and Igathinathane G.(2000) greenhouse Technology and management, B.S. Publications, Hyderbad.

5. S.Ayyappan (2003) Handbook of Aquaculture Indian Council of Agricultural Research, New Delhi

## FS-505 Environmental Science and Engineering 3 (2+1)

**Objective**

The course aims to develop understanding of natural resources, waste water treatment design and layout and solid waste management.

**Theory**

**Unit I:** Natural Resources: Types of resources water resources Food resources Energy resources Renewable and Non-renewable energy resources, wind Energy, Forest Resources, Tidal Energy Forest Resources, Geothermal Energy.

**Unit II:** Design and layout of waste water treatment, Plant environment interactions, thermostatic environmental control.

**Unit III:** Solid waste Management:-Sources of Urban and Industrial wastes, Effects of solid wastes, Management of solid waste, Reuse of waste materials recycling of materials, Sanitary Landfill, Composting, Incineration Cooling, heating, evaluating or hot weather system housing.

**Practicals**

1. Design of solid waste treatment plant.
2. Vermicompost for solid waste 3. To determine BOD of waste water.
4. To determine COD test
5. Temperature/RH/LI control in Agricultural Structures

**Recommended Books:**

1. Perspectives in Environmental Studies-by C.P. Kaushik, New Age International Publishers
2. Dr.D.M. Dharmadhikari -Das Ganuprakashan(Nagpur) India.
3. Birdie G.S: Water Supply and Sanitary Engg., Dhanpat Rai & Sons,
4. Chandra Pritam (2000) Greenhouse construction and environment control, Division of Agricultural engineering, IARI, New Delhi.
5. Whitakar James H.(1986) Agricultural Buildings and Structures, Reston Publishing Co. Virginia

**FS-506 Rural Planning and Safety 3 (2+1)**

**Objective**

The course aims to develop understanding of rural planning and sanitation, low cost housing technologies, structural safety.

**Theory**

**UNIT 1:** Functional Rural planning. Economic planning of the farm operation Approach to building planning, Farmstead planning.

**UNIT II:** Rural Sanitation, composting, land use and physical planning for housing, development and adoption of low cost housing technology, low cost infrastructure services,

**UNIT III:** Rural housing, appropriate rural housing technology, fire retardant treatment for thatch roof, bousing in disaster propone area, earthquake, damages to houses, types of damages and failure of non engineering building.

**UNIT IV:** Requirements of structural safety, earthquake strengthening measures. Safety aspects, Lightning conductors, Fire protection, Work safety.

**Practical**

Survey of village, layout of farm buildings, study of safety measurement, economics in farm operation, Design of anaerobic lagoons for animal waste management, Biochemical properties of waste, equipments for waste handling.

**Suggested Books**

1 Lal A.K. (2001).Handbook of Low Cost Housing. New Age International Pvt. Ltd. Publications, 4835/24, Ansari Road, Daryaganj, New Delhi.

2. Lindley James A. and Whitaker James H., (1997) Agricultural Buildings and Structures, ASAE,USA.

3. Euright FB (1969) Rural Water Supply and sanitation, Wiley Eastern Ltd. Brown Robert H. (1985) Farm Electrification, Allied Pacific Pvt. Ltd., Bombay

**FS-507 Environmental Management 3 (2+1)**

**Objective**

The course aims to understand the ventilation in agricultural buildings, effect thermal and gaseous environment effect and measurement of environment parameters.

**Theory**

**Unit-I :**Heat and moisture control in agricultural buildings, root environment medium composition and quantity, nutrient concentrations, water content, temperature, PH and Electrical Conductivity.

**Unit II:** Aerial environment air temperature, atmospheric composition including moisture and carbon dioxide concentration, air velocity, radiations, edge effect of wall/floor on these parameters.

**Unit III:** Effect of the thermals and gaseous environment on livestock, effect of temperature humidity, air velocity, air contaminations on animal heat loss, production, reproduction and health.

**Unit IV:** Principles and modelling of greenhouse structures, Measurement system for structures environment parameters, environment management for production of tomatoes, cucumbers, capsicum, rose, gerbera and carnation.

**Practical's**

Effect of environment parameters on production and health, study of environmental at different growth stages of vegetables and flowers, Lighting for dairy farms and poultry Industry, Guidelines for measuring and reporting environmental parameters for plant experiments, measurement techniques.

**Recommended Books:**

1. Tiwari GN and Goyal RK (2000) Greenhouse Technology, fundamentals, design, modeling, and application, Naro publishing House, New Delhi
2. Lindley James A. and Whitaker James H., (1997) Agricultural Buildings and Structures, ASAE,USA Engineers.
3. ASAE (1988) Engineering practices: ASAE EP 270, American Society of Agricultural Engineering

**FS-508 Estimating Costing and Contracting 3 (2+1)**

**Objective**

The course aims to develop understanding of design and estimates of agricultural structures and methods of estimates.

**Theory**

**UNIT I:** Estimates-methods, types, measurement unit

**UNIT II:** Specifications, rate analysis, estimates for fences, farm roads, gates, farm house

**UNIT III:** Account formats, store management, material at site accounts

**UNIT IV:** Contract systems, contract documents

Estimation of soil and water conservation system, irrigation system and processing systems, estimation of aeroponic and hydroponic system, dairy barn, visit to agri. Structures.

**Practical**

Design and estimates of septic tank, sanitary works, roads, well, dairy barn, poultry structures, storage structures, check dams.

**Suggested Books**

1. B.N Datta (1991) Estimating and costing in civil engineering, UBS pub. Distributors, Ltd., New Delhi

2. M. Chakraborti (2009) Estimating and costing in civil engineering, 22ndedition

3. S.C. Rangwala (2000) Estimating and costing, Charotar Pub., Anand

4. B.S. Patil (2013) Civil Engineering contracts and estimates. Universities Press (I) Pvt. Ltd., Himayat Nagar, Hyderabad.

5. G.S. Birdie, Estimating and costing, Dhanpatrai and Sons, New Delhi

**FS 509 Engineering Materials for Agricultural Structures 3 (2+1)**

**Objective**

The course aims to develop understanding of specifications ofbuilding materials, material testing methods.

**Theory**

**UNIT I :** Wood, Poles and timber, plywood, particle boards, laminates, fiber boards, veneers, Burnt- clay bricks.

**UNIT II :** Fly-ash bricks, Binders, Concrete, Concrete blocks -sand-cement blocks, Mortar, Ferro cement, Fiber-reinforced concrete..

**UNIT III :** Glass, Plastics, Rubber, Paints, Geo-textile, pre-fabricated structures.

**UNIT IV :** Building materials Testing, BIS codes for building materials, Drainage Materials, Drainage Pipes & Envelope materials. Materials for hydroponic and aeroponic structures

**Practical**

Study of specifications of building materials, Study of water cement ratio] Testing of cement, concrete, boards, bricks, laminates, study of BIS codes, testing of drainage material, study of binders, Block preparation, strength of reinforced concrete, chemical preservation for wood and allied products.

**Suggested Books**

1. Varghese PC (2011) Building Materials; PHI learning Pvt. Ltd., New Delh

2. Rangwala SC (1999) Engineering Materials; Charotar Publishing house, Anand.

3. Singh Gurucharan and Singh Jagdish (2000) Building Materials (Materials for Construction); Standard Publishers Distributors, Delhi;

5. Islam Saiful and Karim Yasir, (2000) Building Materials and Construction, Vayu education of India, New Delhi.

6. IS: 1125-1975;IS: 5218-1969; IS: 1121-part 1-1971; Bureau of Indian Standards, New Delhi.

**FS 510 Design of Storage Structures 3 (2+1)**

**Objective**

The course aims to develop understanding of design of storage structures, quality monitoring and control of stored product.

**Theory**

**UNIT I :** Food Grain storage structures - Traditional and Improved structures, Modern storage systems. Functional and structural design considerations. Grain pressure theories.

**UNIT II :** Storage systems-farm level, bagged storage (warehouse and CAP), bulk storage, hermetic storage, outdoor storage, Controlled atmosphere storage. Losses during storage - insects, mites, fungi, rodents, birds. Moisture migration in bins. Grain protection physical, chemical and biological controls.

**UNIT III :** Silos types, location, filling and packing, size and capacity. Storage structures for horticultural produce-Maturity indices, ripening stages for safe storage. Modification of atmosphere composition-structural design of storage room, controlled atmosphere storage, modified atmosphere storage. Chilling rooms, walk-in cooling room for perishables including livestock produce.

**UNIT IV :** Quality monitoring and control of stored product. Factors/parameters influencing the shelf Life of the stored product, climatograph and deterioration index. Modeling of metabolic activities and prediction of storage life, quality deterioration mechanisms and their control. BIS standards on practices, equipment and design of storage structures and systems for food grains and other commodities. Onion storage structures, solar operated storage structures

**Practical**

Establishing volumetric capacity of grain bins, lateral pressure of grains in bulk, Storage Losses, moisture content in storage, quality control measures, bioengineering properties, Design of grain storage structures, interaction between environmental factors and causes of spoilage, study of handling equipments, shelf life of fruits and vegetables, limit weight of silage and silo capacities, manure storages

**Suggested Books**

1. Relimbart M and Reimbart A. (1976) Silos: Theory and Practicee, Tranastech Publications.

2. Ojha TP and Michael AM. (2001) Principles of Agricultural Engineering, Vol. I., Jain

3. Brothe4rs, New Delhi.

4. Sahay KM and Singh KK. (2006) Unit Operations of Agricultural Processing, Vikas Publications house Pvt. Ltd., New Delhi.

5. Singh IS. (1987) Post Harvest Handling and Processing of Fruits and Vegetables, Westville Publishing House, New Delhi.

6. Thompson AK. (200) Post Harvest Technology of Fruits and Vegetable, Blackwell Scuebce Ltd. USA.

7. Maintainace and Operation of Bulk Grain Stores, FAO, Agricultural Service Bulletin,113.

8. Grain Storage Techniques, FAO,109.

9. IS: 5061-1974 Specifications for cylindrical storage tower silos and recommendations for their use. Bureau of Indian Standards.

**FS-511 Farm Structures and Environmental Control 2 (2+0)**

**Objective**

The course aims to develop understanding of design of farm structures, constructional details and various systems in dairy and poultry structures and energy efficient environmental control practices.

**Theory**

**UNIT I :** Farm structures, their design, constructional details. Heating, ventilating and exhaust systems, air distribution and air cleaning in dairy structures, poultry house,

**UNIT II :** Thermodynamic properties of moist air, psychorometric chart. Humidification and Dehumidification system, air-water contact operations and evaporation, Process and product air conditioning, energy efficient environmental control practices.

**UNIT III :** Instruments and measurements; Codes and Standards. Plant environment interaction, Thermostatic environment control,

**Suggested Books**

1. Albright LD. 1990. Environmental Control for Animals and Plants. ASAE Textbooks.

2. Esmay ML & Dixon JE. 1986. Environmental Control for Agricultural Buildings. The AVI Corp.

3. Gaudy AF & Gaudy ET. 1988. Elements of Bioenvironmental Engineering. Engineering Press.

4. Moore FF. 1994. Environmental Control Systems: Heating, Cooling, Lighting. Chapman & Hall.

5. Threlkeld JL. 1970. Thermal Environmental Engineering. Prentice Hall.

**FS-512 Handling, Packaging And Transportation 3 (2+1)**

**Objective**

The course aims to develop understanding of food grain conveying equipments, energy calculations in conveying and various packaging methods.

**Theory:**

**Unit I:** Bulk handling of food grains Bulk conveying equipments viz. belt conveyors, screw/auger conveyors, bucket elevators and drag/chains conveyors. Estimation of energy requirement and damage to biomaterials during mechanical handling.

**Unit II:** Operation and maintence of conveying equipment. Packaging requirement, techniques and equipment for liquid. Powder and granular biomaterial and horticultural produce. Types of packaging material, barrier properties.

**Unit III:** CFB boxes, Modified atmosphere packaging, controlled atmosphere packaging, nanocomposite packaging, smart and active packaging, edible films, antioxidant and antimicrobial packaging, RFID, time and temperature indicator, Micro and nano-encapsulation.

**Unit IV:** Transportation of agro-produce by bullock carts, trailers, trucks, rail wagons and containers. Cold chain design and operation Refrigerated containers and trucks for perishable foods. damage and losses during transportation feed handling equipment.

**Practical:**

Estimation of energy requirement and damage during handling, maintenance of conveying equipment, study of CFB boxes, study of packaging material for liquid powder and granular bio material. study of damage to agro produce during transportation.

**Recommended Text Books**

1. Sinha RN and Muir WE (1973) Grain Storage: part of system, the AVI Publishing co., Inc.

2. Pingle SV (2005) Handling and Storage of Food Grains, Indian Council of Agricultural Research, New Delhi.

3. Modern Food Packaging by Indian Institute of Packaging, Mumbai..

4. Handling and Storage of Food Grains in Tropical and Subtropical areas (1980) Food and Agricultural Organization (FAO) of the United Nations.

5. Multon JL (1989) Preservation and Storage of grains, seed and their byproduct: cereals, oilseeds, pulses and animal feed, CBS Publishers and distributor, Delhi.

6. Phirke PS (2004) Processing and Conveying Equipment Design, Jain Brithers, New Delhi

**FS-513 Green House Technology 3 (2+1)**

**Objective**

The course aims to develop understanding of greenhouse technology, components of greenhouse, various systems in greenhouse and economics of greenhouse.

**Theory:**

**Unit I:** History, Development and scope of Green House technology, Green House, shade net house planning, layout and its construction.

**Unit II:** Effect of temperature, R. H. and CO2 with reference to micro climate in Green House crops. Role of light, Ventilation, cooling, heating in Greenhouse. Techno-economic feasibility, cost estimation and erection of low cost Green House and shade net house in the field.

**Unit III:** Utility of Green House and shade net house for different crop production. Covering Material: Maintenance of Green House, Computer application in Green House, irrigation system, fumigation, humidification inside Green House, pest and disease control in Green house,

**Unit IV:** Post harvest Technology, packaging of Vegetables from green house and shade net house.

**Practical:**

History, Scope and development of Green House Technology. Study of different types of Green house and shade net house. To study the components of Green House and shade net house their fabrication erection and constructional details. Design of cooling, heating and ventilation system for green house. Study of green house covering materials. Role of CO2 in Green House and shade net house. Control of light in Green House and shade net house. Maintenance of Green House and shade net house. Maintenance of Green House and shade net house in relation to light temperature and humidity. Study of economics of crop production under Green House and shade net house. Visit to Green House in Maharashtra state. Application of Computer in Green House and shade net house management.

**Recommended Text Books :**

1. Vilas M. Salokhe and Ajay K. Sharma . Greenhouse technolgy and applications Agrotech publishing academy Udaipur (Raj.), First Edition (2006). Phone No. 0294-2465635 Mobile 9414169635.

2. K. Radha Manohar, G. Igathinathane Greenhouse Technology and Management (2nd Edition) BS Publications, 4-4-309, Giriraj Lane, Sultan Bazar, Hyderabad-500 095, A.P. (2007)Phone No. 040 23445677, 23445688,

3. G. N. Tiwari Greenhouse technology for controlled environment Narosa publishing house, New Delhi/Mumbai. (2003 Edition).

4. Paul V. Nelson. Greenhouse operation and management Pentice Hall, New Jersey (Fifth Edition 1998). – 07458

**FS 514 Residue Effluent Waste Management 3 (2+0)**

**Objective**

The course aims to develop understanding of handling and treatments to solid and liquid by-products and equipments for by-product handling.

**Theory**

**UNIT I :** Handling of solid and liquid by-products, characterization, physical/chemical/biological/ Biotechnological/ nanotechnology approaches for their treatment and/or utilization.

**UNIT II :** Biological and chemical oxygen demand of effluents.

**UNIT III :** Design of anaerobic lagoons for animal waste management, Biochemical properties of waste, equipments for waste handling,

**Practical**

1) Analysis of waste water from Dairy Barn

2) Study of management practices of solid waste from Dariy Barm/ poutry house

3) Study of management practices of liquid waste from Dairy Barm/ poutry house

4) Case study of handling of liquid waste.

**Suggested Books**

1. Gurucharan Singh (2000) Water Supply and sanitary Engineering, Standars Publishers Distributors, Delhi.

2. Garg SK (2010) Sewage Disposal and Air Pollution Engineering, Khanna Publishers,

3. Wastewater Treatement and Use in Agriculture, FAO, Irrigation and Drainage, Paper 47

**FS-515 Environmental Impact Assessment 3 (2+1)**

**Objective**

The course aims to develop understanding of environment impact and assessment, environmental auditing.

**Theory**

**Unit I :** Environmental impact assessment (EIA): Definition of EIA and EIS, Methodology of EIA, Organising the job, performing the Assessment, preparation of Environmental Impact Statement, Review of EIS.

**Unit II :** Impact assessment methodologies: Definition and concept of impact; Types of impacts (Negative & Positive: Primary& Secondary; Reversible and Irreversible); Environmental Risk Assessment, Role of EIA in sustainable Development, Environmental Impact Assessment of Hazardous Wastes, Limitation of the EIA. Advantage & disadvantages of EIA methodologies.

**Unit III :** Environmental auditing: Notification and guidelines for Environmental audit; Scope, applicability and objective of environmental audit; procedure of environmental auditing; Audit methodology Environmental Audit Report, benefits of Environmental Audit, Designing and implementation of audit tools - pre auditactivities - on site activities-post audit activities - Environmental statement - benefits of environmental audit- EA scenario in India - submission of Environmental Audit report in MOEF format.

**Practicals**

1. Visit to Industry (Pesticide, Textile, Pharmaceutical industry)

2. To prepared record of Environmental Audit for any Industry.

3. To Prepared Environmental Statement Report for any Industry.

**Recommended Books:**

1. Environment Impact Assessment:

2. Introduction of Environmental Impact Assessment: John Glassion, Rikay Therival and A. Chadwick, UGC Press Ltd., London (1994).

