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| **Course code** | **FMPE 501** |
| **Course title** | **Soil Dynamics in Tillage and Traction** |
| **Course credit** | **2+1** |
| **Objective of Course** | • To develop knowledge and skill for technical education and research in soil dynamics.<br>• To develop the ability of the students for formulating and solving solutions to problems pertaining to soil dynamics.<br>• To strengthen the knowledge among students for Industry and R&D organizations. |
| **Course Content** | **Theory**<br>**Unit I**<br>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.<br>**Unit II**<br>Soil cutting forces: The universal earth moving 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.<br>**Unit III**<br>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.<br>**Unit IV**<br>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 vehicles and machines.<br>**Practical**<br>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 coefficients for 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. |

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| **References:** | • Gill, R., & Vanden Berg, G. E. (2013). Soil Dynamics in Tillage and Traction. New Delhi, India: Scientific Publishers.<br>• John B. L., Paul K. T., David W. S., & Makoto, H. (2012). Tractors and their Power Units(4th ed.).New York, USA: Van Nostrand Reinhold.<br>• Koolen, A. J., & Kuipers, H. (1983). Agricultural Soil Mechanics. Heidelberg, Germany: Springer- Verlag.<br>• McKyes, E. (1989). Agricultural Engineering Soil Mechanics. Amsterdam, Netherland: Elsevier science publishers.<br>• McKyes E. (2016). Soil Cutting and Tillage. Developments in Agricultural Engineering-7. Amsterdam, Netherland: Elsevier Science Publisher. |
| **Course Outcomes** | At the end of the course, learners will be able<br>**CO1**: To acquaint and equip with the principles of dynamic properties of soil and its effect on soil tyre performance.<br>**CO2:** Acquire knowledge on basics of soil failure and tillage tool design<br>**CO3**: Understand the theory of 3 dimensional soil failure.<br>**CO4**: To solve the analytical problems related to the soil dynamics.<br>**CO5**: To predict the traction performance of traction device. |

**Mapping between Cos, POs and PSOs**

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| **Course code** | **FMPE 502** |
| **Course title** | **Testing and Evaluation of Agriculture Equipment** |
| **Course credit** | **2+1** |
| **Objective of Course** | • To develop knowledge and skill for technical education and research in testing of farm power and machinery.<br>• To develop the ability of the students for the evaluation of farm power and machinery testing.<br>• To strengthen the knowledge among students for Industry and R&D organizations. |

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| **Course Content** | **Theory**<br>Unit I<br>Importance and significance of testing and types of testing. Test equipment, usage and limitations. Test procedures and various test codes: National and International.<br>Unit II<br>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.<br>Unit III<br>Laboratory and field testing of manual and power operated intercultural machinery and plant protection machine.<br>Unit IV<br>Laboratory and field testing of reaper, thresher and chaff cutter.<br>Unit V<br>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.<br>**Practical**<br>Laboratory and field testing of selected farm equipment: Tillage, sowing and planting. Material testing of critical components. Accelerated testing of fast wearing components. |
| **References:** | • John B. L., Paul K. T., David W. S., & Makoto, H. (2012). Tractors and their Power Units (4th ed.). New York, USA: Van Nostrand Reinhold.<br>• Indian Standard Codes for Agricultural Implements. Published by BIS, New Delhi.<br>• Inns, F M. (1995). Selection, Testing and Evaluation of Agricultural Machines and Equipment. FAO Service Bull. No.-115.<br>• Mehta, M. L., Verma, S. R., Rajan, P. & Singh, S. K.(2019). Testing and Evaluation of Agricultural Machinery. Delhi, India: Daya Publishing House.<br>• Nebraska Tractor Test Code for Testing Tractor, Nebraska, USA.<br>• Smith, D. W., Sims, B. G., & O'Neill, D. H. (1994). Testing and Evaluation of Agricultural Machinery and Equipment - Principle and Practice. FAO Agricultural Services Bull.-110. |
| **Course Outcomes** | At the end of the course, learners will be able<br>**CO1**: To acquaint and equip with standards of farm power and machinery testing. |

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| | **CO2:** Acquire knowledge on testing of tillage implements.<br>**CO3**: Understand the testing of intercultural implements.<br>**CO4**: To test harvesting implements.<br>**CO5**: To test the threshing implements. |

**Mapping between Cos, POs and PSOs**

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| **Course code** | **FMPE 503** |
| **Course title** | **Ergonomics and Safety in Farm Operations** |
| **Course credit** | **2+1** |
| **Objective of Course** | • To develop knowledge and skill of ergonomic aspects for technical education and research in design of farm power and machinery. |
| | • To develop the ability of the students for considering human factors infarm power and machinery design.<br>• To strengthen the knowledge among students for Industry and R&D organizations. |
| **Course Content** | **Theory**<br>Unit I<br>Description of human-machine systems. Ergonomics and its areas of application in the work system. History of ergonomics. Modern ergonomics.<br>Unit II<br>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.<br>Unit III<br>Human factors in tractor seat design: Entry-exit system, controls, shape, colour coding, dial and indicators. Modern technology for comfort in driving places. Noise and vibration measurement.<br>Unit IV<br>Physiological parameters: Psychological and mental stresses and their measurement techniques. Human energy expenditure: Calibration of subjects, human workload and its assessment.<br>Unit V<br>Safety considerations and operators protective gadgets in farm operations. Standards/codes for tractors and agricultural machinery safety.<br>**Practical**<br>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. |
| **References:** | • Bridger,R.S.(2009). Introduction to Ergonomics. Boca Rotan,USA:CRC Press.<br>• Sanders,M.S.,&McCormick,E.J.(2000).Human Factors in Engineering and Design(7th ed.). USA:McGraw Hill.<br>• Astrand,P., Rodahl,K., Dahl,H.A.,&Stromme,S.B.(2003). Textbook of Work Physiology Physiological Basis of Exercise.USA:McGraw Hill.<br>• Gite,L.P.(2009). Anthropometric and Strength Data of Indian Agricultural Workers for Farm Equipment Design. Bhopal, India: Central Institute of Agricultural Engineering.<br>• Gite,L.P.,Agrawal,K.N.,Mehta,C.R.,Potdar,R.R.,&Narwariya,B.S.(2019).H andbook of Ergonomical Design of Agricultural Tools, Equipment and work Places.New Delhi,India:Jain Brothers.<br>• Mehta,C.R.,Kumar,A.,Gite,L.P.,&Agrawal,K.N.(2022).Ergonomics and Safety in Agriculture.New Delhi, India: ICAR.<br>• Tayyari,F.&Smith,J.L.(1997).Occupational Ergonomics. London, Chapman & Hall. |

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| **Course Outcomes** | At the end of the course, learners will be able<br>**CO1**: To acquaint and equip with ergonomic aspects in farm power and machinery design.<br>**CO2:** To get acquaint with physiological parameters.<br>**CO3**:Acquire knowledge on anthropometry.<br>**CO4**: To know human limitations in relation to tractor design.<br>**CO5**: To get used to safety considerations and operators protective. |

**Mapping between Cos, POs and PSOs**

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| **Course code** | **FMPE 504** |
| **Course title** | **Design of Tractor Systems** |
| **Course credit** | **2+1** |
| **Objective of Course** | • To develop knowledge and skill for technical education and research in design of tractor.<br>• To develop the ability of the students,understand latest design procedures of tractor and its systems<br>• To strengthen the knowledge among students for Industry and R&D organizations. |
| **Course Content** | **Theory**<br>**Unit I**<br>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.<br>**Unit II**<br>Engine related terminology. Selection of stroke-bore ratio. Design of engine components; Piston, connecting rod, cylinder, cylinder head, crank shaft etc.<br>**Unit III**<br>Design of tractor systems like clutch, brake, gearbox, steering, steering geometry, turning force, hydraulic system & hitching, chassis, operator's seat, work-place area and controls. Tire selection, aspect ratio etc.<br>**Unit IV**<br>Mechanics of tractor stability. Computer aided design and its application in farm tractors.<br>**Practical**<br>Engine design calculations, transmission component design calculations. Extensive practices on the computer aided design packages. |
| **References:** | • John B. L., Paul K. T., David W. S., & Makoto, H. (2012). Tractors and their Power Units (4th ed.). New York, USA: Van Nostrand Reinhold.<br>• Macmillan, R. H. (2002). The Mechanics of Tractor – Implement Performance and Worked Example. Australia: University of Melbourne.<br>• Sharma, P. C., & Agarwal, D. K. (2000). Machine Design. Delhi, India: S K Kataria and Sons. |
| **Course Outcomes** | At the end of the course, learners will be able<br>**CO1**: To acquaint and equip with the modern trends in tractor design and development.<br>**CO2:** Acquire knowledge on design of tractor engine components.<br>**CO3**: To design components of tractor systems.<br>**CO4**: To know computer aided design and its application in agricultural tractors<br>**CO5**: To get acquaint with mechanics of tractor stability. |

| Mapping between Cos, POs and PSOs | | | | | | | | | | | | | | | |
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| Course code | FMPE 505 |
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| Course title | **Design of Farm Machinery-I** |
| Course credit | **2+1** |
| **Objective of Course** | • To developknowledge and skill for technical education and research in design of tillage and planting implements.<br>• To develop the ability of the students for formulating and solving solutions to problems pertaining to tillage and planting implements.<br>• To strengthen the knowledge among students for Industry and R&D organizations. |
| **Course Content** | **Theory**<br>Unit I<br>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 of basic parameters. Design of coulters, shares, mould boards.<br>Unit II<br>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.<br>Unit III<br>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.<br>Unit IV<br>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.<br>**Practical**<br>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.<br>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. |
| **References:** | • Bernacki, H., Haman, J., & Kanafojski, C. (1972). Agricultural |

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| | Machines Theory and Construction, Volume 1. Virginia, USA: U.S. Dept. of Commerce, National Technical Information Service.<br>• Bosoi, E.S., Verniaev, O.V., Smirnov I. I., & Sultan-Shakh, E.G. (1990). Theory, Construction and Calculations of Agricultural Machinery - Vol.-I. New Delhi, India: Oxonian Press Pvt.<br>• Gill, R., & Vanden Berg, G. E. (2013). Soil Dynamics in Tillage and Traction. New Delhi, India: Scientific Publishers.<br>• Sharma, D. N. & Mukesh, S. (2013). Farm Machinery Design Principles and Problems (3rd ed.). New Delhi: India. Jain Brothers.<br>• Yatsuk, E. P. (1981). Rotary Soil Working Machines Construction, Calculation and Design. New Delhi, India: American Publishing Co. Pvt. Ltd. |
| **Course Outcomes** | At the end of the course, learners will be able<br>**CO1**: To acquaint and equip with the principles, fundamentals and economic considerations for design of farm machinery.<br>**CO2:** Acquire knowledge on design considerations for tillage implements.<br>**CO3**: To know construction and working of various other tillage implements.<br>**CO4:** To design various selected tillage implements.<br>**CO5**:To design various selected seed sowing implements. |

**Mapping between Cos, POs and PSOs**

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| **Course code** | **FMPE 506** |
| **Course title** | **Design of Farm Machinery-II** |
| **Course credit** | **1+1** |
| **Objective of Course** | • To develop knowledge and skill for technical education and research in design of sprayers, harvesters and threshers.<br>• To develop the ability of the students for formulating and solving solutions to problems pertaining to sprayers, harvesters and threshers.<br>• To strengthen the knowledge among students for Industry and R&D organizations. |
| **Course Content** | **Theory**<br>Unit I<br>Pesticide calculation examples. Multidisciplinary nature of pesticide application. Overview of chemical control integrated pest management. Targets for pesticide deposition. Formulation of pesticides.<br>Unit II<br>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.<br>Unit III<br>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. Properties of MOG; Mechanical and aerodynamic.<br>Unit IV<br>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.<br>Unit V<br>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 choppers and shredders.<br>**Practical**<br>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 |

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| | on design of cutterbars, reels, platform auger, conveyors. Design of threshing drum: Radial and axial flow type. Design of cleaning and grading systems. Design of blowers. |
| **References:** | • Bernacki,H., Haman, J., & Kanafojski, C. (1972). Agricultural Machines Theory and Construction, Volume 1. Virginia, USA: U.S. Dept. of Commerce, National Technical Information Service.<br>• Bindra, O. S., & Singh, H. (1971). Pesticides Application Equipments.New Delhi: India, Oxford & IBH Publishing Co.<br>• Bosoi, E. S., Verniaev, O. V., Smirnov I. I., & Sultan Shakh, E. G. (1987). Construction and Calculations of Agricultural Machinery – Vol.-II. New Delhi: India, Oxonian Press Pvt. Ltd.<br>• Miu, P. (2016). Combine Harvesters Modeling and Design. Boca Raton, USA: CRC Press.<br>• Matthews, G. A., & Thornhill, E. W. (1994). Pesticide Application Equipment for Use in Agriculture part 2. Rome, Italy: FAO.<br>• Sharma, D. N. & Mukesh, S. (2013). Farm Machinery Design Principles and Problems (3rd ed.). New Delhi: India. Jain Brothers. |
| **Course Outcomes** | At the end of the course, learners will be able<br>**CO1**:To acquaint and equip with the engineering principles behind application of pesticides.<br>**CO2:** Acquire knowledge on different spraying systems.<br>**CO3**: To know concepts behind design of crop harvesting and threshing equipment.<br>**CO4:** To design various components of harvesting machines.<br>**CO5**: To design various components of threshing machines. |

**Mapping between Cos, POs and PSOs**

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| **Course code** | **FMPE 507** |
| **Course title** | **Management of Farm Power and Machinery System** |
| **Course credit** | **2+1** |
| **Objective of Course** | • To develop knowledge and skill for technical education and research in farm machinery management.<br>• To develop the ability of the students for solving solutions to problems pertaining to farm power and machinery management.<br>• To strengthen the knowledge among students for Industry and R&D organizations. |
| **Course Content** | **Theory**<br>Unit I<br>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.<br>Unit II<br>Tractor power performance in terms of PTO, drawbar and fuel consumption. Power requirement problems to PTO, DBHP.<br>Unit III<br>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.<br>Unit IV<br>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.<br>**Practical**<br>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. |
| **References:** | • Carveille, L. A. (1980). Selecting Farm Machinery. USA: Louisiana Cooperative Extn. Services Publication.<br>• Culpin, C. (1996). Profitable Farm Mechanization. London, UK: Lock Wood and Sons.<br>• FAO. (1990). Agricultural Engineering in Development: Selection of Mechanization Inputs. Rome, Italy: FAO Agricultural Services Bull.-84. |

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| | • Hunt, D. (1979). Farm Power and Machinery Management.USA: Iowa State University Press.<br>• Kapoor, V. K. (2012). Operation Research: Concepts, Problems and Solutions. India: Sultan Chand and Sons.<br>• Singh, S., & Verma, S. R. (2009). Farm Machinery Maintenance and Management. New Delhi, India: Directorate of Information and Publications of Agriculture, ICAR, KAB-I.. |
| **Course Outcomes** | At the end of the course, learners will be able<br>**CO1:** To acquaint and equip with principles of management applied to farm machinery system.<br>**CO2:** Acquire knowledge on tractor power performance measurement.<br>**CO3:** Understand the criterion for selection of farm machinery.<br>**CO4:** To get knowledge on application of programming techniques to farm machinery selection and scheduling.<br>**CO5:** To develop computer program for the selection of power and machinery |

**Mapping between Cos, POs and PSOs**

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| **Course code** | **FMPE 511** |
| **Course title** | **Principles of Automation and Control** |
| **Course credit** | **2+1** |
| **Objective of Course** | • To develop knowledge and skill for technical education and research automation and control systems.<br>• To develop the ability of the students for implementation of systems for automation and control.<br>• To strengthen the knowledge among students for Industry and R&D organizations. |
| **Course Content** | **Theory**<br>**Unit I**<br>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.<br>**Unit II**<br>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.<br>**Unit III**<br>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.<br>**Unit IV**<br>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.<br>**Unit V**<br>Networking of sensors, actuators and controllers, the field bus, the field bus communication protocol, introduction to production control systems.<br>**Practical**<br>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 |

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| | programmable logic controller. Batch process reactor using programmable logic controller. Speed control of AC servo motor using programmable logic controller. |
| **References:** | • https://nptel.ac.in/downloads/108105063/<br>• Manesis, S., & Nikolakopoulos, G. (2018). Introduction to Industrial Automation (1st ed.). USA: CRC Press. |
| **Course Outcomes** | At the end of the course, learners will be able<br>**CO1:**To acquaint and equip with principles behind implementation of systems for automation and control.<br>**CO2:** Acquire knowledge on sequence control systems.<br>**CO3:** Understand the machine tools for control.<br>**CO4:** To get knowledge on various driver systems.<br>**CO5:** To develop PLC program using logic controller. |

**Mapping between Cos, POs and PSOs**

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| **Course code** | **FMPE 512** |
| **Course title** | **Principles of Hydraulic and Pneumatic Systems** |
| **Course credit** | **2+1** |
| **Objective of Course** | • To develop knowledge and skill for hydraulic and pneumatic systems for technical education and research.<br>• To develop the ability of the students for designing simple hydraulic and pneumatic circuits.<br>• To strengthen the knowledge among students for Industry and R&D organizations. |
| **Course Content** | **Theory Unit I**<br>Hydraulic power, its advantages, applications, properties of hydraulic fluids, viscosity, bulk modulus, density. Concepts of energy of hydraulic systems, laws of fluid flow.<br>**Unit II**<br>Hydraulic pump and motors, principle, capacity, classifications, working, performance. Design of various types of pumps and motors.<br>**Unit III**<br>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.<br>**Unit IV**<br>Hydraulic circuit design. Applications in farm power and machinery: Tractor, combine, farm machinery systems, hydrostatic system etc.<br>**Unit V**<br>Power pack, pneumatic circuits, properties of air. Compressors, types. Design of pneumatic circuits.<br>**Practical**<br>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. |
| **References:** | • Anthony, E. (2003). *Fluid Power with Applications*. Singapore, Malaysia: Pearsons Education Pvt. Ltd.<br>• Krutz, G. (1984). *Design of Agricultural Machines*. USA: John Wiley and Sons.<br>• Majumdar, S. R. (2003). *Oil Hydraulics Systems: Principles and Maintenance*. India: Tata McGraw Hill Co.<br>• Merritt, H. E. (1991). *Hydraulic Control System*. USA: John Wiley and Sons Inc. |
| **Course Outcomes** | At the end of the course, learners will be able<br>**CO1:** To acquaint with fundamentals of fluid power systems.<br>**CO2:** Acquire knowledge on hydraulic pump and motors.<br>**CO3:** Understand the working of fluid power actuators, |

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| | hydraulic motors, and hydraulic components.<br>**CO4:** To know the hydraulic circuit design for the applications in farm power and machinery<br>**CO5:** To get knowledge for the design of pneumatic circuits. |

**Mapping between Cos, POs and PSOs**

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| **Course code** | **FMPE 513** |
| **Course title** | **Applied Instrumentation in Farm Machinery** |
| **Course credit** | **2+1** |
| **Objective of Course** | • To develop knowledge and skill of instruments used for technical education and research in farm power and machinery.<br>• To develop the ability of the students for the application of instruments for farm machinery.<br>• To strengthen the knowledge among students for Industry and R&D organizations. |
| **Course Content** | **Theory**<br>Unit I<br>Strain gauges, types and applications in two and three dimensional force measurement in farm machinery. Various methods of determining strain/stresses experimentally. Design, selection and analysis of strain gauges.<br>Unit II<br>Introduction to transducers (sensors). Active and passive transducers, analog and digital modes, null and deflection methods. Performance characteristics of instruments including static and dynamic characteristics.<br>Unit III<br>Load cells, torque meters, flow meters types and principles of working. Devices for measurement of temperature, relative humidity, pressure, sound, vibration, displacement (LVDT) etc. Recording devices and their types. Measuring instruments for calorific value of solid, liquid, and gaseous fuels.<br>Unit IV<br>Basic signal conditioning devices, data acquisition system. 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.<br>**Practical**<br>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. |
| **References:** | • Ambrosius, E. E. (1966). Mechanical Measurement and Instruments. New York, USA: The Ronald Press Company.<br>• Doeblin, E. O. (2004). Measurement System- Application and Design. Tata McGraw Hill<br>• Nakra, B. C., & Chaudhary, K. K. (2009). Instrumentation, Measurement and Analysis (3rd ed.). Tata McGraw Hill.<br>• Nachtigal, C. L. (1990). Instrumentation and Control. Fundamentals and Application. Wiley Series in Mechanical Engineering.<br>• Oliver, F. J. (1971). Practical Instrumentation Transducers. |

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| | Hayden book company Inc. |
| **Course Outcomes** | At the end of the course, learners will be able<br>**CO1**: To acquaint and equip with functional elements of instruments.<br>**CO2:** Acquire knowledge on strain gauges and transducers.<br>**CO3**: Understand the basics of signal conditioning devices<br>**CO4**: To know the measuring instruments for velocity, force, torque, pressure, etc.<br>**CO5**: To gain knowledge on calibration of various devices. |

**Mapping between Cos, POs and PSOs**

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| **Course code** | **FMPE 514** |
| **Course title** | **Systems Simulation and Computer Aided Problem Solving in Engineering** |
| **Course credit** | **1+1** |
| **Objective of Course** | • To develop knowledge and skill for technical education and research in system simulation and computer aided problem solving.<br>• To develop the ability of the students for formulating and solving solutions to problems pertaining to farm power and machinery using computer.<br>• To strengthen the knowledge among students for Industry and R&D organizations. |
| **Course Content** | **Theory**<br>Unit I<br>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.<br>Unit II<br>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.<br>Unit III<br>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, LU decomposition and matrix inversion. Application in: Steady state analysis of chemical reactors, statically determinate truss, current and voltage in circuits, spring mass systems.<br>Unit IV<br>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.<br>**Practical**<br>Comparison of analytical and numerical solutions using Spread sheet. Generation of random variables. Generation of discrete 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.

**References:**


- Balagurusamy, E. (2000). *Numerical Methods.* New Delhi: India: Tata McGraw Hill Publishing Company limited.
- Chapra, S. C., & Canale, R. P. (1994). *Introduction to Computing for Engineers (2nd ed.).*New York, USA: McGraw Hill International Edition.
- Dent, J. B., & Blackie, M. J. (1979). *System Simulation in Agriculture.* London, UK: Applied Science Publishers Ltd.
- Law, A. M. (2015). *Simulation Modeling and Analysis.* New York, USA: McGraw Hill International Edition.
- Schilling, R. J., & Harries, S. L. (2002). *Applied Numerical Methods for Engineers Using MATLAB and C.*Singapore , Malaysia: Thomson Asia Pvt. Ltd.
- Veerarajan, T., & Ramachnadran, T. (2004). *Numerical Methods with Programmes in C and C++.* New Delhi, India: Tata McGraw Hill Publishing Company limited.