3. Methods of Environmental Impact Assessment: Peter Morris, Ricky Therivel, UGC Press Limited, London (1994)

4.Environmental Engineering and Management-By Suresh K Dhameja S.K Kataria & Sons A кані

## e Resources and List of Journals

*Advances in Applied Research*
*Advances in Computational Sciences and Technology [ACST]*
*Advances in Mechanical Engineering*
*Advances in Water Resources*
*Agricultural Engineering*
*Agricultural Engineering Today*
*Agricultural Mechanization in Asia, Africa and Latin America*
*Agricultural Research*
*Agricultural Reviews*
*Agricultural Science Digest*
*Agricultural Water Management*
*Agronomy Journal (Journal of American Society of Agronomy*
*American Journal of Food Technology*
*American Statistician*
*Annals of Agri Bio Research*
*Annals of Agricultural Research*
*Annals of Arid Zone*
*Annals of Biology*
*Annals of Horticulture*
*Annals of Science*
*Annals of Statistics*
*Applied Ecology and Environmental Research*
*Applied Engineering in Agriculture*
*Applied Ergonomics*
*Arid Land Research and Management*
*Asian Journal of Chemistry*
*Asian Journal of Environmental Science*
*Atmospheric Research*
*Australian Journal of Crop Science*
*Australian Journal of Dairy Technology*
*Beverage and Food World*
*CIGR journal*
*Comptes Rendus Geosciences*
*Computers and Electronics in Agriculture*
*Computers & Industrial Engineering*
*Cotton Research Journal*
*Current Advances in Agricultural Sciences*
*Current World Environment*
*Ecological Engineering*
*Ecology, Environment and Conservation*
*Engineering and Technology in India*
*Environment*
*Environment and Ecology*
*Environmental Engineering Science*
*Environmental Monitoring and Assessment*
*Environmental Science and Pollution Research*
*Environmental Science and Technology*

*Environmental Review*
*Forage Research*
*Groundwater*
*Hydrological Processes*
*IETE Journal of Research*
*IETE Journal of Education*
*Indian Journal of Agricultural Chemistry*
*Indian Journal of Agricultural Research*
*Indian Journal of Agricultural Sciences*
*Indian Journal of Dairy Science*
*Indian Journal of Extension Education*
*Indian Journal of Hill Farming*
*Indian Journal of Radio and Space Physics*
*Indian Journal of Science and Technology*
*Indian Journal of Soil Conservation*
*Indian Research Journal of Extension Education*
*Institute of Engineers (India)*
*Journal of Electronics & Tele Communication*
*International Journal of Agricultural Engineering*
*International Journal of Agricultural Science and Research*
*International Journal of Advance Industrial Engineering*
*International Journal of Advanced Mechanical Engineering [IJAME]*
*International Journal of Advanced Engineering Technology (IJAET)*
*International journal of Advanced Research in Engineering & Technology (IJARET)*
*International Journal of Applied Engineering Research [IJAER]*
*International Journal of Current Engineering and Technology*
*International Journal of Design and Manufacturing Technology(IJDMT)*
*International Journal of Engineering Research and Technology [IJERT]*
*International Journal of Engineering, Science and Metallurgy*
*International Journal of Engineering (IJE)*
*International Journal of Engineering Studies [IJES]*
*International Journal of Environmental Analytical Chemistry*
*International Journal of Environmental Research and Public Health*
*International Journal of Environmental Science and Technology*
*International Journal of Extension Education*
*International Journal of Food Engineering*
*International Journal of Food Microbiology*
*International Journal of Food Properties*
*International Journal of Food Science and Nutrition*
*International Journal of Food Science and Technology*
*International Journal of Food and Fermentation Technology*
*International Journal of Innovative Technology and Exploring Engineering (IJITEE)*
*International Journal of Industrial Engineering & Technology*

*[IJIET]*
*International Journal of Industrial Engineering Research and Development (IJIERD)*
*The International Journal of Industrial Engineering: Theory, Application and Practice (IJIETAP)*
*International Journal of Engineering and Management Research (IJEMR)*
*International Journal of Engineering Sciences and Management*
*International Journal of Industrial Engineering Computations*
*International Journal of Engineering and Manufacturing Science [IJEMS]*
*International Journal of Research in Chemistry and Environment*
*International Journal of Research In Mechanical Engineering And Technology (IJRMET)*
*International Journal of Thermal Sciences*
*International Journal of Mechanical Engineering and Robotics Research*
*International Journal of Material and Mechanical Engineering*
*International Journal of Mechanical Engineering & Technology(IJMET)*
*International Journal of Mechanical Engineering and Research(IJMER)*
*International Journal of Mechanical Sciences*
*International Journal of Recent Technology and Engineering(TM) Exploring Innovation*
*International Journal of Industrial & Production Engineering & Tech. [IJIPET]*
*International Journal of Industrial and Systems Engineering*
*International Journal of Advanced Materials Science [IJAMS]*
*International Journal of Research in Mechanical Engineering*
*International Journal of Engineering & Technology Research*
*International Review of Applied Engineering Research [IRAER]*
*International Journal of Mechanical and Materials Engineering*
*International Journal of medical, Health, Biomedical, Bioengineering and Pharmaceutical Engineering*
*International Journal of Production Technology and Management (IJPTM)*
*International Journal of Refrigeration*
*International Journal of Remote Sensing*
*International Journal of Thermal Technologies*
*International Journal of Water Resources Development*
*International Journal on Agricultural Sciences*
*International Journal on Environmental Sciences*
*International Journal of Applied Research on Information Technology and Computing*
*International Journal of Mechanical Engineering*
*International Journal of Mechanical and Production Engineering Research and Development*
*International Scholarly Research Notices, ISRN Mechanical Engineering*

*Irrigation Science*
*Irrigation and Drainage (ICID Bulletin)*
*Irrigation and Drainage System*
*Italian Journal of Food Science*
*Journal of Agricultural Engineering (ISAE)*
*Journal of Agriculture Research and Technology*
*Journal of Agricultural Safety and Health*
*Journal of Applied Ecology*
*Journal of Applied Probability*
*Journal of Applied Statistics*
*Journal of Arid Environments*
*Journal of Cotton Research and Development*
*Journal of Dairy Research*
*Journal of Dairy Science*
*Journal of Ecology*
*Journal of Energy Engineering - ASCE*
*Journal of Engineering*
*Journal of Engineering computers and Applied Sciences*
*Journal of Engineering Research*
*Journal of Ergonomics*
*Journal of Environmental Engineering*
*Journal of Environmental Monitoring*
*Journal of Environmental Protection and Ecology (JEPE)*
*Journal of Environmental Sciences*
*Journal of Environmental Science and Engineering*
*Journal of Environmental Science, Toxicology and Food Technology*
*Journal of Food Biochemistry (Journal of Food Lipids)*
*Journal of Food Composition and Analysis*
*Journal of Food Engineering*
*Journal of Food Legumes*
*Journal of Food Process Engineering*
*Journal of Food Processing and Preservation*
*Journal of Food Quality*
*Journal of Food Safety*
*Journal of Food Science*
*Journal of Food Science and Technology*
*Journal of Food, Agriculture and Environment*
*Journal of Human Ecology*
*Journal of Hydraulic Engineering – ASCE*
*Journal of Hydraulic Research*
*Journal of Hydrologic Engineering*
*Journal of Hydrology*
*Journal of Indian Society of Agricultural Statistics*
*Journal of Indian Water Resources Society*
*Journal of Industrial Engineering International*
*Journal of Irrigation and Drainage Engineering (ASCE)*
*Journal of Mechanical Engineering*
*Journal of Materials in Civil Engineering*
*Journal of Manufacturing Processes*

*Journal of Research, PAU*
*Journal of Soil and Water Conservation*
*Journal of Soil and Water Conservation, India*
*Journal of Statistical Computation and Simulation*
*Journal of Statistical Planning and Inference*
*Journal of Statistical Theory and Practice*
*Journal of Stored Products Research*
*Journal of Sustainable Agriculture*

# Restructured and Revised Syllabi of Post Graduate Programmes

# M. Sc. and Ph. D. (Agriculture)

# in

# Irrigation Water Management

**Compiled**
**by**

**Broad Subject Co-ordinator**
**Associate Dean,**
**Dr. Annasaheb Shinde College of Agricultural Engineering and Technology, MPKV, Rahuri**

**Discipline Coordinator**
**Professor and Head (IWM)**
**College of Agricultural Engineering and Technology, Dr. BSKKV, Dapoli**

# CONTENTS

# Preamble

A scarce natural resource, water is fundamental to life, livelihood, food security and sustainable development. India has more than 18 % of the world's population, but has only 4% of world's renewable water resources and 2.4% of world's land area. There are further limits on utilizable quantities of water owing to uneven distribution over time and space. In addition, there are challenges of frequent floods and droughts in one or the other part of the country. With a growing population and rising needs of a fast developing nation as well as the given indications of the impact of climate change, availability of utilizable water will be under further strain in future with the possibility of deepening water conflicts among different user groups.

Agriculture is the backbone of Indian economy, which contributes nearly 35 per cent to national income and engages 70 per cent of population.

Low consciousness about the scarcity of water and its life sustaining and economic value results in its mismanagement, wastage, and inefficient use, as also pollution and reduction of flows below minimum ecological needs.

The continued escalating growth of human and animal population has put tremendous pressure on the natural resources, particularly land and water. The per capita availability of precious water has declined drastically in past few years. Water supply is limited worldwide usually face acute water scarcity. Therefore, judicious use of water will be a key point in agriculture development for future, both in the irrigation and rainfed areas. This scarce water resource has to be put to use with highest efficiency. In this context, irrigation water management in the field is an answer to increase water use efficiency and crop production.

In the incoming New Education Policy of Govt. of India emphasis has given on multi-disciplinary approach in education and research. In this context the Department of Irrigation Water Management is one example in which the academic and research work related to agronomy, soil science, irrigation and drainage engineering, agricultural economics is going on since 1986.

## Committee for Irrigation Water Management

| ICAR-BSMA Broad Subject | ICAR-BSMA Approved Disciplines | Degree Programmes | | Broad Subject Coordinator (Chairman of all Disciplines' Sub-Committees | Discipline Coordinator (Secretary of respective Discipline Sub-Committee) |
|---|---|---|---|---|---|
| **Physical Science** | **Irrigation Water Management** | M.Sc. (Agri.) | Ph.D. (Agri.) | **Dr D. D. Pawar**, Associate Dean, Dr. A. S. College of Agril. Engineering, MPKV, Rahuri. | **Dr. M. S. Mane** Prof. and Head Dept. Interfaculty Department of Irrigation Water Management, PGI, MPKV, Rahuri |

**Sub-Committee constituted for the finalization of common syllabi in Soil Science Disciplin**

| Sr. No | Sub-Committee | |
|---|---|---|
| 1 | **Dr D. D. Pawar**,<br>Associate Dean,<br>Dr. A. S. College of Agril. Engineering, MPKV, Rahuri.<br>Email:ddpawar1@rediffmaill.com<br>Mobile: 9422082858 | Broad Subject Coordinator |
| 2 | **Dr. M.S.Mane**<br>Head ,IFD-IWM,MPKV,Rahuri.<br>Email:mahanandmane9@gmail.com<br>Mobile: 9423295619 | Discipline Coordinator |
| 3 | **Dr. K.D.Kale**<br>Asstt.Prof.Soil Science and Agricultural Chemistry,<br>MPKV, Rahuri<br>E-mail:kd_kale@rediffmal.comMobile<br>Mobile: 9850558598 | Memebr |
| 4 | **Dr. D.D.Khedkar**<br>Asstt.Prof. of Irrigation and Drainage Engineering<br>E-mail: devidaskhedkar@gmail.com<br>Mobile: 9822584985 | Memebr |
| 5. | **Dr. R.M.Gethe**<br>Associate Professor, Agronomy, MPKV, Rahuri<br>E-mail : rajendragethe15@gmail.com<br>Mobile :8208293924 | Memebr |
| 6 | **Dr. N. J. Danawale**<br>Associate Prof. of Agronomy, MPKV, Rahuri<br>E-mail: n iteendanawale@rediffmail.com<br>Mobile: 9309890825 | Memebr |
| 7 | **Dr. S. U. Bhoite**<br>Asstt.Prof. of Mathematics,<br>MPKV, Rahuri<br>E-mail: subhoite123@gmail.com<br>Mobile: 9881895137 | Memebr |

## Implementation of New Curriculum

The universities offering PG programmes in Irrigation Water Management needs to be supported for establishing specialized laboratories equipped with state-of-the art equipment's for conducting practical classes especially, Soil Genesis, Soil Classification , Soil Survey , Soil fertility, Soil Water and Plant analysis, Soil management, Water management, , Conservation Agriculture, Remote sensing and GIS, Precision Agriculture, Nano technology & Organic farming. One-time catch-up grant should be awarded to each SAU, offering PG programmes in Irrigation Water Management for meeting expenditure for upgrading the course requirements.

Faculty training and retraining should be an integral component. For imparting total quality management, a minimum of two faculties in each department under SAU should be given on job training in reputed national and international institutes. To execute the new PG and Ph.D. programmes in Irrigation Water Management discipline in effective manner, special funds from ICAR would be required for outsourcing of faculty from Indian/Foreign Universities for some initial years.

The already existing M.Sc. and Ph.D. Programmes in Irrigation Water Management will be considered at par with the recommended M.Sc. & Ph.D. programme by V$^{th}$ Deans Committee for admission and employment.

**Expected Outcome**

- Revamping of post graduate programme in whole of irrigation water managementr throughout the country.
- Imparting quality education.
- Development of technical manpower to cater the need of farmers governments, corporate sector and research organization in India and abroad.
- Exposure to the faculty in the latest technical knowhow.

# Organization of Course Contents & Credit Requirements

**Minimum Residential Requirement:**

**M.Sc.: 4 Semesters**

**Ph.D.: 6 Semesters**

**Name of the Departments / Divisions**

Interfaculty Department of Irrigation Water Management

**Nomenclature of Degree Programme**

**(a) M.Sc. Programmes**

i) M.Sc. (Agri.) in Irrigation Water Management

**(b) Ph.D. Programmes**

i) Ph.D. (Agri.) in Irrigation Water Management

**Code Numbers**

- All courses are divided into two series: 500-series courses pertain to Master's level, and 600- series to Doctoral level.
- Credit Seminar for Master' s level is designated by code no. 591 and the Two Seminars for Doctoral level are coded as 691 and 692, respectively
- Master's research: 599 and Doctoral research: 699

**Course Contents**

The contents of each course have been organized into:

- Objective – to elucidate the basic purpose.
- Theory units – to facilitate uniform coverage of syllabus for paper setting.
- Suggested Readings – to recommend some standard books as reference material. This does not obviously exclude such a reference material that may be recommended according to the advancement and local requirement.
- A list of international and national reputed journals pertaining to the discipline is provided at the end which may be useful as study material for 600/700 series courses as well as research topics.
- Lecture schedule and practical schedule has also been given at the end of each course to facilitate the teacher to complete the course in an effective manner.

## Eligibility for Admission

### Master's Degree Programme

### M.Sc. (Agri.) Irrigation Water Management

B.Sc.(Agri.) /B. Sc. (Hons.) Agriculture/ B.Sc.(Hort.) / B.Sc. (Hons.) Horticulture under 10+2+4 system with minimum of 5.50/10 or equivalent percentage of marks or equivalent degree in SAU's/ ICAR and having passed the Common Entrance Test in Agriculture conducted by competent authority.

Deficiency courses of 6 to 10 credits will be given to the candidate as per the Student Advisory Committee (SAC) recommendation.

### Doctoral Degree Programme

### Ph.D. (Agri.) Irrigation Water Management

Master Degree in the discipline of Irrigation Water Management / Soil Science / Agronomy from SAU's / ICAR and appeared Common Entrance Test conducted by competent authority.

## Credit Requirements

| **Course Details** | **Master's Degree** | **Doctoral Degree** |
|---|---|---|
| Major Courses | 20 | 12 |
| Minor Courses | 08 | 06 |
| Supporting / Optional | 06 | 05 |
| Common PGS Courses | 05 | - |
| Seminar | 01 | 02 |
| Research | 30 | 75 |
| **Total** | **70** | **100** |

# Course Layout and Structure of Masters Degree

## LIST OF CORE COURSES/ COMPULSORY/SUPPORTING COURSES

**Major courses (12+8 credits):**

| Sr. No. | Course Code | Semester | Course Title | Credit Hours |
|---|---|---|---|---|
| 1. | IWM-511* | I | Water Resources Planning and Management | 3(2+1) |
| 2. | IWM- 512 | I | Soil Water Plant Environment Relationship | 3(2+1) |
| 3. | IWM- 513* | I | Agro Meteorological Applications in Irrigation Water Management | 3(2+1) |
| 4. | IWM- 521* | II | Crop Water Requirements and Irrigation Scheduling | 3(2+1) |
| 5. | IWM- 522 | II | Farm Irrigation Systems and Design | 3(2+1) |
| 6. | IWM- 523* | II | Soil and Water Quality for Irrigation | 3(2+1) |
| 7. | IWM -531 | III | Economic Issues in Water Resources Management | 2(1+1) |
| 8. | IWM -510 | I | Soil Erosion and Conservation | 3(2+1) |
| 9. | IWM -520 | II | Principles and Practices of Water Management | 3(2+1) |
| 10 | IWM-591* | III | Master's Seminar | 1(1+0) |
| | | | **Total** | **27(18+9)** |
| 11 | IWM - 599 | III &IV | Master's Research | 0+30 |

*Core courses and Compulsory Courses

## Minor and Supporting Courses for Masters Degree

**Minor Courses: (8 credits)**
**Minor Disciplines:**

1. Irrigation and Drainage Engineering
2. Agronomy
3. Plant Physiology
4. Soil Science and Agril. Chemistry
5. Agricultural Economics
6. Agricultural Extension

Following is the list of suggestive minor courses.Students will be required to complete minor courses (8 credits) from the below courses from minor disciplines related to the major discipline in which student admitted and as decided by the Student Advisory Committee.

**Suggestive List of Minor Courses**

| Course Code | Semester | Course Title | CreditHours |
|---|---|---|---|
| IWM 514 | I | Cropping Systems and Sustainable Agriculture | 2(1+1) |
| IWM 515 | I | Principles of Agricultural Land Drainage | 2(1+1) |
| IWM 517 | I | Watershed Development and Management | 3(2+1) |
| IWM 518 | I | Soil Fertility and Fertilizer Use | 2(1+1) |
| IWM 519 | I | Principles and Practices of Protective Cultivation | 2(1+1) |
| IWM 524 | II | Applications of Remote Sensing and GIS in Agriculture | 3(2+1) |
| IWM 526 | II | Basic Soil Physics | 2(1+1) |
| IWM-527 | II | Fertigation | 2(1+1) |
| IWM 528 | II | Principles of Organic Farming | 3(2+1) |
| IWM -529 | II | Evapotranspiration | 2(1+1) |
| IWM 532 | II | Social Issues in Water Resources Management | 2(1+1) |
| IWM- 533 | III | Water Resources System Analysis | 3(2+1) |
| IWM -534 | III | Economic Evaluation of Irrigated Crops and Irrigation Projects | 2(1+1) |
| PP-504 | I | Physiological and Molecular responses of plant to abiotic stress | 2(1+1) |
| AEC -511 | III | International Economics | 2(1+1) |
| EXT- 508 | I | Managing extension organization | 3(2+1) |

**Supporting Courses Disciplines (6 credits):**

1. Statistics
2. Mathematics
3. Computer Science and Information Technology
4. Irrigation and Water Management

Followings are the list of suggestive supporting courses.Students will be required to complete supporting courses (6 credits) from the below courses and may be taken other courses from above disciplines related to the major discipline in which student admitted and as decided by the Student Advisory Committee.

**Suggestive List of Supporting Courses:**

| Course Code | Semester | Course Title | Credit hrs. |
|---|---|---|---|
| IWM–516 | I | Applied Mathematics for Irrigation Water Management-I | **1+1=2** |
| MCA 513 | I | Mathematics for applied sciences | **2+0=2** |
| IWM–525 | II | Applied Mathematics for Irrigation Water Management-II | |
| STAT-502 | I | Statistical Methods for applied sciences | **3+1=4** |
| STAT– 511 | II | Experimental Design | **2+1=3** |
| STAT-522 | II | Data analysis using statistical packages | **2+1=3** |

**Compulsory Non Credit Common PGS Courses: (5 Credits)**

| Course code | Semester | Course Title | Credits |
|---|---|---|---|
| PGS 501 | I | Library and Information Services | 0+1=1 |
| PGS 504 | II | Basic Concepts in Laboratory Techniques | 0+1=1 |
| PGS 502 | I | Technical Writing and Communications Skills | 0+1=1 |
| PGS 503 | II | Intellectual Property and its management in Agriculture | 1+0=1 |
| PGS 505 | III | Agricultural Research, Research Ethics and Rural Development Programmes | 1+0=1 |
| PGS 506 | III | Disaster Management | 1+0 |

## Course Layout and Structure of Doctoral Degree

**LIST OF CORE COURSES/ COMPULSORY/SUPPORTING COURSES**

**Major courses (12 credits): (6 credits of core plus 6 credits of optional)**

| Course Code | Semester | Course Title | Credit hrs. |
|---|---|---|---|
| IWM 611* | I | Advances in farm irrigation System Design | 2 + 1 = 3 |
| IWM-612 | I | Drought Climatology | 2 + 1 = 3 |
| IWM-613* | I | Recent trends in Soil Physics | 2 + 1 = 3 |
| IWM-616 | I | Integrated Farming Systems for Sustainable Agriculture | 2 + 1 = 3 |
| IWM-621 | II | Diagnostic Analysis & Performance Evaluation of Irrigation Projects | 2 + 1 = 3 |
| IWM-622 | II | Plant Growth Modeling and Simulation | 2 + 1 = 3 |
| IWM-631 | III | Management of Saline, Sodic and Acidic Soils | 2 + 1 = 3 |
| **Seminar** | | | |
| IWM–691* | III | Doctoral seminar I | 0+1 =1 |
| IWM–692* | IV | Doctoral seminar II | 0+1=1 |
| | | Total | 14+9 = 23 |
| **Research** | | | |
| IWM–699 | | Doctoral Research | 75 |

*Indicates Core Courses which are Compulsory for Ph.D Programme

## Minor courses:

Students will be required to complete minor courses (6 credits) from the below courses from minor disciplines.

**Minor Disciplines (6 credits):**

1. Irrigation and Drainage Engineering
2. Irrigation and Water Management
3. Agronomy
4. Soil Science and Agril. Chemistry
5. Agricultural Economics
6. Agricultural Extension

Followings are the list of suggestive minor courses.Students will be required to complete minor courses (6 credits) from the below courses from minor disciplines related to the major discipline in which student admitted and as decided by the Student Advisory Committee.

**Suggestive Minor courses:**

| Course Code | Semester | Course Title | Credit hrs. |
|---|---|---|---|
| IWM 614 | I | Watershed Management and Modelling | 2+1=3 |
| IWM 615 | I | On Farm Water Management | 1 + 1 = 2 |
| IWM 626 | II | Soil, Water and Air Pollution | 2 + 1 = 3 |
| AGRON 607 | II | Stress Crop Production | 1 + 1 = 2 |
| IWM 623 | II | Soil Survey applications in Irrigation Water Management | 1 + 1 = 2 |
| AGRON 606 | III | Recent trends in crop growth productivity | 2+1=3 |
| AGRON 603 | II | Irrigation Management | 2+1=3 |

## Supporting Courses:

Students are required to complete supporting courses of 5 credits from any of the following disciplines.

**Supporting Courses disciplines (5 credits):**

1. Statistics
2. Mathematics
3. Computer Science and Information Technology
4. Soil Science and Agril. Chemistry
5. Irrigation and Drainage Engineering
6. Agricultural Economics

Followings are the list of suggestive supporting courses.Students will be required to complete supporting courses (5 credits) from the below courses and may be taken other courses from above disciplines related to the major discipline in which student admitted and as decided by the Student Advisory Committee.

**Suggestive List of Minor courses**

| Course Code | Semester | Course Title | Credit hrs. |
|---|---|---|---|
| IWM 624 | II | Computer Applications in Irrigation Water Management | 1+1=2 |
| IWM-625 | II | Application of Remote Sensing & GIS in Agriculture | 2 + 1 = 3 |
| IWM -632 | III | Economic Analysis of Irrigation Water Use | 1 + 1 = 2 |
| IWM-634 | III | Environmental Impact Assessment of Irrigation Projects | 1 + 1 = 2 |

# Course Syllabus and Contents of Masters Degree

**IWM- 511 Water Resources Planning and Management 3 (2+1)**

**Theory:**

**UNIT I**
Concepts and historical background of Irrigation. Necessity, advantages and disadvantages of Irrigation. India's water resources and their development. Irrigation scenario in Maharashtra state. Impact of climate change onw ater resources and its availability in space and time, Interlinking of rivers.
**UNIT II**
Hydrologic process, Estimation of parameters of hydrologic cycle – rainfall, runoff and soil water balance. Infiltration characteristics, soil moisture constants. Irrigation Systems multidisciplinary approach, role of each discipline. Duty and delta of crop, duty at various places, factors affecting duty, certain important terminology for canal irrigation: GCA & CCA, Reservoir storage terminology, Distribution system for canal command area, Canal seepage and lining of canal, diversion head works and canal head regulators, cross drainage works,
**UNIT III**
Hydraulics of open channel flow; terminology. Design of open channel, Field channel, outlet (chak design), minors, water distribution structures. Water measuring devices.
**UNIT IV**
Major Irrigation projects in India. Approach methodology for conducting survey and formulation of projects. Performance and Bench marking of irrigation projects. Principles of command area development in India: Composition and functions. Water User's Association.
**UNIT V**
Aquifer and its types; classification of wells, artificial groundwater recharge techniques; water lifting devices; classification of pumps, component parts of centrifugal pumps, propeller pumps, mixed flow pumps, deep well turbine pump and submersible pump priming, pump selection, installation, effect of speed on capacity, head and power,

**Practical:**

| Sr. No. | Practical |
|---|---|
| 1-2 | Irrigation water requirement of crops based on duty, delta concept |
| 3-4 | Preparation of layout of canal irrigation network. |
| 5-6 | Determination of field capacity and PWP of soil by pressure plate apparatus. |
| 7 | Measurement of infiltration rate of soil |
| 8 | Design of open channel |
| 9 | Study of different water measuring devices. |
| 10<br>11 | Installation and testing of centrifugal and submersible pump. |
| 12-13 | Study of canal outlets |
| 14-16 | Visit to irrigation project and study on WUAs |

**Suggested Readings :**

**Irrigation Theory and Practice by A.M. Micheal.**

Irrigation Engineering and hydraulics Structures by S.K. Garg.

Water well and pump engineering (9th Edition, 2005) by A.M.Michael and S.D.Khepar

**Special course on " Dignostic Analysis for Trainers", WALMI, Aurangabad ( May 27-July 6, 1985).**

**Operation and management of irrigation system WALMI Publ. No. 20, 1987.**

**Warabandi systems and its infrastructure. Pub. No. 157, Central Board of Irrigation and Power, New Delhi, April 1982.**

**On farm development works. WALMI Publ. No. 12, 1986.**

**Warabandi for Irrigated Agriculture in India. Pub. No. 146, Central Board of Irrigation and Power, New Delhi, June, 87.**

**IWM-512 Soil Water Plant Environment Relationship 3(2+1)**

**Theory**

**UNIT I**

Soil characteristics in relation to irrigation, soil hydraulic properties. Dynamic properties of soils; soil consistency, soil plasticity, soil physical constraints that affect crop production, Management of physically constrained soils

**UNIT II**

Soil water properties, water structure, energy concepts of soil water, redox potential, soil water retention, soil water movement under saturated and unsaturated conditions, solute transfer in soil- Effect of solute on water movement, driving force, hydraulic conductivity.

**UNIT III**

Soil salinity and alkalinity, salt balance of the profile.

**UNIT IV**

Function and structure of root, root growth in relation to soil physical environment, Processes involved in root growth, constraints involved in root growth.

**UNIT V**

Essential nutrients, functions and deficiency symptoms, concept of nutrient availability, Nutrient movement, nutrient uptake by plants and nutrient use efficiency. Movement and uptake of ion, uptake properties of root, pathways of cell to cell, cell wall, root-shoot relationship, ion uptake mechanism, plant growth in terms of yield availability.

**UNIT VI**

Plant water relations, role of water in plants, concept of water potential, components of water potential and their measurements, water relationships of cell and whole plant, water and ion uptake and movement mechanism in plant systems.

**UNIT VII**

Water loss through plants (transpiration) and factors affecting transpiration, Soil strength, soil water status, soil temperature, soil aeration status, variation of water potential and flux in soil plant system.

**UNIT VIII**

Soil-water-plant-atmosphere continuum, energy balance at crop surface and measurement of crop evapotranspiration, weather parameters and measurements,

**UNIT IX**

Climatic factors influencing crop water loss, aridity indices, water stress in relation to plant physiological processes, influence of water stress on crop yield.

**Practical :**

| Sr. No. | Practical |
|---|---|
| **1.** | Estimation of evapotranspiration losses under water limiting and excess water conditions |
| **2.** | Estimation of transpiration losses. |

| | |
|---|---|
| **3.** | Determination of water profile changes during infiltration in vertical soil column |
| **4.** | Estimation of water movement during horizontal infiltration in soil |
| **5.** | Determination of weighted mean diffusivity, sorptivity and penetration coefficient. |
| **6.** | Measurement of soil water potential by psycrometer method |
| **7.** | Measurement of hydraulic conductivity and diffusivity by Bruce and Klute method |
| **8.** | Estimation of leaf diffusion resistance |
| **9.** | Measurement of canopy temperature, |
| **10.** | Determination of components of water balance in a cropped field. |

**Suggested Readings :**


1. Doorenbos, J. and Pruitt, W.O. 1975. Crop water requirements. FAO Irrigation and Drainage, paper 24, Rome Italy.
2. Hillel, D. 1977. Soil and water : Physical principles and processes. Academic Press. Inc. New York.
3. Richards, L.A. 1975. Retention and transmission of water in soil. Year Book of Agriculture. 14-151.
4. Slatyer, R.O. 1967. Plant water relations. Academic Press, New York.
5. Turner, A.K. Willatt, S.T., Wilson, J.H. and Jobling, G.A. 1984. Soil water management IDP, Canbera, Australia.
6. Hillel D. Environmental soil physics

**IWM-513* Agrometeorological Applications in Irrigation Water Management 3(2+1)**

**Theory**

**UNIT I**

Meaning and scope of agricultural meteorology; components of agricultural meteorology; role and responsibilities of agricultural meteorologists. Importance of meteorological parameters in agriculture. Agro-climatic zones and agro-ecological regions of India.

**UNIT II**

Efficiency of solar energy conversion into dry matter production; meteorological factors in photosynthesis, respiration and net assimilation; Basic principles of water balance in ecosystems; soil-water balance models and Different water production functions for yield assessment.

**UNIT III**

Crop weather calendars. weather forecasts for agriculture at short, medium and long range levels; Agromet advisories services (AAS), Preparation, Dissemination and Economic Impact analysis; use of satellite imageries in weather forecasting. Synoptic charts and synoptic approach to weather forecasting.

**UNIT IV**

Concept, definition, types of drought and their causes; prediction of drought; crop water stress index, crop stress detection Contingent crop planning for aberrant weather condition in dry land agriculture. Air pollution and its influence on vegetation. Concepts of mechanistic and determination of different models. General features of dynamical and statistical modelling techniques. Weather data and phenology-based approaches in crop modelling. its validation and testing of models.

**UNIT V**

Climatic change, Green house effect, $CO_2$ increase, global warming and their impact on agriculture Climate classification. Extreme climate events, its effect on Agriculture.

**Practical**

| Sr.No. | Practical |
|---|---|
| 1. | To Prepare crop weather calendars for Paddy crop. |
| 2. | To Prepare crop weather calendars for *kharif* Sorghum crop. |
| 3. | To Prepare crop weather calendars for *kharif* Groundout crop. |
| 4. | To Prepare crop weather calendars for *kharif* Maize crop. |
| 5. | To Prepare crop weather calendars for cotton crop. |
| 6. | To Prepare crop weather calendars for Sugarcane crop. |
| 7. & 8. | To prepare weather based Agro-Advisory services (AAS) |
| 9. & 10. | Orientation of weather simulation model for different crops- Empirical statistical model crop weather modelling, Dynamic simulation model CERES models for Rice. |
| 11. & 12. | Orientation of weather simulation model for pest and disease related to different crops. |
| 13. & 14. | Visit and study of Auto weather station (AWS) |
| 15. & 16. | Visit to Agrometerological observatory at AICRP on water management Project |

**<u>Suggested Books</u>**

1. Agricultural Meterology by G.S.H.V. Prasad Rao
2. Principles of Agronomy by Yellamanda Reddi & G.H. Sankara Reddi

**IWM-521* Crop Water Requirement and Irrigation Scheduling 3 (2+1)**

**Theory**

**UNIT I**

Concept of crop water requirement, Water requirement of different Agronomic crops. Evaporation, Transpiration, Evapo-transpiration, Potential and reference crop evapotranspiration and consumptive use of water.

**UNIT II**

Soil moisture characteristics curve, Criteria for scheduling of irrigation, different approaches to irrigation scheduling, Real time irrigation scheduling. Methods for estimation of ET – Lysimeter, field experimental plots, soil moisture depletion studies, Water balance method. Estimation of evapotranspiration from climatological data: Penman-Monteith (FAO 56), Hargreaves-Samani.

**UNIT III**

Soil moisture measurement approach, methods for measurement of soil moisture/tension- tensiometer, neutron probe, infrared moisture meter, gravimetric, electrical resistance and soil moisture sensor.

**UNIT IV**

Depth of irrigation: Net irrigation requirement, Gross irrigation requirement, water requirement, factors affecting irrigation water requirement, effective rainfall, Different irrigation efficiencies.

**UNIT V**

Crop response functions to irrigation, matching of net irrigation demand to water supply characteristics through modification of irrigation technology. Concept of critical stages of crop growth in relation to water supplies, Crop coefficients. Deficit irrigation strategies.

**UNIT VI**

Crop planning in relation to changing Scenario of input availability. Impact of climate change on crop water requirement.

**Practical**

| Sr. No. | Practical |
|---|---|
| 1-3 | Measurement of soil moisture by gravimetric, tensiometer, gypsum block, neutron probe and soil moisture sensor |
| 3 | Determination of bulk density by core sampler method |
| 4 | Estimation of Irrigation requirements of crops |
| 5 | Scheduling of irrigation by IW/CPE ratio |
| 6 | Scheduling of irrigation based on Climatological data |
| 7 | Study of real time irrigation scheduling. |
| 8-9 | Estimation of irrigation efficiencies. |
| 10-11 | Study of CROPWAT model |
| 12-13 | Estimation of evapotranspiration based on climatological data by Penman- Monteith and Hargreaves-Samani. |
| 15-16 | Visit to Meteorological laboratory and Instructional farm of IFD-IWM, MPKV, Rahuri. |

**Suggested Books:**

1. Allen, R.G., L.S. Pereira, D. Raes and M. Smith. 1998. Crop Evapotranspiration, Guideline for Computing Crop Water Requirements. FAO Irrigation and Drainage, Paper 56.
2. Irrigation : Theory and Practice by A.M. Michael
3. Doorenbos, J. and Pruitt, W.O. 1975. Crop water requirements, FAO Irrigation and Drainage, paper 24, Rome Italy.
4. Integrated Water Management for Crop Production. Edited by B.N. Shinde and N.N. Firake
5. Principles and practices of water management, Panda S.C. (2005)

6. Irrigation Water management principles and practices, Published by Prentice Hall of India pvt Ltd; New Delhi, by Dilip Kumar Mujumdar (2002)
7. Efficient use of Irrigation Water, Kalyani publishers, New Delhi by G.H. Shankara Reddi and T. Yellamanda Reddy (2002)
8. Principles of Agronomy, kalyani publishers, New Delhi, S.R. Reddy 1999
9. Principles of Agronomy by Yellamanda Reddi & G.H. Sankara Reddi

**IWM-522*    Farm Irrigation Systems and Design    3 (2+1)**

**Theory:**

**UNIT I**

Farm resources inventory, land leveling, Water measuring devices: weirs/notches, parshall flume, cut throat flume, orifices

**UNIT II**

Surface irrigation methods and their classification, Factor influencing irrigation methods. Advantage and disadvantages and selection criteria of irrigation methods, irrigation efficiencies. Design concepts for border, furrow and check basin methods. Hydraulics of advance and recession of waterfront. Surge flow irrigation technique. Evaluation of surface irrigation systems and practices.

**UNIT III**

Concept of pressurised irrigation, Types of pressurised irrigation systems. Micro-irrigation; Concept, advantages and limitations, components, pipe distribution network. Preliminary design criteria of pressurized irrigation systems, estimation of water requirement,

**UNIT VI**

Drip design procedure: Selection of emitters, design of lateral, manifold, submain, main and pump, Head loss through emitter, lateral. Drip design problems. Case studies on vegetables, sugarcane and orchard crops. Filtration: necessity, phenomenon, types, filtration capacity. Fertigation. Care and maintenance of system. Clogging of emitters, acidification, chlorination. Automated fertigation unit.

**UNIT V**

Cost estimation Evaluation. Sprinkler irrigation systems: Concept, advantages and limitations. System components, layouts, types of sprinkle systems. Uniformity coefficient. Design and layouts of system, Selection of nozzles, Case studies. Automation in Irrigation – IoT based smart irrigation, sensor based automation and weather based automation.

**Practical:**

| **Sr. No.** | **Practical** |
|---|---|
| 1-3 | Preparation and Evaluation of border, furrow and check basin layouts |
| 4 | Study of different components and types of sprinkler irrigation system. |
| 5-6 | Design and installation of sprinkler irrigation system. |
| 7 | Study of different components of drip irrigation. |
| 8-9 | Design and installation of drip irrigation system. |
| 10 | Study of pressure-discharge relationship of sprinkler nozzles and drippers |
| 11 | Determination of uniformity coefficient and emission uniformity |
| 12 | Study of different fertilizer applicator devices. |
| 13 | Study of different types of filters and determination of filtration efficiency. |
| 14 | Acidification and chlorination of drip irrigation system |
| 15 | Evaluation of sprinkler and drip system |
| 16-17 | Visit to Irrigation park and Instructional farm of IFD-IWM, MPKV, Rahuri. |

**Suggested Readings :**


1. Principles of Sprinkler Irrigation by M. S. Mane and B. L. Ayare
2. Principles of Drip Irrigation Systems by M. S. Mane, B. L. Ayare and S. S. Magar.
3. Irrigation: Theory and Practice by A.M. Micheal
4. Surface Irrigation : Systems and Practice by Melvyn kay
5. Land and Water Management Engineering by V.V.N. Murthi
6. Operation and Management of Irrigation Systems. WALMI Pub. No.20, 1987.
7. Integrated Water Management for Crop Production. Edited by B.N. Shinde and N.N. Firake
8. Finkel HJ. 1983. *Handbook of Irrigation Technology*. Vols. I-II. CRC Press.
9. Ivan E Henk. 1951. *Irrigation Engineering*. Vol. I. John Wiley & Sons.
10. Karmeli D, Peri G & Todes M. 1985. *Irrigation Systems: Design andOperation*. Oxford Univ. Press.
11. Trickle Irrigation for Crop Production: Design, Operation and Management by F.S. Nakayama and D.A. Bucks.
12. Sprinkle and Trickle Irrigation by Jack Keller and R.D. Bliesner
13. Trickle Irrigation design by Jack Keller and D. Karmeli.
14. Drip Irrigation by R.K. Sivanappan, O.Padmakumari and V. Kumar.
15. Design, Operation and Maintenance of Drip Irrigation, MPKV Pub. No.55
16. Sprinkler Irrigation by R.K. Sivanappan 1987.
17. Design of trickle irrigation by D. Karmeli and J. Keller.
18. Pillsbury AF. 1972. Sprinkler Irrigation. FAO Agricultural Development Paper No. 88, FAO
19. Rydzewski 1987. Irrigation Development Planning. John Wiley & Sons.

**IWM 523*   Soil and Water Quality for Irrigation   3 (2+1)**

**Theory**

**UNIT I**

Soil quality and soil health: specific soil functions, Assessment of soil quality, factors affecting soil quality, Processes and factors of soil formation, Types of soils, soil physical and chemical properties, Texture, structure, soil reaction (pH), soil air, soil temperature.

**UNIT II**

Soil degradation-salinity, alkanity, sodicity, acidity, soil pollution. Characteristics of saline, saline-sodic soils, crop tolerance to salinity and alkalinity, acid soils, Effects of salts on plant nutrient availability in problem soils.

**UNIT III**

Fertilizer and cultural management in saline and alkali soils, G.R., L.R. use of brackish water for irrigation. Management practices for improving the soil conditions.

**UNIT IV**

Sources of water for irrigation. Quality and compositions of irrigation water, evaluation of irrigation water- salinity, sodium carbonate, bicarbonates, chlorides, fluorides and boron hazards.

**UNIT V**

Effect of water quality on soil properties and plant growth. Use of saline water for crop production.

**UNIT VI**

Methods and models for assessing the suitability of saline water for irrigation and crop production. Management principles and practices for safe use of saline water.

**Practical :**

| No. | Practical |
|---|---|
| 1-2 | Determination of pH of soil extract and irrigation water |
| 3-4 | Determination of electrical conductivity of soil extract and irrigation water |
| 5-6 | Determination of carbonates and bicarbonates in soil extract and irrigation water |
| 7-8 | Determination of chlorides in soil extract and irrigation water |
| 9-10 | Estimation of SO4 (Sulfate) in soil extract and irrigation water |
| 11-12 | Estimation of calcium and magnesium in soil extract and irrigation water |
| 13-14 | Determination of sodium and potassium in soil extract and irrigation water |
| 15 | Determination of BOD from irrigation water |
| 16 | Determination of COD from irrigation water |
| 17 | Estimation of iron, manganese, copper and zinc from in soil extract and irrigation water (atomic absorption sprctron photometer) |
| 18 | Determination of fluorides in soil extract and irrigation water |

**Suggested Readings :**


1. Daji, J.A., J.R. Kadam and N.D. Patil. 1999. A text book of Soil Science, Media promoters and publishers Mumbai.
2. Dakshinamurthi, C. Advances Soil Physics, ICAR, Publication, New Delhi.
3. Ghildyal B.P. and R.P. Tripathi. Soil Physics. Wiley eastern Ltd., New Delhi.
4. Hillel, D. 1980. Application of Soil Physics, Academic Press, New York.
5. Kadam, J.R. and B.P. Ghildyal 1992. Dictionary of Soil and Water Management Nirali Prakashan Pune-2.
6. Mortvedt, J.J., Shuman, L.M., Cox, F.R. and Weich, R.M. (ed) 1991. Micronutrients in Agriculture, Soil Science Society of Americal.
7. Oswal, M.C. 1994. Soil Physics-Oxford IBH, New Delhi.
8. Rhoades, J.D., A. Kandiah and A.M. Mashali. 1992. The use of saline waters for crop production, FAO, 48.
9. Richards, L.A. 1968. Diagnosis and improvement of saline and alkali soils. Hand book No.60.
10. Singh, Dhyan, Chhonkar, P.K. and Pandey, R.N. 1999. Soil Plant Water Analysis. A methods manual I.A.R.I. New Delhi.