**Course Outcomes**

At the end of the course, learners will be able

**CO1**: To acquaint and equip with concept of mathematical modelling and engineering problem solving.

**CO2:** Acquire knowledge on basics of simulation and system models.

**CO3**: Understand the application of commuters for problem solving.

**CO4**: To know the simulation of continuous and discrete engineering systems.

**CO5**: To gain knowledge on optimization techniques.

**Mapping between Cos, POs and PSOs**

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| Course code | **FMPE 515** |
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| **Course title** | **Computer Aided Design of Machinery** |
| **Course credit** | **0+2** |
| **Objective of Course** | • To develop knowledge and skill for technical education and research in computer aided design of machinery.<br>• To develop the ability of the students to conceptualize spatial concepts and design components and assemblies of farm machinery.<br>• To strengthen the knowledge among students for Industry and R&D organizations. |
| **Course Content** | **Practical**<br>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.<br>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.<br>Parts and features: Sketched features and applied features, pattern and mirror features. Documenting design. Assembly: Creating and organizing assemblies, connecting parts and sub assemblies with mates. Organizing the assembly by using layouts.<br>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. |
| **References:** | • Jankowski, G., & Doyle, R. (2007). SolidWorks® For Dummies® (2nd ed.). Wiley Publishing, Inc.<br>• Shih, R. H. (2021). AutoCAD 2021. Tutorial-First Level: 2D Fundamentals. SDC Publications. |
| **Course Outcomes** | At the end of the course, learners will be able<br>**CO1**: To acquaint and equip with basics of computer graphics |

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| | and tools for designing and drafting.<br>**CO2:** Acquire knowledge on basics of 2 D & 3D drafting.<br>**CO3**: Understand the concept of coordinate system.<br>**CO4**: To develop documentation of design.<br>**CO5**: To make drawing assemblies of farm implements and their components |

**Mapping between Cos, POs and PSOs**

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| **Course code** | **FMPE 516** |
| **Course title** | **Advanced Manufacturing Technologies** |
| **Course credit** | **2+1** |
| **Objective of Course** | • To develop knowledge and skill for technical education and research in modern manufacturing techniques and their application.<br>• To develop the ability of the students for formulating and solving solutions to select suitable manufacturing technique to fabricate different components used in Farm machinery.<br>• To strengthen the knowledge among students for Industry and R&D organizations. |
| **Course Content** | **Theory**<br>Unit I<br>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.<br>Unit II<br>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.<br>Unit III<br>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).<br>Unit IV<br>Joining processes: Gas flame processes, arc processes, brazing and soldering, adhesive and bonding.<br>Unit V<br>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.<br>**Practical**<br>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. |
| **References:** | • Begeman, M. L., Ostwald, P. F., & Amstead, B. H. (1979). Manufacturing Processes: SI Version (7th ed.). John Wiley and |

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| | Sons.<br>• Chapman, P. A. J. (1996). Workshop Technology, Part III(3rd ed.). CBS Publisher and distributors Pvt. Ltd.<br>• Gupta, R. B. (2017). Production Technology, Vol I - Production Process. New Delhi, India: Satya Prakashan.<br>• Hoyos, L. (2010). Fundamentals of Tool Design (6th Edition). USA: American Society of Tool and Manufacturer Engineers.<br>• Jain, R. K. (1994). Production Technology: A Textbook for Engineering Students. New Delhi, India: Khanna Publishers.<br>• Polukin, P., Gringerg, B., Kantenik, S., Zhadan, V., & Vasilye, D. Metal Process Engineering. Moscow, Russia: MIR Publishers. |
| **Course Outcomes** | At the end of the course, learners will be able<br>**CO1**: To acquaint and equip with the material and their characteristics used for manufacturing.<br>**CO2:** Acquire knowledge on measurement and quality assurance.<br>**CO3**: To know workshop practices applied in prototype production.<br>**CO4:** To get exposure of different joining processes.<br>**CO5**: To aware about numerical control and automation in manufacturing production system. |

**Mapping between Cos, POs and PSOs**

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| **Course code** | **FMPE 517** |
| **Course title** | **Machinery for Precision Agriculture** |
| **Course credit** | **2+1** |
| **Objective of Course** | • To develop knowledge and skill in principles behind precision agriculture for technical education and research.<br>• To develop the ability of the students for implementing precision agriculture systems.<br>• To strengthen the knowledge among students for Industry and R&D organizations. |
| **Course Content** | **Theory**<br>Unit I<br>Importance of precision agriculture. Mapping in farming for decision making. Geographical concepts of PA. Understanding and identifying variability<br>Unit II<br>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.<br>Unit III<br>Data analysis, concepts of data analysis, resolution, Surface analysis. Analysis application interpretive products (map, charts, application map etc).<br>Unit IV<br>Electronics and Control Systems for Variable rate applications, Precision Variable Equipment, Tractor-Implement interface technology, Environmental Implications of Precision Agriculture.<br>Unit V<br>Goals based on end results of Precision Agriculture, Record keeping, 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.<br>**Practical**<br>Calculation of the benefits of Data and Mapping, Determining Latitude/Longitude, UTM or State Plane Position Navigation with Way points, Configuring a GPS System. Defining area of field for prescriptive treatment. Making the Grid, The Grid Sampling Process, generation of yield maps, Thematic or Spatial Resolution, Yield Map Example, Surface Analysis in Arc-View. |
| **References:** | • Clay, S. A., Clay, D. E., & Bruggeman, S. A. (2017). Practical Mathematics for Precision Farming. Madison, USA: American |

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| | Society of Agronomy, Crop Science Society and Soil Science Society of America.<br>• Henten, E. J. V., Goense, D., & Lokhorst, C. (2009). Precision Agriculture. Wageningen Academic Publishers.<br>• Ram, T., Lohan, S. K., Singh, R., & Singh, P. (2014). Precision Farming: A New Approach. New Delhi, India: Astral International Pvt. Ltd.<br>• Shannon, D. K., Clay, D. E., & Kitchen, N. R.(2018). Precision Agriculture Basics. American Society of Agronomy. Madison, USA: Crop Science Society and Soil Science Society of America.<br>• Singh, A. K., & Chopra, U. K. (2007). Geo informatics Applications in Agriculture. New Delhi , India: New India Publishing Agency. |
| **Course Outcomes** | At the end of the course, learners will be able<br>**CO1**: To acquaint and equip with the principles and fundamentals of precision agriculture.<br>**CO2:** Acquire knowledge on GIS and GPS application.<br>**CO3**: To do the data analysis and interpretation from the images.<br>**CO4:** To design variable rate applicators for farm operations.<br>**CO5**: To calculate the cost economics of precision agriculture. |

**Mapping between Cos, POs and PSOs**

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| Course code | **FMPE 518** |
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| **Course title** | **Machinery for Horticulture and Protected Agriculture** |
| **Course credit** | **2+0** |
| **Objective of Course** | • To develop knowledge and skill of machinery used for horticultural crops and protected agriculture for technical education and research.<br>• To develop the ability of the students for selection of machinery for horticultural crops and protected agriculture.<br>• To strengthen the knowledge among students for Industry and R&D organizations. |
| **Course Content** | **Theory**<br>Unit I<br>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.<br>Unit II<br>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.<br>Unit III<br>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.<br>Unit IV<br>Machinery for lawn and garden: Grass cutters, special machinery for turf maintenance. Turf aerators and lime applicators.<br>Unit V<br>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. |
| **References:** | • Bell, B., & Cousins, S. (1997). Machinery for Horticulture. Old Pond Publishing Ltd.<br>• FAO. (2017). Good Agricultural Practices for Greenhouse Vegetable Production in the South East European countries. Rome, Italy: FAO.<br>• Ponce, P., Molina, A., Cepeda, P., Lugo, E., & MacCleery, B. (2014). Greenhouse Design and Control (1st ed.).CRC Press. |
| **Course Outcomes** | **CO1**: To acquaint and equip with the principles and fundamentals of machinery for vegetable crops. |

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| | **CO2:** Acquire knowledge on machinery for orchard crops.<br>**CO3**: To aware about machines for special crops.<br>**CO4:** To know the working of machines for protected cultivation.<br>**CO5**: To get exposure to machinery for lawn and gardens. |

**Mapping between Cos, POs and PSOs**

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<tr><td>Course code</td><td>FMPE 601</td></tr>
<tr><td>Course title</td><td>Advances in Farm Machinery and Power Engineering</td></tr>
<tr><td>Course credit</td><td>2+1</td></tr>
<tr><td>Objective of Course</td><td>• To develop knowledge and skill for technical education and research in modern developments in construction, design and analysis of farm machinery system.<br>• To develop the ability of the students for formulating and solving solutions to problems pertaining to tillage and planting implements.<br>• To strengthen the knowledge among students for Industry and R&D organizations.</td></tr>
<tr><td>Course Content</td><td>Theory<br>Unit I<br>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.<br>Unit II<br>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.<br>Unit III<br>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.<br>Unit IV<br>board sensors, computing hardware, algorithms and software. Manipulator type ag-robots: Use in food processing, dairy, horticulture, and orchard industries.<br>Unit V<br>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.<br>Practical<br>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.</td></tr>
<tr><td>References:</td><td>• Chen, G. (2018). Advances in Agricultural Machinery and</td></tr>
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| | Technologies. Boca Raton: CRC Press.<br>https://doi.org/10.1201/9781351132398.<br>• Edwards, G. T. C., Hinge, G., Skou-Nielsen, N., & Villa-Henriksen, A. (2017). Route planning evaluation 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.<br>• Seyyedhasani, H. (2017). Using the Vehicle Routing Problem (VRP) to Provide Logistic Solutions in Agriculture. Ph.D. dissertation. University of Kentucky, Kentucky, USA. https://www. researchgate. net/publication/264791116_Advances in Agricultural Machinery Management A Review.<br>• Srivastava, A. K. (2006). Engineering Principles of Agricultural Machines (2nded.).USA: American Society of Agricultural and Biological Engineers. |
| **Course Outcomes** | At the end of the course, learners will be able<br>**CO1**: To aware about the advances in mechanization.<br>**CO2:** To acquaint with the principles and fundamentals sustainable mechanization management.<br>**CO3**: Acquire knowledge on optimization of production processes to minimize energy loss in agriculture.<br>**CO4**: To know various hardware and softwares for automation.<br>**CO5**:To get knowledge of precision livestock farming techniques. |

**Mapping between Cos, POs and PSOs**

| **CO** | **PO** | | | | | | | | | | | | **PSO** | | |
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| | 1 | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **1** | **2** | **3** |
| **CO1** | | | | | | | | | | | | | | | |
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| **CO3** | | | | | | | | | | | | | | | |
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| Course code | FMPE 602 |
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| Course title | **Advances in Machinery for Precision Agriculture** |
| Course credit | **2+1** |
| **Objective of Course** | • To develop knowledge and skill in hardware system used in precision agriculture for technical education and research.<br>• To develop the ability of the students for using systems for precision agriculture.<br>• To strengthen the knowledge among students for Industry and R&D organizations. |
| **Course Content** | **Theory**<br>**Unit I**<br>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.<br>**Unit II**<br>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.<br>**Unit III**<br>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.<br>**Unit IV**<br>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.<br>**Practical**<br>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 |

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| | 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. |
| **References:** | • Clay, D. E., Clay, S. A., & Bruggeman, S. A. (2017). Practical Mathematics for Precision Farming. Madison, USA: American Society of Agronomy.<br>• Ram, T., Lohan, S. K., Singh, R., & Singh, P. (2014). Precision Farming: A New approach. New Delhi, India: Astral International Pvt. Ltd.<br>• Shannon, D. K., Clay, D. E., & Kitchen, N. R. (2018). Precision Agriculture Basics. Madison, USA: American Society of Agronomy.<br>• Singh, A. K., & Chopra, U. K. (2007). Geo informatics Applications in Agriculture. New Delhi, India: New India Publishing Agency.<br>• Van-Henten, E. J., Goense, D., & Lokhorst, C. (2009). Precision Agriculture. Wageningen, Netherlands : Wageningen Academic Publishers. |
| **Course Outcomes** | At the end of the course, learners will be able<br>**CO1**: To acquire ability for application of GIS & GNSS.<br>**CO2:** To know working and construction of various systems of yield monitor.<br>**CO3**: Acquire knowledge on sources of soil variability.<br>**CO4:** To acquaint with various sensors.<br>**CO5**:To aware about remote sensing platforms and sensors. |

**Mapping between Cos, POs and PSOs**

| **CO** | **PO** | | | | | | | | | | | | **PSO** | | |
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| | 1 | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **1** | **2** | **3** |
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| **Course code** | **FMPE 603** |
| **Course title** | **Energy Conservation and Management in Production Agriculture** |
| **Course credit** | **3+0** |
| **Objective of Course** |  To develop knowledge and skill to analyse agricultural systems in terms of energy flow and balance for technical education and research.<br> To develop the ability of the students to take energy conservation measures in different operations in agricultural production systems.<br> To strengthen the knowledge among students for Industry and R&D organizations. |
| **Course Content** | **Theory**<br>Energy Sources for Agriculture, Energy requirement of different operations in agricultural production systems viz. crop, livestock and aquaculture. Economic Impacts of Energy Prices on Agriculture.<br>**Unit II**<br>Energy conservation through proper management and maintenance of farm machinery, planning and management of agricultural production systems for energy conservation and energy returns assessment.<br>**Unit III**<br>Development of energy model of farm for efficient energy management in a given agricultural production system.<br>**Unit IV**<br>Design of integrated energy supply system, Assessment of energy conservation technology.<br>**Unit V**<br>Case studies on application of various techniques of energy conservation and management. Energy use planning and forecasting for a given system. |
| **References:** | • Jochen, B., & Guangnan, C. (2017). Sustainable Energy Solutions in Agriculture. Boca Rotan, USA: CRC Press.<br>• Mittal, J. P., Panesar, B. S., Singh, S., Singh, C. P., & Mannan, K. D. (1987). Energy in Production Agriculture and Food Processing. Ludhiana, India: ISAE Publication.<br>• Pimental, D. (1980). Handbook of Energy Utilization in Agriculture. Boca Rotan, USA: CRC Press.<br>• Singh, &Singh, R.S. (2014).Energy for Production Agriculture. New Delhi, India:ICAR.<br>• Stanhil, G. (ed.) (1984). Energy and Agriculture. Springer- Verlag Berlin. |
| **Course Outcomes** | At the end of the course, learners will be able<br>**CO1**: To acquaint and equip with estimation of energy requirement of different operations in agricultural productionsystems.<br>**CO2:** Acquire knowledge on energy conservation measures.<br>**CO3**: To develop model for efficient energy management on farm.<br>**CO4**: To design integrated energy supply system.<br>**CO5**: To develop the energy use plan and forecast energy for a given system. |
| **Mapping between Cos, POs and PSOs** | |

| CO | PO | | | | | | | | | | | | PSO | | |
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| **Course code** | **FMPE 604** |
| **Course title** | **Mechanics of Tillage in Relation to Soil and Crop** |
| **Course credit** | **2+1** |
| **Objective of Course** | • To develop knowledge and skill related to mechanics of tillage for technical education and research.<br>• To develop the ability of the students for formulating and solving solutions to problems pertaining to tillage techniques.<br>• To strengthen the knowledge among students for farm equipment Industry and R&D organizations. |
| **Course Content** | **Theory**<br>**Unit I**<br>Soil condition and soil strength determining factors. General aspects of mechanical behavior of 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.<br>**Unit II**<br>Occurrence of soil breaking fundamentals. Measures of resistance against breaking. Shear failure 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.<br>**Unit III**<br>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 tillage and those not affected by tillage. Soil compaction, formation of clods and dust. Effect of tillage on erosion and water logging. Impact of climate factors on soil. Tillage requirement for various types of soils.<br>**Unit IV**<br>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: Appropriate conditions 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.<br>**Unit V**<br>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.<br>**Practical**<br>Characterization of soil condition before and after tillage. Cone penetrometer resistance, bulk density, moisture content. |

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| | 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 and hard 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. |
| **References:** | • Birkas, M. (2014). Book of Soil Tillage. Godollo, Hungary: SzentIstvan University Press.<br>• Koolen, A. J., & Kuipers, H. (1983). Agricultural Soil Mechanics. New York, USA: Springer- Verlag. |
| **Course Outcomes** | At the end of the course, learners will be able<br>**CO1**: To acquaint with soil condition and soil strength determining factors<br>**CO2:** Acquire knowledge on basics of soil failure.<br>**CO3**: Able to interpret the soil tillage and crop interaction.<br>**CO4**: To get knowledge on details about specific tillage operations.<br>**CO5**: To understand the forces and soil movement around plough bodies. |

**Mapping between Cos, POs and PSOs**

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| **Course code** | **FMPE 611** |
| **Course title** | **Mechanics of Traction and its Application** |
| **Course credit** | **2+1** |
| **Objective of Course** | • To develop knowledge and skill for technical education and research in soil traction device interaction.<br>• To develop the ability of the students to model vehicle traction mechanics.<br>• To strengthen the knowledge among students for Industry and R&D organizations. |
| **Course Content** | **Theory**<br>**Unit I**<br>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 and rigid wheel on soft surface. Empirical prediction of tractive force: Bekker's model, stress deformation relation in soil, analysis of tractive performance of tracks.<br>**Unit II**<br>Empirical modelling of tractor performance, tractive performance modelling and mobility number. Empirical models for rolling resistance and traction by GeeClough. Derivation of equations for drawbar pull and drawbar power.<br>**Unit III**<br>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.<br>**Unit IV**<br>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.<br>**Unit V**<br>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 forc**es** on a steered wheel under driving and braking conditions. Relation between cornering force and self-aligning torque.<br>**Practical** |

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| | 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. |
| **References:** | • Muro, T., & O'Brien, J. (2004). Terramechanics: Land Locomotion Mechanics. Lisse, Netherlands: CRC Press.<br>• Macmillan, R. H. (2010). The Mechanics of Tractor-Implement Performance: Theory and Worked Examples: A Textbook for Students and Engineers. Melbourne, Australia : University of Melbourne. |
| **Course Outcomes** | At the end of the course, learners will be able<br>**CO1**: To acquaint with performance of traction device on different soil conditions.<br>**CO2:** Acquire knowledge on traction performance modelling.<br>**CO3**: Understand the performance of wheel system in relation to soil.<br>**CO4**: To analyze the braked wheel performance.<br>**CO5**: To predict the traction performance of the tyre. |

**Mapping between Cos, POs and PSOs**

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| **Course code** | **FMPE 612** |
| **Course title** | **Farm Machinery Management and Systems Engineering** |
| **Course credit** | **2+1** |
| **Objective of Course** | • To develop knowledge and skill for technical education and research in farm machinery management.<br>• To develop the ability of the students for solving solutions to problems pertaining to farm machinery management.<br>• To strengthen the knowledge among students for Industry and R&D organizations. |
| **Course Content** | **Theory**<br>**Unit I**<br>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.<br>**Unit II**<br>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.<br>**Unit III**<br>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.<br>**Unit IV**<br>System modeling in farm machinery: Numerical methods, analogs, models with uncertainty stochastic service system. Feasibility system design-stability. Deterministic systems and stochastic systems.<br>**Unit V**<br>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.<br>**Practical**<br>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. |
| **References:** | • Hunt, D. R. (1986). Engineering Models for Agricultural |

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| | Production. Westport, USA: AVI Pub. Co.<br>• Hunt, D., & Wilson, D. (2015). Farm Power and Machinery Management. Illinois, USA : Waveland Press.<br>• Singh, S., & Verma, S. R. (2009). Farm Machinery Maintenance and *Management*. New Delhi,India: ICAR. |
| **Course Outcomes** | At the end of the course, learners will be able<br>**CO1:** To acquaint with mathematical models of field machinery system.<br>**CO2:** Acquire knowledge on engineering economics.<br>**CO3:** Understand the uncertainty criterion for farm machinery management.<br>**CO4:** To get knowledge on system modeling in farm machinery.<br>**CO5:** Able to solve estimation design problems. |

**Mapping between Cos, POs and PSOs**

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| **Course code** | **FMPE 613** |
| **Course title** | **Machinery for Special Farm Operations** |
| **Course credit** | **2+0** |
| **Objective of Course** | • To develop knowledge and skill of machinery used for special farm operations for technical education and research.<br>• To develop the ability of the students for selection of machinery for specific operation.<br>• To strengthen the knowledge among students for Industry and R&D organizations. |
| **Course Content** | **Theory**<br>**Unit I**<br>Machinery for land development. Tractor operated and self-propelled machines for laying drainage system, sub surface drip laying machines, subsoiler, trenchers, laser levelers.<br>**Unit II**<br>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.<br>**Unit III**<br>Field plot machinery and its importance. Fertilizer and manure spreader.<br>**Unit IV**<br>Machines for residue management. Silage and hay making machines.<br>**Unit V**<br>Machinery for horticultural crops. Crop specific machines for cotton, sugarcane, forage/fodder. Machines for processing and handling of agricultural products. |
| **References:** | • Boson, E. S., Sultan-Shakh, E. G., Smirnov, I. I., & Verniaev, O. V. (2016). Theory, Construction and Calculation of Agricultural Machines. New Delhi, India: Scientific Publishers.<br>• Kanafozski, C., & Karwowiki, T. (1976). Agricultural Machines: and Construction. Vol. I & II.Washington DC, USA: US Dept. of Agriculture and National Science Foundation.<br>• Kepner, R. A., Bainer, R., & Barger, E. L. (2017). Principles of Farm Machinery. New Delhi, India: CBS publishers and Distributors Pvt. Ltd. |
| **Course Outcomes** | At the end of the course, learners will be able<br>**CO1**: To acquaint with machinery for land development.<br>**CO2:** Acquire knowledge on machinery for plant protection.<br>**CO3**: To aware about field plot machinery. |

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| | **CO4:** To know the working of machines for residue management.<br>**CO5**: To get exposure to machinery for horticultural crops. |

**Mapping between Cos, POs and PSOs**

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| **Course code** | **FMPE 614** |
| **Course title** | **Ergonomics in Working Environment** |
| **Course credit** | **2+1** |
| **Objective of Course** | • To develop knowledge and skill of designing the working environment and farm machinery for technical education and research.<br>• To develop the ability of the students for considering human factors in farm machinery design.<br>• To strengthen the knowledge among students for Industry and R&D organizations. |
| **Course Content** | **Theory**<br>**Unit I**<br>Musculoskeletal problems in sitting and standing postures-behavioral aspects of posture, body mechanics. Workspace design for standing and seated workers. Display units, controls and human- machine interaction, design of static work.<br>**Unit II**<br>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 in agricultural machines.<br>**Unit III**<br>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.<br>**Unit IV**<br>Time motion study and its purpose. Application of Time motion study in agricultural and processing operations. Recent research works related to ergonomics in agriculture.<br>**Practical**<br>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.

**References:**


- Astrand, P. O., Rodahl, K., Dahl, H. A., & Stromme, S. B. (2003). Textbook of Work Physiology: Physiological Bases of Exercise. Champaign IL: Human Kinetics.
- Bridger, R. S. (2009). Introduction to Ergonomics (3rd ed.). Boca Raton, USA: CRC Press.
- Gite, L. P., Majmudar, J., Mehta, C.R., & Khadatkar, A. (2009). Anthropometric and Strength Data of Indian Agricultural Workers for Farm Equipment Design. Bhopal, India: Central Institute of Agricultural Engineering.
- Gite, L. P., Agrawal, K. N., Mehta, C. R., Potdar, R. R., & Narwariya, B. S. (2019). Handbook of Ergonomical Design of Agricultural Tools, Equipment and work Places. New Delhi, India: Jain Brothers.
- Kroemer, K. H. E., & Grandjean, E. (1997). Fitting the Task to the Human: A Textbook of Occupational Ergonomics (5thed.). Philadelphia, USA: Taylor & Francis.
- Mehta, C. R., Kumar, A., Gite, L.P., & Agrawal, K.N. (2022). Ergonomics and Safety in Agriculture. New Delhi, India: ICAR.
- Pearsons, K. (2003). Human Thermal environments: The Effects of Hot, Moderate and Cold Environment on Human Health, Comfort and Performance. New York, USA: Taylor and Francis.
- Sanders, M. S., & McCormick, E. J. (1993). Human Factors in Engineering and Design. New York, USA: McGraw Hill.