**IWM-531* Economic Issues in Water Resources Management 2 (1+1)**

**Theory:**

**UNIT I**

Basic concepts of production function with water as a input. Production relationship ( Factor - Product Relationship ). Three regions of production function. Maximization of net returns with water as in important input.

**UNIT II**

Tools of farm management, scope and importance, farm planning and budgeting, UNIT III

Economic measures of water use efficiency, Importance of irrigation in an agrarian economy, Economic issues related to marketing and finance. Role of co-operations in irrigation development, economic changes due to irrigation infrastructure development.

**UNIT III**

The genesis of growth and utilization of irrigation, Irrigation Development Corporations, Irrigation policy, Sectoral distribution of Plan Allocation for irrigation.

**Practical :**

| Sr.No. | **Practical** |
|---|---|
| 1. | Specification and estimation of different production functions, |
| 2. | Estimation of profit functions, working out optimal use of resources |
| 3. | Three regions of classical production function |
| 4. | Economic analysis of co-operative lift irrigation projects |
| 5. | Estimation of growth rates of irrigated area |
| 6. | Estimation of irrigation potential created and utilized under different projects. |

**Suggested Readings :**

1. Economics of Irrigation by Colin Clark
2. Irrigation and Agricultural Development by U.M. Jha.
3. Fundamentals of Farm Business and Management by Johl and Kapur.
4. Economic Surveys of India and Maharashtra.

**IWM 510 Soil Erosion and Conservation 3 (2+1)**

**Theory**

**Unit I**

History, distribution, identification and description of soil erosion problems in India.

**Unit II**

Forms/type of soil erosion; effects of soil erosion and factors affecting soil erosion; types and mechanisms of water erosion; raindrops and soil erosion; rainfall erosivity - estimation as EI30 index and kinetic energy; factors affecting water erosion; empirical andquantitative estimation of water erosion; methods of measurement and prediction of runoff; soil losses in relation to soil properties and precipitation.

**Unit III**

Wind erosion- types, mechanism and factors affecting wind erosion; eXtent of problem in the country.

**Unit IV**

Principles of erosion control; erosion control measures – agronomical and engineering; erosion control structures - their design and layout.

**Unit V**

Soil conservation planning; land capability classification; soil conservation in special problem areas such as hilly, arid and semi-arid regions, waterlogged and wet lands.

**Unit VI**

Watershed management - concept, objectives and approach; water harvesting and recycling; flood control in watershed management; socioeconomic aspects of watershed management; use of remote sensing in assessment and planning of watersheds, sediment measurement; case studies in respect to monitoring and evaluation of watersheds;

**Practical**

- Determination of different soil erodibility indices - suspension percentage, dispersion ratio, erosion ratio, clay ratio, clay/moisture equivalent ratio, percolation ratio, raindrop erodibility index
- Computation of kinetic energy of falling rain drops
- Computation of rainfall erosivity index (EI30) using rain gauge data
- Land capability classification of a watershed
- Visits to a watersheds

**Suggested Reading**


- Biswas TD and Narayanasamy G. (Eds.) 1996. *Soil Management in Relation to Land Degradation and Environment*. Bull. Indian Society of Soil Science No. 17.
- R. P. C. Morgan.2005 Soil Erosion and Conservation , Third Edition, Blackwell Publishing 350 Main Street, Malden, MA 02148-5020, USA.
- Hudson and Norman , *Soil Conservation 3rd Editions 2015* , , NIPA Books
- Dr. R. Suresh, Soil and Water Conservation Engineering Standards publishers and Distributers.
- R K Mehra (Author) ICAR Textbook of Soil Science HB Hardcover – 1 January 2006 by
- *RPC Morgan. Soil Erosion and conservation*
- Doran JW and Jones AJ. 1996. *Methods of Assessing Soil Quality*. Soil Science Society of America, Spl Publ. No. 49, Madison, USA.
- Gurmal Singh, Venkataramanan C, Sastry G and Joshi BP. 1990. *Manual of Soil and WaterConservation Practices*. Oxford & IBH.

- Hudson N. 1995. *Soil Conservation*. Iowa State University Press.
- Indian Society of Soil Science 2002. *Fundamentals of Soil Science*. ISSS, New Delhi.
- Oswal MC. 1994. *Soil Physics*. Oxford & IBH.

**IWM 520 Principles and Practices of Water Management 3 (2+1)**

**Theory**

**UNIT I**

Water and its role in plants; Irrigation: Definition and objectives, water resources and irrigation development in India and concerned state, major irrigation projects, extent of area and crops irrigated in India and in different states.

**UNIT II**

Field water cycle, water movement in soil and plants; transpiration; soil-water-plant relationships; water absorption by plants; plant response to water stress, crop plant adaptation to moisture stress condition. Water availability and its relationship with nutrient availability and losses, Soil water potentials; Kinds of water**.**

**UNIT III**

Soil, plant and meteorological factors determining water needs of crops, consumptive use of water; scheduling, depth and methods of irrigation; micro irrigation systems; automated irrigation system; deficit irrigation; fertigation; management of water in controlled environments, polyhouses and Hydroponics.

**UNIT IV**

Water management of crop and cropping system; crop water requirement; estimation of ET and effective rainfall; irrigation efficiency and water use efficiency', Water management of the major crops under climate change scenario, Virtual Water.

**UNIT V**

Excess of soil water and plant growth;, drainage requirement of crops and methods of field drainage, their layout and spacing;

**UNIT VI**

Quality of irrigation water and management of saline water for irrigation, water management in problem soils

**UNIT VII**

Soil moisture conservation, conjunctive water uses; water harvesting; roof-water harvesting; rain water management and its utilization for crop production.

**Practical**

1. Determination of Field capacity by field method
2. Determination of Permanent Wilting Point by sunflower pot culture technique
3. Determination of Field capacity and Permanent Wilting Point by Pressure Plate Apparatus
4. Determination of Hygroscopic Coefficient
5. Determination of maximum water holding capacity of soil
6. Measurement of matric potential using gauge and mercury type tensiometer
7. Determination of soil-moisture characteristics curves
8. Determination of saturated hydraulic conductivity by constant and falling head method
9. Determination of hydraulic conductivity of saturated soil below the water table by auger hole method
10. Measurement of soil water diffusivity
11. Estimation of unsaturated hydraulic conductivity
12. Estimation of upward flux of water using tensiometer and from depth ground water table
13. Determination of irrigation requirement of crops (calculations)
14. Determination of effective rainfall (calculations)
15. Determination of ET of crops by soil moisture depletion method
16. Determination of water requirements of crops
17. Measurement of irrigation water by volume and velocity-area method
18. Measurement of irrigation water by measuring devices and calculation of Irrigation efficiency
19. Determination of infiltration rate by double ring infiltrometer
20. Use of different apps for irrigation and fertigation scheduling
21. Estimation of Potential ET by Thornthwaite method

22. Estimation of uniformity coefficient of pressurized irrigation system.
23. Artificial intelligence and machine learning in irrigation management
24. Estimation of Reference ET by Penman Monteith Method

**Suggested Reading:**

Majumdar D.K. 2014. Irrigation Water Management: Principles and Practice.PHL Learning private publishers

Mukund Joshi. 2013.A Text Book of Irrigation and Water Management Hardcover, Kalyani publishers

Lenka D. 1999. Irrigation and Drainage. Kalyani.

Michael AM. 1978. Irrigation: Theory and Practice. Vikas Publ.

Paliwal KV. 1972. Irrigation with Saline Water. IARI Monograph, New Delhi. Panda SC. 2003. Principles and Practices of Water Management. Agrobios.

Prihar SS &Sandhu BS. 1987. Irrigation of Food Crops - Principles and Practices. ICAR.

Reddy SR. 2000. Principles of Crop Production. Kalyani.

Singh Pratap & Maliwal PL. 2005. Technologies for Food Security and Sustainable Agriculture. Agrotech Publ.

**IWM 514* Cropping Systems and Sustainable Agriculture 2 (1+1)**

**Theory**

**UNIT I**

Cropping systems : definition, indices and its importance; physical resources, soil and water management in cropping systems; assessment of land use. i.e Land equivalent ratio (LER)Mechanism of yield Assessment of yield advantages.

**UNIT II**

Concept of sustainability in cropping systems and farming systems, scope and objectives; production potential under monoculture cropping, multiple cropping, alley cropping, sequential cropping and intercropping, Integrated farming system model for rainfed and irrigated conditions. Mechanism of yield advantage in intercropping systems.

**UNIT III**

Above and below ground interactions and allelopathic effects; competition relations; multistoried cropping and yield stability in intercropping, role of non-monetary inputs and low cost technologies; research need on sustainable agriculture.

**UNIT IV**

Crop diversification for sustainability; role of organic matter in maintenance of soil fertility; crop residue management; fertilizer use efficiency and concepts of fertilizer use in intensive cropping system.

**UNIT V**

Plant ideotypes for dry lands; plant growth regulators and their role in sustainable agriculture.

**Practical**

| Sr. No. | Practical |
|---|---|
| 1-2 | To study the yield advantages in intercropping system |
| 3-4 | To study the aggressivity index in cropping system |
| 5-6 | To study the integrated farming system model for rainfed agriculture and integrated farming system model for irrigated condition |
| 7-8 | To study the cropping system in sustainable agriculture |
| 9-10 | To study the concept of fertilizer use in intensive cropping system |
| 11-12 | To study the plant growth regulator and their role in sustainability |
| 13-14 | To study the field experiments relevant to the cropping systems and Integrated farming system models. |
| 15-18 | Visit to AICRP on Integrated Farming systems Projects |

**Suggested Books**

1. Palaniappan SP &Sivaraman K. 1996. Cropping Systems in the Tropics; Principles and Management. New Age.
2. Panda SC 2003. Cropping and Farming Systems. Agrobios.
3. Radddy SR 2000. Principles of Crop Production. Kalyani.
4. Sankaran S &Mudaliar TVS. 1997. Principles of Agronomy. The Bangalore Printing & Publ. Co.
5. Singh SS. 2006. Principles and Practices of Agronomy. Kalyani.
6. Tisdale SL, Nelson WL, Beaton JD &Havlin JL. 1997. Soil Fertility and Fertilizer. Prentice Hall.

**7.** Reddy T.Y. and Reddy G.H. 2002,Principles of Agronomy. Kalyani publishers

**8.** Chatterji B.N. and Maiti S 1984, cropping systems theory and practices, oxford & IBH Publishing Co. Calcultta.

**9.** Palaniappan SP 1985. Cropping Systems in the Tropics; Principles and Practices, willey eastern limited, New Delhi.

**IWM 515* Principles of Agricultural Land Drainage 2 (1+1)**

**Theory:**

**UNIT I**

Water logging – causes and impacts, objectives of drainage. Theories and applications of surface and sub-surface drainage, Drainage properties of soils, drainage coefficient investigation.

**UNIT II**

Drainage types, parameters and layout. Design of open ditch system, tile drainage system. Leaching requirement and management practices under drained conditions.

**UNIT III**

Design of different components of sub-surface drainage systems, Installation of the drainage systems. drainage pipes, drain envelope, Vertical drainage. Bio-drainage, mole drains.

**UNIT IV**

Evaluation of drainage system. Management of drainage projects of waterlogged and salt affected soils, case studies.

**Practical:**

| Sr. No. | Practical |
|---|---|
| 1-2 | Measurement of in-situ hydraulic conductivity by inverse and single auger hole method |
| 3-4 | Estimation of drainage coefficient |
| 5-7 | Installation of piezometer and observation well |
| 7-8 | Preparation of iso- bath and isobar maps. |
| 9-10 | Determination of drainable porosity by sand tank model and field method. |
| 11-12 | Design of surface drainage system |
| 13-14 | Design of subsurface drainage system |
| 15-16 | Visit to drainage project |

**Suggested Readings**


Agril. Engineering Vol. II – By A.M. Michael and T.P. Ojha

Land and water management engineering. V.V.N. Murthi

Planning and design of on farm development works. Walmi Publication No. 10, 1985.

Application of soil survey in irrigation water management WALMI Pub. No. 21, 1967

Operation and management of irrigation system WALMI Publ. No. 20, 1987.

Land drainage Vol. 2 to 4 by International Institute for Land Reclamation and improvement

Drainage Engineering – By J.N. Luthin

On farm development works. WALMI Publ. No. 12, 1986

Battacharaya AK & Micheal AM. 2003. Land Drainage. Vikas Publ.

Ritzema HP. (Ed.). 1994. Drainage Principles and Applications. ILRI

Roe CE 1966. Engineering for Agricultural Drainage. McGraw Hill.

**IWM 517* Watershed Development and Management 3 (2+1)**

**Theory:**

**UNIT I**

Concept of watershed, delineation, Morphological characteristics of watershed. Types of watershed,

**UNIT II**

Land capability classification, Study of raingauage chart and rainfall characteristics. Probability analysis of rainfall data. Computation of runoff volume and peak rate of runoff.

**UNIT III**

Types of soil erosion and their preventive measures. Different in situ soil and water conservation measures on arable and non arable lands. Temporary gully control structures. Water storage structures- Nala bunds, farm ponds, percolation tanks. Preparation of plan for watershed development considering rainfall, soil and morphology of watershed.

**UNIT IV**

Integration of in situ and ex situ rainwater harvesting structures. Study of water balance in the watershed. Planning of watershed development considering the water harvesting and recycling, management of excess/deficit water.

**UNIT V**

India's watershed development program, Community participation, role of NGOs, economic evaluation and environmental impact.

**Practical:**

| Sr. No. | Practical |
|---|---|
| 1 | Exercise on watershed delineation |
| 2-3 | Determination of morphological characteristics of watershed |
| 4-5 | Study of rainguage chart |
| 6-7 | Probability analysis of rainfall data |
| 8-9 | Computation of runoff volume |
| 10-11 | Computation of peak rate of runoff |
| 12 | Determination of soil loss with universal soil loss equation |
| 13 | Design of farm pond |
| 14-15 | Design of nala bund |
| 16 | Study of water balance in the watershed |
| 17-18 | Visit to watershed and NGO |

**Suggested Readings**:

Isobel W Heathcote**.** 1998. Integrated Watershed Management: Principles and Practice. Wiley Publ.

Kenneth N Brooks, Peter F Ffolliott, Hans M Gregersen, Leonard F DeBano. 1991. Hydrology and the Management of Watersheds. Wiley-Blackwell

Singh G. and Shastri Manual of soil and water conservation works

**SOIL 502 Soil Fertility and Fertilizer Use 3 (2 +1)**

**Theory**

**Unit I**

Soil fertility and soil productivity; fertility status of major soils group of India; Special emphasis on Maharashtra nutrient sources – fertilizers and manures; Criteria of essentiality, classification, law of minimum and maximum, essential plant nutrients - functions and deficiency symptoms, Nutrient uptake, nutrient interactions in soils and plants; long term effect of manures and fertilizers on soil fertility and crop productivity.

**Unit II**

Soil and fertilizer nitrogen – sources, forms, immobilization and mineralization, nitrification, denitrification; biological nitrogen fixation -types, mechanism, microorganisms and factors affecting; nitrogenous fertilizers and their fate in soils; management of fertilizer nitrogen in lowland and upland conditions for high fertilizer use efficiency.

**Unit III**

Soil and fertilizer phosphorus – sources, forms, immobilization, mineralization, fixation, reactions in acid and alkali soils; factors affecting phosphorus availability in soils; phosphatic fertilizers - behavior in soils and management under field conditions.

**Unit IV**

Potassium – Sources, forms, equilibrium in soils and its agricultural significance; mechanism of potassium fixation; management of potassium fertilizers under field conditions.

**Unit V**

Sulphur - source, forms, fertilizers and their behavior in soils; role in crops and human health; calcium and magnesium– factors affecting their availability in soils; management of sulphur, calcium and magnesium fertilizers.

**Unit VI**

Micronutrients – Source, factors affecting their availability, critical limits in soils and plants, correction of their deficiencies in plants; role of chelates in nutrient availability.

**Unit VII**

Common soil test methods for fertilizer recommendations; quantity– intensity relationships; soil test crop response correlations and response functions.

**Unit VIII**

Fertilizer use efficiency; site-specific nutrient management; plant need based nutrient management; integrated nutrient management; specialty fertilizers concept, need and category. Current status of specialty fertilizers use in soils and crops of India,

**Unit IX**

Soil fertility evaluation - biological methods, soil, plant and tissue tests; soil quality in relation to sustainable agriculture,, DRIS, critical limits of nutrient.

**Unit X**

Definition and concepts of soil health and soil quality; Longterm effects of fertilizers andsoil quality.

**Practical**

- Soil and plant sampling and processing for chemical analysis
- Determination of soil pH, total and organic carbon in soil
- Chemical analysis of soil for total and available nutrients (major and micro)
- Analysis of plants for essential elements (major and micro)

**Suggested Reading**

Brady NC and Weil RR. 2002. *The Nature and Properties of Soils*. 13th Ed. Pearson Edu.

Kabata-Pendias A and Pendias H. 1992. *Trace Elements in Soils and Plants*. CRC Press.

Kannaiyan S, Kumar K and Govindarajan K. 2004. *Biofertilizers Technology*. ScientificPubl.

Leigh J G. 2002. *Nitrogen Fixation at the Millennium*. Elsevier.

Mengel K and Kirkby EA. 1982. *Principles of Plant Nutrition*. International Potash Institute, Switzerland.

Mortvedt JJ, Shuman LM, Cox FR and Welch RM. 1991. *Micronutrients in Agriculture*.2nd Ed. SSSA, Madison.

Pierzinsky GM, Sims TJ and Vance JF. 2002. *Soils and Environmental Quality*. 2ndEd.CRC Press.

Stevenson FJ and Cole MA. 1999. *Cycles of Soil: Carbon, Nitrogen, Phosphorus,Sulphur, Micronutrients*. John Wiley & Sons.

Tisdale SL, Nelson SL, Beaton JD and Havlin JL. 1999. *Soil Fertility and Fertilizers*. 5th Ed. Prentice Hall of India.

Troeh FR and Thompson LM. 2005. *Soils and Soil Fertility*. Blackwell.

Soil Fertility Fertilizers and Agrochemicals Joga Pravin K. 2018 Astral International pubLtd.

Fertilizers in Indian Agriculture-from 20$^{th}$ to 21$^{st}$ century 2004 Dr. HLS Tondon ,FDCO Sohna Road Gurgaon122018

Soil Fertility, Fertilizers and INM 2011 Dr. HLS Tondon FDCO Sohna Road Gurgaon122018

## IWM 519* Principles and Practices of Protective Cultivation 2 (1+1)

**Theory:**

**UNIT I**

Greenhouse :history, concept, Greenhouse – Indian scenario,: present and future, Basics of greenhouse design, different types of structures – glasshouse, shade net, poly tunnels.

**UNIT II**

Design and development of low cost greenhouse structures. Greenhouse Systems: Ventilation, cooling, heating, light, $CO_2$, micro irrigation and fertigation. Automated greenhouses. Scheduling of irrigations, root media, crop production technology in greenhouse, economics of greenhouse farming.