**Course Outcomes**

At the end of the course, learners will be able

**CO1**: To acquaint with body mechanics aspects in farm machinery design.

**CO2:** Acquire knowledge on sound and vibration measurement and their effect.

**CO3**: To have understanding of human factors in relation to working environments.

**CO4**:To get acquaint with time motion study application

**Mapping between Cos, POs and PSOs**

| **CO** | **PO** | | | | | | | | | | | | **PSO** | | |
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**Department of Irrigation and Drainage Engineering - M.Tech**

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| **Course code** | **IDE 501** |
| **Course title** | **Design of Surface Irrigation Systems** |
| **Corse credit** | **3 (2+1)** |
| **Objective of 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. |
| Course Content | Climate and irrigation water requirement. Irrigation principles, losses, conveyance, distribution, application and water budgeting. Estimation techniques of effective rainfall. Irrigation softwares: CROPWAT, AQUACROP<br>Farm irrigation systems. Irrigation efficiencies. Economic feasibility. Irrigation water quality and salinity management techniques. Design of water conveyance, control and distribution systems.<br>Hydraulics: Design and operation of border, check basin, furrow, sprinkler and trickle irrigation systems. Flow dynamics, drop size distribution and spray losses in sprinklers. Cablegation, surge and bubbler irrigation. Automation of irrigation system.<br>Basic water management concepts and objectives. Alternative irrigation scheduling techniques. Integrated approach to irrigation water management.<br>Design and evaluation of border, furrow, check basin, sprinkler and micro-irrigation. Computation of frictional losses. Design of underground water conveyance systems. Economics of irrigation methods. Visit to mechanized farms. |
| References: | • Finkel HJ. 1983. Handbook of Irrigation Technology. Vols. I-II, CRC Press.<br>• James LG. 1988. Principles of Farm Irrigation System Design. John Wiley and Sons, New York, USA.<br>• Karmeli D, Peri G and Todes M. 1985. Irrigation Systems: Design and Operation. Oxford University Press.<br>• Michael AM. 2008. Irrigation Theory and Practices. Vikas Publishing House Pvt. Ltd, New Delhi.<br>• Pillsbury AF. 1972. Sprinkler Irrigation. FAO Agricultural Development Paper No. 88, FAO.<br>• Rydzewski. 1987. Irrigation Development Planning. John Wiley and Sons.<br>• Sivanappan RK 1987. Sprinkler Irrigation. Oxford and IBH. |
| Course Outcomes | At the end of the course, learners will be able<br>**CO1:** Apply scientific principles and engineering knowledge to design and evaluate different surface irrigation systems, including border, furrow, check basin, sprinkler, and micro-irrigation systems.<br>**CO2:** Analyze the hydraulic characteristics of water flow in open channels and pipelines, and design efficient water conveyance and distribution networks for irrigation systems<br>**CO3:** Utilize irrigation software tools like CROPWAT and |

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| | AQUACROP to estimate crop water requirements, calculate water budgets, and assess irrigation water use efficiency.<br>**CO4:** Develop an integrated approach to irrigation water management, considering factors such as water quality, salinity, environmental sustainability, and economic feasibility.<br>**CO5:** Communicate effectively about irrigation design and management practices, both orally and in writing, and collaborate effectively with stakeholders to implement sustainable irrigation solutions. |

Mapping between COs with POs and PSOs

**Mapping between Cos, POs and PSOs**

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| **Course code** | **IDE 502** |
| **Course title** | **Design of Farm Drainage Systems** |
| **Corse credit** | **2+1** |
| **Objective of Course** | To provide in depth knowledge of water logging and salt affected areas, surface and sub-surface drainage systems, design and reclamation of salt affected waterlogged areas. |
| Course Content | Unit I<br>Salt affected waterlogged areas in India. Water quality criteria and brackish water use for agriculture. Drainage requirements and crop growth under salt affected waterlogged soil.<br>Unit II<br>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.<br>Unit III<br>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.<br>Unit IV<br>Steady and unsteady state drainage equations for layered and non-layered soils. Principle and applications of Hooghoudt, Kirkham, Earnst, Glover Dumm, Kraijenhoff-van-de-leur equations. Drainage for salinity control.<br>Unit V<br>Salt balance, leaching requirement and management practices under drained conditions. Disposal of drainage effluents. Case study for reclamation of salt affected waterlogged areas. |
| References: | • Bhattacharaya AK and Michael AM. 2003. Land Drainage. Vikas Publ.<br>• Clande Ayres and Daniel Scoates AE. 1989. Level Drainage and Reclamation. Mc.GrawHill<br>• Luthin JN. 1978. Drainage Engineering. Wiley Eastern.<br>• Ritzema HP (Ed.) 1994. Drainage Principles and Applications. ILRI<br>• Roe CE. 1966. Engineering for Agricultural Drainage. McGraw Hill.<br>• Schilfgaarde Jan Van (Editor). 1974. Drainage for Agriculture. Monograph No. 17. American Society<br>• of Agronomy Madison, Wisconsin, USA. |
| Course Outcomes | At the end of the course, learners will be able<br>**CO1:** Identify and assess salt-affected and waterlogged areas in India, analyzing their impact on crop growth and water quality.<br>**CO2:** Understand the concept of critical water table depth and determine drainage requirements based on soil characteristics and crop water needs.<br>**CO3:** Design and implement surface and subsurface drainage |

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| | systems, including vertical drainage, horizontal subsurface drainage, and multiple well points, considering different drainage theories and materials.<br>**CO4:** Analyze and solve drainage problems using steady and unsteady state drainage equations (Hooghoudt, Kirkham, etc.) for layered and non-layered soils.<br>**CO5:** Develop strategies for salt balance management, leaching requirements, and drainage effluent disposal to reclaim salt-affected and waterlogged areas for sustainable agriculture. |

Mapping between COs with POs and PSOs

**Mapping between Cos, POs and PSOs**

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| **Course code** | **IDE 503** |
| **Course title** | **Command Area Management** |
| **Corse credit** | **2+1** |
| **Objective of 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. |
| Course Content | Unit I<br>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.<br>Unit II<br>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.<br>Unit III<br>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.<br>Unit IV<br>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.<br>Unit V<br>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. |
| References: | • Jos´eLiria Montanes. 2006. Design, Construction, Regulation and Maintenance. Taylor and Francis Publication.<br>• Modi PN. Irrigation Water Resources and Water Power Engineering. Standard Publishers.<br>• Singh VP. 2014. Entropy Theory in Hydraulic Engineering: An Introduction. ASCE Press.<br>• Sharma SK. Irrigation Water Resources and Water Power Engineering. Standard Publishers.<br>• Swamee PK and Chahar BR. Design of Canals. Springer |

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| | Publications. |
| Course Outcomes | At the end of the course, learners will be able<br>**CO1:** Understand the concept of command area development (CAD) as an integrated approach and analyze its role in major, medium, and minor irrigation projects in India.<br>**CO2:** Apply laser-based land grading techniques and design lined and unlined canals, diversion headworks, canal head regulators, cross drainage works, and canal falls to optimize water delivery in command areas.<br>**CO3:** Assess and improve water availability in command areas by addressing water management problems, determining and improving duty of water, and evaluating the feasibility of drip irrigation integration.<br>**CO4:** Utilize canal performance indices and diagnostic analysis to evaluate the performance of command area projects and propose strategies for improvement.<br>**CO5:** Analyze the socio-economic aspects of irrigation management, facilitate the formation and function of water user associations (WUAs), and develop participatory irrigation management (PIM) strategies for enhanced water resource management and stakeholder participation. |
| Mapping between COs with POs and PSOs | |

**Mapping between Cos, POs and PSOs**

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| **Course code** | **IDE 504** |
| **Course title** | Water and Nutrient Management Under Protected |
| **Corse credit** | **2+1** |
| **Objective of 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. |
| Course Content | Unit I<br>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.<br>Unit II<br>Roots as source and sink for organic compounds and plant hormones. Physical and chemical properties of soilless media.<br>Unit III<br>Water content and water potential in soilless media. Water movement in soilless media. Uptake of water by plants in soilless media and water availability.<br>Unit IV<br>Production technology for vegetables under protected conditions in soil and soilless media. Automation for climate control in protected structures. Thermal modelling of greenhouse environment for protected cultivation. |
| References: | • Howard M Resh. Hydroponic Food Production. CRC Press, New York.<br>• Michael Raviv and Heinrich J Lieth 2014. Soilless Culture. CRC Press.<br>• Meier Schwarz. Soilless Culture Management. Springer publications, New York. |
| Course Outcomes | At the end of the course, learners will be able<br>**CO1:** Explain the significance of soilless culture in agriculture, analyze the functions of the root system, and understand the interaction of root growth with nutrient concentrations and environmental conditions.<br>**CO2:** Describe the role of roots as sources and sinks for organic compounds and plant hormones, and evaluate the physical and chemical properties of different soilless media for optimal plant growth.<br>**CO3:** Analyze water content and water potential in soilless media, understand water movement dynamics, and assess water uptake by plants in relation to water availability in different soilless systems.<br>**CO4:** Design and implement production technologies for vegetables in protected environments using both soil and soilless media, considering automation strategies for climate control and thermal modelling for optimized greenhouse cultivation.<br>**CO5:** Develop and apply advanced soilless culture techniques for various crops and evaluate their impact on yield, resource use efficiency, and environmental sustainability compared to |

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| Mapping between COs with POs and PSOs | |
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| **Course code** | **IDE 505** |
| **Course title** | **Design of Drip and Sprinkler Irrigation Systems** |
| **Corse credit** | **2+1** |
| **Objective of 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. |
| Course Content | Unit I<br>Suitability of sprinkler and drip irrigation systems under Indian conditions. Basic hydraulics of sprinkler and micro irrigation system.<br>Unit II<br>Pipe flow analysis. Friction losses and pressure variation. Flow in nozzles and emitters.<br>Unit III<br>Design and evaluation of sprinkler and micro irrigation systems in relation to source, soil, climate and topographical conditions.<br>Unit IV<br>Selection of pipe size, pumps and power units. Layout, distribution, efficiency and economics.<br>Unit V<br>Fertigation through sprinkler and micro irrigation systems. Fertigation techniques involved in drip and sprinkler irrigation system. |
| References: | • Jensen ME. (Editor). 1983. Design and Operation of Farm Irrigation Systems. ASAE, Monograph No. USA.<br>• James LG. 1988. Principles of Farm Irrigation System Design. John Wiley and Sons, New York, USA.<br>• Michael AM. 2006. Irrigation Theory and Practice. Vikas Publ. New Delhi.<br>• Withers Bruce and Vipond Stanley. 1974. Irrigation: Design and Practice. B.T. BatsfordLtd, London.<br>• Sivanappan RK. 1987. Sprinkler Irrigation. Oxford and IBH Publishing Co. New Delhi. |
| Course Outcomes | At the end of the course, learners will be able<br>**CO1:** Analyze the suitability of sprinkler and drip irrigation systems under Indian conditions, considering factors like climate, soil, topography, and water availability.<br>**CO2:** Apply basic hydraulics principles to sprinkler and micro irrigation systems, calculating friction losses, pressure variations, and flow in nozzles and emitters.<br>**CO3:** Design and evaluate sprinkler and micro irrigation systems based on water source, soil type, climate, and topography, ensuring efficient operation and water use.<br>**CO4:** Select appropriate pipe size, pumps, and power units for specific irrigation systems, considering layout, distribution, and economic feasibility.<br>**CO5:** Implement fertigation techniques through sprinkler and micro irrigation systems, utilizing appropriate methods and equipment to ensure efficient nutrient delivery and crop growth. |

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Mapping between COs with POs and PSOs

**Mapping between Cos, POs and PSOs**

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| **Course code** | **IDE 506** |
| **Course title** | **Ground Water Engineering** |
| **Corse credit** | **2+1** |
| **Objective of Course** | To provide comprehensive knowledge to the students in aquifers, groundwater flow, artificial groundwater recharge techniques, well hydraulics and groundwater models. |
| Course Content | Unit I<br>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.<br>Unit II<br>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.<br>Unit III<br>Derivation of hydraulics of fully and partially penetrating wells in confined, leaky and unconfined aquifers. Flow net analysis.<br>Unit IV<br>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.<br>Unit V<br>Design of well field. Salt water intrusion in inland and coastal aquifers. Application of groundwater models for groundwater management. Calibration and validation of models. |
| References: | • Boonstra J and de Ridder NA. 1981. Numerical Modeling of Groundwater Basins. ILRI.<br>• Demenico PA. 1972. Concept and Models in Groundwater Hydrology. McGraw Hill.<br>• Huisman L 1972. Ground Water Recovery. Mac Millan.<br>• Jat ML and SR Bhakar 2008. Ground Water Hydrology. Agro-tech Publishing Academy. Udaipur.<br>• Polubarinova Kochina P Ya. 1962. Theory of Ground Water Movement. Princeton Univ. Press.<br>• Raghunath HM 1992. Ground Water. Wiley Eastern.<br>• Todd DK 1997. Ground Water Hydrology. Wiley Eastern. |
| Course Outcomes | At the end of the course, learners will be able<br>**CO1:** Analyze the occurrence, storage, and movement of groundwater in various geological formations, including alluvial and hard rock environments, understanding the principles of groundwater flow and interaction with surface water.<br>**CO2:** Design and implement strategies for natural and artificial groundwater recharge, considering conjunctive use of surface and groundwater resources, maintaining groundwater balance, and utilizing remote sensing, GIS, and MODFLOW models for |

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| | potential zone delineation.<br>**CO3:** Analyze hydraulics of wells in confined, leaky, and unconfined aquifers, including fully and partially penetrating wells, applying flow net analysis and solving multi-aquifer systems with interfering wells.<br>**CO4:** Conduct and interpret pumping tests for accurate estimation of aquifer parameters, analyze well behavior near recharge and impermeable boundaries, and understand the principles and applications of skimming well technology.<br>**CO5:** Design and optimize well fields, address issues like saltwater intrusion in coastal and inland aquifers, apply groundwater models for management purposes, and calibrate and validate models for reliable decision-making in sustainable groundwater resource utilization. |

Mapping between COs with POs and PSOs

**Mapping between Cos, POs and PSOs**

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| **Course code** | **IDE 507** |
| **Course title** | **Remote Sensing and GIS for Land and Water Resource Management** |
| **Corse credit** | **2+1** |
| **Objective of 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. |
| Course Content | Unit I<br>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.<br>Unit II<br>Sensor Characteristics and tracking systems, Photogrammetry, Satellite data analysis. Visual / Image interpretation. Digital image and its processing. Image pre-processing. Image enhancement. Image classification. Data merging. GPS.<br>Unit III<br>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.<br>Unit IV<br>Thematic mapping. Measurement in GIS: Length, perimeter and areas. Query analysis. Reclassification, Buffering and Neighbourhood functions. Map overlay: Vector and raster overlay. Interpolation and network analysis. Digital elevation modelling. Analytical Hierarchy Process. Object oriented GIS, AM/FM/GIS and Web Based GIS.<br>Unit V<br>Application of remote sensing, Spatial data sources. 4M GIS approach 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. |
| References: | • Charles Elach and Jakob van Zyl. 2006. Introduction to the Physics and Techniques of Remote Sensing. John Wiley & Sons publications.<br>• Ian Heywood Sarah, Cornelius and Steve Carver. 2002. An Introduction to Geographical Information Systems. Pearson Education. New Delhi.<br>• James B Campbell and Randolph H Wynne. 2011. Introduction to Remote Sensing. TheGuilford Press.<br>• Lillesand TM and Kiefer RW. 2008. Remote Sensing and |

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| | Image Interpretation. John Wiely and Sons.<br>• Paul Curran PJ. 1985. Principles of Remote Sensing. ELBS Publications.<br>• Rees WG. 2001. Physical Principles of Remote Sensing. Cambridge University Press.<br>• Thanappan Subash. 2011. Geographical Information System. Lambert Academic Publishing. |
| Course Outcomes | At the end of the course, learners will be able<br>**CO1:** Analyze the interaction of electromagnetic radiation with the Earth's surface, understand remote sensing platforms and data sources, and utilize Indian Space Programme resources for water resources monitoring.<br>**CO2:** Interpret visual and digital images, perform image pre-processing, enhancement, and classification, and apply data merging and GPS techniques for spatial analysis.<br>**CO3:** Comprehend the basic components of GIS, map projections, coordinate systems, spatial data structures, and geodatabase models for efficient data management and analysis.<br>**CO4:** Implement thematic mapping, spatial measurement, query analysis, data manipulation functions (reclassification, buffering, overlay), interpolation, network analysis, and digital elevation modeling for water resources applications.<br>**CO5:** Apply remote sensing and GIS to rainfall-runoff modeling, groundwater modeling, water quality assessment, flood inundation mapping, drought monitoring, cropping pattern analysis, irrigation system performance evaluation, artificial recharge site selection, reservoir sedimentation monitoring, and other water resource management tasks using the 4M GIS approach. |
| Mapping between COs with POs and PSOs | |

**Mapping between Cos, POs and PSOs**

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| **Course code** | **IDE 508** |
| **Course title** | **Waste Water Management and Utilization in Agriculture** |
| **Corse credit** | **2+1** |
| **Objective of 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. |
| Course Content | Unit I<br>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.<br>Unit II<br>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.<br>Unit III<br>Control measures for preventing soil and other surface/groundwater source contamination. Different types of waste water, pollutants and contaminants. Impact of wastewater on ecosystem, eutrophication, biomagnification, water borne diseases.<br>Unit IV<br>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.<br>Unit V<br>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. |
| References: | • Charis Michel Galanakis. Sustainable Water and Wastewater Processing. Elsevier Publication, Amsterdam.<br>• Sean X Liu. 2014. Food and Agricultural Wastewater Utilization and Treatment. Wileu Blackwell New York.<br>• 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.<br>• Stuetz Richard. Principles of Water and Wastewater Treatment Processes (Water and<br>• Syed R Qasim and Guang Zhu. 2018. Wastewater Treatment and Reuse: Theory and Design Examples. CRC Press. |
| Course Outcomes | At the end of the course, learners will be able |

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| | **CO1:** Analyze the status of wastewater in India, identify sources of contamination, and characterize urban and rural wastewater for irrigation purposes considering physical, chemical, and biological parameters.<br>**CO2:** Evaluate water quality standards for potable water, wastewater effluents, and irrigation water, and apply these standards to assess the suitability of wastewater for restricted and unrestricted agricultural uses.<br>**CO3:** Design control measures to prevent soil and water contamination from wastewater, considering the impact of different types of wastewater pollutants and contaminants on ecosystems, eutrophication, biomagnification, and potential waterborne diseases.<br>**CO4:** Analyze and compare various wastewater treatment methods (physical, chemical, biological), including natural treatment systems like constructed wetlands and reed bed systems, considering carbon footprint implications and environmental standards.<br>**CO5:** Understand the regulatory framework for wastewater management in India, including CPCB norms and environmental impact assessment (EIA) stages and procedures, to ensure compliance and minimize environmental impacts of wastewater reuse. |

Mapping between COs with POs and PSOs

**Mapping between Cos, POs and PSOs**

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| **Course code** | **IDE 509** |
| **Course title** | **Water Conveyance and Distribution** |
| **Corse credit** | **2+1** |
| **Objective of 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. |
| Course Content | Unit I<br>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.<br>Unit II<br>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 their computations.<br>Unit III<br>Energy dissipation. Flow control structures and flow measurement. Theories and methods of open channel design.<br>Unit IV<br>Sediment transport in channels. Regime flow theories. Tractive force theory. Design of stable channels.<br>Unit V<br>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. |
| References: | • Chaudhry MH. 1993. Open Channel Flow. Prentice-Hall, NJ.<br>• Chow VT. 1979. Open Channel Hydraulics. McGraw Hill Inc. N York.<br>• French RH. 1986. Open Channel Hydraulics. McGraw Hill Pub Co., N York<br>• Henderson FM. 1966. Open Channel Flow. Macmillan Co. New York.<br>• Prabhata K Swamee and Ashok K Sharma. Design of Water Supply Pipe Networks. John Wiley New York.<br>• Subramanya K. 2008. Flow in Open Channels. Tata McGraw Hill Pub.<br>• Terry Sturm. 2011. Open Channel Hydraulics. Tata McGraw Hill Pub. |
| Course Outcomes | At the end of the course, learners will be able<br>**CO1:** Analyze and differentiate between prismatic and non- |

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| | prismatic channels, steady and unsteady flow, uniform and non-uniform flow, and open channel properties, applying energy and momentum principles to critical flow computations.<br>**CO2:** Understand the concepts of free surface flow, classify flow types, analyze velocity and pressure distribution, and apply conservation laws and specific energy principles to solve uniform flow problems.<br>**CO3:** Design and analyze channel transitions, considering different flow regimes (critical, uniform, gradually varied, rapidly varied, spatially varied, unsteady), and implement flow control structures and flow measurement techniques.<br>**CO4:** Assess sediment transport in channels, analyze regime flow theories and tractive force theory, and design stable channels to minimize sediment transport and erosion.<br>**CO5:** Analyze pipe flow principles and solve related problems, apply network synthesis and pipe network analysis techniques to optimize water transmission lines, and design cost-effective water distribution systems for various scenarios (single-input, branched, looped, multi-input) considering decomposition and optimal zone size. |

Mapping between COs with POs and PSOs

**Mapping between Cos, POs and PSOs**

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| **Course code** | **IDE 510** |
| **Course title** | **Minor Irrigation** |
| **Corse credit** | **2+1** |
| **Objective of 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. |
| Course Content | Unit I<br>Definition, scope, historical background and progress in minor irrigation works in India, Assessment of surface water resource. Design and operation of surface water storage structures.<br>Unit II<br>Evaporation and seepage control. Groundwater development methods and their scope. Groundwater ex- traction devices and methods. Aquifer characteristic and their evaluation. Wells in alluvial and rocky aquifers.<br>Unit III<br>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.<br>Unit IV<br>Well design, drilling and construction. 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.<br>Unit V<br>Conjunctive use of surface and groundwater. Legislation for groundwater development and management. Groundwater recharge and its use. |
| References: | •Garg SK. 1987. Irrigation Engineering and Hydraulic Structures. Khanna Publisher, Delhi.<br>•Garg SK. 1987. Hydrology and Water Resource Engineering. Khanna Publishers, Delhi.<br>•Michael AM. 2006. Irrigation Theory and Practice. Vikas Publications, New Delhi.<br>•Sharma RK. 1987. Hydrology and Water Resources Engineering. Dhanpat Rai and Sons, New Delhi.<br>•Subramanian K. 1993. Engineering Hydrology. Tata Mc-Graw-Hill Co. New Delhi. |
| Course Outcomes | At the end of the course, learners will be able<br>**CO1:** Understand the concept of minor irrigation in India, historical background, progress, and assess surface water resources for irrigation purposes. Design and operate surface water storage structures for efficient water management.<br>**CO2:** Analyze evaporation and seepage control methods, evaluate groundwater development options and their scope, understand groundwater extraction devices and methods, and assess aquifer characteristics for sustainable groundwater utilization.<br>**CO3:** Analyze well interference, spacing, and multiple well |

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| | point systems for controlled groundwater pumping, determine safe yield from wells, and implement strategies for well yield augmentation through pumping and recovery time management.<br>**CO4:** Understand and apply well design principles, drilling and construction techniques, tube well strainer selection, gravel packing considerations, and analyze resistance to flow in wells. Select and install appropriate pumps and prime movers for groundwaterlifting. Diagnose and remediate sick and failed wells for sustainable operation.<br>**CO5:** Combine surface and groundwater resources through conjunctive use strategies, understand and comply with groundwater legislation and management practices, and implement groundwater recharge techniques for long-term sustainability of water resources. |

Mapping between COs with POs and PSOs

**Mapping between Cos, POs and PSOs**

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| **Course code** | **IDE 511** |
| **Course title** | **Design of Pumps for Irrigation and Drainage** |
| **Corse credit** | **2+0** |
| **Objective of 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. |
| Course Content | Unit I<br>Basic hydraulic design of centrifugal pump. Net positive suction head and cavitation, vapour pressure,<br>water hammering problem in centrifugal pump.<br>Unit II<br>Principles and design of pumping systems for agricultural drainage. Selection and performance of<br>characteristics of vertical turbine pump, submersible pump and axial flow pump.<br>Unit III<br>Multiple well point system and their design. Energy requirement in groundwater pumping.<br>Unit IV<br>Non-conventional energy sources for pumping, wind mills, micro turbines, solar pumps. Hydraulic ram:<br>Selection and design criteria. Solar photovoltaic system.<br>Unit V<br>Design of pumping station. Techno-economic evaluation. Efficient pumping system operation, flow control<br>strategies and conservation measures for pumping systems. |
| References: | • Bansal RK. 1990. A Text Book of Fluid Mechanics and Hydraulic Machines. Laxmi Publications, New Delhi.<br>• Church AH and Jagdish Lal. 1973. Centrifugal Pumps and Blowers. Metropolitan Book Co. Pvt. Ltd. Delhi.<br>• Luthin JN. 1966. Drainage Engineering. Wiley and Sons. New York, USA.<br>• Michael AM and Khepar SD. 1989. Water Wells and Pump Engineering. Tata McGraw Hill Publishing Co., New Delhi. |
| Course Outcomes | At the end of the course, learners will be able<br>**CO1:** Analyze the basic hydraulic design of centrifugal pumps, including net positive suction head (NPSH), cavitation, vapor pressure, and water hammering issues.<br>**CO2:** Design and select pumping systems for agricultural drainage, considering pump types (vertical turbine, submersible, axial flow) and their performance characteristics.<br>**CO3:** Design and apply multiple well point systems for efficient drainage, calculate energy requirements for groundwater pumping, and optimize pump selection.<br>**CO4:** Evaluate non-conventional energy sources for pumping (windmills, micro turbines, solar pumps), design hydraulic ram systems, and understand the principles and selection criteria for solar photovoltaic systems.<br>**CO5:** Design pumping stations, perform techno-economic |

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| | evaluations, implement efficient pumping system operation strategies, and apply flow control and conservation measures to optimize energy use and water resources in irrigation and drainage systems. |

Mapping between COs with POs and PSOs

**Mapping between Cos, POs and PSOs**

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| Course code | IDE 512 |
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| **Course title** | **Crop Environmental Engineering** |
| **Corse credit** | **2+0** |
| **Objective of 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. |
| Course Content | Unit I<br>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.<br>Unit II<br>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.<br>Unit III<br>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 water movement. ET-yield relations.<br>Unit IV<br>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 for monitoring plant environments.<br>Unit V<br>Design and operation of controlled environment facilities and their instrumentation. Climatic changes and plant response to environmental stresses. Evapotranspiration models. |
| References: | Abtew W and Melese A. 2017. Evaporation and Evapotranspiration: Measurements and Estimations. Springer Publications.<br>Campbell GS and Norman JM. An Introduction to Environmental Biophysics. Springer Publication New York.<br>Ghildyal BP and Tripathy RP. 1987. Fundamental of Soil Physics. Wiley Eastern.<br>Monteith JL and Unsworth MH. Principles of Environmental Physics. Elsevier, Amsterdam.<br>Slatyor O P 1967. Plant Water Relationship. Academic Press.<br>Yang Y. Evapotranspiration over Heterogeneous surfaces: Models and Applications. Springer Publications. |
| Course Outcomes | At the end of the course, learners will be able<br>**CO1:** Analyze the principles of heat, mass, and momentum transport, including radiant energy, microclimatology, turbulent |

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| | transfer profiles, and flux measurement and estimation.<br>**CO2:** Understand the profile balance of heat, mass, and momentum within and above crop communities, analyze plant response to environmental stresses, and estimate potential evapotranspiration on different scales.<br>**CO3:** Explain root anatomy and water flow in roots, model root density, and analyze stem anatomy and pressure-volume curves. Assess plant water status using various methods and estimate evapotranspiration using temperature models and satellite data.<br>**CO4:** Apply optimal scheduling algorithms (LP and DP) for irrigation and water allocation, utilize production functions to assess crop yield and model crop growth, and monitor plant environments using appropriate instrumentation and techniques.<br>**CO5:** Design and operate controlled environment facilities, considering climatic changes and plant responses to environmental stresses. Analyze evapotranspiration using different models and implement appropriate strategies for irrigation management based on evapotranspiration assessment. |