**Practical :**

| Sr. No. | Practical |
|---|---|
| 1-2 | Designs of greenhouse. |
| 3-4 | Study of construction details of low cost poly tunnels, net house. |
| 5-6 | Regulation of Ventilation system, Heating system, |
| 7-8 | Micro Irrigation and fertigation systems in green house. |
| 9-10 | Interaction of light, temperature, humidity, CO2, water on crop regulation |
| 11-12 | Instruments and measurements; codes and standards. |
| 13-14 | Greenhouse. Economic analysis Planning and management of greenhouse |
| 15-16 | Success stories |
| 17-18 | Visit to different types of greenhouses |

**Suggested Readings:**

Mastalerz, J.W.(1977). The greenhouse environment. John Wiley and Sons, USA.
Chandra Pitam (1992). Greenhouse construction and environmental control, IARI, New Delhi.
International Course on “Research and Development in Irrigation and Technology of Protected Crops” (27 Oct. – 16 Dec., 1999), Institute of Soil Water and Environmental Science, Israel.
Nelson, P.V. Greenhouse Operation Management. Reston Pub. Co. INC A Prentice hall Co., Reston, Virginia.
Hannan, J.J., W.D., Holley, K.L. Goldsberry. 1978. Greenhouse management. Springervering Berlin, Berlin Hlidelherg, New York.
Showell Cooper. The ABC of the greenhouse. The English Universities Press Ltd., St. Paud’s House, Warwick Lane, London-E.C. 4.
Tiwari S.N. and Goyal, Greenhouse design.
Aldrich RA & Bartok JW. 1994. Green House Engineering. NRAES,
Riley, Robb Hall, Cornell University, Ithaca, New York.
Esmay ML & Dixon JE. 1986. Environmental Control for Agricultural Buildings. The AVI Corp.

**IWM 524* Application of Remote Sensing and GIS in Agriculture 3 (2+1)**

**Theory:**

**UNIT I**

Basic principles of remote sensing. components of remote sensing : signals, sensors and sensing systems : active and passive remote sensing ; Electromagnetic spectrum, characteristics of electromagnetic radiation,

**UNIT II**

Energy interaction with matter; spectral features of earth's surface features; imaging and non imaging systems; framing and scanning systems; resolution of sensors; sensors platforms, their launching and maintenance; data acquisition system, data preprocessing, storage and dissemination.

**UNIT III**

digital image processing and information extraction; microwave remote sensing; visual and digital image interpretation; introduction to Geographical Information System (GIS) and GPS. Digital techniques for crop discrimination and identification; crop stress detection,

**UNIT IV**

GIS and remote sensing for land and water resources data collection, inventory of ground water and satellite measurement of surface soil moisture and temperature; drought monitoring, monitoring of crop disease and pest infestation; soil resource inventory; land use/land cover mapping and planning; Integrated watershed development; crop yield modeling and crop production forecasting.

**Practical :**

| Sr. No. | Practical |
|---|---|
| 1-2 | Interpretation of Arial photographs for mapping |
| 3-4 | Interpretation of satellite image for mapping |
| 5-6 | Study of image processing software |
| 7-8 | Study of image enhancement; image classification methods |
| 9-10 | Familiarization with remote sensing and GIS hardware, software and their principle of working |
| 11-12 | Comparison between ground truth and remotely sensed data |
| 13-14 | Study of GIS package |
| 15-16 | Use of GIS package for Crop acreage estimations |
| 17-18 | Use of GIS package for water resources assessment |

**Suggested Readings:**

Colwell, R.N. (editor). Manual of Remote Sensing-Vol. I & II, Am Soc. Photogrammetry, Virginia.

Curan, P.J. Principles of Remote sensing, ELBS/Longman.

Jain, A.K. 1989. Fundamentals of Digital Image Processing, Prentice Hall of India,

Saddle river, NJ. Kamat, D.S. and Sinha, S.K. (Eds)1984. Proceedings of the Seminar on Crop Growth Condition and Remote Sensing, June 22-23, ICAR & ISRO.

Lillesand T.M. and Kiffer, R.W. Remote Sensing and image interpretation, John Wiley & sons.

Majumdar, K.L. et.al. 1983. Selection of spectral bands and their widths for the Indian Remote Sensing satellite (IRS), RSP-1P/TN03/83, Space Applications Centre, Ahmedabad-380053.

Sabins, F.F. 1997. Remote Sensing-Principles and Interpretation, 3rd ed. WH Freeman

De Mess MN. 2004. Fundamental of Geographic Information System. John Wiley & Sons.

Schowengerdt, R.A. 1997. Remote Sensing, Models and Methods for Image Processing, 2nd edn. Academic Press.

**IWM 526 Basic Soil Physics 3(2+1)**

**Theory**

**Unit I**

Basic principles of physics applied to soils, soil as a three phase system.

**Unit II**

Soil texture, textural classes, mechanical analysis, specific surface.

**Unit III**

Soil consistence; dispersion and workability of soils; soil compaction and consolidation; soil strength; swelling and shrinkage - basic concepts. Alleviation of soil physical constraints for crop production. Soil erosion and erodability

**Unit IV**

Soil structure - genesis, types, characterization and management soil structure; soil aggregation, aggregate stability; soil tilth, characteristics of good soil tilth; soil crusting - mechanism, factors affecting and evaluation; soil conditioners; puddling, its effect on soil physical properties; clod formation.

**Unit V**

Soil water: content and potential, soil water retention, soil-water constants, measurement of soil water content, energy state of soil water, soil water potential, soil-moisture characteristic curve; hysteresis, measurement of soil-moisture potential.

**Unit VI**

Water flow in saturated and unsaturated soils, Poiseuille‟s law, Darcy‟s law; hydraulic conductivity, permeability and fluidity, hydraulic diffusivity; measurement of hydraulic conductivity in saturated and unsaturated soils.

**Unit VII**

Infiltration; internal drainage and redistribution; evaporation; hydrologic cycle, field water balance; soil-plant-atmosphere continuum.

**Unit VIII**

Composition of soil air; renewal of soil air - convective flow and diffusion; measurement of soil aeration; aeration requirement for plant growth; soil air management.

**Unit IX**

Modes of energy transfer in soils; energy balance; thermal properties of soil; measurement of soil temperature; soil temperature in relation to plant growth; soil temperature management.

**Practical**

Determination of B.D, P.D and mass volume relationship of soil, Mechanical analysis by hydrometer and international pipette method, Measurement of Atterberg limits, Aggregate analysis - dry and wet, Measurement of soil-water content by different methods, Measurement of soil-water potential by using tensiometer and gypsum Blocks, Determination of soil-moisture characteristics curve and computation of pore-size, distribution, Determination of hydraulic conductivity under saturated and unsaturated conditions, Determination of infiltration rate of soil, Determination of aeration porosity and oxygen diffusion rate, Soil temperature measurements by different methods, Estimation of water balance components in bare and cropped fields.

**Suggested Reading**

Baver LD, Gardner WH and Gardner WR. 1972. Soil Physics. John Wiley & Sons.

Ghildyal BP and Tripathi RP. 2001. Soil Physics. New Age International.

Hanks JR and Ashcroft GL. 1980. Applied Soil Physics. Springer Verlag.

Hillel D. 1972. Optimizing the Soil Physical Environment toward Greater Crop Yields.Academic Press.

Hillel D. 1980. Applications of Soil Physics. Academic Press.
Hillel D. 1980. Fundamentals of Soil Physics. Academic Press.
Hillel D. 1998. Environmental Soil Physics. Academic Press.
Hillel D. 2003. Introduction to Environmental Soil Physics. Academic Press.
Indian Society of Soil Science. 2002. Fundamentals of Soil Science. ISSS, New Delhi.
Kirkham D and Powers WL. 1972. Advanced Soil Physics. Wiley-Interscience.
Kohnke H. 1968. *Soil Physics*. McGraw Hill.
Lal R and Shukla MK. 2004. *Principles of Soil Physics*. Marcel Dekker.
Oswal MC. 1994. *Soil Physics*. Oxford & IBH.
Text books of soil physics by Arun Kumar Saha, Anuradha Saha Kalyani Publication New Delhi
Soil Physics An Introduction *By Manoj K. Shukla* Published December 2, 2013 by CRC Press 478 Pages 201 B/W Illustrations
Principles of Soil Physics *By Rattan Lal, Manoj K. Shukla* Published September 27, 2019 by CRC Press 736 Pages
17Applications of Soil Physics 1st Edition - October 28, 1980 Daniel Hillel Elsevier
18 Fundamental Principal of Soil Science by Deepak Sarkar and Abhijit Haldar Today and tomorrows Printers and Publishers

**IWM 527* Fertigation 2(1+1)**

**Theory:**

**UNIT I**

Introduction, principles of fertigation, selection of fertilizers for fertigation,

**UNIT II**

Fertigation under saline condition, distribution of nutrient status in rhizosphere and in plants, root growth in relation to fertigation injection devices,

**UNIT III**

Operation and maintenance of drip irrigation system, poly phosphate sequences try ability, liquid fertilizers,

**UNIT IV**

Fertigation for cash crops.

**Practical:**

| Sr. No. | Practical |
|---|---|
| 1-2 | Analysis of N, P, K in the soil |
| 3-4 | Study of solid soluble fertilizers |
| 5-6 | Study of liquid fertilizers |
| 7-8 | Study of uniformity of fertilizer application |
| 13-14 | Study and use of ventury for fertigation |
| 15-16 | Study and use of fertigation pump for fertigation |
| 9-10 | Acidification of drip system |
| 11-12 | Clorination of drip system |
| 17-18 | Visit to hi tech agricultural farms |

**Suggested Readings:**

Keller Jack and R.D. Bliesner. 1990. Sprinkler and trickle irrigation. An available book, Van Nostrond Reinhold, New York.

Nakayama, F.S. and D.S. Bucks, 1986. Trickle irrigation for crop production, El sevier, New York.

Tisdale, S.L., Nelson, W.L. and J.B. Beakan. 1985. Soil fertility and fertilizers, Macmillion, New York.

Drip Trickle irrigation in action. 1985. Proc. III. Int. Drip Irri. Congress. Am. Soc.,

Agric. Engg. Nov. 13-21, Fresno, USA.

**IWM 528 Principles of Organic Farming 3 (2+1)**

**Theory**

**UNIT I**

Organic farming-concept and definition, its relevance to India and global agriculture and future prospects; land and water management-land use,minimum tillage; shelter zones, hedges, pasture management, agro-forestry.

**UNIT II**

Organic farming and water use efficiency; soil fertility, nutrient recycling, organic residues, organic manures, compositing, soil biota and decomposition of organic residues, earthworms and vermicompost, green manures and biofertilizers.

**UNIT III**

Farming systems, crop rotations, multiple and relay cropping systems, intercropping in relation to maintenance of soil productivity.

**UNIT IV**

Control of weeds in organic farming system. Diseases and insect pest managementin organic farming system. Biological agents and pheromonestraps, Bio-pesticides in organic farming system.

**UNIT V**

Socio-economic impacts; marketing and export potential; inspection, certification, labeling and accreditation procedures; organic farming and national economy.

**Practical:**

| Sr. No. | Practical |
|---|---|
| 1. | Different methods for preparation of compost (Aerobic and anaerobic) |
| 2. | Preparation of vermicompost |
| 3. | Preparation of Jeevamrut and analysis of Jeevamrut |
| 4. | Preparation of Panchgavya and analysis of Panchgavya |
| 5. | Preparation of different organic formulations in organic farming system |
| 6. | To study the organic farming systemsfor Rainfed and Irrigated conditions. |
| 7. | To study important weeds in major crops of organic farming system. |
| 8. | To study pest management in major cropsof organic farming system. |
| 9. | Identification and nursery raising of important agro-forestry trees and trees for shelter belts |
| 10. & 11. | Efficient use of biofertilizers - Technique of treating legume seeds with Rhizobium cultures, use of Azotobacter, Azospirillum, and PSB cultures in field |
| 12. | Quality standards for organic products. |
| 13. & 14. | Inspection, certification and labelling for organic farm produce. |
| 15. & 16. | Accreditation procedure for organic farm produce. |
| 17. & 18. | Visit to an Organic Farming Research and Training Centre |

**Suggested Readings :**


Ananthakrishnan TN (ED). 1992. Emerging Trends in Biological Control of Phytophagous Insects. Oxford & IBH.

Gaur AC. 1982. A Manual of Rural Compostig, FAO/UNDP Regional Project Document, FAO.

Lampin N. 1990. Organic Farming. Press Books, Ipswitch, UK.

Palaniappan SP &Anandurai K. . 1999. Organic Farming – Theory and Practice. Scientific Publ.

Rao BV Venkata. 1995. Small Farmer Focused Integrated Rjural Development: Socio-economic Environment and Legal Perspective: Publ. 3, ParisaraprajnaParishtana, Bangalore.

Reddy MV.(ED.), 1995. Soil Organisms and Liter Decomposition in the Tropics, Oxford & IBH.

Sharma A. 2002. Hand Book of Organic Farming. Agrobios.

Sigh SP. (ED.). 1994. Technology for Productioin of Natural Enermies, PDBC, Bangalore

Subba Rao NS. 2002. Soil Microbiology. Oxford & IBH.

Trivedi RN. 1993. A Text Book okf Environmental Science, Anmol Publ.

Veeresh GK, Shivashankar K &Suiglachar MA. 1997. Organic Farming and Sustainable Agriculture. Association for Promotion of Organic Farming, Bangalore.

WHO. 1990. Public Health Impact of Pesticides Used in Agriculture. WHO.

Woolmer PL & Swift MJ. 1994. The biological Management of Tropical Soil Fertility. TSBF & Wiley.

**IWM 529* Evapotranspiration 2(1+1)**

**Theory:**

**UNIT I**

Basic laws of radiation, Radiation interaction with plant environment, crop canopy. The atmosphere near the ground.

**UNIT II**

. Theories of evapotranspiration and their comparison. Aerodynamic, energy balance, water balance and other methods, Application under different Agro-climatic conditions. Measurements of temperature, solar radiation. Humidity and Wind profile.

**UNIT IV**

Concepts of Potential, Reference and Actual evapotranspiration-modified techniques. Influence of microclimatic, plant soil and cultural factors. Techniques of lysimetry in measuring actual evapotranspiration.

**UNIT V**

Yield functions, water use efficiency and scheduling of irrigation based on evapotranspiration. Radiation instruments. Advanced techniques for measurement of radiation and energy balance. Computation of K values and their use.

**Practical:**

| Sr.No. | Practical |
|---|---|
| 1-2 | Measurement and evaluation of radiation components. |
| 3-4 | Computation and comparison of evapotranspiration by different methods<br>Energy balance method; Aerodynamic method ; Penman method ; |
| 5. | Measurement of wind speed by anemometer. |
| 6-8 | Measurement of wet bulb and dry bulb temperatures and relative humidity. |
| 9-10 | Study of lysimeter and measurement of evapotranspiration. |
| 11 | Measurement of evaporation from USWB class A pan. |
| 12-13 | Determination of Crop coefficient of various crops |
| 14-15 | Preparation of programme in MS Excel for determination of reference evapotranspiration using different empirical equations. |
| 16 | Visit to Meteorological observatory |

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**Suggested Readings**:

Allen, R.G., L.S. Pereira, D. Raes and M. Smith. 1998. Crop Evapotranspiration, Guideline for Computing Crop Water Requirements. FAO Irrigation and Drainage, Paper 56.

Change, J.H. 1968. Climate and Agriculture, Aldine Pub. Chicago

Evans, L.T. 1963. Environmental Control and Plant Growth Academic Press, New York.

Grace, John 1983. Plant Atmospheric Relationships Outline studies in Ecology,
Chapman and Hall, New York, pp. 92.

Rose, C.W. 1966. Agricultural Physics, Pugaman London.

Sellers, W. 1967. Physical Climatology. The University of Chicago Press, Chicago.

**IWM-532* Social Issues in Water Resources Management 2(1+1)**

**Theory:**

**UNIT I**

Sociology, rural sociology - meaning, characteristics of rural society. Importance of study of rural sociology as inter-disciplinary approach to water management.

**UNIT II**

Culture-meaning and importance. Rural Social Systems, Rural institution and Organizations.

**UNIT III**

Diagnostics analysis and Social aspects of irrigation management- systems, with interdisciplinary approach, Identifying problems and seeking solutions for improving performance of the irrigation system.

**UNIT IV**

Farmers participation in water management. Mechanisms for strengthening the participation and involvement of farmers in water management. Outlet committees, water users co-operatives. Use of Local leader in farmers participation in water management.

**UNIT V**

Social process Type – competition, conflict, Co-operation, assimilation and accommodation.

**Practical :**

Rural sociology and extension definitions. Individual/group assignment on social survey in command area. Visits in command areas and assignments on the discussions with the irrigator farmers and officials in the command area – methods of sampling, diagnostics analysis of irrigation system. A study of physical subsystem of irrigation. A study of economic sub-system.

**Suggested Readings :**

Education and Communications for Development by Danama O.P. and Bhatnagar O.P. (1980), Oxford and IBH Publishing Co. New Delhi.

Extension Education by Reddy A.S. (1976). Shree Laxmi Press Baptala (A.P.)

Diffusion of Innovations by Regers E.M. (1962). Free Press New York.

Lecture Notes on Farmers Participation in Irrigation Management, USA, by Brewer J.D. (1986).

Irrigation Water Management in Western Region by Dhamaner

Rural Sociology by Desai A.R.

**IWM 533* Water Resources System Analysis 3(2+1)**

**Theory:**

**UNIT I**

Concepts and significance of optimization in water resources, objective functions, deterministic and stochastic inputs, Principles of decision making in water resources planning and management-system analysis.

**UNIT II**

Optimization theory, Classical optimization techniques, Linear programming, LP models, formulation of problems, Identification of objectives, benefits, costs, decision variables, constraints and production functions, limitations, simplex method, duality principle, application of LP.

**UNIT III**

Developing LP problem, Solution of LP problem, LINDO software, Multi-objective optimization, Goal programming, Transportation model, CPM and PERT analysis. Application of optimization techniques to water resources systems. non linear programming,

**UNIT IV**

Development and management including conjunctive use, crop production functions and irrigation optimization.

**Practical :**

| Sr. No. | Practical |
|---|---|
| 1-2 | Numerical on formulation of LP problems |
| 3-4 | Solution of LP problems by graphical analysis |
| 5-6 | Solution of LP problems by simplex method |
| 7-8 | Exercises on duality principles |
| 9-10 | Solution of LP problems using LINDO software |
| 11-12 | Exercises on Multi-objective optimization, |
| 13-14 | Exercises on Goal programming |
| 15-16 | Exercises on transportation model programming |
| 17-18 | Exercises on CPM and PERT analysis |

**Suggested readings**

Larry WM. 1996. Water Resources Handbook. McGraw-Hill.

Loucks DP et al. 1981. Water Resource System Planning and Analysis. Prentice Hall.

Rao, S.S. 1990. Optimization- Theory and Applications.

Sharma, S.D. 1999. Operations Research. Kedar Nath Ram Nath and Co. Publishers, Meerut.

Taha, H.A. 1989. Operations Research- An Introduction. Maxwell Macmillan, New York.

Vohra, N.D. 1990. Quantitative Techniques in Management. Tata McGraw-Hill Publishing Co. New Delhi.

**IWM 534* Economic Evaluation of Irrigated Crops and Irrigation Projects 2(1+1)**

**Theory:**

**UNIT I**

Need for irrigation projects, Economic planning for irrigation projects, Economic viability and technical feasibility of a project, Economic changes due to introduction of irrigation, Economics of modern methods of irrigation.

**UNIT II**

Financial and economic analysis of a project, Basic steps involved in project appraisal-identifying costs and benefits of irrigation project, Measures of economic evaluation of irrigation project Benefit-cost ratio, Internal rate of returns, sensitivity analysis, social cost-benefit analysis shadow price and market price, critical review of studies on economic evaluation of irrigation projects.

**UNIT III**

Importance of costs studies in agriculture, valuation of farm assets, irrigation structure, Depreciation, cost concepts, concepts of production economics used in agriculture, cost accounts procedures for estimating irrigation charges under different systems of irrigation,

**UNIT IV**

Imputation of values of owned inputs in irrigated agriculture, Items included in estimation of cost of cultivation of seasonal/annual irrigated crops, and perennial crops, efficiency measures of production costs and returns per unit cost of production, Input-output relationships in irrigated agriculture.

**Practical:**

Economic viabilities of lift, sprinkler, drip irrigation methods, appraisal of irrigation projects, generation of data on production of irrigated crops, method of computing of depreciation and valuation of irrigation structure and farm building, estimation of irrigation charges under different irrigation systems. Study of item wise cost of cultivation of perennial irrigated crops, visit to nearby irrigated farm and collection of data on cultivation of one irrigated crop; working out per ha cost of cultivation and study of efficiency measures in productions of the crops, study of input output relationships in irrigated agriculture, linear/non-linear/exponential functions.

**Suggested Readings :**

Economic analysis of Agricultural Projects by J. Price Gittinger ( A World Bank Publication).

Project appraisal and planning for developing countries by Little and Mirrlees.

**I.**

**PP 504 Physiological and Molecular Responses of Plants to Abiotic Stresses 3(2+1)**

**Theory**

**Block 1:Abiotic Stresses**

**Unit 1:Introduction to Abiotic Stresses**

Abiotic stresses major constraints to realize potential yields of crop plants, yield losses. Drought prone areas in India- Frequency of occurrence of drought, Rainfed-kharif, Rabi, Areas affected by salinity, heavy metals, waterlogging, high temperature scenario due to global warming.

**Block 2:DroughtStress**

**Unit 1:Moisture Stress Responses in Plants**

Drought-characteristic features; water potential in the soil-plant-air continuum. Physiological and biochemical processes affected by drought Oxidative stress- generation of ROS and other cytotoxic compounds, their effect on cellular process. Effect on total carbon gain-decrease in photosynthetic area and function, protein turnover and lipid characters, phenology-reproductive aspects, critical stages.

**Unit 2: Stress Perception and Molecular Responses of Plants to Drought Stress**

Stress perception and signal transduction leading to expression of regulatory genes, stress specific kinases, stress specific transcription factors, functional genes associated with adaptive mechanisms.

**Unit 3:Plant Adaptive Mechanisms to Drought**

Escape and desiccation avoidance mechanism : Concept of stress escape- exploiting genetic variability in phenology, Drought avoidance mechanisms-Maintenance of cell turgor, watermining by root characters. Moisture conservation-Regulation of transpiration- traits reducing heat load, Stomatal factors guard cell metabolism, moisture conservation by waxes. Water use efficiency (WUE) and concept of water productivity- regulation of transpiration efficiency-stomatal conductance, mesophyll efficiency, relevance of WUE and Passioura's model.

Desiccation tolerance-Concept of acquired tolerance : Decreased turgor mediated upregulation of cellular tolerance mechanisms, Osmolytes, managing cytotoxic compounds, ROS, RCC, scavenging - enzymatic and non-enzymatic, protein turnover, stability, chaperones, membrane stability, photo-protection of chlorophylls.

**Unit 4:Approaches to Improve Drought Tolerance**

Development of genetic resources- donor genotypes for specific traits, Genomic resources- genes, QTL's regulating adaptive mechanisms, Conventional, transgenic and molecular breeding approaches to improve relevant adaptive traits, concept of trait introgression.

**Block 3:Salt, Heavy Metal, Water Logging, Temperature and Light Stress**

**Unit 1:Salt Stress**

Soil salinity-Effect of salt stress, ionic and osmotic effects; species variation in salt tolerance; glycophytes and halophytes, Salt tolerance mechanisms - exclusion, extrusion and compartmentalization, Signaling during salt stress – SOS pathway, Approaches to improve sal ttolerance.

**Unit 2:Heavy Metal Stress and Water Logging**

Heavy metal toxicity in plants (eg. Al, Cd), tolerance mechanisms and approaches to improve. Plant response to water logging, role of hormones- ethylene, mechanism of tolerance and approaches to improve.

**Unit 3:Temperature and Light Stress**

High and low temperatures; effect on plants; adaptive mechanisms, evaporation cooling, concept of cellular tolerance, protein stability, chaperones, HSPs, HSFs, membranes. High light and high ionizing radiation- photo oxidation and photo-inhibition; mechanisms of tolerance, plant adaptation to low light, concept of shade avoidance response (SAR).

**Practical**

| S No. | Title of the experiment |
|---|---|
| 1 | Measurement of soil and plant water status |
| 2 | Drought stress imposition and measurement of physiological and biochemical changes in plants under stress –gas exchange and fluorescence measurements |

| | |
|---|---|
| 3 | Determination of water use efficiency as a drought resistant trait |
| 4 | Drought Susceptibility Index (DSI) -precise field technique to identify productive genotypes under stress |
| 5 | Approaches to quantify root characters |
| 6 | Determination of stomatal parameters and canopy temperature as a reflection of transpiration and root activity |
| 7 | Determination of Salinity Tolerance Index |
| 8 | Studying acclimation response - Temperature induction response |
| 9 | Heat tolerance and membrane integrity- Sullivans heat tolerance test |
| 10 | Quantification of osmolytes – proline under stress |
| 11 | Oxidative stress imposition- Quantification of oxidative stress |
| 12 | Quantification of ROS under stress |
| 13 | Estimation of ABA content in leaf and root tissues under stress |
| 14 | Determination of Sodium and Potassium in plant tissue grown under salt stress |
| 15 | Estimation of antioxidant enzymes |

**Suggested Reading**

Plant Physiology Book by Eduardo Zeigerand Lincoln Taiz.
Plant Physiology Book by Frank B.Salisbury, Cleon W. Ross Salisbury, Frank B
Pereira A.2016. Plant Abiotic Stress Challenges from the Changing Environment. Front. Plant Sci.7:1123.doi:10.3389/fpls.2016.01123
Sergey Shabala, 2012. Plant Stress Physiology.
https://www.mapsofindia.com/maps/india/drought-prone-areas.html
Abid M, Ali S, Qi LK, Zahoor R, Tian Z, Jiang D, Snider JL and Dai T.2018 .Physiological and bio chemical changes during drought and recovery period sattillering and jointing stages in wheat (Triticumae stivum L.). Scientific Reports, 8(1),p.4615.
Fathi, Amin and Barari, Davood. 2016. Effect of Drought Stress and its Mechanism in Plants. International Journal of Life Sciences. 10.1.10.3126/ijls.v10i1.14509.
Pareek A, Sopory SK, Bohnert HJ and Govindjee 2010. Abiotic Stress Adaptation in Plants, Springer, The Netherlands.
Dumont S and Rivoal J.2019. Consequences of oxidative stress on plant glycolytic and respiratory metabolism. Frontiers in plant science,10.
Mittler R.2002. Oxidative stress, antioxidants and stress tolerance. Trends in Plant Science,7(9),pp.405-410.
Demidchik V.2015. Mechanisms of oxidative stress in plants: from classical chemistry to cell biology. Environmental and experimental botany,109,pp.212-228.
Yadav P, Kumar S and Jain V. 2016. Recent Advances in Plant Stress Physiology. Daya Publishing House, New Delhi.
Rout GR and Das AB.2013. Molecular Stress physiology of plants. Springer, India.
Mahalingam, Ramamurthy (Ed.) 2015. Combined Stresses in Plants Physiological, Molecular, and Biochemical Aspects
Gill SS, Anjum NA, Gill R and Tuteja N,2016. Abiotic Stress signaling in plants–an overview. Abiotic Stress Response in Plants, 3,pp.1-12.
Prakash M and Dr K Balakrishnan. 2014. Abiotic Stress tolerance in crop plants. Satish Serial Publishing House. Delhi. ISBN:978-93-81226-92-6.
Kumar S, Muthappa (Ed.)2017. Plant Tolerance to Individual and Concurrent Stresses
Fernando VD and Schroeder DF. 2016. Role of ABA in Arabidopsis salt, drought, and desiccation tolerance. In Abiotic and Biotic Stress in Plants-Recent Advances and Future Perspectives. Intech Open.
Ali A, Ali Z, Quraishi UM, Kazi AG, Malik RN, Sher Hand Mujeeb-Kazi A. 2014. Integrating physiological and genetic approaches for improving drought tolerance in crops. In Emerging

technologies and management of crop stress tolerance (pp.315-345).Academic Press.
Dixit S, Yadaw RB, Mishra KK and Kumar A. 2017.Marker-assisted breeding to develop the drought-tolerant version of Sabitri, a popular variety from Nepal. Euphytica, 213(8),p.184.
Mir RR, Zaman-Allah M, Sreenivasulu N., Trethowan R and Varshney RK. 2012.Integrated genomics, physiology and breeding approaches for improving drought tolerance in crops. Theoretical and Applied Genetics, 125(4),pp.625-645.
Gupta B and Huang B. 2014. Mechanism of salinity tolerance in plants: physiological, biochemical, and molecular characterization. International journal of genomics, 2014.
Tuteja N. 2007. Mechanisms of high salinity tolerance in plants. In Methodsin enzymology (Vol.428, pp.419-438). Academic Press.

**IWM– 516 : Applied Mathematics for Irrigation Water Management -I 2(1+1)**

**Theory:**

**UNIT I**

Determinants : Introduction, Definition and Expansion of determinants, properties of determinants, Cramer's rule, application of determinants.

**UNIT II**

Matrix Theory : Introduction, Definition and Types of matrices, Algebra of matrices, inverse of a matrix, application of matrices.

**UNIT III**

Differential calculus : Concepts of limits, Definition and theorems on limits, Limit of different types of functions. Differentiation principle and rules of differentiation, Differentiation of different types of functions, Maxima and Minima and their applications.

**UNIT IV**

Partial differentiation: Functions of more than one variable, Definition of partial differentiation, Introduction to ordinary differential equations and their solution.

**UNIT V**

Integral calculus : Indefinite integral and basic properties of integral, standard elementary integrals, integration by substitution and by parts. Integration of trigonometric functions, rational functions. Definite, improper, multiple integrals, application of integrations.

**UNIT VI**

Linear and Non-linear relationship : Concept of linear relationship, concept of curvilinear relationship, different types of curvilinear equations such as $Y = ae^x$, $y = ab^x$, $y = aX^b$. Changing curvilinear relationship to linear relationship.

**Practicals:**

| Sr.No. | Practicals |
|---|---|
| 1. | Exercise on determinants and its application. |
| 2. | Exercise on algebra of matrices. |
| 3. | Exercise on inverse of a matrix. |
| 4. | Exercise on of limit of a function. |
| 5-6. | Exercise on derivate of different types of functions. |
| 7. | Exercise on higher order derivatives, maxima and minima of a function. |
| 8. | Exercise on partial differentiation and formation of differential equation. |
| 9-10. | Exercise on integration of different types of functions. |
| 11. | Exercise on different methods of integration: integration by substitution. |
| 12. | Integration by partial fraction, integration by parts |
| 13-14. | Exercise on Solution to a differential equation. |
| 15-16. | Exercise on linear and curvilinear relationship. |

**Suggested Readings :**

1. Elements of applied mathematics by P.N. Wartikar and J.N. Wartikar.
2. Mathematics : By B.S.Grewal
3. Introduction to Mathematics For Life Scientists : Biomathematics Volume 2 : By K. Krickerberra. R.C. Lewontin, J. Neyman And M. Schreieber.

**STAT 501 Mathematics for Applied Sciences 2+0**

**Theory**

**Unit I**

Set theory-set operations, finite and infinite sets, operations of set, function.

**Unit II**

Vectors and vector spaces, Matrices notations and operations, laws of matrix algebra; transpose and inverse of matrix,. Determinants - evaluation and properties of determinants, Solutions of Linear Equations.

**Unit III**

Variables and functions, limits and continuity of specific functions. Differentiation: theorems of differentiation, differentiation of logarithmic, introductory trigonometric function, exponential and inverse functions, Differentiation of function of a function, derivatives of higher order, partial derivatives. Application of derivatives, Application of partial derivative, derivatives determination of points of inflexion, maxima

**Unit IV**

Integration, methods of integration, reduction formulae, definite and indefinite integral, Applications of integration in Agriculture, Differential Equations

**Suggested Reading**

Hohn FE. 2013. Elementary Matrix Algebra, 3rd Ed., Kindle Edition

Harville D.A. 1997. Matrix Algebra from a Statistician's Perspective. Springer.

Hohn F.E. 1973. Elementary Matrix Algebra. Macmillan.

Searle S.R. 1982.Matrix Algebra Useful for Statistics.John Wiley. Stewart J. 2007. Calculus. Thompson.

Thomas G.B. Jr. and Finney R.L. 1996.Calculus. 9th Ed. Pearson Edu

**IWM-525 Applied Mathematics for Irrigation Water Management-II 2(1+1)**

**Theory :**

**UNIT I**

Mensuration: Computation of areas of regular sections and irregular sections with the help of formulas, computation of volumes of regular and irregular sections with the help of formulas.

**UNIT II**

Numerical methods : Introduction, finite difference and difference formula, difference tables, other difference operators, divided differences, interpolation formulae for equal and unequal intervals , numerical differentiation, numerical interaction.

**UNIT III**

Mathematical models : Introduction to modelling , different stages and importance of mathematical modeling, different types of models and its applications, S-curve, logistic growth equations, introduction to Gompertz, Richards and Chanter growth equations

**UNIT IV**

Two phase dry and saturated system model : relation between porosity and voids ratio, moisture content expressions, relationship between dry weight and wet weight.

**Practical :**

| Sr.No. | Practicals |
|---|---|
| 1. | Problems on areas of regular sections and irregular sections. |
| 2. | Problems on volumes of regular and irregular sections. |
| 3-4 | Problems on Finite differences . |
| 5. | Problems on other difference operators. |
| 6-7,8 | Problems on Interpolation Formulas. |
| 9-10. | Problems on Numerical Differentiation |
| 11-12. | Problems on Numerical Integration. |
| 13. | Problems on mathematical models |
| 14. | Problems on Logistic Growth Equations |
| 15. | Problems on Gompertz, Richards And Chanter Growth Equations. |
| 16. | Problems on Two Phase Dry System Model Two Phase Saturated System. |

**Suggested Readings :**

Numerical Methods in Engineering By Salvadori & Baron.

Calculus of finite differences and Numerical Analysis :by Gupta & Malik , Krishna Prakashan ,Meerut.

Statistical Procedures for Agricultural Research By K.A. Gomez And A.A. Gomez.

Engineering Mathematics - By B.S. Grewal

Mathematical Model in Agriculture : Quantitative Proach To Problems in Agriculture and Related Sciences By J. France And J.H.M. Thornley.

Mathematical Modeling: Models, Analysis and Applications: by Sandeep Banerjee

Mathematical Modelling by J.N. Kapur

**STAT 502 Statistical Methods for Applied Sciences 4(3+1)**

**Unit I**
Box-plot, Descriptive statistics, Exploratory data analysis, Theory of probability, Random variable and mathematical expectation.

**Unit II**
Discrete and continuous probability distributions, Binomial, Poisson, Normal distribution, and their applications. Concept of sampling distribution: chi-square, t and F distributions. Tests of significance based on Normal, chi-square, t and F distributions.

**Unit III**
Introduction to theory of estimation and confidence-intervals, Simple and multiple correlation coefficient, partial correlation, rank correlation, Simple and multiple linear regression model, test of significance of correlation coefficient and regression coefficients, Coefficient of determination, Fitting of quadratic models.

**Unit IV**
Non-parametric tests – sign, Wilcoxon, Mann-Whitney U-test, Run test for the randomness of a sequence. Median test.

**Unit V**
Introduction to ANOVA: One way and Two Way, Introduction to Sampling Techniques, Introduction to Multivariate Analysis, Transformation of Data.

**Practical**

| Sr. No. | Practicals |
|---|---|
| 1 | Some basic concepts , Exploratory data analysis, Descriptive statistics, count, mean, standard deviation, minimum and maximum values and the quantiles of the data etc. Box plot graph |
| 2 | Fitting of Binomial distributions |
| 3 | Fitting of Poisson distributions |
| 4 | Fitting of Normal distributions |
| 5 | Large sample tests based on Normal, Z – test : One and two sample for mean and proportion , |
| 6 | Tests of significance : t – test : One sample, Paired and independent test., testing of significance of r. |
| 7 | Testing of significance F – test : Two variances, |
| 8 | Chi – square test: applications Chi – square Test 2x2 , m x n : testing of goodness of fit. |
| 9 | Confidence-intervals estimation |
| 10 | Simple correlation, testing of simple correlation, Spearman's rank correlation |
| 11 | Multiple and Partial correlation with testing . |
| 12 | Linear regression (a, b, r, Tests of significance). |
| 13 | Multiple Linear regression of Y on X1,X2,$R^2$ and Tests of significance. |
| 14 | Non linear regression, exponential and power function, Fitting of quadratic models. |
| 15,16,17 | Non-parametric tests – sign, Wilcoxon, Mann-Whitney U-test, Run test for the randomness of a sequence. Median test. With examples. |
| 18 | ANOVA- one way and Two way |
| 19 | Simple random sampling with and without replacement practical consideration. |

**Suggested Reading**

Goon A.M, Gupta M.K and Dasgupta B. 1977.An Outline of Statistical Theory. Vol. I. The World Press.

Goon A.M, Gupta M.K. and Dasgupta B. 1983.Fundamentals of Statistics. Vol. I. The World Press.

Hoel P.G. 1971. Introduction to Mathematical Statistics. John Wiley.

Hogg R.V and Craig T.T. 1978.Introduction to Mathematical Statistics. Macmillan.

Morrison D.F. 1976. Multivariate Statistical Methods. McGraw Hill.

Hogg RV, McKean JW, Craig AT. 2012. Introduction to Mathematical Statistics 7th Edition.

Siegel S, Johan N & Casellan Jr. 1956.Non-parametric Tests for Behavior Sciences. John Wiley.

Anderson TW. 2009. An Introduction to Multivariate Statistical Analysis, 3rd Ed . John Wiley

http://freestatistics.altervista.org/en/learning.php.

http://www.statsoft.com/textbook/stathome.html.

**STAT 511 Experimental Designs 3(2+1)**

**Theory**

**Unit I**

Need for designing of experiments, characteristics of a good design. Basic principles of designs- randomization, replication and local control.

**Unit II**

Uniformity trials, size and shape of plots and blocks, Analysis of variance, Completely randomized design, randomized block design and Latin square design.

**Unit III**

Factorial experiments, (symmetrical as well as asymmetrical). orthogonality and partitioning of degrees of freedom. Concept of confounding.

**Unit IV**

Split plot and strip plot designs, analysis of covariance and missing plot techniques in randomized block and Latin square designs; Transformations, Balanced Incomplete Block Design, randomization procedure, analysis and interpretation of results. Response surfaces. Combined analysis.

**Practical**

1. Uniformity trial data analysis
2. formation of plots and blocks,
3. Fairfield Smith Law,
4. Analysis of data obtained from CRD, RBD, LSD,
5. Analysis of factorial experiments,
6. Analysis with missing data
7. Split plot and strip plot designs.

**Suggested Reading**

Cochran WG and Cox GM. 1957. Experimental Designs.2nd Ed. John Wiley.

Dean AM and Voss D. 1999. Design and Analysis of Experiments. Springer. Montgomery DC. 2012. Design and Analysis of Experiments, 8th Ed. John Wiley.

Federer WT. 1985. Experimental Designs. MacMillan.

Fisher RA. 1953. Design and Analysis of Experiments. Oliver & Boyd.

Nigam AK and Gupta VK. 1979. Handbook on Analysis of Agricultural Experiments. IASRI Publ.

Pearce SC. 1983. The Agricultural Field Experiment: A Statistical Examination of Theory and Practice. John Wiley.

www.drs.icar.gov.in.

**STAT 522 Data Analysis Using Statistical Packages 3(2+1)**

**Theory**

**Unit I**

Introduction to various statistical packages: Excel, R, SAS, SPSS. Data Preparation; Descriptive statistics; Graphical representation of data, Exploratory data analysis.

**Unit II**

Test for normality; Testing of hypothesis using chi-square, t and F statistics and Z-test.

**Unit III**

Data preparation for ANOVA and ANCOVA, Factorial Experiments, contrast analysis, multiple comparisons, Analyzing crossed and nested classified designs.

**Unit IV**

Analysis of mixed models; Estimation of variance components; Correlation and regression analysis, Probit, Logit and Tobit Models.

**Unit V**

Discriminant function; Factor analysis; Principal component analysis; Analysis of time series data, Fitting of non-linear models; Neural networks.