**Mapping between Cos, POs and PSOs**

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| **Course code** | **IDE 513** |
| **Course title** | **Water Resources Systems Engineering** |
| **Corse credit** | **2+1** |
| **Objective of 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. |
| Course Content | Unit I<br>Concepts and significance of optimization in water resources management. Model development in water management. Objective functions, deterministic and stochastic inputs.<br>Unit II<br>Soil plant atmosphere system. Problem formulation. Mathematical programming techniques: Linear programming, simplex method.<br>Unit III<br>Non-linear programming, quadratic programming, integer programming. Transportation problem and solution procedure. Geometric programming and dynamic programming.<br>Unit IV<br>Application of optimization techniques for water resources planning. Conjunctive use of water resources. Crop production functions and irrigation optimization.<br>Unit V<br>Multi objective water resources planning. Critical path method. Programme evaluation and review technique. Economic models. Project evaluation and discounting methods. |
| References: | • Larry WM. 1996. Water Resources Handbook. Mc-Graw-Hill.<br>• Loucks DP et al. 1981. Water Resources System Planning and Analysis. Prentice Hall.<br>• Rao SS. 1978. Optimization Theory and Application. Wiley Eastern.<br>• Wallander WW and Bos M. 1990. Water Resource System Planning and Management. |
| Course Outcomes | At the end of the course, learners will be able<br>**CO1:** Understand the concepts and significance of optimization in water resources management, including model development, objective function design, and handling deterministic and stochastic inputs.<br>**CO2:** Analyze the soil-plant-atmosphere system, formulate optimization problems related to water management, and apply linear programming techniques (Simplex method) to solve various water management problems.<br>**CO3:** Utilize non-linear programming techniques (quadratic programming, integer programming) and solve transportation problems related to water distribution. Implement geometric programming and dynamic programming for optimizing water resource allocation.<br>**CO4:** Apply optimization techniques to various water resources |

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| | planning problems, including conjunctive use of surface and groundwater, crop production functions, and irrigation optimization.<br>**CO5:** Analyze multi-objective water resources planning problems, utilize critical path method and program evaluation and review technique for project planning and control, and implement economic models and discounting methods for project evaluation and decision-making. |

**Mapping between Cos, POs and PSOs**

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| **Course code** | **IDE 514** |
| **Course title** | **Irrigation Economics Planning and Management** |
| **Corse credit** | **2+0** |
| **Objective of 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. |
| Course Content | Unit I<br>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.<br>Unit II<br>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.<br>Unit III<br>Indian agriculture, main problems, population, government policies, systems, organizing agriculture production. Farm Management: Definition, importance, scope, relation with other sciences and its characteristics.<br>Unit IV<br>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.<br>Unit V<br>Role of farm management principles in decision making for irrigated agriculture. Decision making process, assessing risk and uncertainty in planning. |
| References: | • Heady, Early Orel, Hexem R and Roger W. 1978. Water Production Functions for Irrigated Agriculture.<br>• James Douglas and Lee Rober R. 1995. Economics of Water Resource Planning. Tata Mcgraw-Hill Publication Company Ltd, Bombay, New Delhi.<br>• Joshi SS and TR Kapoor. 2001. Fundamentals of Farm Business Management. KalyaniPublishers, Ludhiana.<br>• Management of Water Project-Decision Making and Investment Appraisal. Oxford Publication Co.<br>• Sharma VK. 1985. Water Resource Planning and Management. Himalaya Publication House, New Delhi. |

| Course Outcomes | At the end of the course, learners will be able<br>**CO1:** Analyze economic principles and methods for project selection, apply water pricing approaches, assess investment criteria, evaluate social benefits and causes of project under-utilization, and perform cost-benefit analysis considering discounting techniques.<br>**CO2:** Understand the role of financial analysis and distinguish it from economic analysis, perform financial feasibility analysis, assess the impact of public policies on water management, compare economic efficiency of alternative irrigation models, and optimize irrigation systems for improved water use efficiency using simulation and optimization techniques.<br>**CO3:** Analyze the state of Indian agriculture, including population trends, government policies, and agricultural systems, and understand the importance, scope, and characteristics of farm management, its relationship with other disciplines.<br>**CO4:** Plan and conduct socio-economic surveys for irrigation projects, including questionnaire design, sampling methodology, data collection, editing, classification, and analysis, to inform project planning, implementation, and performance evaluation.<br>**CO5:** Apply farm management principles to decision-making in irrigated agriculture, considering risk and uncertainty factors in planning and resource allocation for optimal production and profitability. |
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**Mapping between Cos, POs and PSOs**

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| **Course code** | **IDE 515** |
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| **Course title** | **Sensing and Automation in Irrigation Systems** |
| **Corse credit** | **3+0** |
| **Objective of 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. |
| Course Content | Unit I<br>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.<br>Unit II<br>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).<br>Unit III<br>Communication interfaces, serial peripheral interface, inter-integrated circuit, the IMote node architecture, The XYZ node architecture, the Hogthrob node architecture.<br>Unit IV<br>Applications in surface irrigation automation, automation based on volume, time, fertigation scheduling, water logging, salinity, oxygen diffusion systems, etc.<br>Unit V<br>Applications in surface irrigation automation, automation based on volume, time, fertigation scheduling, water logging, salinity, oxygen diffusion systems, etc. |
| References: | • Cauligi S Raghavendra, Krishna M Sivalingam and Taieb Znati. Wireless Sensor Networks. Springer.<br>• Edgar H, Callaway Jr. and Edgar H Callaway. Wireless Sensor Networks: Architectures and Protocols.<br>• Holger Karl and Andreas Willig. Protocols and Architectures for Wireless Sensor Networks. John Wiley & Sons.<br>• Waltenegus Dargie and Christian Poellabauer. Fundamentals of Wireless Sensor Networks: Theory and Practice. A John Wiley and Sons, Ltd, Publication. |
| Course Outcomes | At the end of the course, learners will be able<br>**CO1:** Analyze the principles of sensing and various sensor classifications, understand the concept of wireless sensor networks (WSNs) and their history, and identify key design constraints such as energy, self-management, wireless networking, decentralized management, and security.<br>**CO2:** Explain the architecture of WSN nodes, including the sensing subsystem, analog-to-digital converters, processor subsystems (microcontrollers, DSPs, ASICs, FPGAs), and |

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| | communication interfaces (SPI, I2C).<br>**CO3:** Analyze specific WSN node architectures like IMote, XYZ, and Hogthrob, understanding their design choices and functionalities.<br>**CO4:** Apply WSN technology to surface irrigation automation, designing systems for automated irrigation based on volume, time, and fertigation scheduling, as well as monitoring waterlogging, salinity, and oxygen diffusion.<br>**CO5:** Evaluate the effectiveness of WSN-based irrigation automation systems, considering factors like energy efficiency, data accuracy, system reliability, and cost-effectiveness, and propose improvements for further optimizing irrigation practices. |

**Mapping between Cos, POs and PSOs**

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**Department of Irrigation and Drainage Engineering - PhD**

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| **Course code** | **IDE 601** |
| **Course title** | **Recent Developments in Irrigation Engineering** |
| **Corse credit** | **2+1** |
| **Objective of 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. |
| Course Content | Unit I<br>Geospatial analysis of hydraulic properties of the soil. Surge flow irrigation systems. One dimensional and two-dimensional zero inertia modelling of border irrigation, surge irrigation and furrow irrigation. Integral equation solutions to surface irrigation. Design of irrigation runoff recovery systems. Cablegation: Automated supply for surface irrigation. analysing wind distortion in sprinkler irrigation systems uniformity.<br>Unit II<br>Design of sub-surface drip irrigation systems. Modeling soil water regimes and solute distribution emanating from surface and sub-surface drip irrigation systems. Recent developments in designs of surface and sub-surface drip irrigation systems. 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.<br>Unit III<br>Drip irrigation for poor quality water. Drip automation for time and volume. Drip irrigation system modification for waste water utilization. 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.<br>Unit IV<br>Drip irrigation in command area development. Mulching and its effect on crop productivity. analysing moisture and temperature profiles with time and depth. Effect of shading and mulching on crop productivity, vapour phase movement. |
| References: | • Cuenca RH. 1989. Irrigation System Design: An Engineering Approach. Prentice Hall, New York.<br>• 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.<br>• James LG. 1988. Principles of Farm Irrigation System Design. John Wiley and Sons, New York, USA.<br>• Nakayama FS and Bucks DA. 1986. Trickle Irrigation for Crop Production: Design, Operation and Management. Elsevier Publications, Amsterdam.<br>• Skogerboe GV and Walkar WR. 2008. Surface Irrigation Theory and Practice. Prentice Hall, New York. |

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| Course Outcomes | At the end of the course, learners will be able<br>**CO1**: Apply geospatial analysis to assess soil hydraulic properties and design surge flow irrigation systems for improved water management.<br>**CO2**: Model and analyze surface irrigation systems (border, furrow, surge) using one- and two-dimensional models to optimize irrigation efficiency.<br>**CO3**: Design and evaluate sub-surface drip irrigation systems, considering soil water regimes, solute distribution, and emitter variability for optimal crop growth and water use.<br>**CO4**: Develop irrigation scheduling strategies through partial root zone irrigation and low-energy drip systems to improve water use efficiency and crop yield under various water salinity conditions.<br>**CO5**: Analyze the impact of mulching on soil moisture, temperature, vapor movement, and crop productivity for sustainable agricultural practices in drip irrigation systems. |

**Mapping between Cos, POs and PSOs**

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| **Course code** | **IDE 602** |
| **Course title** | **Advances in Drainage Engineering** |
| **Corse credit** | **2+1** |
| **Objective of Course** | To provide comprehensive knowledge of advances in land drainage, synthetic materials for drainage systems, linear flow laws and environmental issues related to drainage. |
| Course Content | Unit I<br>Physics of land drainage. Forces, surface tension and energy effects water. Energy of soil water. Capillary potential.<br>Unit II<br>Devices to measure capillary potential. Hysteresis, Darcy’s law. Synthetic materials for drainage systems. Environmental issues related to drainage. Socio-economic impacts of drainage systems.<br>Unit III<br>Laplace equation its derivation and solution in various forms. Boundary value problems, Liner flow laws.<br>Unit IV<br>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.<br>Unit V<br>Flow equations in general and the approach. Flow problem and physical boundary conditions. |
| References: | • Chauhan HS. 1999. Mathematical Modeling of Agricultural Drainage, Ground Water and Seepage. ICAR Publication New Delhi.<br>• Kirkham DL and Powers WL. 1972. Advanced Soil Physics. Inter Science, New York.<br>• Lambert K Smedema, Willem FV, Lotman and David Rycroft. 2004. Modern Land Drainage: Planning, Design and Management of Agricultural Drainage Systems. CRC Press.<br>• Ritzema HP. (Ed.). 1994. Drainage Principles and Applications. ILRI.<br>• Skaggs RW and Schilfgaarde Jan Van. 1999. Agriculture Drainage. Monograph No. 17.American Society of Agronomy Madison, Wisconsin, USA. |
| Course Outcomes | At the end of the course, learners will be able<br>**CO1**: Understand and apply the physical principles governing water movement in soil, including capillary potential, Darcy's law, and environmental considerations.<br>**CO2**: Analyze and design land drainage systems using various tools and models, including Laplace equation, saturated flow theory, and simulation models.<br>**CO3**: Develop and implement drainage strategies for agricultural land, considering both crop water needs and environmental sustainability, including controlled drainage for pollution |

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| | reduction.<br>**CO4**: Critically evaluate the socio-economic impacts of land drainage systems and propose solutions for mitigating negative consequences.<br>**CO5**: Apply advanced mathematical and computational skills to solve complex flow problems in drainage systems and interpret the results for informed decision-making. |

**Mapping between Cos, POs and PSOs**

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| **Course code** | **IDE 603** |
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| **Course title** | **Hydro-Mechanics and Ground Water Modeling** |
| **Corse credit** | **3+0** |
| **Objective of 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. |
| Course Content | Unit I<br>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.<br>Unit II<br>Physical models, Analog models, Mathematical modelling, Unsaturated flow models, Numerical modelling of groundwater flow, Finite difference equations and solutions. Successive over relax- ation. Alternating direction implicit procedure. Crank Nicolson equation. Iterative methods. Direct methods. Inverse problem. Finite element method.<br>Unit III<br>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.<br>Unit IV<br>Fence diagram and aquifer mapping. Movement of groundwater in fractured and swelling porous media. Spatial variability, theory of krigging.<br>Unit V<br>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. |
| References: | • Anderson MP and Woessner WW. 1992. Applied Groundwater Modelling: Simulation of Flow and Advective Transport. Academic Press, Inc.<br>• Elango L and Jayakumar R. 2001. Modelling in Hydrology. Allied Publishers Ltd.<br>• Fetter CW. 1999. Contaminant Hydrogeology. Prentice Hall.<br>• Kirkham and Powers. 1972. Advanced Soil Physics. John Wiley & Sons.<br>• Muskat M. 1937. The Flow of Homogeneous Fluid through Porous Media. McGraw Hill.<br>• Rushton KR. 2003.Groundwater Hydrology: Conceptual and Computational Models. Wiley, |
| Course Outcomes | At the end of the course, learners will be able |

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| | **CO1**: Analyze soil-water interaction and pressure distribution in unsaturated zones using physical models, mathematical models, and numerical methods like finite difference and finite element.<br>**CO2**: Estimate unsaturated hydraulic conductivity and model water movement in porous media, considering infiltration, exfiltration, and water table fluctuations.<br>**CO3**: Construct fence diagrams, map aquifers, and analyze groundwater flow in fractured and swelling porous media, accounting for spatial variability.<br>**CO4**: Design and execute conceptual models of aquifer systems, including parameter estimation, input-output stresses, and boundary conditions, for steady-state and transient simulations.<br>**CO5**: Calibrate and validate groundwater models through sensitivity analysis, considering uncertainties in model predictions, to ensure reliable groundwater management strategies. |

**Mapping between Cos, POs and PSOs**

| **CO** | **PO** | | | | | | | | | | | | **PSO** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **1** | **2** | **3** |
| **CO1** | | | | | | | | | | | | | | | |
| **CO2** | | | | | | | | | | | | | | | |
| **CO3** | | | | | | | | | | | | | | | |
| **CO4** | | | | | | | | | | | | | | | |
| **CO5** | | | | | | | | | | | | | | | |

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|---|---|
| **Course code** | **IDE 604** |
| **Course title** | **Soil-Water-Plant-Atmospheric Modeling** |
| **Corse credit** | **2+1** |
| **Objective of Course** | To impart the knowledge of measurement of radiation within plant cover, thermodynamics of flow through plant cells, heat transfer and radiation exchange under plant cover. |
| Course Content | Unit I<br>Radiation balance of earth's surface. Turbulent transport of heat and momentum. Radiation exchange and heat transfer in a low plant cover.<br>Unit II<br>Measurement of radiation, leaf and air temperature, humidity and wind profiles within plant cover. Predicting potential evapotranspiration.<br>Unit III<br>Thermodynamics of flow through plant cells. Dynamics of water movement through soil plant atmosphere system. Stomatal aperture, photosynthesis and actual evapotranspiration relationship.<br>Unit IV<br>Production functions of evapotranspiration. Evapo-transpiration in mathematical modelling and optimization of design and regulation of irrigation systems and for utilization of limited water<br>resources in agriculture.<br>Unit V<br>Crop water requirement under protected cultivation and remote sensing-based modeling. |
| References: | • Amarjit Basra. 1994. Mechanisms of Plant Growth and Improved Productivity. CRC Press New York.<br>• Daniel Hillel. Advances in Irrigation. All Volumes.<br>• Nieder AR and Benbi D. 2003. Handbook of Processes and Modeling in the Soil-Plant System. CRC Press New York.<br>• Peter J Gregory. Plant Roots, their Growth Activity and Interaction with Soils. Wiley Blackwell New York. |
| Course Outcomes | At the end of the course, learners will be able<br>**CO1**: Analyze radiation balance and turbulent transport processes in plant canopies to understand energy exchange between the atmosphere and agricultural ecosystems.<br>**CO2**: Measure and interpret micrometeorological parameters (radiation, temperature, humidity, wind) within plant canopies to accurately estimate potential evapotranspiration.<br>**CO3**: Explain the thermodynamics of water flow through plant cells and the dynamics of water movement within the soil-plant-atmosphere system (SPAS).<br>**CO4**: Model and analyze the relationship between stomatal aperture, photosynthesis, and actual evapotranspiration to predict plant water use and optimize irrigation management.<br>**CO5**: Utilize production functions of evapotranspiration and |

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| | remote sensing techniques to design and optimize irrigation systems for efficient water resource utilization in agriculture, particularly under protected cultivation conditions. |

**Mapping between Cos, POs and PSOs**

| **CO** | **PO** | | | | | | | | | | | | **PSO** | | |
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| | 1 | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **1** | **2** | **3** |
| **CO1** | | | | | | | | | | | | | | | |
| **CO2** | | | | | | | | | | | | | | | |
| **CO3** | | | | | | | | | | | | | | | |
| **CO4** | | | | | | | | | | | | | | | |
| **CO5** | | | | | | | | | | | | | | | |

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| **Course code** | **IDE 605** |
| **Course title** | **Plant Growth Modeling and Simulation** |
| **Corse credit** | **2+0** |
| **Objective of Course** | To impart the in-depth knowledge of plant growth modeling, type of modeling approach, quantitative analysis of photosynthesis and remote sensing-based modeling. |
| Course Content | Unit I<br>Introduction to plant growth modeling. Simulation and simulation language. Types of models and modeling approaches.<br>Unit II<br>Relational diagram of principle process. Structure of a generalized agricultural simulator. Input environment and techniques for monitoring plant environment.<br>Unit III<br>Process and aspects of growth and development. Input yield models. Quantitative analysis of photosynthesis, respiration, growth, water and nutrient uptake. Yield functions.<br>Unit IV<br>Remote sensing-based modeling and field variability of growth influencing factors. |
| References: | • Charls-Edwards DA. 1981. The Mathematics of Photosynthesis and Productivity. Academic Press, London.<br>• Evans LT. 1963. Environmental Control of Plant Growth. Academic Press, New York, USA.<br>• Goudriaan J and Van Laar HH. 1994. Modelling Potential Crop Growth Process. Kluweer Academic Publisher, Dordrecht, The Netherlands.<br>• Jones JW and Ritchie JT. 1990. Crop Growth Models. In: ASAE Monograph on Management of Farm Irrigation.<br>• Thorwey JHM and Johnson IR. 1990. Plant and Crop Modelling: A Mathematical Approach to Plant and Crop Physiology. Clarendon Press, Oxford. |
| Course Outcomes | At the end of the course, learners will be able<br>**CO1**: Apply principles of plant growth modeling and simulation to analyze and predict crop growth and development under diverse environmental conditions.<br>**CO2**: Design and implement agricultural simulators using appropriate simulation languages and techniques to address specific research or management questions.<br>**CO3**: Quantify and analyze the relationships between photosynthesis, respiration, growth, water and nutrient uptake, and yield using mathematical models.<br>**CO4**: Utilize remote sensing data to model and assess the impact of field variability on growth-influencing factors for improved spatial management.<br>**CO5**: Develop and apply crop growth models for optimizing agricultural practices and decision-making to enhance agricultural productivity and sustainability. |

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**Mapping between Cos, POs and PSOs**

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| CO1 | | | | | | | | | | | | | | | |
| CO2 | | | | | | | | | | | | | | | |
| CO3 | | | | | | | | | | | | | | | |
| CO4 | | | | | | | | | | | | | | | |
| CO5 | | | | | | | | | | | | | | | |

| **Course code** | **IDE 606** |
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| **Course title** | **Multi Criteria Decision Making System** |
| **Corse credit** | **2+0** |
| **Objective of Course** | To acquaint students about multi criteria decision making system which include multi-attribute decision making and multi-objective decision making. |
| Course Content | Unit I<br>Introduction: MCDM overview, basic foundations and Pareto optimality elementary decision analysis. Decision trees and influence diagrams.<br>Unit II<br>Multi–attribute decision making (MADM): Deterministic utility theory, value decomposition, additive value decomposition, Multi–facility location analysis, eXpected utility theory, single attribute utility functions, multi–attribute overview, two–attribute utility models, multi–attribute computer programs, multi–attribute assessment.<br>Unit III<br>Multi-objective decision making (MODM): Vector optimization theory, weighting methods, weighting example. Linear vector optimization (LVOP), parametric decomposition, LVOP algorithm, LVOP example.<br>Unit IV<br>Non interactive and interactive methods: Geoffrion's Bi-criterion method, linear goal programming, nonlinear and integer goal programming.<br>Unit V<br>Interactive trade-off methods: Zionts–Wallenius, Surrogate worth, Group decision making methods. |
| References: | • Cohon JL. 2004. Multiobjective Programming and Planning. Dover Publications.<br>• Doumpos M and Grigoroudis E. 2013. Multicriteria Decision Aid and Artificial Intelligence: Links, Theory and Applications. Wiley-Blackwell.<br>• Figueira J, Greco S and Ehrgott M 2007. Multiple Criteria Decision Analysis: State of the Art Surveys. Springer.<br>• Tzeng GH and Huang JJ. 2011. Multiple Attribute Decision Making: Methods andApplications. Chapman and Hall/CRC.<br>• Tzeng GH and Huang JJ. 2013. Fuzzy Multiple Objective Decision Making. Chapman and Hall/CRC. |
| Course Outcomes | At the end of the course, learners will be able<br>**CO1**: Understand the fundamental concepts of MCDM, including basic foundations, Pareto optimality, decision trees, influence diagrams, and decision analysis techniques.<br>**CO2**: Apply multi-attribute decision making (MADM) approaches like deterministic utility theory, value decomposition, and expected utility theory to solve complex |

decision problems with multiple conflicting criteria.

**CO3**: Implement multi-objective decision making (MODM) methods, including vector optimization theory, weighting methods, linear vector optimization, and parametric decomposition, to identify optimal solutions for problems with multiple objectives.

**CO4**: Analyze and compare non-interactive and interactive methods for MCDM, such as Geoffrion's Bi-criterion method, goal programming, and Zionts-Wallenius method, to choose the most suitable approach for specific scenarios.

**CO5**: Utilize group decision making methods to facilitate collaborative decision-making processes and reach consensus in situations involving diverse stakeholder perspectives and preferences.