**Practical**

1. Use of software packages for summarization and tabulation of data, obtaining descriptive statistics, graphical representation of data;
2. Testing the hypothesis for one sample t-test, two sample t-test, paired t-test, test for large samples - Chi-squares test, F test, one-way analysis of variance;
3. Designs for Factorial Experiments, fixed effect models, random effect models, mixed effect models, estimation of variance components;
4. Linear regression, Multiple regression, Regression plots;
5. Discriminant analysis - fitting of discriminant functions, identification of important variables;
6. Factor analysis. Principal component analysis - obtaining principal component

**Suggested Reading**

Anderson C.W. and Loynes R.M. 1987.The Teaching of Practical Statistics. John Wiley.
Atkinson A.C. 1985. Plots Transformations and Regression. Oxford University Press.
Chambers J.M., Cleveland W.S., Kleiner B and Tukey P.A. 1983. Graphical Methods for Data Analysis. Wadsworth, Belmount, California.
Chatfield C. 1983. Statistics for Technology.3rd Ed. Chapman & Hall. Chatfield C. 1995. Problem Solving: A Statistician's Guide. Chapman & Hall.
Cleveland W.S. 1985.The Elements of Graphing Data. Wadsworth, Belmont, California.
Ehrenberg ASC. 1982. A Primer in Data Reduction. John Wiley.
Erickson B.H. and Nosanchuk T.A. 1992.Understanding Data. 2nd Ed. Open University Press, Milton Keynes.
Snell E.J. and Simpson HR. 1991.Applied Statistics: A Handbook of GENSTAT Analyses. Chapman and Hall.
Sprent P. 1993.Applied Non-parametric Statistical Methods.2nd Ed. Chapman & Hall.
Tufte ER. 1983. The Visual Display of Quantitative Information. Graphics Press, Cheshire, Conn.
Velleman PF and Hoaglin DC. 1981. Application, Basics and Computing of Exploratory Data Analysis. Duxbury Press.
Weisberg S. 1985. Applied Linear Regression. John Wiley.
Wetherill GB. 1982. Elementary Statistical Methods. Chapman & Hall.

# Course Syllabus and Contents for Doctoral Degree

## IWM-611* Advances in farm irrigation system design 3(2+1)

**Theory:**

**UNIT I**

Resources inventory of irrigation in world and India.

**UNIT II**

Surface irrigation; Evaluation of border, basin and furrow irrigation methods, Evaluation objectives. inflow-outflow, advance and recession opportunity time, surface storage, infiltration, different irrigation efficiencies. Design Objectives, data collection,

**UNIT III**

Design of border, basin and furrow irrigation methods based on volume balance approach. Advances in surface irrigation systems- surge irrigation: effect of surging on surface flow hydraulics, cablegation: water supply management.

Sprinkler irrigation systems: planning factors, sprinkler uniformity and efficiency, pipe line hydraulics and economics. Lateral design, mainline design. Pressure requirement. Pump and power unit selection criteria. Evaluation of sprinklers, Atomization in sprinkler irrigation, modern sprinkler systems like micro, mini and gun sprinkler. Design of rain gun sprinklers. Micro sprinklers and spray jet methods of irrigation and their utility.

**UNIT IV**

Trickle irrigation: hydraulics of drip irrigation, design of filters, emitter selection, lateral design and selection. Manifold and main line design.

**UNIT V**

Evaluation of trickle irrigation. Automization in micro irrigation. Selection of proper irrigation system. Special uses of micro irrigation like Fertigation. Comparison of different fertigation methods. Cost estimation Evaluation. Concepts of some latest technologies like porous pipe irrigation.

**Practical :**

1. Basin irrigation evaluation
2. Border irrigation evaluation
3. Furrow irrigation evaluation
4. Estimation of seepage losses through unlined channel
5. Use of gated pipe for furrow and border irrigation
6. Sprinkler irrigation system components functions and testing.
7. Nozzle discharge measurement with pressure variation in system for different types of sprinklers.
8. Uniformity coefficient determination.
9. Computation of head losses in system by different formulae.
10. Case study on Design & layout of sprinkler system.
11. Drip irrigation system components: functions and testing.
12. Pressure-discharge relationship and emission uniformity measurement.
13. Study of filtration capacity of drip irrigation.
14. Computation of head losses in the system.
15. Fertilizer application through ventury and fertilizer tank.
16. Design case study on drip irrigation.
17. Evaluation of drip irrigation system.

**Suggested Readings :**

Irrigation Theory and Practices (1978) by A.M. Michael

Land and Water Management Engineering by V.V.N. Murthi.

Trickle Irrigation for Crop Production: Design, Operation and Management by F.S. Nakayama and D.A. Bucks.

Sprinkle and Trickle Irrigation by Jack Keller and R.D. Bliesner

Trickle Irrigation design by Jack Keller and D. Karmeli.

Drip Irrigation by R.K. Sivanappan, O.Padmakumari and V. Kumar.

Design, Operation and Maintenance of Drip Irrigation, MPKV Pub. No.55

Sprinkler Irrigation by R.K. Sivanappan 1987.

Design of trickle irrigation by D. Karmeli and J. Keller.

Pillsbury AF. 1972. *Sprinkler Irrigation*. FAO Agricultural Development Paper No. 88, FAO.

Rydzewski 1987. *Irrigation Development Planning*. John Wiley & Sons.

FAO. 1982. *Mechanized Sprinkler Irrigation*. FAO Irrigation & Drainage Paper 35.

Surface Irrigation : Systems and Practice by Melvyn kay

**IWM-612* Drought Climatology 3(2+1)**

**Theory**

**UNIT I**

Concept, definition, types of drought and their causes; prediction of drought; crop water stress index, crop stress detection; air pollution and its influence on vegetation.

**UNIT II**

Definitions; causes, climatology of Draught. EL Nino and La Nina, Synoptic weather systems during droughts, drought indices and characteristics, significant drought in India,

**UNIT III**

Agronomic practices during drought. Forest fire and drought, drought impact and assessment,

**UNIT IV**

Drought monitoring. Drought mitigation and advisory services, Drought prediction, appraisal and drought policy.

**UNIT V**

Crop weather forecasting, modification of microclimate through heat evasion and trapping, modification of weather through solar radiation management, case studies of successful micrometeorological applications.

**Practical**

Study of drought indices, study of cropping patterns during drought, drought intensity, impact on agriculture, case studies of past droughts, drought impact and assessment.

**Suggested Readings**

Agricultural Meterology by G.S.H.V. Prasad Rao
Principles of Agronomy by Yellamanda Reddi & G.H. Sankara Reddi

**IWM-613 Recent Trends in soil physics 3 (2+1)**

**Theory**

**UNIT- I**

Colloidal properties of soil clays, DDL, flocculation, non-ionic adsorption, Forces and energy in water-van der walls forces, London forces.

**UNIT -II**

Theory of flow of water through saturated soils, water movement-Steady state and isothermal moisture flow-Darcy's law, Laplace equation and boundary value problems. Transient state and isothermal moisture flow,

**UNIT-III**

Fundamental concepts of unsaturated flow, water diffusivity. Water infiltration, simultaneous movement of water and other materials. Miscible displacement – Types of flow, mathematical models for miscible displacement,

**UNIT- IV**

Gaseous diffusion in soils: Ficks law and differential equations of gaseous diffusion. Gas transport in the soil environment, Soil air and plant response-Direct effect. Indirect effect, measurement of soil aeration,

**UNIT-V**

Temperature- Thermal properties of soil. Thermal conductivity, diffusivity of soil, different methods-Smith, Micklay Gemants and Johnsons methods. Mathematical equations for heat flow, Fouriers law, Non steady state, heat flow,

**UNIT -VI**

Water flow in soil. Infiltration, evaporation horizontal and vertical infiltration into soil, numerical examples, Evaporation, soil aeration mass flow, conduction, diffusion gas phase, movement in soils, numerical example,

**UNIT -VII**

Soil water characteristics curves, hysteresis, Solute potential-problems.

**UNIT-VIII**

Soil- plant –Atmosphere relations, radiation, energy budget. Estimating evapotranspiration from climato-logical and soil data, crop coefficient, numerical examples.

**Practical:**

| | |
|---|---|
| 1 | Water content of soils by neutron thermalization method. |
| 2 | Water content of soils by calcium carbide method. |
| 3 | Specific surface of soil by glycol method. |
| 4 | Soil moisture and tension relationships by sintered Glass Funnel method capillary and non-capillary porosity. |
| 5 | Determination of pore size distribution and specific water capacity of soil. |
| 6 | Determination of soil water diffusivity by Bruce and Klute method. |
| 7 | Measurement of soil strength by weighing type penetrometer. |
| 8 | Measurement of permeability of soil. |
| 9 | Measurement of soil temperature by use of thermocouples thermistore. |
| 10 | Determination of oxygen diffusion rates of soil. |
| 11 | Measurement of net radiation. |
| 12 | Measurement of crop canopy temperature by infrared thermometer. |
| 13 | Determination of saturated hydraulic conductivity of soil by augar hole method. |

| | |
|---|---|
| 14 | Determination of leaf water potential by pressure chamber apparatus. |
| 15-16 | Soil moisture and tension relationship with the use of pressure plate apparatus. |

**Suggested Readings**

Baver LD, Gardner WH & Gardner WR. 1972. Soil Physics. John Wiley & Sons.

Hanks and Ascheroft. 1980. Applied Soil Physics. Springer Verlag.

Hillel D. 1980. Applications of Soil Physics. Academic Press.

Hillel D. 1998. Environmental Soil Physics. Academic Press.

Indian Society of Soil Science 2002. Fundamentals of Soil Science. ISSS, New Delhi.

Kirkham, D. & Powers, W L. 1972. Advanced Soil Physics. Wiley Interscience.

Lal R & Shukla MK. 2004. Principles of Soil Physics. Marcel Dekker.

Oswal MC.1994. Soil Physics. Oxford & IBH.

## IWM-621* Diagnostic Analysis & Performance Evaluation of Irrigation projects 3(2+1)

**Theory:**

**UNIT I**

Basic concepts of diagnostic analysis, objectives, activities. Fundamental of conceptual framework for performance evaluation of irrigation project. Study and measurement of performance parameters.

**UNIT II**

The development model, reconnaissance survey, physical, cropping system, economic, social and organizational system, importance of data and data base management in decision making process.

**UNIT III**

Interaction of productivity and water use efficiency under different fertility levels. Efficient utilization of irrigation water. Operational management of irrigation networks. Participatory irrigation water management. Equitable water distribution in command area.

**UNIT IV**

Socioeconomic, political and organizational implication in management of irrigation systems. Irrigation behaviour and decision making, special analysis of irrigation, evaluation of environmental impacts of irrigation systems.

**UNIT V**

Pricing irrigation water. economics of irrigation system farm budget, cash flow technique. Case studies.

**Practical**

| Practical No. | Title |
|---|---|
| 1. | Study of soils and topography of commend area |
| 2-3 | Study of cropping pattern of command area |
| 4 | Study of information/data of command area |
| 5-6. | Study of reconnaissance survey of main irrigation system |
| 7-8 | Study of field tests and measurement of canal flow |
| 9 | Preliminary analysis and data verification of command area project |
| 10. | Study of data analysis and synthesis |
| 11. | Identification of values and constraints and prioritizing solutions |
| 12. | Study of social organization in a command area |
| 13. | Compilation and report writing of D.A. |
| 14-15 | Report presentation by individual team and evaluation |

**Suggested Readings**

Irrigation Theory and Practices by A.M. Micheal
Special course on “ Dignostic Analysis for Trainers”, WALMI, Aurangabad ( May 27-July 6, 1985).
Operation and management of irrigation system WALMI Publ. No. 20, 1987.
Warabandi systems and its infrastructure. Pub. No. 157, Central Board of Irrigation and Power, New Delhi, April 1982.
On farm development works. WALMI Publ. No. 12, 1986.
Warabandi for Irrigated Agriculture in India. Pub. No. 146, Central Board of Irrigation and Power, New Delhi, June, 87.
Irrigation Engineering and hydraulics Structures by S.K. Garg.
Report on diagnosis analysis of Nirgudi. Minor irrigation scheme, WALMI, Pub. 24, Aurangabad 1984.

**IWM-622* Plant Growth Modeling and Simulation 3(2+1)**

**Theory**

**UNIT I**

Systems classification; flow charts, modeling techniques and methods of integration - state, rates and driving variables, feedbacks and relational diagrams.

**UNIT II**

Elementary models for crop growth based on basic methods of classical growth analysis. Crop modeling methods for crop-weather interaction, climate change and variability components.

**UNIT III**

Potential production: leaf and canopy $CO_2$ assimilation, respiration, dry matter accumulation, crop phenology and dry matter distribution and development in different crops.

**UNIT IV**

Production by moisture availability, potential evapotranspiration, water balance of the soil, and production with nutrient and moisture limitations. Introduction to important crop growth models.

**Practical**

1. Simulation of elementary models for crop growth
2. Simulation of potential production
3. Simulation with limitations of water and nutrient management options
4. Sensitivity analysis using different climatic years and crop management practices

**Suggested Readings**

Gordan G. 1992. *System Simulation*. 2nd Ed. Prentice Hall.

Kropff MJ & Vann Laar HH. (Ed.). 1993. *Modelling Crop Weed Interactions*. ISBN.

Mathews RB, Kropff MJ, Bachelet D & Vaan Laar HH. (Eds.). 1993.

*Modelling the Impact of Climate Change on Rice Production in Asia*. CABI. 74

Penning de Vries FWT & Van Laar HH. (Eds.). 1982. *Simulation of Plant Growth and Crop Production*. Wageningen Centre for Agricultural publications and Documentation, Netherlands.

Ritchie JT & Hanks J. 1991. *Modelling Plant and Soil Systems*. American Society of Agronomy, Madison.

Zeigler BP. 1976. *Theory of Modeling and Simulation*. John Wiley & Sons.

**IWM 631*   Management of Saline, Sodic and Acidic soils   3( 2+1)**

**Theory:**

UNIT-I

Processes and factors of soil formation, physical and chemical properties of soils, Texture, structure, soil reaction (pH), soil air, soil temperature, classification of soils of Maharashtra.

UNIT-II

Essential plant nutrients, their functions. Organic manures, Types of fertilizers, methods of fertilizer application, fertilizer use efficiency.

UNIT-III

Land use capability classification and irritability classification, soil physical environment and plant growth.

UNIT-IV

Characteristics of saline, saline-sodic soils, crop tolerance to salinity and alkalinity, acid soils, Effects of salts on plant nutrient availability in problem soils, fertilizer and cultural management in saline and alkali soils, G.R., L.R. use of brackish water for irrigation.

UNIT-V

Quality of irrigation water, use of saline water for crop production, methods and types of drainage.

UNIT-VI

Methods and models for assessing the suitability of saline water for irrigation and crop production. Management principles and practices for safe use of saline water.

**Practical :**

Soil water measurement by neutron probe, tensiometer, Determination of soil moisture characteristic curve with the help of pressure plate and pressure membrane apparatus. Determination of hydraulic conductivity by constant head method, measurement of leaf water potential, Determination of canopy temperature by infrared thermometer, G.R. water quality parameters pH, EC, SAR and RSC. Characterization of saline/sodic soils.

**Suggested Readings :**

Daji, J.A., J.R. Kadam and N.D. Patil. 1999. A text book of Soil Science, Media promoters and publishers Mumbai.

Dakshinamurthi, C. Advances in Soil Physics, ICAR, Publication, New Delhi.

Ghildyal B.P. and R.P. Tripathi. Soil Physics, Wiley eastern Ltd., New Delhi.

Hillel, D. 1980. Application of Soil Physics, Academic Press, New York.

Kadam, J.R. and B.P. Ghildyal 1992. Dictionary of Soil and Water Management Nirali Prakashan Pune-2.

Mortvedt, J.J., Shuman, L.M., Cox, F.R. and Weich, R.M. (ed) 1991. Micronutrients in Agriculture, Soil Science Society of Americal.

Oswal, M.C. 1994. Soil Physics-Oxford IBH, New Delhi.

Rhoades, J.D., A. Kandiah and A.M. Mashali. 1992. The use of saline waters for crop production, FAO, 48.

Richards, L.A. 1968. Diagnosis and improvement of saline and alkali soils. Hand book No.60.

Singh, Dhyan, Chhonkar, P.K. and Pandey, R.N. 1999. Soil Plant Water Analysis. A methods manual I.A.R.I. New Delhi.

## IWM-614* Watershed Management and Modeling 3(2+1)

**Theory**

**UNIT I**

Morphological characteristics of watershed. Computation of runoff volume and peak rate of runoff.

**UNIT II**

Types of soil erosion and their preventive measures. Different in situ soil and water conservation measures on arable and non arable lands. Water storage structures- Nala bunds, farm ponds, percolation tanks. Integration of in situ and ex situ rainwater harvesting structures.

**UNIT III**

Study of water balance in the watershed. Planning of watershed development considering the water harvesting and recycling, management of excess/deficit water. India's watershed development program,

**UNIT IV**

The role of hydrology models: Objectives and concepts. Types of models. Model components. Modelling procedures: problem definition, boundary identification, data requirements, calibration and validation. Designing a conceptual model

**UNIT V**

Rainfall-runoff models: conceptual models, unit hydrograph models, mechanistic catchment models. Sensitivity analysis, parameterisation, calibration, validation, and evaluation. Stanford Watershed model

**Practicals**

| Sr. No. | Practical |
|---|---|
| 1 | Exercise on watershed delineation |
| 2-3 | Determination of morphological characteristics of watershed |
| 4-5 | Probability analysis of rainfall data |
| 6-7 | Computation of runoff volume |
| 8-9 | Computation of peak rate of runoff |
| 10-11 | Determination of soil loss with universal soil loss equation |
| 12 | Study of water balance in the watershed |
| 13-14 | Study of hydrology models |
| 15-16 | Study of watershed models |
| 17-18 | Visit to watershed and NGO |

**Suggested Readings**

Vijay P. Singh AND Donald K. Frevert. 2005. Watershed Models. CRC Press, Taylor and Francis Group

Isobel W Heathcote. 1998. Integrated Watershed Management: Principles and Practice. Wiley Publ.

Kenneth N Brooks, Peter F Ffolliott, Hans M Gregersen, Leonard F DeBano. 1991. Hydrology and the Management of Watersheds. Wiley-Blackwell

Singh G. and Shastri Manual of soil and water conservation works

**IWM 615* On Farm Water Management 2(1+1)**

**Theory:**

**UNIT I**

Approaches and concepts of micro distribution network, survey and mapping, planning, structures of field channels,

**UNIT II**

Estimates of O.F.D. works construction, operation and testing maintenance of O.F.D. works. Land shaping farmers involvement, development, centroid method of land leveling, laser beam land leveling. Operation control signals.

**UNIT III**

Irrigation scheduling, cropping system, water measuring devices, equivalence of crops, leveling on irrigation efficiencies and crop yield.

**UNIT IV**

Design of chak, management of one cusec flow use of siphon tubes, irrigation equipments, evaluation of MAD values, on farm water measurement, irrigation efficiencies, water users association, role of NGOs and Govt. in Planning and execution of on farm water management.

**Practical**

| Sr. No. | Practicals |
|---|---|
| 1. | Planning of O.F.D. structures |
| 2. | Use and working of O.F.D. structures |
| 3-4. | Land leveling by different methods : conventional and centriod |
| 5. | Irrigation scheduling-different approaches |
| 6. | Water measuring devices-Notch's, weirs, flumes, orifices etc. |
| 7. | Equivalence of crops evaluation of cropping systems |
| 8. | Design of chak |
| 9. | Management of one cusec flow using siphon tube. |
| 10. | Evaluation of MAD values |
| 11-12. | Determination of irrigation efficiencies application, storage and distribution efficiency. |
| 13. | Study of water users association role and functioning |

**Suggested Readings**

Irrigation theory and practice by A.M. Michel 1978

Principles of Agriculture Engineering Volume II by A.M. Michel and T.P. Ojha. 1978

**IWM- 623* Soil Survey Applications in Irrigation Water Management 2(1+1)**

**Theory:**

**UNIT I**

Soil Survey procedures; Manual survey, Remote Sensing techniques including aerial photo interpretation

**UNIT II**

Cartography- principles and techniques for preparation of soil and other interpretative maps, processing of field sheets, compilation and abstraction of maps on different scales.

**UNIT III**

Soil correlation; Criteria for classification at different levels in soil Taxonomy; Soil quality assessment; Interpretation of soil resource information for agricultural and irrigation uses.

**UNIT IV**

Land irrigability classification, Soil survey for assessment of problematic soils, Land use planning, concepts of benchmark soils for agro technology transfer in soils; Geographic Information Systems for resource inventorilization.