**Mapping between Cos, POs and PSOs**

| **CO** | **PO** | | | | | | | | | | | | **PSO** | | |
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| | 1 | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **1** | **2** | **3** |
| **CO1** | | | | | | | | | | | | | | | |
| **CO2** | | | | | | | | | | | | | | | |
| **CO3** | | | | | | | | | | | | | | | |
| **CO4** | | | | | | | | | | | | | | | |
| **CO5** | | | | | | | | | | | | | | | |

**w.e.f.: 2022-2023**

**Degree: M. Tech (Agril. Engg.)**
**Major Subject: Processing and Food Engineering**

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| **Course code** | **PFE – 501** |
| **Course title** | **Transport Phenomena in Food Processing** |
| **Corse credit** | 3 (2 + 1) |
| **Objective of Course** | 1. To acquaint and equip the students with the principles of heat transfer and its applications in food processing.<br>2. To acquaint and equip the students with the principles of mass transfer and its applications in food processing.<br>3. To acquaint and equip the students with the principles of momentum transfer and its applications in food processing. |
| Course Content | Introduction to heat and mass transfer and their analogy. Steady and unsteady state heat transfer. Ana-lytical and numerical solutions of unsteady state heat conduction equations. Use of Gurnie-Lurie and Heisler Charts in solving heat conduction problems: Applications in food processing including freezing and thawing of foods. Convective heat transfer in food processing systems involving laminar and turbulent flow. Heat trans- fer 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. Momentum transfer. Mass flow and balance. Steady and unsteady flow. Theory and equation of con- tinuity. Bernoulli’s theorem and application. Flow through immerged bodies, Measurement of flow, pressure and other parameters. Flow driving mechanism. 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. |
| References: | • Bird RB, Stewart WE, Lightfoot EN 2006. Transport Phenomena (2nd Ed.), John Wiley & Sons. ISBN: 978-0-470-11539-8<br>• Raj B 2012. Introduction to Transport Phenomena: Momentum, Heat and Mass, PHI. ISBN 978- 8120345188<br>• Geankoplis CJ. 2015. Transport Processes and Separation Process Principles (Includes Unit Operations) (4th Ed.), Pearson Education India, ISBN: 978-9332549432<br>• Coulson JM, Richardson JF, Backhurst JR, Harker JH. 2002. Chemical Engineering. Vol. 2 (5th Ed.), Elsevier, ISBN: 9780750644457 |

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| | • Earle RL. 1985. Unit Operations in Food Processing. Pergamon Press.<br>• Holman JP, Bhattacharyya S. 2017. Heat Transfer. McGraw Hill.<br>• Welti-Chanes J, Velez-Ruiz JF, Barbosa-Canovas GV. 2002. Transport Phenomena in Food Processing. CRC Press ISBN: 9781566769938.<br>• McCabe WL, Smith JC, Harriott P. 2005. Unit Operations of Chemical Engineering (7th Ed.). McGraw's Hill.<br>• Plawsky JL. 2020. Transport Phenomena Fundamentals (4th Ed.), Routledge Taylor & Francis Group, ISBN: 9781138080560.<br>• Datta AK. 2001. Transport Phenomena in Food Process Engineering, Himalaya Publishing House |
| Course Outcomes | At the end of the course, learners will be able<br>**CO1**: To impart requisite knowledge about transport phenomenon with respect to heat, mass and momentum transfer which is necessary to understand the food processing operations.<br>**CO2**: At the end of courses, students will be able to understand, analyse and solve numerically the food processing operations where heat/mass/momentum transfer is involved. |

**Mapping between Cos, POs and PSOs**

| CO | PO | | | | | | | | | | | | PSO | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 |
| **CO1** | | | | | | | | | | - | | | | | |
| **CO2** | | | | | | | | | | - | | | | | |
| **Avg.** | | | | | | | | | | - | | | | | |

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|---|---|
| **Course code** | PFE 502 |
| **Course title** | Unit Operations in Food Process Engineering |
| **Corse credit** | 3 (2 + 1) |
| **Objective of Course** | 1. To acquaint and equip the students with different unit operations applicable in food industries.<br>2. To understand the scope and importance of various food processing operations with basic engineering mathematics and mass & energy balance.<br>3. To understand the laws of size reduction and importance of material handling devices. |
| **Course Content** | 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. 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, |

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| | pasteurization and sterilization, death rate kinetics, process time calculations, sterilization equipment. Refrigeration and freezing: Principles, freezing curve, freezing time calculation, freezing equipment, cold chain. 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 screw conveyors. Size reduction: Principles of size reduction, size reduction laws. Size reduction equipment: Jaw crusher, gyratory crusher, roller mill, hammer mill. |
| **References:** | • Berk. 2018. Food Process Engineering and Technology, Academic Press, ISBN: 978-0-12812018-7<br>• Brennan JG, Butters JR, Cowell ND and Lilly AEI. 1990. Food Engineering Operations. Elsevier.<br>• Fellows P 1988. Food Processing Technology: Principle and Practice. VCH Publ.<br>• McCabe WL and Smith JC. 1999. Unit Operations of Chemical Engineering. McGraw Hill. • Sahay<br>• KM and Singh KK. 1994. Unit Operation of Agricultural Processing. Vikas Publ. House.<br>• Singh RP and Heldman DR. 1993. Introduction to Food Engineering. Academic Press.<br>• Smith. 2011. Introduction to Food Process Engineering, Springer.<br>• Toledo. 2007. Fundamentals of Food Process Engineering, Springer.<br>• Varzakas. 2015. Food Engineering Handbook, CRC press.<br>• Sharma HK and Kumar N. 2022. Agro-Processing and Food Engineering, Springer<br>• Earle RL. 1985. Unit Operations in Food Processing. Pergamon Press.<br>• Ibarz A and Barbosa-Canovas GV. 2002. Unit Operations in Food Engineering, CRC Press<br>• Jafari SM. 2001. Engineering Principles of Unit Operations in Food Processing, Woodhead Publishing |
| Course Outcomes | At the end of the course, learners will be able<br>**CO1**: To acquaint the students with various unit operations in food process engineering.<br>**CO2**: To acquaint the students with various types of dryers, blanching, pasteurization processes.<br>**CO3**: To explain the functions of various unit operations and working of size reduction equipments in processing of food materials.<br>**CO4:** To explain principles and equipments involved in sieving, filtration, sedimentation and centrifugation.<br>**CO5:** Explain the importance, design and working of milling and material handling devices. |

**Mapping between Cos, POs and PSOs**

| CO | PO | PSO |
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| **CO1** | | | | | | | | | | - | | - | | | |
| **CO2** | | | | | | | | | | - | | - | | | |
| **CO3** | | | | | | | | | | - | | - | | | |
| **CO4** | | | | | | | | | | - | | - | | | |
| **CO5** | | | | | | | | | | - | | - | | | |

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| **Course code** | PFE 503 |
| **Course title** | Field Crops Process Engineering |
| **Corse credit** | 3 (2 + 1) |
| **Objective of Course** | 1. To understand the scope and importance of various field crops.<br>2. To understand the processes for milling various field crops.<br>3. To acquaint and equip the students with production and utilization of cereals and pulses. |
| Course Content | Production and utilization of cereals and pulses, grain structure of major cereals, pulses and oilseeds and their milling fractions. Grain quality standards and physico-chemical methods for evaluation of quality of flours. 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. Dal mills, handling and storage of by-products and their utilization. Storage of milled products. Expeller and solvent extraction processing. Assessment of processed product quality. Packaging of processed products. Design characteristics of milling equipment, selection, installation and their performance. Quality standards for various processed products. Value added products of cereals, pulses and oilseeds. |
| References: | • Asiedu JJ. 1990. Processing Tropical Crops. ELBS/ MacMillan.<br>• Chakraverty A. 1995. Post-Harvest Technology of Cereals, Pulses and Oilseeds. Oxford and IBH.<br>• Golob 2002. Crop Post-Harvest: Science and Technology Vol. 1, Wiley-Blackwell.<br>• Hodges 2004. Crop post-harvest: science and technology Vol. 2, Wiley-Blackwell.<br>• Morris Lieberman. 1983. Post-Harvest Physiology and Crop Preservation. Plenum Press.<br>• Pandey PH. 1994. Principles of Agricultural Processing. Kalyani.<br>• Pillaiyar P. 1988. Rice - Post Production Manual. Wiley Eastern.<br>• Sahay KM and Singh KK. 1994. Unit Operations in |

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| | Agricultural Processing. Vikas Publ. House.<br>• Sharma HK, Kumar N. 2022. Agro-Processing and Food Engineering, Springer |
| Course Outcomes | At the end of the course, learners will be able<br>**CO1**: To acquaint the students with various post harvest operations of cereal, pulses and oil seeds.<br>**CO2**: Explain the functions of various unit operations and working of size reduction equipments for processing of fibrous and dry size reduction in processing of agriculture produce.<br>**CO3:** To explain the assessment of processed product quality.<br>**CO4:** To explain the design characteristics of milling equipment, selection, installation and their performance.<br>**CO5:** Explain the important quality standards for various processed products. |

**Mapping between Cos, POs and PSOs**

| CO | PO | | | | | | | | | | | | PSO | | |
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| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 |
| CO1 | | | | | | | | | | - | | - | | | |
| CO2 | | | | | | | | | | - | | - | | | |
| CO3 | | | | | | | | | | - | | - | | | |
| CO4 | | | | | | | | | | - | | - | | | |
| CO5 | | | | | | | | | | - | | - | | | |

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| **Course code** | PFE 504 |
| **Course title** | Horticultural Crops Process Engineering |
| **Corse credit** | 3 (2 + 1) |
| **Objective of Course** | 1. To acquaint and equip the students with processing of fruits and vegetables.<br>2. T acquaint with the design features of the equipment used in their processing. |
| Course Content | Importance of post harvest technology of fruits and vegetables, structure, cellular components, composition and nutritive value of fruits and vegetables, fruit ripening, spoilage of fruits and vegetables. Harvesting and washing, pre-cooling, blanching, preservation of fruits and vegetables, commercial canning of fruits and vegetables, minimal processing of fruits and vegetables. Cold storage of fruits and vegetables, controlled atmosphere and modified atmosphere packaging of fruits and vegetables, quality deterioration and storage. Dehydration of fruits and vegetables, methods, osmotic dehydration, foam mat drying, freeze drying, microwave heating, applications, radiation preservation of fruits and vegetables, irradiation sources. Intermediate moisture foods, ohmic heating principle, high pressure processing of fruits and vegetables, applications, |

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| | sensory evaluation of fruit and vegetable products, packaging technology for fruits and vegetables, general principles of quality standards and control, FPO, quality attributes. |
| References: | • Bhatti S and Varma U. 1995. Fruit and Vegetable Processing. CBS.<br>• Cruesss WV. 2000. Commercial Fruit and Vegetable Products. Agrobios Publisher.<br>• Danthy ME. 1997. Fruit and Vegetable Processing. International Book Publisher.<br>• Simson. 2016. Post-Harvest Technology of Horticultural crops. AAP.<br>• Singh. 2018. Advances in Post-Harvest Technologies of Vegetable Crops. AAP.<br>• Srivastava RP and Kumar S. 1994. Fruit and Vegetable Preservation. Principles and Practices. InternationalBook Distr.<br>• Thompson AK. 1996. Post Harvest Technology of Fruits and Vegetables. Blackwell.<br>• Sharma HK, Kumar N. 2022. Agro-Processing and Food Engineering, Springer<br>• Verma LR and Joshi VK. 2000. Post Harvest Technology of Fruits and Vegetables. Vols. I-II. Indus Publisher. |
| Course Outcomes | At the end of the course, learners will be able<br>**CO1:** Explain about various properties and factors affecting quality of fruits and vegetables.<br>**CO2:** Classify various post harvest operations involved in horticulture processing.<br>**CO3:** Identify various preservation techniques for processed foods.<br>**CO4:** Application the advanced packaging technology in fruits and vegetables.<br>**CO5:** Explain food quality control, food laws, standards and FPO standards.. |

**Mapping between Cos, POs and PSOs**

| **CO** | **PO** | | | | | | | | | | | | **PSO** | | |
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| | 1 | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **1** | **2** | **3** |
| **CO1** | | | | | | | | | | - | | - | | | |
| **CO2** | | | | | | | | | | - | | - | | | |
| **CO3** | | | | | | | | | | - | | - | | | |
| **CO4** | | | | | | | | | | - | | - | | | |
| **CO5** | | | | | | | | | | - | | - | | | |

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| **Course code** | **PFE – 505** |
| **Course title** | **Storage Engineering and Handling of Agricultural Produce** |
| **Corse credit** | 3 (2 + 1) |
| **Objective of Course** | 1. To acquaint and equip the students with the safe storage of food materials.<br>2. To demonstrate design of storage structures<br>3. To explain design of different material handling equipment used in the industries. |
| Course Content | Storage of grains, biochemical changes during storage, production, distribution and storage capacity estimate models, storage capacity models, ecology, storage factors affecting losses, storage require ments. 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. 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. 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.<br>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. |
| References: | • Boumans. 1985. Grain Handling and Storage. Elsevier.<br>• FAO. 1984. Design and Operation of Cold Stores in Developing Countries. FAO.<br>• Golob. 2002. Crop Post-Harvest: Science and Technology. Vol 1 Wiley-blackwell.<br>• Hall CW. 1970. Handling and Storage of Food Grains in Tropical and Sub-Tropical Areas. FAO Publisher Oxford & IBH.<br>• Henderson S and Perry SM. 1976. Agricultural Process Engineering. 5th Ed. AVI Publisher.<br>• Hodges 2004. Crop Post-Harvest: Science and Technology. Vol 2, Wiley-blackwell.<br>• Ripp BE. 1984. Controlled Atmosphere and Fumigation in Grain Storage. Elsevier.<br>• Shefelt RL and Prussi SE. 1992. Post Harvest Handling – A System Approach. Academic Press.<br>• Sharma HK, Kumar N. 2022. Agro-Processing and Food Engineering, Springer<br>• Vijayaraghavan S 1993. Grain Storage Engineering and |

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| | Technology. Batra Book Service. |
| Course Outcomes | At the end of the course, learners will be able<br>**CO1**: To understand and undertake mechanical handling of food as per requirement of food industries.<br>**CO2**: To understand storage devices and systems for safe storage of food for longer period of time. |

**Mapping between Cos, POs and PSOs**

| CO | PO | | | | | | | | | | | | PSO | | |
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| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 |
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| CO2 | | | | | | | | | | - | | | | | - |

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|---|---|
| **Course code** | **PFE – 506** |
| **Course title** | **Food Packaging Engineering** |
| **Corse credit** | 2 (1 + 1) |
| **Objective of Course** | 1. To acquaint and equip the students with packaging methods, packaging materials, packaging machineries etc.,<br>2. To acquaint and equip the students with modern packaging techniques etc. |
| Course Content | Introduction of packaging: Package, functions and design. Principle in the development of protective packaging. Deteriorative changes in foodstuff and packaging methods of prevention. Food containers: Rigid containers, glass, wooden boxes, crates, plywood and wire bound boxes, corrugated and fibre board boxes, textile and paper sacks, corrosion of containers (tin plate). Flexible packaging materials and their properties. Aluminum as packaging material. Evaluation of packaging material and package performance. Packaging equipment: Food packages, bags, types of pouches, wrappers, carton and other traditional package. Retortable pouches: Shelf life of packaged foodstuff. Methods to extend shelf life. Packaging of perishables and processed foods. Special problems in packaging of food stuff. 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, microencapsulation and nano encapsulation. |
| References: | • Crosby NT. 1981. Food Packaging Materials. Applied Science Publisher. |

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| | • Frank A. 1992. A Handbook of Food Packaging. Springer.<br>• Mahadeviah M and Gowramma RV. 1996. Food Packaging Materials. Tata McGraw • Hill.Palling<br>• SJ. 1980. Developments in Food Packaging. Applied Science Publisher.<br>• Robertson GL. 2013. Food Packaging - Principles and Practice. 3rd Ed Taylor & Francis.<br>• Sacharow S and Grittin RC. 1980. Principles of Food Packaging. AVI Publisher |
| Course Outcomes | At the end of the course, learners will be able<br>**CO1**: Student's capability to develop packages for all kinds of food products as per requirement of food industries and thereby adding value to the food products.<br>**CO2:** To acquaint the students with various aspects of advanced packaging methods and technology.<br>**CO3:** To strength industry-institute linkage with leading institutes for promoting entrepreneurship among students. |

**Mapping between Cos, POs and PSOs**

| CO | PO | | | | | | | | | | | | PSO | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **1** | **2** | **3** |
| **CO1** | | | | | | | | | | | | | | | |
| **CO2** | | | | | | | | | | | | | | | |
| **CO3** | | | | | | | | | | | | | | | |

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| **Course code** | **PFE – 507** |
| **Course title** | **Instrumentation and Sensors in Food Processing** |
| **Corse credit** | 3 (2 + 1) |
| **Objective of Course** | 1. To acquaint and equip the students with instrumentation in food processing operations.<br>2. To acquaint and equip the students with the use of sensors in food processing operations. |
| Course Content | Basic instrumentation systems and transducer principles. Displacement transducers, Potential meters, LDVT, Piezoelectric and capacitive transducers, Digital transducers, velocity transducers. 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. Temperature measurement using bi-metals, thermisters, thermocouples, humidity measurement, manometers. Flow transducer, positive displacement, venturimeter, Rotameter, Drag force, hot wire anemometer. Theory and classifications of chemical sensors, biosensors, fibre optic sensors, gas sensors etc. Biosensor: Concepts, types of biosensors, methods of |

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| | 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. 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. |
| References: | • Doebelin EO. 1990. Measurement Systems Applications and Design. Tata McGraw Hill.<br>• Erika KR and Brimelow JB. 2001. Instrumentation and Sensors for the Food Industry. CRC Wood- head.<br>• Nakra BC and Chaudhary KK. 2004. Instrumentation Measurement and Analysis. Tata McGraw Hill.<br>• Mukhopadhyay. 2014. Novel Sensors for Food Inspection: Modelling, Fabrication and Experimen- tation. Springer.<br>• Mukhopadhyay SC. 2017. Sensors for Everyday Life. Springer.<br>• Paré JRJ and Bélanger JMR. 1997. Instrumental Methods in Food Analysis. Elsevier Academic Press. |
| Course Outcomes | At the end of the course, learners will be able<br>**CO1**: To enhance student's capability to control the process operations through precise instrumentation.<br>**CO2**: To enhance student's capability to apply knowledge of sensors for precision analysis of food quality in food industries. |

**Mapping between Cos, POs and PSOs**

| **CO** | **PO** | | | | | | | | | | | | **PSO** | | |
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| | 1 | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **1** | **2** | **3** |
| **CO1** | | | | | | | | | | - | | | | | - |
| **CO2** | | | | | | | | | | - | | | | | - |

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| **Course code** | **PFE – 508** |
| **Course title** | **Application of Engineering Properties in Food Processing** |
| **Corse credit** | 3 (2 + 1) |
| **Objective of Course** | 1. To acquaint the students with different techniques of measurement of engineering properties<br>2. To acquaint the students with application of engineering properties in the design of processing equipment. |
| Course Content | Physical characteristics of different food grains, fruits and vegetables: Shape and size, description of shape and size, |

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| | 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. Contact stresses between bodies, Hertz problems, firmness and hardness, mechanical damage, dead load and impact damage, vibration damage, friction, effect of load, sliding velocity, temperature, water film and surface roughness. Friction in agricultural materials, rolling resistance, angle of internal friction, angle of repose, flow of bulk granular materials, aero dynamics of agricultural products, drag coefficients, terminal velocity. 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. Application of engineering properties in design and operation of agricultural equipment and structures.<br><br>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. |
| References: | • Ludger F and Teixeira AA. 2007. Food Physics Physical Properties - Measurement and Application.<br>• Springer.<br>• Mohesenin NN. 1980. Thermal Properties of Foods and Agricultural Materials. Gordon and Breach Science Publisher.<br>• Mohesenin NN. 1980. Physical Properties of Plant and Animal Materials. Gordon & Breach Sci- ence Publisher.<br>• Peleg M and Bagelay EB. 1983. Physical Properties of Foods. AVI Publisher.<br>• Peter B. 2007. The Chemical Physics of Food. Wiley-Blackwell.<br>• Rao MA and Rizvi SSH. 1986. Engineering Properties of Foods. Marcel Dekker. |

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| | • Singhal OP and Samuel DVK. 2003. Engineering Properties of Biological Materials. Saroj Prakasan.<br>• Sharma HK, Kumar N. 2022. Agro-Processing and Food Engineering, Springer<br>• Sitkei. 1986. Mechanics of Agricultural Materials. Elsevier. |
| Course Outcomes | At the end of the course, learners will be able<br>**CO1**: Student's capability to apply properties of food for design of equipment.<br>**CO2:** Student's capability to apply properties of food for design of structures. |

**Mapping between Cos, POs and PSOs**

| **CO** | **PO** | | | | | | | | | | | | **PSO** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **1** | **2** | **3** |
| **CO1** | | | | | | | - | | - | - | | | | | |
| **CO2** | | | | | | | - | | - | - | | | | | |

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| **Course code** | **PFE - 509** |
| **Course title** | **Food Quality and Safety** |
| **Corse credit** | 3 (2 + 1) |
| **Objective of Course** | 1. To acquaint and equip the students with the need of quality control and scope for food toxicology.<br>2. To acquaint and equip the students with the latest standards to maintain food quality and safety. |
| **Course Content** | 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. 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. Process equipment and machinery auditing, consideration of risk, environmental consideration, mechanical quality control. Personnel hygienic standards, preventative pest control, cleaning and disinfesting system, biological factors underlying food safety. Preservation and stability, contaminants of processed foods, adulteration, prevention and control, FS- SAI, ISO, Codex, GMP, BIS and HACCP. Practices, principles, standards, specifications, application establishment and implementation, HACCP and quality management system. Food Safety Manage- ment Systems (FSMS), Traceability.<br>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. |

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| **References:** | • Herschdoerfer, SM. 1984. Quality Control in the Food Industry. Vol. 1 Academic Press.<br>• Herschdoerfer SM. 2012. Quality Control in the Food Industry. Vol. 2 Elsevier Science.<br>• Hubbard MR. 2003. Statistical Quality Control for the Food Iindustry. Springer.<br>• Mahadeviah M and Gowramma R V. 1996. Food Packaging Materials. Tata McGraw Hill.<br>• Mehmet M. 2011. Biosensors in Food Processing, Safety, and Quality Control. CRC Press.<br>• Palling SJ. 1980. Developments in Food Packaging. Applied Science Publisher.<br>• Sacharow S and Grittin RC. 1980. Principles of Food Packaging. AVI Publisher.<br>• Yanbo H, Whittaker AD and Lacey RE. 2001. Automation for Food Engineering. Food Quality Quantization and Process Control-CRC Press.<br>• FSSAI (2021) Manual for Food Safety Officers (2nd Ed), Food Safety and Standards Authority of India, New Delhi |
| **Course Outcomes** | At the end of the course, learners will be able<br>**CO1**: Student's capability to measure food quality as well as ensure food safety in food supply chain.<br>**CO2:** To acquaint the students with various food processing standards.<br>**CO3:** To acquaint the students with quality control and food plant hygiene' and HACCP techniques used in processing and development of food products. |

**Mapping between Cos, POs and PSOs**

| CO | PO | | | | | | | | | | | | PSO | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 |
| CO1 | | | | | | | | | | - | | | | | |
| CO2 | | | | | | | | | | - | | | | | |
| CO3 | | | | | | | | | | - | | | | | |

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|---|---|
| **Course code** | **PFE-510** |
| **Course title** | **Food Processing Technologies** |
| **Corse credit** | 3 (2 + 1) |
| **Objective of Course** | 1. To acquaint and equip the students with knowledge of different unit operations, mixing, homogenization operations to be performed in food industries and study of their related equipment.<br>2. To acquaint and equip the students with principles and equipments used for different drying techniques like, osmotic, foam mat, puff, freeze, microwave drying, etc.<br>3. To acquaint and equip the students with knowledge of noval |

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| | processing techniques like ohmic heating, pulsed electric field preservation, hydrostatic pressure technique, ultrasonic technology, nanotechnology in food processing, etc.<br>4. To acquaint and equip the students with knowledge of techniques like distillation, crystallization, phase equilibria, multistage calculations, leaching principles and equipment, solvent extraction, super-critical fluid extraction, near critical fluid extraction, etc.<br>5. To acquaint and equip the students with food plant hygiene' waste disposal methods, food processing plant utilities and HACCP in food processing industries. |
| Course Content | Mixing and homogenization; Principles of solid and liquid mixing, types of mixers for solids, liquid and pastes homogenization. Emulsification: Principles and equipments. Novel dehydration technologies; Osmotic dehydration, foam mat drying, puff drying, freeze drying, microwave drying, dehumidified air drying. Extrusion: Theory, equipment, applications. 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. 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 andaroma recovery. Food plant hygiene; Cleaning, sterilizing, waste disposal methods, Food processing plant utilities, steam requirements in food processing, HACCP in food processing industries. |
| References: | • Brennan JG, Butters JR, Cowell ND and Lilly AEI 1990. *Food Engineering Operations*.Elsevier.<br>• Earle RL. 1985. *Unit Operations in Food Processing*. Pergamon Press.<br>• Fellows P. 1988. *Food Processing Technology: Principle and Practice*. VCH Publisher.<br>• Geankoplis JC. 1999. *Transport Process and Unit Operations*. Allyn & Bacon.<br>• Gould GW. 1996. *New Methods of Food Preservation*. Blackie Academic & Professional.<br>• Heldman DR and Lund BD. 1992. *Hand Book of Food Engineering*. Marcel Dekker.<br>• McCabe WL and Smith JC. 1999. *Unit Operations of Chemical Engineering*. McGraw Hill.<br>• Sahay KM and Singh KK. 1994. *Unit Operation of Agricultural Processing*. Vikas Publ. House. |

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| | • Singh RP 1991. *Fundamentals of Food Process Engineering*. AVI Publisher.<br>• Singh RP and Heldman DR 1993. *Introduction to Food Engineering*. Academic Press |
| Course Outcomes | At the end of the course, learners will be able<br>**CO1**: Student's capability to develop food products using recent techniques as per requirement of food industries.<br>**CO2:** To acquaint the students with novel processing techniques used in processing of food products<br>**CO3:** To acquaint the students with quality control and food plant hygiene' and HACCP techniques used in processing and development of food products. |

**Mapping between Cos, POs and PSOs**

| CO | PO | | | | | | | | | | | | PSO | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **1** | **2** | **3** |
| **CO1** | | | | | | | | | | - | | | | | |
| **CO2** | | | | | | | | | | - | | | | | |
| **CO3** | | | | | | | | | | - | | | | | |

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| **Course code** | PFE 511 |
| **Course title** | Food Processing Equipment and Plant Design |
| **Corse credit** | 2 (1 + 1) |
| **Objective of Course** | 1. To acquaint and equip the students with the design features of different food processing equipments being used in the industries and with the layout.<br>2. To understand the planning of different food and processing plants. |
| Course Content | Design considerations of processing agricultural and food products. Design of machinery for drying, milling, separation, grinding, mixing, evaporation, condensation, membrane separation. 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. 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. 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 |

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| | report and its appraisal. |
| References: | • Antonio LG and Gustavo VBC. 2005. Food Plant Design. CRC Press.<br>• Couper. 2012. Chemical Process Equipment. Selection and Design Elsevier.<br>• George S and Athanasios EK. 2015. Handbook of Food Processing Equipment. Springer.<br>• Lloyd EB and Edwin HY. 1959. Process Equipment Design. Wiley-Interscience.<br>• Michael MC. 2013. Food Plant Sanitation: Design, Maintenance, and Good Manufacturing Practices.CRC Press. |
| Course Outcomes | At the end of the course, learners will be able<br>**CO1:** To acquaint the students with various design considerations of processing agricultural and food products.<br>**CO2:** To acquaint the students with design of machinery for drying, milling, separation, grinding, mixing.<br>**CO3:** To explain the different Plant design concepts and general design considerations.<br>**CO4:** Explain the feasibility analysis and preparation of feasibility report.<br>**CO5:** Explain the management techniques in plant design including preparation of project report. |

**Mapping between Cos, POs and PSOs**

| CO | PO | | | | | | | | | | | | PSO | | |
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| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 |
| CO1 | | | | | | | | | | - | | - | | | |
| CO2 | | | | | | | | | | - | | - | | | |
| CO3 | | | | | | | | | | - | | - | | | |
| CO4 | | | | | | | | | | - | | - | | | |
| CO5 | | | | | | | | | | - | | - | | | |

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| **Course code** | **PFE-512** |
| **Course title** | **Seed Process Engineering** |
| **Corse credit** | 2 (1 + 1) |
| **Objective of Course** | 1. To acquaint and equip the students with seed processing.<br>2. To acquaint and equip the students with design features of the equipment used in seed processing |
| Course Content | Processing of different seeds and their engineering properties, principles and importance of seed processing. 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, |

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| | 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. 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. 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.<br>Study of various seed processing equipments such as pre-cleaners, scalpers, air screen cleaners, grad- ers, spiral and pneumatic separators, seed treating equipment, bag closures, scale etc. and their per- formance 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. |
| References: | • Babasaheb. 2004. Seeds Handbook: Processing and Storage. CRC.<br>• Gregg et al. 1970. Seed Processing. NSC.<br>• Guar. 2012. A Handbook of Seed Processing and Marketing Agrobios.<br>• Henderson S and Perry S M. 1976. Agricultural Process Engineering. 5th Ed. AVI Publisher.<br>• Mathad. 2017. Seed Processing: A Practical Approach. NIPA.<br>• Sahay KM and Singh KK. 1994. Unit Operation of Agricultural Processing. Vikas Publisher House.<br>• Vaugha. 1968. Seed Processing and Handling. https://www.mcia.msstate.edu/pdf/seedprocess- ing-and-handling_1.pdf. |
| Course Outcomes | At the end of the course, learners will be able<br>**CO1**: Student's capability to understand seed processing as per requirement of seed industries.<br>**CO2**: Student's capability to understand storage requirement of seed maintaining its vigor and viability, suitable equipment for seed processing. |

**Mapping between Cos, POs and PSOs**

| CO | PO | | | | | | | | | | | | PSO | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **1** | **2** | **3** |
| **CO1** | | | | | | | | | | - | | | | | |
| **CO2** | | | | | | | | | | - | | | | | |

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| **Course code** | **PFE-513** |
| **Course title** | **Agri-Project Planning and Management** |
| **Corse credit** | 3 (2 + 1) |
| **Objective of Course** | 1. To acquaint and equip the students with the techniques of project development.<br>2. To acquaint and equip the students with different standards like BIS/FSSAI/ISO<br>3. To acquaint and equip the students with guidelines on practices, equipment design, operation for handling processing and storage of food. |
| Course Content | Project development, market survey and time motion analysis. Selection of equipment, technology option, techno-economic feasibility and processing in production catchment. 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. BIS/FSSAI/ISO standards/ guidelines on best practices, equipment and their design and operation for handling, processing and storage of food/feed. |
| References: | • Ahmed T. 1997. Dairy Plant Engineering and Management. 4th Ed. Kitab Mahal.<br>• Albert L. 2017. Project Management, Planning and Control.<br>• Anandajayasekeram P. 2004. Agricultural Project Planning and Analysis. |
| Course Outcomes | At the end of the course, learners will be able<br>**CO1**: Student's capability to plan, scheduling of activities relating to food related project.<br>**CO2**: Student's capability to manage a food related project as per requirement of food industries. |

**Mapping between Cos, POs and PSOs**

| CO | PO | | | | | | | | | | | | PSO | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 |
| CO1 | | | | | | | | | | - | | | | | |
| CO2 | | | | | | | | | | - | | | | | |

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| **Course code** | **PFE -514** |
| **Course title** | **Farm Structures and Environment Control** |
| **Corse credit** | 3 (2 + 1) |
| **Objective of Course** | 1. To acquaint and equip the students with the different types of farm structures and techniques, to control atmospheric parameters and to create favorable environment in the |

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| | agricultural structures.<br>2. To impart knowledge on need of control atmospheric parameters and to create favorable environment in the agricultural structures<br>3. To enable the students to acquire skills to understand farm structures, design grain storage/godwon, farm machinery storage etc.<br>4. To enable the students to acquire skills for rural development activities like electrification, water supply, sanitation, etc. |
| Course Content | 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 and case studies. 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. Drying and dehumidification system, air-water contact operations and evaporation, process and product air conditioning, energy efficient environmental control practices. Rural electrification, house-hold's electric wiring, rural water supply and sanitation. Instruments and measurements: Codes and standards. |
| References: | • Albright LD. 1990. *Environmental Control for Animals and Plants*. ASAE Textbooks.<br>• Esmay ML and Dixon JE. 1986. *Environmental Control for Agricultural Buildings*. The AVI Corp.<br>• Gaudy AF and Gaudy ET. 1988. *Elements of Bioenvironmental Engineering*. Engineering Press.<br>• Moore FF. 1994. *Environmental Control Systems: Heating, Cooling, Lighting*. Chapman and Hall.<br>• Threlkeld JL. 1970. *Thermal Environmental Engineering*. Prentice Hall.<br>• Pandey PH. 2014. *Principles and Practices of Agricultural Structures and Environmental Control*, Kalyani Publishers<br>• O P Singhal. 2002. *Farm Structure*, Aman Publishing House |
| Course Outcomes | At the end of the course, learners will be able<br>**CO1**: Student's capability to design new farm structures and create suitable atmosphere within it.<br>**CO2:** To acquaint the students with various aspects of environmental control within the farm structures.<br>CO3: Grasp the ramifications of the agricultural structural solution within around and awareness for sustainable development<br>CO4: Design solutions for engineering aspects of agricultural structures and environmental part to fulfil the requirements, giving due regards to public health and safety and environmental factors. |

**Mapping between Cos, POs and PSOs**

| CO | PO | | | | | | | | | | | | PSO | | |
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| | 1 | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **1** | **2** | **3** |
| **CO1** | | | | | | | | | | - | | | | | |
| **CO2** | | | | | | | | | | - | | | | | |
| **CO3** | | | | | | | | | | - | | | | | |
| **CO4** | | | | | | | | | | - | | | | | |

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| **Course code** | PFE 515 |
| **Course title** | Dairy Product Processing |
| **Corse credit** | 3 (2 + 1) |
| **Objective of Course** | 1. To understand the scope and importance of dairy process operations.<br>2. To understand the laws of deterioration in products and their controls.<br>3. To acquaint and equip the students with the various dairy products, processing methods and related equipment. |
| Course Content | 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. Condensed milk: Methods of manufacture and related equipment, evaluation of condensed and evaporated milk. Dried milk: Definition, methods of manufacture of skim and whole 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. 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. Indigenous milk products: Method of manufacture of *yoghurt*, *dahi*, *khoa*, *burfi*, *kalakand*, *gulabjamun*, *rosogolla*, *srikhand*, *chhana*, *paneer*, *ghee*, *lassi*, etc. Probiotic milk product. |
| References: | • Adnan T. 2009. Dairy Powders and Concentrated Products (Society of Dairy Technology). Wiley-Blackwell.<br>• Adnan T. 2006. Probiotic Dairy Products (Society of Dairy Technology series). WileyBlackwell.<br>• Britz. 2008. Advanced Dairy Science and Technology. Blackwell Publisher: Blackwell PublisherProfessional.<br>• De. 2001. Outlines of Diary Technology. Oxford.<br>• Hui YH. 1992. Dairy Science and Technology Handbook. Vol. I, II and III Wiley.<br>• Spreer E. 2017. Milk and Dairy Product Technology. Taylor |

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| | and Francis.<br>• Walstra P, Jan TM, Wouters and Geurts TJ. 2006. Dairy Science and Technology. CRC, Taylor andFrancis. |
| Course Outcomes | At the end of the course, learners will be able<br>**CO1**: To acquaint the students with various milk properties.<br>**CO2**: Illustrate heat treatment processes used in milk preservation.<br>**CO3:** Determine the energy required to process the fresh milk.<br>**CO4:** Demonstrate the working of homogenizer and cream separator.<br>**CO5:** Preparation of various dairy products, processing methods and related equipments. |

**Mapping between Cos, POs and PSOs**

| CO | PO | | | | | | | | | | | | PSO | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 |
| CO1 | | | | | | | | | | - | | - | | | |
| CO2 | | | | | | | | | | - | | - | | | |
| CO3 | | | | | | | | | | - | | - | | | |
| CO4 | | | | | | | | | | - | | - | | | |
| CO5 | | | | | | | | | | - | | - | | | |

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| **Course code** | **PFE -516** |
| **Course title** | **Processing of Meat, Poultry and Fish** |
| **Corse credit** | 3 (2 + 1) |
| **Objective of Course** | 1. To acquaint and equip the students with processing of meat, fish and poultry and the design features of the equipment used for their processing.<br>2. To impart knowledge on the design features of the equipment used for meat processing. |
| Course Content | Meat: Genetic engineering of farm animals for better meat quality, automation for the modern slaughter house, hot-boning of meat, new spectroscopic techniques for online monitoring of meat quality, re- al-time PCR for the detection of pathogens in meat, 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 analyzing raw meat, modified atmosphere packaging, perspectives for the active packaging of meat products. Poultry: Breeding and 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 |

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| | waste. Fish and seafood: Fresh fish handling and chill storage, modified atmospheric packaging of sea- foods, 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. 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.<br>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 |
| References: | • Chooksey MK. 2003. Fish Processing and Product Development. CIFE, Kochi.<br>• Chooksey MK and Basu S. 2003. Practical Manual on Fish Processing and Quality Control. CIFE, Kochi.<br>• Hall GM. 1997. Fish Processing Technology. Blabie Academic and Professional.<br>• Lawrie RS. 1985. Developments in Meat Sciences. Vol III Applied Science Publishers.<br>• Mead GC. 1989. Processing of Poultry. Elsevier.<br>• Pearson AM and Tauber FW. 1984. Processed Meats. AVI Publishers.<br>• Stadelman WJ and Cotterill OJ. 1980. Egg Science and Technology. AVI Publishers.<br>• Ahmed T. 1997. Dairy Plant Engineering & Management, Kitab Mahal |
| Course Outcomes | At the end of the course, learners will be able<br>**CO1**: Student’s capability to process meat, fish and poultry.<br>**CO2**: Student’s capability to manufacture value added products of meat as per requirement of food industries. |

**Mapping between Cos, POs and PSOs**

| CO | PO | | | | | | | | | | | | PSO | | |
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| **CO1** | | | | | | | | | - | | | | | | |
| **CO2** | | | | | | | | | - | | | | | | |

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|---|---|
| **Course code** | **PFE -517** |
| **Course title** | **Design of Aquacultural Structures** |
| **Corse credit** | 3 (2 + 1) |
| **Objective of Course** | 1. To acquaint and equip the students with aquaculture structures and their design features like dykes, sluice, channel, etc.<br>2. To impart knowledge on need of aquaculture physiology and their micro climatic consideration.<br>3. To impart knowledge on recirculatory systems used in Aquaculture<br>4. To acquaint and equip the students with recirculation of water, reuse system, water treatment plants for managing Aquaculture specis. |
| Course Content | Inland fish farming and associated considerations. Fish physiology and micro-climatic considerations. Site selection for aquaculture structures. Design of dykes, sluice, channels etc. Aeration and feeding systems: Design of fish rearing structures, hatcheries, containers for live fish, fingerlings, fish seeds. Aquaculture in recirculatory systems, oxygen and aeration, sterilization and disinfection. Recirculation of water: Reuse systems, water exchange, and design of reuse systems, Inlet and outlet structures and water treatment plants. |
| References: | • FAO. 1983. Inland Aquaculture Engineering. ISBN 92-5-102168-6 |
| Course Outcomes | At the end of the course, learners will be able;<br>**CO1**: Student's capability to design suitable aquaculture structures.<br>**CO2:** To acquaint the students with various aspects of aquaculture physiology and their micro climatic consideration.<br>CO3: Grasp the ramifications of the aquaculture structural solution within around and awareness for sustainable development. |

**Mapping between Cos, POs and PSOs**

| **CO** | **PO** | | | | | | | | | | | | **PSO** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **1** | **2** | **3** |
| **CO1** | | | | | | | | | | - | | | | | |
| **CO2** | | | | | | | | | | - | | | | | |
| **CO3** | | | | | | | | | | - | | | | | |

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|---|---|
| **Course code** | PFE 518 |
| **Course title** | Thermal Environmental Engineering for Agricultural Processing |
| **Corse credit** | 3 (3 + 0) |
| **Objective of Course** | 1. To acquaint and equip the students with the concept of thermodynamic properties of air.<br>2. To acquaint application of thermodynamic properties in food processing. |
| Course Content | Requirements of temperature and moisture in food preservation, processing, storage, animal and plant production systems, human comfort etc. 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. 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. Thermal insulation materials for environmental control systems, applications of environmental control in green house, dairy industry, potato storage etc. |
| References: | • *P*erry's Chemical Engineers' Handbook, Section 12. (2007).<br>• Threlkald JL. Thermal Environmental Engineering, Pearson. |
| Course Outcomes | At the end of the course, learners will be able<br>**CO1:** Explain the requirements of temperature and moisture in food preservation.<br>**CO2:** Compare different thermodynamic properties of moist air.<br>**CO3:** To explain the psychrometric chart, psychrometric processes and its applications.<br>**CO4:** Design the machinery required in process control of air conditioning systems.<br>**CO5:** Applications of environmental control in green house and dairy industry. |

**Mapping between Cos, POs and PSOs**

| CO | PO | | | | | | | | | | | | PSO | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 |
| **CO1** | | | | | | | | | | - | | - | | | |
| **CO2** | | | | | | | | | | - | | - | | | |
| **CO3** | | | | | | | | | | - | | - | | | |
| **CO4** | | | | | | | | | | - | | - | | | |
| **CO5** | | | | | | | | | | - | | - | | | |

**Degree: Ph.D. (Agril. Engg.)**
**Major Subject: Processing and Food Engineering**

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| **Course code** | **PFE -601** |
| **Course title** | **Advances in Food Process Engineering** |
| **Corse credit** | 3 (2 + 1) |
| **Objective of Course** | 1. To acquaint and equip the students with the modern and latest techniques of food engineering.<br>2. To acquaint the students with low temperature preservation, hurdle technology in food processing<br>3. To acquaint and equip the students with advanced technologies viz. microwave, high pressure, pulse electric filed and extrusion in food processing applications. |
| Course Content | Preservation of foods: Physical and chemical methods, microbiological aspects, thermo bacteriology, process calculation and selection. Thermal processing of canned foods: Introduction, commercial sterilization systems, thermal inactivation, kinetics of bacterial spores, heat transfer in canned foods, process calculations, numerical computer simulation of heat transfer, aseptic processing. 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 thermodynamic 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. Application of heat energy and ultrasound; 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. Ohmic heat- ing 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 PFE technology, influence on food ingredients, pulsed electric field treat- ment unit, modeling PFE microbial inactivation, alternative applications of PFE technology, decontamination of microorganisms by surface treatment. Extrusion cooking: |

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| | Rheology of extrudates, newtonian models of single-screw extruder performance, non-new- tonian 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, equip- ment, design criteria of extruders.<br>Thermal processing of foods, sterilization, irradiation, membrane concentration, ultrasound, ohmic heating, pulsed electric field preservation, extrusion cooking, product quality determination. Visit of related food indus- tries, Microwave processing, High pressue processing. |
| References: | • Brennan JG, Butters JR, Cowell ND and Lilly AEI. 1990. Food Engineering Operations. Elsevier Publications.<br>• Fellows P. 1988. Food Processing Technology: Principle and Practice. VCH Publications.<br>• Geankoplis J Christie. 1999. Transport Process and Unit Operations. Allyn & Bacon.<br>• Henderson S and Perry SM. 1976. Agricultural Process Engineering. 5th Ed. AVI Publishing Company.<br>• McCabe WL and Smith JC. 1999. Unit Operations of Chemical Engineering. McGraw Hill.<br>• Sahay KM and Singh KK. 1994. Unit Operation of Agricultural Processing. Vikas Publishing House Pvt Ltd.<br>• Singh RP and Heldman DR. 1993. Introduction to Food Engineering. Academic Press.<br>• Singh RP. 1991. Fundamentals of Food Process Engineering. AVI Publishing Company. |
| Course Outcomes | At the end of the course, learners will be able;<br>**CO1**: Student's capability to understand advanced food processing applications as per requirement of food industries.<br>**CO2**: Student's capability to preserve food products using advance techniques as per requirement of food industries.<br>**CO3**: To acquaint the students with recent technologies in food processing. |

**Mapping between Cos, POs and PSOs**

| **CO** | **PO** | | | | | | | | | | | | **PSO** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **1** | **2** | **3** |
| **CO1** | | | | | | | | | | | | | | | |
| **CO2** | | | | | | | | | | | | | | | |
| **CO3** | | | | | | | | | | | | | | | |

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| **Course code** | PFE 602 |
| **Course title** | Drying and Dehydration of Food Materials |
| **Corse credit** | 3 (2 + 1) |
| **Objective of Course** | 1. To acquaint and equip the students with the latest technologies of dehydration of food products.<br>2. To study the various types of dryers and design features of different dryers. |
| Course Content | Importance of drying, principles of drying, moisture determination, equilibrium moisture content, determination of EMC, methods and isotherm models. Psychrometry; Psychrometric terms, construction and use of psychrometric charts. Air flow 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. 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. Drying of liquid foods, spray drying, drum drying, freeze drying, foam mat drying, heat pump drying, refractance window drying, infrared drying osmotic dehydration. Principles, methods, construction and adjustments, selection of dryers, heat utilization factor and thermal efficiency. |
| References: | • Bala BK. 1998. Drying and Storage of Cereal Grains. Oxford and IBH.<br>• Brooker DB, Bakker Arkema FW and Hall CW. 1974. Drying Cereal Grains. The AVI Publishing Company.<br>• Chakraverty A and De DS. 1999. Post-Harvest Technology of Cereals, Pulses and Oilseeds. Oxford & IBH.<br>• Hall CW. 1970. Drying Farm Crops. Lyall Book Depot.<br>• Kudra and Mujumdar. 2009. Advanced Drying Technologies. CRC press.<br>• Shukla BD and Singh G.2018. Drying and dryers (Foods and Agricultural Crops). Jain Brothers |
| Course Outcomes | At the end of the course, learners will be able<br>**CO1:** To acquaint the students with drying principles and moisture determination in agricultural and food products.<br>**CO2:** Identify various methods for determining moisture content, EMC and drying process.<br>**CO3:** To explain the different principles and equipments for air movement and heating.<br>**CO4:** Explain the heat requirements and thermal efficiency of drying system.<br>**CO5:** Explain the drying equipments for liquid foods with principles and methods. |

**Mapping between Cos, POs and PSOs**

| CO | PO | PSO |
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| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 |
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| **CO1** | | | | | | | | | | - | | - | | | |
| **CO2** | | | | | | | | | | - | | - | | | |
| **CO3** | | | | | | | | | | - | | - | | | |
| **CO4** | | | | | | | | | | - | | - | | | |
| **CO5** | | | | | | | | | | - | | - | | | |

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| **Course code** | **PFE -603** |
| **Course title** | **Textural and Rheological Characteristics of Food Materials** |
| **Corse credit** | 3 (2 + 1) |
| **Objective of Course** | 1. To acquaint and equip the students with advances in measurement of textural characteristics affecting the food quality.<br>2. To acquaint and equip the students with advances in measurement of rheological characteristics affecting the food quality<br>3. To acquaint and equip the students with advances in measurement of viscoelastic characteristics of foods and their associated mathematical models. |
| Course Content | Rheological properties of foods; Food rheology, physical states of materials, classical ideal material, 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. Viscometry; Capillary viscometry, casson model, 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. 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. Mathematical models and their application along with pipe line design and pump selection for non-newtonian fluids. Recent advances in textural, rheological |

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| | and viscoelastic characteristics of foods and their associated mathematical models. |
| References: | • Bourne MC. 2002. Food Texture and Viscosity: Concept and Measurement. Academic Press.<br>• Deman JM. 1976. Rheology and Texture in Food Quality. AVI Publications.<br>• Mohsanin NN. 1989. Physical Properties of Plant and Animal Material. Vol. I, II. Gordon and Breach Science Publications.<br>• Steffe JF. 1992. Rheology and Texture in Food Quality. AVI Publications |
| Course Outcomes | At the end of the course, learners will be able;<br>**CO1**: Student's capability to determine textural properties of food materials and their application in control of food processing operations.<br>**CO2**: Student's capability to determine rheological properties of food materials and their application in control of food processing operations.<br>**CO3**: To acquaint the students with various viscoelastic characteristics of foods and their application in control of food processing operations. |

**Mapping between Cos, POs and PSOs**

| CO | PO | | | | | | | | | | | | PSO | | |
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| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 |
| CO1 | | | | | | | | | | - | | | | | |
| CO2 | | | | | | | | | | - | | | | | |
| CO3 | | | | | | | | | | - | | | | | |

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| **Course code** | PFE 604 |
| **Course title** | Agricultural Waste and By-Products Utilization |
| **Corse credit** | 3 (2 + 1) |
| **Objective of Course** | 1. To acquaint and equip the students with the proper utilization of agricultural waste and by-products.<br>2. To acquaint students with development of value added products from wastes. |
| Course Content | 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. 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. 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 oil cake, cattle feed and industrial uses. Utilization of starch and other industrial wastes: Microcrystalline 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. 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.

References:


- ASAE Standards. 1984. Manure Production and Characteristics.
- Bor SL. (Ed.). 1980. Rice: Production and Utilization. AVI Publ.
- Chahal DS. 1991. Food, Feed and Fuel from Biomass. Oxford & IBH.
- Chakraverty A. 1989. Biotechnology and other Alternative Technologies for Utilisation of Biomass/Agricultural Wastes. Oxford & IBH.
- Donald LK and Emert HG. 1981. Fuels from Biomass and Wastes. Ann. Arbor. Science Publ.
- Srivastava PK, Maheswari RC and Ohja TP. 1995. Biomass Briquetting and Utilization. Jain Bros.
- USDA. 1992. Agricultural Waste Management Field H*andbook*. USDA.