**Practical:**

| | |
|---|---|
| 1-2 | Study of soil profiles developed in different moisture and temperature regimes and their classification |
| 3 | preparation of soil monoliths, |
| 4-5 | Development of a soil survey map of a command |
| 6 | Preparation of land irrigability classes for the command |
| 7-8 | Preparation of problematic soil map of the command |
| 9-10 | Use of MS ACCESS for soil survey data analysis |
| 11-12 | Soil survey of a project area using aerial photographs and preparation of soil survey report |
| 13-14 | Study of satellite image for soil survey |
| 15-16 | Study of landforms using remote sensing data |
| 17-18 | Use of GIS for preparation of different thematic maps |

**Suggested Readings**

Application of soil survey in irrigation water management, WALMI Pub. No 21

**IWM-624 Computer Applications in Irrigation Water Management 2(1+1)**

**Theory:**

**UNIT I**

Introduction to MS-Word, MS Excel, Use of MS Excel for data analysis and problem solving.

**UNIT II**

Introduction to C language. Syntax rules, Variables and Constants, C-instructions

UNIT III

Decision control structure: if and if- else statement, nested if , forms of if, Use of Logical Operators, Loop and control structures

**UNIT IV**

Developing small modules of irrigation water management using C language, Study and use of existing softwares e.g. CROPWAT etc. introduction to Functions & Pointers, Arrays

**Practicals:**

| Sr.No. | Practicals |
|---|---|
| 1. | Exercise on MS-Word. |
| 2-3. | Exercise on use of MS Excel for data analysis. |
| 4. | Exercise on defining constant, variables and related rules. |
| 5-6. | Exercise on C – instructions. |
| 7-8. | Exercise on Decision control structure. |
| 9. | Exercise on using Logical Operators |
| 10-11. | Writing simple C-programs |
| 12-13. | Exercise on Loop and control structures |
| 14-15. | Developing small modules of irrigation water management using C language. |
| 16. | Introduction to Functions & Pointers, Arrays |

**Suggested Readings** :

C- Programming by Balguruswami.
Let us C by Yashwant Kanetkar.

**IWM 633* Economic Analysis of Irrigation Water use 2(1+1)**

**Theory**

**UNIT I**

Crop response to irrigation and application of production function.

**UNIT II**

Mathematical models of computer simulation/ system analysis to water allocation and management problems.

**UNIT III**

Linear programming, dynamic programming, multi-purpose, multi-objective water resources development, allocation and optimization.

**UNIT IV**

Groundwater economics and conjunctive use plan of water resources.

**Practical:**

Optimization models for economics of irrigation, simulation models, Linear, dynamic programming

**Suggested Reading**

Heady, Early Orel, Hexem R and Roger W. 1978. *Water Production Functions for Irrigated Agriculture*.

James Douglas and Lee Rober R. 1995. *Economics of Water Resource Planning*. Tata Mcgraw-Hill Publication Company Ltd, Bombay, New Delhi.

Joshi SS and TR Kapoor. 2001. *Fundamentals of Farm Business Management*. Kalyani Publishers, Ludhiana.

*Management of Water Project-Decision Making and Investment Appraisal*. Oxford Publication Co.

Sharma VK. 1985. *Water Resource Planning and Management*. Himalaya Publication House, New Delhi.

**IWM 634*	Environmental Impact Assessment of Irrigation Projects	2(1+1)**

**Theory**

**UNIT I**

Nature of environmental impacts of water resources development, environmental impact assessment for irrigation and drainage projects.

**UNIT II**

Protocols, procedures and regulations in India.

**UNIT III**

Use of GIS for assessment and prediction of impacts. Preparation of EIA reports on water resources projects. Social assessment, Risk and uncertainty in EIA.

**UNIT IV**

Agricultural non point pollution sources. Modelling pollutant transport in runoff and sediments; modelling pollutant loadings to groundwater.

**UNIT V**

Case studies on EIA of irrigation and drainage projects.

**Practicals**

1. Prediction and Assessment of Impacts on the Surface-Water Environment
2. Prediction and Assessment of Impacts on the Soil and Groundwater Environments
3. EIA of irrigation projects
4. EIA of watershed development projects
5. EIA of drainage projects

**Suggested readings**

Jain, R.K., et al. 2001. Environmental Assessment. Second Edition. McGraw-Hill Professional Publishing.

Canter, Larry W. 1996. Environmental Impact Assessment. Second Edition. McGraw-Hill Inc. Series in Water Resources & Environmental Engineering.

Environmental Science for Environmental Management. 2000. Edited by Timothy O'Riordan. Second Edition. Prentice Hall. Pearson Education Limited.

Glasson, John. 1999. Introduction to Environmental Impact Assessment: Principles and Procedures, Process, Practice, and Prospects. UCL Press.

Wood, Christopher. 1995. Environmental Impact Assessment / A Comparative Review. Prentice Hall. Pearson Education Limited.

Calow, Peter. 1999. Handbook of Environmental Impact Assessment. Blackwell Science

Westman, Walter E. 1985. Ecology, Impact Assessment, and Environmental Planning. Wiley-Interscience.

Gilpin, Alan. 1995. Environmental impact assessment (EIA): cutting edge for the twenty-first century, Cambridge University Press.

## MCA 513 MATHEMATICS FOR APPLIED SCIENCES 2+0

**Objective**

This course is meant for students who do not have sufficient background of Mathematics. The students would be exposed to elementary mathematics that would prepare them to study their main courses that involve knowledge of Mathematics. The students would get an exposure to Linear Algebra, differentiation, integration and differential equations etc.

**Theory**

**UNIT I**

Set theory-set operations, finite and infinite sets, operations of set, function.

**UNIT II**

Vectors and vector spaces, Matrices notations and operations, laws of matrix algebra; transpose and inverse of matrix, Eigen values and Eigen vectors. Determinants - evaluation and properties of determinants, Solutions of Linear Equations.

**UNIT III**

Variables and functions, limits and continuity of specific functions. Differentiation: theorems of differentiation, differentiation of logarithmic, trigonometric, exponential and inverse functions, Differentiation of function of a function, derivatives of higher order, partial derivatives. Application of derivatives, determination of points of inflexion, maxima and minima.

**UNIT IV**

Integration, methods of integration, reduction formulae, definite and indefinite integral, Applications of integration in Agriculture, Differential Equations.

**Suggested Readings**

Franz E. Hohn (2013). Elementary Matrix Algebra, 3rdEd., Kindle Edition
Harville DA. 1997. Matrix Algebra from a Statistician's Perspective.
Springer.
Hohn FE. 1973. Elementary Matrix Algebra. Macmillan.
Searle SR. 1982. Matrix Algebra Useful for Statistics. John
Wiley. Stewart J. 2007. Calculus. Thompson.
Thomas GB. Jr. & Finney RL. 1996. Calculus. 9th Ed. Pearson Edu

**RPE 601 Research and Publication Ethics 1+1**

**Aim of the Course:**
This course is mainly focusing on basics of philosophy of science and ethics, research integrity, publication ethics. Hands on sessions are designed to identify research misconduct and predatory publications. Indexing and citation databases, open access publications, research and p metrics and plagiarism tools introduced in the course.

**THEORY**
**Unit 1: Philosophy and Ethics**
1. Introduction to philosophy: definition, nature and scoope, concept, branches
2. Ethics: definitino, moral philosophy, nature of moral judgements and reations.

**Unit 2: Scientific Conduct**
1. Ethics with respcet to science and research
2. Intellectual honest and research integrity
3. Scientific misconducts: falsification, fabrication, and plagiarism.
4. Redundant publications: duplicate and overlapping publications, salami slicing
5. Selective reporting and misrepresentation of data.

**Unit 3: Publication Ethics**
1. Publication ethics: definition, introduction and importance
2. Best practices/standards setting initiatives and guidelines: COPE, WAME, etc.
3. Conflicts of interest
4. Publication misconduct: definition, concept, problems that lead to unethical behavior and vice verse, types
5. Violation of publication ethics, authorship and contributor ship
6. Identification of publication misconduct, complaints and appeals
7. Predatory publishers and journals

**Unit 4: Open Access Publishing**
1. Open access publications and initiatives
2. SHERPA/RoMEO online resourse to check publisher copyright and self-archiving policies.
3. Software tool to identify predatory publications developed by SPPU
4. Journal finder/ journal suggestion tools viz. JANE, Elsevier Journal Finder, Springer Journal Suggester, etc.

**Unit 5: Publication Misconduct**
A. Group Discussions
1. Subject specific ethical issues, FFP, authorship
2. Conflicts of interest
3. Complaints and appeals: examples and fraud from India and abroad

B. Software tools
Use of plagiarism software like Turnitin, Urkund and other open source software tools.

**Unit 6: Databases And Research Metrics**
A Databases
1. Indexing detabeses
2. Citation detabases: Web of Science, Scopus, etc.

B. Research Metrics
Impact Factor of journal as per journal citation report, SNIP, SJR, IPP, Cite Score.
Metrics: h-index, g index, i10 index, altmetrics

**Practicals**

**1. Types of Reaserach**

1. Basic Research:
2. Applied Research:
3. Descriptive Research:
4. Analytical Research:
5. Correlational Research:
6. Qualitative Research:
7. Quantitative Research:
8. Experimental Research:
9. Explanatory Research:
10. Exploratory Research:
11. Selection of Domain/Area of Research:

**2. Formulating a Research Problem and Identification of Keywords:**

1. Literature Survey:
2. Redefining Research Problem, Objectives and Outcomes:
3. Research Proposal:
4. Identifying Variable /Parameters and Research Design:
5. Data Collection and Representation:
6. Testing of Proposed Design on Collected Data/Hypothesis Testing:

**3. Results and Analysis:**

1. Research Report Writing:
2. Features of Good Research Study

**4. Journal Search**

1. Open Access Publishing
2. Impact Factor of journal as per journal citation report, SNIP, SJR, IPP, Cite Score.
   Metrics: h-index, g index, i10 index, altmetrics

**Suggested Readings**


- Bird,A. (2006). Philosophy of Sciences. Routledge
- MacIntyre, Alasdair (1967). A Short History of Ethics. London
- P.Chandah. (2018). Ethics in Competitive Research: Do not get Scooped; do not get plagiarized.
- National Academy of Sciences, National Academy of Engineering and Institute of Medicine (2009)., National On being a Scientist: A guide to responsible conduct in Research : third edition, National Academies Press
- Hall GM. Book Farthing MJG. How to Write a Paper. UK Blackwell Publishing; 2008
- NAS-NAE-IOM. Responsible Science: Ensuring the Integrity of the Research Process. Washington, DC: National Academy Press; 1992.
- Alexander M. Novikov & Dmitry A. Novikov, Research Methodology: From Philosophy of Science to Research Design, CRC Press Taylor & Francis Group, (2013).
- C. R. Kothari, Research Methodology: Methods and Techniques, New Age International (P) Ltd., New Delhi (2004).
- David Bridges, Philosophy in Educational Research: Epistemology, Ethics, Politics and Quality, Springer International Publishing AG (2017).
- Deepak Chawla & Neena Sondhi, Research Methodology: Concepts and Cases, VIKAS® Publishing House Pvt Ltd, New Delhi (2015).

- Paul Smeyers & Marc Depaepe, Educational Research: Ethics, Social Justice, and Funding Dynamics, Springer International Publishing AG, (part of Springer Nature) (2018).
- Peter Pruzan, Research Methodology: The Aims, Practices and Ethics of Science, Springer International Publishing Switzerland (2016).
- Ranjit Kumar, Research Methodology: a step-by-step guide for beginners, SAGE Publications India Pvt Ltd, New Delhi (2011).
- Richard Pring, Philosophy of Educational Research, Continuum, London (2000).
- Robyn Brandenburg & Sharon McDonough, Ethics, Self-Study Research Methodology and Teacher Education, Springer Nature Singapore Pte Ltd. (2019).
- S. K. Yadav, Elements of Research Writing, UDH Publishers and Distributers, New Delhi (2015).
- Surbhi Jain, Research Methodology in Arts, Science and Humanities, Society Publishing, Oakville, Canada (2019).
- Vinayak Bairagi and Mousami V. Munot, Research Methodology A Practical and Scientific
- Approach, CRC Press Taylor & Francis Group, New York, NY (2019).

**E resources and List of Journals**

- *Advances in Applied Research*
- *Advances in Computational Sciences and Technology [ACST]*
  *Advances in Mechanical Engineering*
  *Advances in Water Resources*
  *Agricultural Engineering*
  *Agricultural Engineering Today*
  *Agricultural Mechanization in Asia, Africa and Latin America*
  *Agricultural Research*
  *Agricultural Reviews*
  *Agricultural Science Digest*
  *Agricultural Water Management*
  *Agronomy Journal (Journal of American Society of Agronomy*
  *American Journal of Food Technology*
  *American Statistician*
  *Annals of Agri Bio Research*
  *Annals of Agricultural Research*
  *Annals of Arid Zone*
  *Annals of Biology*
  *Annals of Horticulture*
  *Annals of Science*
  *Annals of Statistics*
  *Applied Ecology and Environmental Research*
  *Applied Engineering in Agriculture*
  *Applied Ergonomics*
  *Arid Land Research and Management*
  *Asian Journal of Chemistry*
  *Asian Journal of Environmental Science*
  *Atmospheric Research*
  *Australian Journal of Crop Science*
  *Australian Journal of Dairy Technology*
  *Beverage and Food World*
  *CIGR journal*
  *Comptes Rendus Geosciences*
  *Computers and Electronics in Agriculture*
  *Computers & Industrial Engineering*
  *Cotton Research Journal*
  *Current Advances in Agricultural Sciences*
  *Current World Environment*
  *Ecological Engineering*
  *Ecology, Environment and Conservation*
  *Engineering and Technology in India*
  *Environment*
  *Environment and Ecology*
  *Environmental Engineering Science*
  *Environmental Monitoring and Assessment*
  *Environmental Science and Pollution Research*
  *Environmental Science and Technology*
  *Environmental Review*
  *Forage Research*

- *Groundwater*
  *Hydrological Processes*
  *IETE Journal of Research*
  *IETE Journal of Education*
  *Indian Journal of Agricultural Chemistry*
  *Indian Journal of Agricultural Research*
  *Indian Journal of Agricultural Sciences*
  *Indian Journal of Dairy Science*
  *Indian Journal of Extension Education*
  *Indian Journal of Hill Farming*
  *Indian Journal of Radio and Space Physics*
  *Indian Journal of Science and Technology*
  *Indian Journal of Soil Conservation*
  *Indian Research Journal of Extension Education*
  *Institute of Engineers (India)*
  *Journal of Electronics & Tele Communication*
  *International Journal of Agricultural Engineering*
  *International Journal of Agricultural Science and Research*
  *International Journal of Advance Industrial Engineering*
  *International Journal of Advanced Mechanical Engineering [IJAME]*
  *International Journal of Advanced Engineering Technology (IJAET)*
  *International journal of Advanced Research in Engineering & Technology (IJARET)*
  *International Journal of Applied Engineering Research [IJAER]*
  *International Journal of Current Engineering and Technology*
  *International Journal of Design and Manufacturing Technology(IJDMT)*
  *International Journal of Engineering Research and Technology [IJERT]*
  *International Journal of Engineering, Science and Metallurgy*
  *International Journal of Engineering (IJE)*
  *International Journal of Engineering Studies [IJES]*
  *International Journal of Environmental Analytical Chemistry*
  *International Journal of Environmental Research and Public Health*
  *International Journal of Environmental Science and Technology*
  *International Journal of Extension Education*
  *International Journal of Food Engineering*
  *International Journal of Food Microbiology*
  *International Journal of Food Properties*
  *International Journal of Food Science and Nutrition*
  *International Journal of Food Science and Technology*
  *International Journal of Food and Fermentation Technology*
  *International Journal of Innovative Technology and Exploring Engineering (IJITEE)*
  *International Journal of Industrial Engineering & Technology [IJIET]*
  *International Journal of Industrial Engineering Research and Development (IJIERD)*
  *The International Journal of Industrial Engineering: Theory,*

- *Application and Practice (IJIETAP)*
  *International Journal of Engineering and Management Research (IJEMR)*
  *International Journal of Engineering Sciences and Management*
  *International Journal of Industrial Engineering Computations*
  *International Journal of Engineering and Manufacturing Science [IJEMS]*
  *International Journal of Research in Chemistry and Environment*
  *International Journal of Research In Mechanical Engineering And Technology (IJRMET)*
  *International Journal of Thermal Sciences*
  *International Journal of Mechanical Engineering and Robotics Research*
  *International Journal of Material and Mechanical Engineering*
  *International Journal of Mechanical Engineering & Technology(IJMET)*
  *International Journal of Mechanical Engineering and Research(IJMER)*
  *International Journal of Mechanical Sciences*
  *International Journal of Recent Technology and Engineering(TM) Exploring Innovation*
  *International Journal of Industrial & Production Engineering & Tech. [IJIPET]*
  *International Journal of Industrial and Systems Engineering*
  *International Journal of Advanced Materials Science [IJAMS]*
  *International Journal of Research in Mechanical Engineering*
  *International Journal of Engineering & Technology Research*
  *International Review of Applied Engineering Research [IRAER]*
  *International Journal of Mechanical and Materials Engineering*
  *International Journal of medical, Health, Biomedical, Bioengineering and Pharmaceutical Engineering*
  *International Journal of Production Technology and Management (IJPTM)*
  *International Journal of Refrigeration*
  *International Journal of Remote Sensing*
  *International Journal of Thermal Technologies*
  *International Journal of Water Resources Development*
  *International Journal on Agricultural Sciences*
  *International Journal on Environmental Sciences*
  *International Journal of Applied Research on Information Technology and Computing*
  *International Journal of Mechanical Engineering*
  *International Journal of Mechanical and Production Engineering Research and Development*
  *International Scholarly Research Notices, ISRN Mechanical Engineering*
  *Irrigation Science*
  *Irrigation and Drainage (ICID Bulletin)*
  *Irrigation and Drainage System*
  *Italian Journal of Food Science*
  *Journal of Agricultural Engineering (ISAE)*
  *Journal of Agriculture Research and Technology*

- *Journal of Agricultural Safety and Health*
  *Journal of Applied Ecology*
  *Journal of Applied Probability*
  *Journal of Applied Statistics*
  *Journal of Arid Environments*
  *Journal of Cotton Research and Development*
  *Journal of Dairy Research*
  *Journal of Dairy Science*
  *Journal of Ecology*
  *Journal of Energy Engineering - ASCE*
  *Journal of Engineering*
  *Journal of Engineering computers and Applied Sciences*
  *Journal of Engineering Research*
  *Journal of Ergonomics*
  *Journal of Environmental Engineering*
  *Journal of Environmental Monitoring*
  *Journal of Environmental Protection and Ecology (JEPE)*
  *Journal of Environmental Sciences*
  *Journal of Environmental Science and Engineering*
  *Journal of Environmental Science, Toxicology and Food Technology*
  *Journal of Food Biochemistry (Journal of Food Lipids)*
  *Journal of Food Composition and Analysis*
  *Journal of Food Engineering*
  *Journal of Food Legumes*
  *Journal of Food Process Engineering*
  *Journal of Food Processing and Preservation*
  *Journal of Food Quality*
  *Journal of Food Safety*
  *Journal of Food Science*
  *Journal of Food Science and Technology*
  *Journal of Food, Agriculture and Environment*
  *Journal of Human Ecology*
  *Journal of Hydraulic Engineering – ASCE*
  *Journal of Hydraulic Research*
  *Journal of Hydrologic Engineering*
  *Journal of Hydrology*
  *Journal of Indian Society of Agricultural Statistics*
  *Journal of Indian Water Resources Society*
  *Journal of Industrial Engineering International*
  *Journal of Irrigation and Drainage Engineering (ASCE)*
  *Journal of Mechanical Engineering*
  *Journal of Materials in Civil Engineering*
  *Journal of Manufacturing Processes*
  *Journal of Research, PAU*
  *Journal of Soil and Water Conservation*
  *Journal of Soil and Water Conservation, India*
  *Journal of Statistical Computation and Simulation*
  *Journal of Statistical Planning and Inference*
  *Journal of Statistical Theory and Practice*
  *Journal of Stored Products Research*
  *Journal of Sustainable Agriculture*