Course Outcomes

At the end of the course, learners will be able

**CO1:** Summarize the importance of sanitation and waste water management.

**CO2:** Estimate the rate of sewage flow and storm water drainage

**CO3:** Identify the various characteristics of sewage and plan the treatment system.

**CO4:** To explain the utilization of wastes for preparation of various products.

**CO5:** Explain the by-products of fruits and vegetables based agro-industries.

**Mapping between Cos, POs and PSOs**

| **CO** | **PO** | | | | | | | | | | | | **PSO** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **1** | **2** | **3** |
| **CO1** | | | | | | | | | | - | | - | | | |
| **CO2** | | | | | | | | | | - | | - | | | |
| **CO3** | | | | | | | | | | - | | - | | | |
| **CO4** | | | | | | | | | | - | | - | | | |
| **CO5** | | | | | | | | | | - | | - | | | |

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| **Course code** | **PFE -605** |
| **Course title** | **Mathematical Modeling in Food Processing** |
| **Corse credit** | 3 (3 + 0) |
| **Objective of Course** | 1. To acquaint and equip the students with the mathematical techniques.<br>2. To acquaint and equip the students with the application of mathematics in food processing applications. |
| Course Content | An overview of the modeling process. Introduction to mathematical, correlative and explanatory models. Formulation, idealization and simplification of the problems. Probability models, series and linear mathematical approximation, dynamic and interacting dynamic processes. 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. Stochastic finite element analysis of thermal food processes. Neural networks approach to modelling food processing operations. |
| References: | • Brennan JG, Butters JR, Cavell ND and Lilly AEI. 1990. Food Engineering Operations. Elsevier.<br>• Coulson JM and Richadson JF. 1999. Chemical Engineering. Vols. II, IV. The Pergamon Press.<br>• Greanoplis JC. 1999. Transport Process and Unit Operation. Allyn & Bacon<br>• Treybal RE. 1981. Mass Transfer Operations. 3rd Ed. Harper & Row |
| Course Outcomes | At the end of the course, learners will be able;<br>**CO1**: Student's capability to develop models for food processing operations.<br>**CO2**: Student's capability to develop models for prediction and control of operations |

**Mapping between Cos, POs and PSOs**

| **CO** | **PO** | | | | | | | | | | | | **PSO** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **1** | **2** | **3** |
| **CO1** | | | | | | | | | | - | | | | | |
| **CO2** | | | | | | | | | | - | | | | | |

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| **Course code** | **PFE -606** |
| **Course title** | **Bioprocess Engineering** |
| **Corse credit** | 3 (2 + 1) |
| **Objective of Course** | 1. To acquaint and equip the students with the basic principles |

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| | of biochemical process engineering<br>2. To acquaint and equip the students with the media sterilization, media formulations of industrial fermentation.<br>3. To acquaint and equip the students with aerobic and agitated rheology of fermentative fluids during biochemical processing. |
| Course Content | Applications of engineering principles: Mass and energy balance, fluid flow principles, Unit operations of process engineering. Fundamentals of growth kinetics, maintenance energy and yield concepts, principles of media sterilization, media formulations of industrial fermentation. Aerobic and agitated rheology of fermentative fluids, design and scale-up of bioreactors, enzyme reactors. |
| References: | • Brennan JG, Butters JR, Cavell ND and Lilly AEI. 1990. Food Engineering Operations. Elsevier.<br>• Coulson JM and Richadson JF. 1999. Chemical Engineering. Vols. II, IV. The Pergamon Press.<br>• Greanoplis JC. 1999. Transport Process and Unit Operation. Allyn & Bacon<br>• Treybal RE. 1981. Mass Transfer Operations. 3rd Ed. Harper & Row |
| Course Outcomes | At the end of the course, learners will be able;<br>**CO1**: Student's capability to calculate the mass and energy balances in ant process operations,<br>**CO2**: Student's capability to understanding growth kinetics<br>**CO3**: Student's capability to design bioreactors as per requirement of food industries. |

**Mapping between Cos, POs and PSOs**

| **CO** | **PO** | | | | | | | | | | | | **PSO** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **1** | **2** | **3** |
| **CO1** | | | | | | | | | | - | | | | | |
| **CO2** | | | | | | | | | | - | | | | | |
| **CO3** | | | | | | | | | | - | | | | | |

**Post Graduate Master Program in Renewable Energy Engineering (BSMA)**

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| **Course code** | **Renewable Energy Technologies** |
| **Course title** | **REE 501** |
| **Corse credit** | **3 (2+1)** |
| **Objective of Course** | 1. To provide knowledge, understanding and application oriented skills on renewable energy sources and relevant technologies towards their effective utilization.<br>2. To provide knowledge of solar energy, biomass energy concept and applications.<br>3. To understand the important parts of a biogas plant, design and principle of bio-diesel.<br>4. To understand the design of wind mills and applications, turbines and generators for small scale hydroelectric generation.<br>5. To impart knowledge of geothermal, ocean and tidal energy and |
| **Course Content** | Theory:<br>**Unit –I**<br>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.<br>**Unit-II**<br>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.<br>**Unit-III**<br>Wind energy: Resource estimation, technologies, performance curves, power and torque characteristics. Airfoils and rotors: Wind mill parameters, wind farms design and considerations.<br>**Unit-IV**<br>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.<br>**Practicals:** |
| **References:** | 1. Culp, A.W. 1991. *Principles of Energy Conversion*, McGraw Hill pub. Co Inc. New York.<br>2. Duffie, J.A. and Beckman W.A. 1991. *Solar Engineering of Thermal Processes*. John Willey,New York.<br>3. Garg, H.P. and Praksh J. 1976. *Solar Energy, Fundamentals and Applications*. Tata Mc Graw, Hill pub.Co.Inc., New Delhi<br>4. Odum. H.T. and Odum, E.C. 1976. *Energy Basis For Man and Nature*. Mc Graw, Hill Pub.Co.Inc., New York. |

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| | 5. Sukhatme S.P. 1997. *Solar Energy, Principles of Thermal Collection and Storage*. Tata Mc Graw Hill. pub. Co. Ltd., New Delhi.<br>6. Twidell, J.W. & Weir, A.D. 1986. *Renewable Energy Sources*, E & FN Spon Ltd. London.<br>7. Rai G.D. 2001. *Non Conventional Energy Sources*, Khanna Publishers, Delhi. |
| **Course Outcomes** | At the end of the course, learners will be able<br>**CO1**: To provide knowledge with a solid foundation for developing the use of renewable energy systems in society.<br>**CO2:** To study different suitable solar technology for those who wish to work with renewable energy systems.<br>**CO3:** To understand the renewable energy systems, its components and interactions between the components. This includes all renewable energy technologies, different storage technologies, distribution grid, smart grid including sensors. Regulation and control, and both "stand alone" systems and large integrated distribution systems.<br>**CO4**: To acquaint 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 steps an economic analysis of supply technologies. |

Mapping between COs with POs and PSOs

**Please refer mapping of PO and PSO for the style of mapping.**

**Mapping between Cos, POs and PSOs**

| **CO** | **PO** | | | | | | | | | | | | **PSO** | | |
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| | 1 | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **1** | **2** | **3** |
| **CO1** | | | | | | | | | | | | | | | |
| **CO2** | | | | | | | | | | | | | | | |
| **CO3** | | | | | | | | | | | | | | | |
| **CO4** | | | | | | | | | | | | | | | |

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|---|---|
| **Course code** | **Solar Thermal Energy Conversion Technologies** |
| **Course title** | **REE 502** |
| **Corse credit** | **3 (2+1)** |
| **Objective of Course** | 1. To provide in-depth knowledge, understanding and application oriented skills on solar thermal.<br>2. To discuss in details, the theory and various design aspects of various types of solar thermal collectors.<br>3. To study thermal performance of different thermal collector configurations.<br>4. To discuss and emphasis on concentrating collector for power generation and the application of solar energy for industrial process heat. |
| **Course Content** | **Theory : Unit-I**<br>Characteristics of solar radiation: attenuation, absorption, scattering and air mass. Solar earth geometry.<br>**Unit-II**<br>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.<br>**Unit-III**<br>Solar thermal energy collectors (track and untrack): Heat capacity effect, time constant measurement, design and efficiency calculations, F chart method utility.<br>**Unit-IV**<br>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.<br>**Practicals:**<br>Solar radiation measurement. Estimation model applications. Design of collectors. Study of materials used in solar system. Energy balance and efficiency calculation of collectors. |

**References:**


1. Bansal N K, Kleeman MK and Meliss M. 1990. Renewable Energy Sources and ConversionTechnologies. Tata Mc Graw, Hill pub.Co.Inc., New Delhi.
2. Duffie JA and Beckman WA 2006. *Solar Thermal Engineering Process*. John Willey & Sons,New Jersey.
3. Hsien JS. 2014. Solar Energy, Prentice Hall Inc., New Jerssey.
4. Garg H P. 1990. Advances in Solar Energy Technology, Springer Publishing Company,Dordrecht, Netherland.
5. Kalogirou S A. 2013. Solar Energy Engineering. Academic Press, Cambridge, Massachusetts.
6. Kishore VVN. 2008. Renewable Energy Engineering and Technology- A knowledgeCompendium. Teri Press, New Delhi, India.
7. Pai BR and Ramprasad MS. 1991. Power Generation through Renewable Sources of Energy.Tata McGraw- Hill Pub. Co., New Delhi.
8. Sukhatme S P and Nayak J. 2008. Solar Energy: Principles of Thermal Collection and Storage. Tata McGraw- Hill Publishing Company Limited, New Delhi, India.


**Course Outcomes**

At the end of the course, learners will be able

**CO1:** To explain the principles that underlie the ability of various natural phenomena to deliver solar energy.

**CO2:** To understand the detail knowledge about working and design of various solar thermal devices able to design different solar thermal devices.

**CO3:** To outline the technologies that are used to harness the power of solar energy.

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Mapping between COs with POs and PSOs

**Please refer mapping of PO and PSO for the style of mapping.**

**Mapping between Cos, POs and PSOs**

| **CO** | **PO** | | | | | | | | | | | | **PSO** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **1** | **2** | **3** |
| **CO1** | | | | | | | | | | | | | | | |
| **CO2** | | | | | | | | | | | | | | | |
| **CO3** | | | | | | | | | | | | | | | |
| **CO4** | | | | | | | | | | | | | | | |

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|---|---|
| **Course code** | **Biomass Energy Conversion Technologies** |
| **Course title** | **REE 503** |
| **Corse credit** | **3 (2+1)** |
| **Objective of Course** | 1. To understand the bio-conversion technologies and fuels system, types of biomass derived fuels and energy, thermochemical conversion of biomass to heat and power, value adding of agro-residues.<br>2. To study various properties thermochemical and biochemical properties of biomass.<br>3. To design different biomass based technology for energy generation.<br>4. To provides overall information on concepts, tools and techniques for |
| **Course Content** | **Theory : Unit-I**<br>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.<br>**Unit-II**<br>Biochemical conversion of biomass: Feedstock, process design, operation, optimized process parameters and utilization for biogas and bioethanol production.<br>**Unit-III**<br>Biomass combustion: Stoichiometric air requirement, chemistry of combustion, design of combustion system, combustion zones; flame structure, stability, emissions. Co-firing of biomass.<br>**Unit-IV**<br>Thermo-chemical conversion of biomass: Feedstock, chemistry, reactor design, operation, optimized process parameters and utilization for gasification, carbonization, torrefaction and pyrolysis.<br>**Unit-V**<br>Cogeneration technologies; Cycles, topping, bottoming, selection, problems, applications. Wasteheat recovery: Estimation, systems, design and application. **Practicals:**<br>Biomass characterization. Design of bioreactors. Study of techno-economical feasibility of bio-chemical conversion process. Performance evaluation of combustion gadgets, gasifiers and pyrolytic converters. Design of waste heat recovery system. |

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|---|---|
| **References:** | 1. Chakravorty A. 1985. Biogas Technology & other Alternative Technologies, Oxford & IBHPublication Ltd, Delhi.<br>2. Chaturvedi P. 1995. Bio-Energy Resources: Planning, Production and Utilization., ConceptPub.Co., New Delhi.<br>3. Goswami DY. 1986. Alternative Energy in Agriculture, Vol. II (Ed), CRC, Press Inc.Florida,USA.<br>4. Stout BA. 1984. Biomass Energy Profiles, FAO Agril. Services Bulletin No.54., ElsevierScience Publishers Ltd., England.<br>5. Twidell JW. and Weir AD. 2006. Renewable Energy Sources. E & F N Spon Ltd., New York.<br>6. Vimal OP. 1984. Energy from Biomass. Agrcole Publishing Academy, New Delhi. |
| **Course Outcome** | At the end of the course, learners will be able<br>**CO1:** To understand the bio-conversion technologies and fuels system, |
| | types of biomass derived fuels and energy, thermochemical conversion of biomass to heat and power, value adding of agro-residues.<br>**CO2:** To develop knowledge in properties of biomass and energy conversion process.<br>**CO3:** To compare the characteristics of products obtained from biomass pyrolysis.<br>**CO4:** To understand the basics of biomass gasification and gasifier design<br>**CO5:** To assess the potential of electrical power production from |

Mapping between COs with POs and PSOs

**Please refer mapping of PO and PSO for the style of mapping.**

**Mapping between Cos, POs and PSOs**

| **CO** | **PO** | | | | | | | | | | | | **PSO** | | |
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| | 1 | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **1** | **2** | **3** |
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| **CO2** | | | | | | | | | | | | | | | |
| **CO3** | | | | | | | | | | | | | | | |
| **CO4** | | | | | | | | | | | | | | | |
| **CO5** | | | | | | | | | | | | | | | |

| Course code | **Energy Auditing, Conservation and Management** |
|---|---|
| **Course title** | **REE 504** |
| **Corse credit** | **3 (2+1)** |
| **Objective of Course** | 1. To acquaint and equip about the sources of energy, conservation of energy and its management.<br>2. To study the energy efficiency, energy planning, forecasting and energy economics.<br>3. To understand the concept of energy auditing, conservation and management.<br>4. To study the quantification, conservation opportunity and retrofitting of energy efficient system integration is expected from the course. |
| **Course Content** | **Theory : Unit-I**<br>Energy conservation: Concepts, energy classification, equivalents, scenario, energy pricing,importance. Energy conservation act.<br>**Unit-II**<br>Energy auditing and economics: Energy management, energy audit strategy, types. Energy performance: Bench marking, fuel substitutions, energy audit instruments, material and energy balance. Energy conversion: Energy index; cost index. Financial management.<br>**Unit-III**<br>Thermal energy audit: Performance evaluation; energy conservation opportunities in boilers, steam system and furnaces, insulation, refractory's and other thermal utilities.<br>**Unit-IV**<br>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.<br>**Unit -V**<br>Energy auditing and reporting in industries. Replacement of renewable energy technology option. Case study in agro-industries.<br>**Practicals:**<br>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. |

**References:**


1. Energy Management, Bi-monthly Journal National Productivity Council, New Delhi.
2. Guide books for National Certification Examination for Energy Managers and Energy Auditors, Book 1 – 4, 2005 Bureau Energy Efficiency, New Delhi.
3. Murgai MP and Ram Chandra. 1990. Progress in Energy Auditing and Conservation, Boiler Operations, Wiley Eastern Ltd., New Delhi.
4. Murphy WR and McKay G. 1982. Energy Management. Butterworth & Co., Publishers
5. Ltd., London.
6. Porter R and Roberts T. 1985. Energy Saving by Waste Recycling. Elsevier Applied Science Publishers, New York, USA.
7. Smith CB. 1981. Energy Management Principles, Applications, Benefits & Savings. Pergamon Press Inc., Oxford, England.
8. Victor B. 1983. Ottaviano, Energy Management. An OTIS Publication, Ottaviano Technical Service Inc., Melville, New York.


**Course Outcomes**

At the end of the course, learners will be able

**CO1:** To understand the concept of energy auditing, conservation and management and to outline energy scenario, audit and management.

**CO2:** To learn in-depth knowledge about the quantification, conservation opportunity and retrofitting of energy efficient system integration.

**CO3:** To apply energy conservation policy, regulations in industrial practices. **CO4:** To evaluate energy economics and Identify

**Mapping between Cos, POs and PSOs**

| CO | PO | | | | | | | | | | | | PSO | | |
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| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 |
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| CO3 | | | | | | | | | | | | | | | |
| CO4 | | | | | | | | | | | | | | | |
| CO5 | | | | | | | | | | | | | | | |

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|---|---|
| **Course code** | **Wind Energy Conversion and Utilization** |
| **Course title** | **REE 505** |
| **Corse credit** | **3 (2+1)** |
| **Objective of Course** | 1. To acquire the in-depth knowledge of wind energy conversion systems.<br>2. To study the wind potential mapping, estimation and analysis of wind data.<br>3. To acquire knowledge regarding mechanism of wind energy and different types of wind machines available to harness wind power |
| **Course Content** | **Theory : Unit-I**<br>Wind mapping and assessment: Wind energy potential, nature of wind, Weibull and Rayleigh analysis, instruments, history and taxonomy of wind mills, wind power laws.<br>**Unit-II**<br>Wind turbine aerodynamics: Momentum theories, basic aerodynamics, airfoils 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.<br>**Unit-III**<br>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.<br>**Unit-IV**<br>Wind turbine loads: Aerodynamic loads in steady operation, wind turbulence, static. Wind energy control system (WECS). Synchronous and asynchronous generators. Annual Energy Output (AEO). Testing of WECS. |
| **References:** | 1. Cheremision NP. 1978. *Fundamental of Wind Energy*. Ann Arbor Science, Pub. Inc. Michigan.<br>2. Eldridge FR. 1978. Wind Machines. Van Nostr and Reinhold Co., New York.<br>3. More HG and Maheshwari RC. Wind Energy Utilization in ndia, Technical Bulletin No.CIAE/82/38,CIAE, Bhopal.<br>4. Lipman NH, Muggrove PJ and Pontin, GW. 1982. Wind Energy for the Eighties, Peter Peregrinus Ltd. Stenvenage, New York.<br>5. Lysen, EH. 1983. Introduction to Wind Energy. Consultancy Services Wind Energy Developing Countries, Netherland.<br>6. Manwell JF, McGswan JG and Rogers AL. 2012. Wind Energy Explained – Theory Design and Application, John Wiley and Sons, New Jersey. |
| **Course Outcome** | At the end of the course, learners will be able to acquire knowledge regarding mechanism of wind energy and different types of wind |

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| | harness wind power. Able to design wind turbine for irrigation as well as for power generation.<br>**CO1:** To describe how wind energy is harnessed to create electricity.<br>**CO2:** To state the major pros and cons of using wind energy.<br>**CO3:** To demonstrate how wind energy can be utilized to create work. **CO4:** To contribute to the complex task of wind farm project development. **CO5:** To simulate and analyze the design of wind farms, lay outs etc. |

**Mapping between Cos, POs and PSOs**

| CO | PO | | | | | | | | | | | | PSO | | |
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| | 1 | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **1** | **2** | **3** |
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| **CO4** | | | | | | | | | | | | | | | |
| **CO5** | | | | | | | | | | | | | | | |

| Course code | **Solar Photovoltaic System Design and Analysis** |
|---|---|
| **Course title** | **REE 506** |
| **Corse credit** | **2(1+1)** |
| **Objective of Course** | 1. To provide detail knowledge about working and design of various solar photovoltaic systems for power generation.<br>2. To develop the skills of youth, considering the opportunities for employment in the growing Solar Energy Power project's installation, operation & maintenance in India and abroad.<br>3. To design and prepare the documentation for new entrepreneurs in Solar Energy sector. |
| **Course Content** | **Theory : Unit-I**<br>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.<br>**Unit-II**<br>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.<br>**Unit-III**<br>Solar PV systems: Balance of System (BoS), SPV system design guideline and methodologies, introduction to PVSyst, designing of standalone/grid connected PV systems for domestic/ commercial use. Rooftop business models: CAPEX and RESCO, canal top, floating PV system design.<br>**Unit-IV**<br>Materials and devices for energy storage: Batteries, Carbon Nano-Tubes (CNT), fabrication of CNTs, CNT-polymer composites, ultra-capacitors etc.<br>**Practicals:**<br>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. Batteries performance testing. |

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| **References:** | 1. Garg HP. 1990. Advances in Solar Energy Technology. D. Publishing Company, Tokyo.<br>2. Duffle JA & Beckman WA. 1991. Solar Engineering of Thermal Processes. John Wiley, New Jersey.<br>3. Green MA. 1981. Solar Cells Operating Principles, Technology, and System Applications.<br>4. Prentice, Hall, Upper Saddle River, New Jersey.<br>5. Kreith F and Kreider JF. 1978. Principles of Solar Engineering. McGraw, Hill, New York.<br>6. Luque A and Hegedus S. 2011. Handbook of Photovoltaic Science and Engineering, Education, John Wiley & Sons, New Jersey.<br>7. Solanki CS. 2011. Solar Photovoltaic: Fundamentals, |
| | edition, John Wiley & Sons, New Jersey.<br>9. Veziroglu TN. 1977. Alternative Energy Sources. Vol.5. McGraw Hill, New York. |
| **Course Outcomes** | At the end of the course, learners will be able<br>**CO1:** To teach the basics of electrical, SPV applications and solar power plant including standards, preventive maintenance, trouble-shooting etc.<br>**CO2:** To understand the basics solar energy and concept of solar PV (photovoltaic) system<br>**CO3:** To design and prepare the students to become new entrepreneurs in Solar Energy sector.<br>**CO4:** To survey a solar PV installation site and to understand all equipment related to solar PV system<br>**CO5:** To design any solar PV system as per Customer's requirements |

**Mapping between Cos, POs and PSOs**

| CO | PO | | | | | | | | | | | | PSO | | |
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| Course code | Renewable Energy Policy, Planning and Economics |
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| Course title | REE 507 |
| Corse credit | 3 (3+0) |
| Objective of Course | 1. To provide the in-depth knowledge about the current energy policy and planning, environmental economics, policy and ecology.<br>2. To discuss the energy scenario, energy conservation and its importance, energy strategy for the future, energy conservation act-2001 and its features, Kyoto protocol and global warming.<br>3. To learn about the concepts of energy management & audit.<br>4. To develop an interdisciplinary knowledge base that will enable them to understand and solve contemporary energy policy, planning and environmental problems. |
| Course Content | **Theory**<br>**: Unit-**<br>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 & SERC, Statutory bodies. Typical issues of Indian power sector<br>**Unit-II**<br>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.<br>**Unit-III**<br>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.<br>**Unit-IV**<br>Energy economics: Economic evaluation of renewable energy systems, life cycle costing, components of energy investment and risk and uncertainties in energy investment. |

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| **References:** | 1.BEE Reference book: no.1/2/3/4.<br>2.Bhattacharyya SC. 2011. *Energy Economics*. Springer, New York City, USA. 3.Brown CE.2002. World Energy Resources. Springer , New York City, USA. 4.Conti J. 2016. International Energy Outlook. US Energy Information Administration (EIA), Washington.<br>5.Culp AW.1991. Principles of Energy Conversion. McGraw Hill Int. edition, New York.<br>6.Krithika PR and Mahajan S. 2014. Governance of renewable energy in India: Issues and challenges. TERI, New Delhi.<br>7.Parikh JK. 1981. Modeling approach to Long Term Demand and Energy Implication for India. IIASA, Laxenburg, Austria.<br>8.Reddy AKN, Williams RH, Goldenberg J ans Johansson TB. 1987. Energy for a Sustainable World. Wiley- Eastern Ltd., New Delhi, India.<br>9.Bansal, N.K. and Dayal M. Techno Economics of Renewable Power Systems.<br>10. TEDDY Year Book Published by Tata Energy Research Institute (TERI). |
| **Course Outcomes** | At the end of the course, learners will be able<br>**CO1:** To understand the conceptualization of renewable energy policy and regulation.<br>**CO2:** To learn an opportunity for best practices from global experts using renewable energy technology.<br>**CO3:** Develop the ability to deal with the practical problems such as RE generation fore casting, scheduling and dispatch.<br>**CO4:** To integrate and optimize distributed energy sources to enhance the grid's reliability.<br>**CO5:** To develop an interdisciplinary knowledge base that will enable them to understand and solve contemporary energy policy, planning and environmental problems. |

**Mapping between Cos, POs and PSOs**

| **CO** | **PO** | | | | | | | | | | | | **PSO** | | |
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| | 1 | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **1** | **2** | **3** |
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| Course code | **Alternate Fuels and Applications** |
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| **Course title** | **REE 508** |
| **Corse credit** | **3 (3+0)** |
| **Objective of Course** | 1. To get acquainted with various alternate fuels, their applications and also to learn safety factors of alternate fuel, efficiency, economics and commercial considerations.<br>2. To impart the knowledge of basics of alternative fuels for internal combustion engine and alternative drive systems for automobiles, principle of solar energy collection<br>3. To impart the knowledge of methods of production of bio gas, methanol, ethanol, SVO, bio diesel and various aspects of electrical and hybrid vehicles |
| **Course Content** | **Theory : Unit-I**<br>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.<br>**Unit-II**<br>Fuel cell: Principle, classification, system efficiency. Life cycle assessment of fuel cell systems.<br>**Unit-III**<br>Hydrogen fuel: Production, gas cleanup, challenges and opportunities. Hydrogen storage and energy economy.<br>**Unit-IV**<br>Utilization: Thermal and mechanical applications. Environmental impact and safety factors of alternate fuel, efficiency, economics and commercial considerations<br>**Practicals:**<br>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. |

<table>
<tr><td>References:</td><td>
1. Babu MKG and Subramanian KA. 2013. Alternative Transportation Fuels: Utilization in Combustion Engines. CRC Press, Florida.<br>
2. Bungay HR 1981. Energy, the Biomass Options. John Willey & Sons, New York.<br>
3. Dahiya A. 2014. Bioenergy: Biomass to Biofuels. Engines. Springer, New York City, New York.<br>
4. Demirbas A. 2010. Biodiesel: A Realistic Fuel Alternative for Diesel Chemicals. Academic Press, Cambridge, England.<br>
5. Klass DL. 1998. Biomass for Renewable Energy, Fuels, and Chemicals. Academic Press, Cambridge, England.<br>
6. Mukunda HS. 2011. Understanding Clean Energy and Fuels from Biomass. Wiley India.<br>
7. San PA..1980. Biochemical and Photosynthetic: Aspects of Energy Production. Academic Press. London.<br>
8. Speight JG and Loyalka SK. 2007. Handbook of Alternative Fuel Technologies. CRC Press, Florida.<br>
9. Twidell, JW and Weir AD. 1986. Renewable Energy Sources. E & FN Spon Ltd., New York.
</td></tr>
<tr><td>Course Outcomes</td><td>At the end of the course, learners will be able<br>
CO1: To understand broad comprehension of alternative transportation fuels and their production technologies.<br>
CO2: To explain various properties, methods of production of Bio gas, methanol, ethanol, SVO, Bio diesel.<br>
CO3: To illustrate the use of hydrogen and various gaseous fuels, reformulated conventional fuels & future alternative fuels for internal combustion engine application..<br>
CO4: To explain the various aspects of electrical and Hybrid vehicles.<br>
CO5: To discuss economic considerations of alternative fuels.</td></tr>
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**Mapping between Cos, POs and PSOs**

| CO | PO | | | | | | | | | | | | PSO | | |
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| **CO4** | | | | | | | | | | | | | | | |
| **CO5** | | | | | | | | | | | | | | | |

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|---|---|
| **Course code** | **Biogas Technology and Mechanism** |
| **Course title** | **REE 509** |
| **Corse credit** | **2 (1+1)** |
| **Objective of Course** | 1. To provide the in-depth knowledge about biogas technology and its mechanism in detail to use the biogas as domestic as well as commercial fuel.<br>2. To select, estimate and analyzed the biogas technology, chemical and physical conditions and get acquainted with various biogas appliances.<br>3. To understand the important parts of a biogas plant.<br>4. To analyze the different effluent materials generated by industries and based on availability to design appropriate size of biogas plant. |
| **Course Content** | **Theory**<br>**: Unit-**<br>Biogas Technology: Potential and status, chemistry, Physical conditions and utilization of alternate feedstock materials.<br>**Unit-II**<br>Types of reactors: single phase, two phase processes. High rate bio-methanation process, selection of model and size, construction technique, material requirement. Design concept of night soil, kitchen waste, solid state cold condition biogas plants.<br>**Unit-III**<br>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.<br>**Unit-IV**<br>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.<br>**Practicals:**<br>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 burner for heat transfer, thermal and cooking efficiency. Bio digested slurry analysis, use of biogas spent slurry. Carbon credits. |

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| **References:** | 1. Abbasi SA and Nipaney PC. 1993. Modeling and Simulation of Biogas System Economies. Ashish pub. House. New Delhi.<br>2. Chawala OP. 1986. Advances in Biogas Technology. ICAR, New Delhi.<br>3. Khandelwal KC and Mahdi SS. 1986. Biogas Technology. A Practical Hand Book. Vol-I. Tata McGraw Hill pub. Co., Ltd. New Delhi.<br>4. Mittal KM. 1996. Biogas systems: Principles and Applications. New Age International (P)<br>5. Ltd. New Delhi.<br>6. 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 Agricultural Wastes. National Academy of Sciences, Washington D.C.<br>7. Tasneem A, Tauseef SM and Abbasi SA. 2012. Biogas Energy. Springer Publications, Springer Science and Business Media, New |
| **Course Outcomes** | At the end of the course, learners will be able<br>**CO1:** To characterize different biomass feedstocks and wastes based on its constituents and properties<br>**CO2:**To understand and evaluate various biomass pre-treatments and processing techniques in terms of their applicability for different biomass type for biomass conversion processes<br>**CO3:** To understand the process of combustion, pyrolysis, gasification and liquefaction for production of value added bio-products, biogas, bio-CNG generation etc.<br>**CO4:**To understand basics of biofuels, their production technologies and applications in various energy utility routes |

**Mapping between Cos, POs and PSOs**

| **CO** | **PO** | | | | | | | | | | | | **PSO** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **1** | **2** | **3** |
| **CO1** | | | | | | | | | | | | | | | |
| **CO2** | | | | | | | | | | | | | | | |
| **CO3** | | | | | | | | | | | | | | | |
| **CO4** | | | | | | | | | | | | | | | |

| Course code | Energy, Ecology and Environment |
|---|---|
| **Course title** | **REE 510** |
| **Corse credit** | **3 (3+0)** |
| **Objective of Course** | 1. To provide detail knowledge of carbon cycle, ecosystem, climate change and global environmental change and interlinkages of renewable energy sources.<br>2. To understand the relationship between carbon cycle, energy policies, energy use and economic growth and factors affecting environment.<br>3. To impart basic knowledge about current energy scenario, energy analysis in transportation, buildings etc.<br>4. To inculcate systematic knowledge and skill about assessing the environment impact of energy use. |
| **Course Content** | **Theory**<br>**: Unit-**<br>Global carbon cycle; Carbon reservoirs flow and human interventions; global<br>warming and climate change. Energy efficient technology; efficiency hierarchy, energy dependent activities, energy policies, linkage between energy use and economic growth and environment.<br>**Unit-II**<br>Ecosystem: kinds, transfection, components of ecosystem, ecosystem development of evaluation, major ecosystem of the world, physical environment and metrology.<br>**Unit-III**<br>Climate change: Impact and models. Energy for sustainable development; development indices, pillers, subsystems, principles and dimensions. Low carbon technologies; energy efficiency projects, carbon trading.<br>**Unit-IV**<br>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.<br>**Unit-V**<br>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. |

**References:**


1. Canter LC. 1979. Environmental Impact Assessment. McGraw Hill Pub. Co., New York.
2. Coley D. Energy and Climate Change. John Wiley & Sons, Ltd., New Jersey.
3. Dessler A. 2011. Introduction to Modern Climate Change. Cambridge University Press, Cambridge, England.
4. Essam E and Hinnami EI. 1991. Environmental Impact of Production and Use of Energy. Tycooly Press Ltd., Dublin.
5. Fowler JM. 1984. Energy and the Environment, Second Edition. McGraw Hill, New York.
6. Kaushika ND and Kaushik K. 2004. Energy, Ecology and Environment: A Technological Approach. Capital Publishing, New Delhi.
7. Mathur AN, Rathore NS and Vijay VK. 1995. Environmental Awareness, Himanshu Pub.,Udaipur.
8. Puppy HG. Energy and Environment, Mankind and Energy Needs. Elsevier Pub. Co., New York.
9. Rathore NS and Kurchania AK. 2001. Climatic Changes and their Remedial Measures. Shubhi Publications, Gurgaon.
10. Thomdike EH. 1978. Energy and Environment: A Premier for Scientists and Engineers. Adson, Wesley Pub. Co., Boston, US.
11. Wilson R & Jones WJ. 1974. Energy, Ecology & the Environment. Academic Press Inc., Cambridge, Massachusetts, US.


**Course Outcomes**

At the end of the course, learners will be able

**CO1:** To study current emerging technologies and Effectively apply basic principles of the natural and social sciences to current issues of natural resources and the environment.

**CO2:** To understand and appropriately use the vocabularies of the natural and social sciences relevant to issues of natural resources and the environment.

**CO3:** To understand various components of the environment and interfaces and ecosystem and its various component and functions.

**CO4:** To acquire the knowledge on ecology, and ecological dynamics.

**CO5:** To understand the various ecosystem services and their role in sustaining the environment.

**Mapping between Cos, POs and PSOs**

| **CO** | **PO** | | | | | | | | | | | | **PSO** | | |
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| | 1 | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **1** | **2** | **3** |
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| **CO3** | | | | | | | | | | | | | | | |
| **CO4** | | | | | | | | | | | | | | | |
| **CO5** | | | | | | | | | | | | | | | |

| Course code | **Design and Analysis of Renewable Energy Conversion Systems** |
|---|---|
| **Course title** | **REE 511** |
| **Corse credit** | **3 (2+1)** |
| **Objective of Course** | 1. To keep the knowledge of students upgraded with the current thoughts and newer technology options along with their advances in the field of the utilization of different renewable energy technologies for energy production.<br>2. To design and analyze renewable energy conversion systems, thermodynamics involved in it and performance of renewable energy systems.<br>3. To design of various energy conversion systems, standards and test codes of renewable energy systems and their performance analysis.<br>4. To give an introduction to Software assisted design and drawing and to learn PVsyst/PVSol/HOMER software skills and to learn basic engineering drawing formats for Renewable Energy systems" |
| **Course Content** | **Theory : Unit-I**<br>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.<br>**Unit-II**<br>Thermodynamics of renewable energy conversion: Energy and exergy analysis of renewable energypower systems. Optimum design of hybrid renewable energy systems: Concept, considerations and methodologies.<br>**Unit-III**<br>Design of renewable energy systems: Design concept, operational parameters, consideration andrational values for agro industrial applications.<br>**Unit-IV**<br>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.<br>**Practicals:**<br>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. |

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| **References:** | 1. Boyle G.1996. *Renewable Energy: Power for Sustainable Future*. Oxford Univ. Press,England.<br>2. Culp AW. 1991. *Principles of Energy Conservation*. Tata McGraw Hill, New Delhi.<br>3. Duffle JA and Beckman WA. 1991. *Solar Engineering of Thermal Processes*. John Wiley,Hoboken, North America.<br>4. Garg HP and Prakash J.1997. *Solar Energy: Fundamental and Application*. Tata McGraw Hill, New Delhi.<br>5. Grewal NS, Ahluwalia S, Singh S and Singh G. 1997. *Hand Book of Biogas Technology*.TMH New Delhi.<br>6. Lambert T and Lilienthal P.2004. *Homer: The Micro-Power Optimization Model.* National Renewable Energy Lab., Philippines.<br>7. Manwell JF, McGowan JG and Rogers AL. 2003. *Wind Energy Explained*. John Wiley,Hoboken, North America.<br>8. Mittal KM. 1985. *Biomass Systems: Principles & Applications*. New Age International, NewDelhi.<br>9. Patel MK. 1999. *Wind and Solar Power Systems.* CRC Press, Florida. |
| **Course Outcomes** | At the end of the course, learners will be able<br>**CO1:** To study the design technology and system on renewable and carbon- neutral energy.<br>**CO2:** To analyse energy economics and business model.<br>**CO3:** To formulate energy policy and planning.<br>**CO4:** To develop interdisciplinary research in energy systems engineering. **CO5:** To understand professional and ethical responsibility in renewable energy. |

**Mapping between Cos, POs and PSOs**

| CO | PO | | | | | | | | | | | | PSO | | |
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| CO4 | | | | | | | | | | | | | | | |
| CO5 | | | | | | | | | | | | | | | |

| Course code | Energy Generation from Agricultural Waste and Byproducts |
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| **Course title** | **REE 512** |
| **Corse credit** | **3 (2+1)** |
| **Objective of Course** | 1. To focus on agricultural wastes and by products for its utilization for energy generation.<br>2. To understand the estimation, characterization, storage and handling of agricultural wastes and by products to generate the energy.<br>3. To keep the knowledge of current thoughts and newer technology options along with their advances in the field of the utilization of different types of wastes for energy production.<br>4. To understand the various waste generation sources and their management. |
| **Course Content** | **Theory : Unit-I**<br>By Products: Generation, estimation and utilization. Agricultural and agro industrial byproducts/ wastes: Properties, characterization, on site handling, storage and processing. Concept, scope and maintenance of waste management and effluent treatment<br>**Unit-II**<br>Waste as fuel: Utilization pattern, pretreatments, secondary treatments, mechanism, construction, efficiency and suitability.<br>**Unit-III**<br>Utilization of agro based industrial wastes for paper production, production of particle board, fertilizer through vermi-composting and fuel.<br>**Unit-IV**<br>Thermo-chemical and biochemical conversion of agricultural waste and byproducts: Densification, combustion, gasification, extraction, pyrolysis, carbonization, torrefaction, liquefaction, anaerobic digestion and fermentation process. |
| **References:** | 1. Anonymous. 1984. Manure Production and Characteristics. ASAE Standards, America.<br>2. Chahal DS. 1991. Food, Feed and Fuel from Biomass. Oxford & IBH, New Delhi.<br>3. David C Wilson. 1981. Waste Management, Planning, Evaluation, Technologies. Clarendon Press, Oxford, England, UK.<br>4. Klass DL and George EH. 1981. Fuels from Biomass and Wastes. Ann. Arbor. Science Publ, New York.<br>5. Luh BS. 1980. Rice: Production and Utilization. AVI Publ.,Company Inc., Westport, Connecticut.<br>6. Srivastava PK, Maheswari RC and Ohja TP. 1995. Biomass Briquetting and Utilization. Jain Bros. publications, New Delhi. |
| **Course Outcomes** | At the end of the course, learners will be able<br>**CO1:** To apply the knowledge about the operation of waste to energy plants.<br>**CO2:** To analyze the various aspects of waste to energy plant.<br>**CO3:** To apply the knowledge in planning & operation of waste to energy plants |

Mapping between COs with POs and PSOs

**Please refer mapping of PO and PSO for the style of mapping.**

**Mapping between Cos, POs and PSOs**

| CO | PO | | | | | | | | | | | | PSO | | |
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| Course code | Agro Energy Audit and Management |
|---|---|
| Course title | REE 513 |
| Corse credit | 3 (2+1) |
| Objective of Course | 1. To emphasize the energy audit and its management in agriculture production system and agro based industries.<br>2. To learn detail energy audit, energy balance techniques, energy management strategies, energy conservation planning and practices in agriculture production system.<br>3. To encourage implementation and proper and efficient use of energy.<br>4. To minimize energy costs / waste without affecting production, quality and environmental effects |
| Course Content | **Theory : Unit-I**<br>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.<br>**Unit -II**<br>Direct and indirect energy, energy audit of production agriculture, rural living and scope of conservation.<br>**Unit -III**<br>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.<br>**Unit -IV**<br>Energy analysis techniques and methods: Energy balance, output and input ratio, resource utilization, conservation of energy sources. Energy conservation planning and practices.<br>**Practicals:**<br>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. |
| References: | 1. Fluck RC and Baird CD.1984. Agricultural Energetics. AVI Publ. Company, Inc., Westport, Connecticut<br>2. Kennedy WJ Jr. and Turner WC.1984. Energy Management. Prentice Hall, Upper Saddle River, New Jersey.<br>3. Pimental D. 1980. Handbook of Energy Utilization in Agriculture. CRC Press, Florida.<br>4. Rai GD. 1998. Non conventional Sources of Energy. Khanna Publ., New Delhi.<br>5. Singh CP. 1978. Energy Requirement of Important Farm Operations for Existing Cropping System in Punjab, PAU, Ludhiana.<br>6. Twindal JW and Wier AD. 1986. Renewable Energy Sources. E & F.N. Spon Ltd., New York.<br>7. Verma SR, Mittal JP and Singh S. 1994. Energy Management and |

| **Course Outcomes** | At the end of the course, learners will be able<br>**CO1:** To understand the principles of energy auditing, energy flow diagram,economics of energy conservation opportunities in buildings.<br>**CO2:**To understand thermal performance study,building performance simulation and thermal comfort.<br>**CO3:**To understand the energy conservation buildings codes, rating systems and case studies on energy efficient buildings in India. |
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**Mapping between Cos, POs and PSOs**

| **CO** | **PO** | | | | | | | | | | | | **PSO** | | |
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| Course code | Green house Energetic and Passive Architecture |
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| Course title | REE 514 |
| Corse credit | 2 (1+1) |
| Objective of Course | 1. To provide the in-depth knowledge about greenhouse design, energetics, production technique, passive heating concept and evaporative cooling etc.<br>2. To get knowledge of thermal energy flows, analysis of green house, instrumentation and control in green house.<br>3. To equip with fundamental understanding, knowledge and skills to contribute in the practice of energy efficient green house.<br>4. To design and develop a different types of energy efficient green house. |
| Course Content | **Theory : Unit-I**<br>Green House: Environmental requirement, analysis of thermal energy flows, analysis of a green house as solar collector. Instrumentation and control in green house.<br>**Unit-II**<br>Passive concepts and components: Passive heating concepts, direct gain, indirect grain, isolated gains and sunspace passive cooling concepts,<br>**Unit -III**<br>Evaporative cooling: Evaporative air and water coolers, application of wind, water and earth for cooling, use of isolation, shading, paints and cavity walls for cooling.<br>**Unit-IV**<br>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.<br>**Practicals:**<br>Design of passive structures for animals, rural housing, study of evaporative cooling, air and light flows in house, survey of green houses, green house energetic. |
| References: | 1. Parkar BE. 1991. *Solar Energy in Agriculture*. Elsevier, Amsterdam.<br>2. Pattern AR. 1975. *Solar Energy for Heating and Cooling of Building*. Noyal Date Corporation(NDC), Park Ridge, New Jersey, USA.<br>3. Paul JK. 1975. *Passive Solar Energy Design and Materials*. Noyel Data Corporation (NDC), Park Ridge, New Jersey, USA.<br>4. Radhamanohar K and Igathinathane C. 2000. *Green House Technology and Management*., B.S. Publication.,4309 Sultan Basar, Hyderabad.<br>5. Sodha MS, Bansal NK, Kumar, PKA and Malik MAS. 1986. *Solar Passive: Building Scienceand Design*., Pergamon Press. New York. |

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| **Course Outcomes** | At the end of the course, learners will be able<br>**CO1:** To understand the physical basis of the natural greenhouse effect, including the meaning of the term radiative forcing<br>**CO2:** To get detailed knowledge about the importance of passive solar architecture and passive systems design at various building typologies.<br>**CO3:** To articulate the elements of energy efficiency in green house and its importance for all.<br>**CO4:** To acquire the knowledge on effects of micro-climate in cooling and energy efficiency of green house environments. |

Mapping between COs with POs and PSOs

| **CO** | **PO** | | | | | | | | | | | | **PSO** | | |
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|---|---|
| **Course code** | **Energy Management in Food Processing Industries** |
| **Course title** | **REE 515** |
| **Corse credit** | **2 (1+1)** |
| **Objective of Course** | 1. To acquaint and equip with different energy management techniques including energy auditing of food industries.<br>2. To understand energy sources, analyze energy requirement in food processing operations and to economize it in food industries.<br>3. To understand and apply the basics of calculations related to material and energy flow in the processes.<br>4. To understand processing and limitations of fossil fuels (coal, petroleum and natural gas) and necessasity of harnessing alternate energy resources.<br>5. To understand and practice various characterization techniques for fuels |

**Course Content**

**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.

**Practicals:**

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

**References:**


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.


**Course Outcomes**

At the end of the course, learners will be able

**CO1:** To understand of energy conservation and identification of energy conservation opportunities in various industrial processes.

**CO2:** To acquire the knowledge of modern energy conversion technologies **CO3:** To evaluate the performance of industrial boilers, furnaces etc. By direct and indirect methods.

**CO4:** To be able to identify available nonconventional (renewable) energy resources and techniques to utilize them effectively.

**CO5:** To understand cogeneration in industry and waste heat recovery techniques and devices.

Mapping between COs with POs and PSOs

| CO | PO | | | | | | | | | | | | PSO | | |
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| CO5 | | | | | | | | | | | | | | | |

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| **Course code** | **Seminar** |
| **Course title** | **REE 591** |
| **Corse credit** | **1 (0+1)** |
| **Objective of Course** | 1. To prepare students to compete for a successful career in Renewable Energy Engineering profession through global education standards.<br>2. To enable the students to aptly apply their acquired knowledge in basic sciences and mathematics in solving Renewable Energy Engineering problems.<br>3. To produce skillful graduates to analyze, design and develop a system/component/ process for the required needs under the realistic constraints.<br>4. To train the students to approach ethically any multidisciplinary engineering challenges with economic, environmental and social contexts.<br>5. To create an awareness among the students about the need for life long learning to succeed in their professional career. |
| **Course Content** | - |
| **References:** | - |
| **Course Outcomes** | At the end of the course, learners will be able<br>**CO1:** To get the knowledge and to demonstrate the ability to identify, formulate and solve engineering problems.<br>**CO2:** To demonstrate the ability to design and conduct experiments, analyze and interpret data.<br>**CO3:** To visualize the ability and work on laboratory and multi-disciplinary tasks.<br>**CO4:** To demonstrate the skills to use modern engineering tools, software's and equipment to analyze problems.<br>**CO5:** To demonstrate the knowledge of professional, ethical responsibilities and in both verbal and written form and to develop confidence for self education and ability for life-long learning. |

Mapping between COs with POs and PSOs
**Please refer mapping of PO and PSO for the style of mapping.**

**Mapping between Cos, POs and PSOs**

| **CO** | **PO** | | | | | | | | | | | | **PSO** | | |
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| **CO5** | | | | | | | | | | | | | | | |

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|---|---|
| **Course code** | **Thesis Research** |
| **Course title** | **REE 599** |
| **Corse credit** | **30 (0+30)** |
| **Objective of Course** | To provide a comprehensive understanding of the concepts and methodologies for project identification, project preparation, project evaluation and project financing<br>2. To make the student understand the project cycle and their wide socio- economic and environmental impacts<br>3. To make the student learn how to evaluate a project in view of global concern about sustainable development of energy and environment projects<br>6. |
| **Course Content** | - |
| **References:** | - |
| **Course Outcomes** | At the end of the course, learners will be able<br>**CO1:** To identify various Renewable Energy Engineering and Environmental features of a project.<br>**CO2:** Laboratory and field based study.<br>**CO3:** Small and comprehensive projects for renewable energy engineering development and sustainability.<br>**CO4:** To develop a project with suitable technology/systems and global environmental impacts as well as energy saving.<br>**CO5:** To carry out techno-economic evaluation of Renewable Energy Engineering projects compared with other conventional systems as well as environmental considerations. |

Mapping between COs with POs and PSOs

**Please refer mapping of PO and PSO for the style of mapping.**

**Mapping between Cos, POs and PSOs**

| **CO** | **PO** | | | | | | | | | | | | **PSO** | | |
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| **CO4** | | | | | | | | | | | | | | | |
| **CO5** | | | | | | | | | | | | | | | |

**Post Graduate Doctor of Philosophy (Ph.D.) Program in Renewable Energy Engineering (BSMA)**

<table>
<tr><td>Course code</td><td>Biochemical Conversion of Biomass</td></tr>
<tr><td>Course title</td><td>REE 601</td></tr>
<tr><td>Corse credit</td><td>3 (2+1)</td></tr>
<tr><td>Objective of Course</td><td>1. To impart the advanced knowledge about biochemical conversion technologies of biomass, engineering design and kinetic of bio-energy systems.<br>2. To design, analyze and evaluate the various biomass conversion technologies.<br>3. To evaluate different parameters related to biomass for utilization of it for fuel extraction.</td></tr>
<tr><td>Course Content</td><td>Theory<br>: Unit-<br>I<br>Biomass formation: Energy recovery and recycling. Biochemical conversion of organic wastes: Methane production, vertical through digesters, high solid digestion, sludge treatment.<br>Unit-II<br>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, pre-digestion of waste.<br>Unit-III<br>Engineering design of biogas units: Biogas boosters, structural behavior, alternate construction materials, multi-criteria optimization, immobilization, modular biogas for tropical areas, kinetic models.<br>Unit-IV<br>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.<br>Practicals:<br>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.</td></tr>
<tr><td>References:</td><td>1. Culp AW. 1979. Principles of Energy Conversion. McGraw Hill Book Company, New York, USA.<br>2. Kiang YH. 1981. Waste Energy Utilization Technology. Marcel Dekkar, New York, USA.<br>3. Klan E. 1985. Energy from Biomass and Wastes. Institute of Gas Technology, Chicago.<br>4. Wilson DG and Reinhold VN. 1977. Hand Book of Solid Waste Management. McGraw Hill Book Company, New York, USA.</td></tr>
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| **Course Outcomes** | At the end of the course, learners will be able<br>**CO1:** To describe the nature and principle of different biomass energy extraction systems and know how to choose the suitable biomass fuels for different bio-energy applications.<br>**CO2:** To address the desirable features of these biomass energy sources and their advantages over traditional fuels such as coal and oil. |
| | **CO3:** To Identify their limited scope in terms of suitable sites, dependence on the elements, capital costs, and cost effectiveness compared with traditional sources. |

Mapping between COs with POs and PSOs

**Please refer mapping of PO and PSO for the style of mapping.**

**Mapping between Cos, POs and PSOs**

| **CO** | **PO** | | | | | | | | | | | | **PSO** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **1** | **2** | **3** |
| **CO1** | | | | | | | | | | | | | | | |
| **CO2** | | | | | | | | | | | | | | | |
| **CO3** | | | | | | | | | | | | | | | |

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|---|---|
| **Course code** | **Thermo-Chemical Conversion of Biomass** |
| **Course title** | **REE 602** |
| **Corse credit** | **3 (2+1)** |
| **Objective of Course** | 1. 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.<br>2. To analyze critical analysis of thermo-chemical conversion of fuel.<br>3. To design thermochemical conversion technologies for domestic and industrial applications within the context of a whole systems approach<br>4. To analyse the main biomass systems that can be used for biomass energy conversion and utilisation. |
| **Course Content** | **Theory : Unit I**<br>Biomass: Characterization, resources and energy recovery. Thermo-chemical conversion of organic wastes. Chemical thermodynamics, stoichiometry and thermodynamics.<br>**Unit -II**<br>Combustion of fuels: Solid fuels, stoker, types, fluidized bed. Liquid fuels: Atomization, vapour concentration, combustion phenomena. Gaseous fuel: Flam characteristics, inflammability limits, submerged combustion, combustion with explosion flame, pulsating combustion.<br>**Unit III**<br>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.<br>**Unit IV**<br>Pyrolysis: Models, regimes, kinetics and effect of process parameters. Radiant heat flux, heterogeneous reactions, wall heat transfer. Fluidized bed reactors: Heat transfer circulating beds, moving bed reactor.<br>**Unit V**<br>Torrefaction and charcoal production: Carbonization parameters, temperature zone, input output, energy density ratios and characterization of finished products.<br>**Practicals:**<br>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, charcoal and bio oil production. |

**References:**


1. Culp AW. 1979. *Principles of Energy Conversion*. McGraw Hill Book Company, New York,USA.
2. Glassman I. 1987. *Combustion*. Academic Press Inc. Orlando, Florida, USA.
3. Klan E. 1985. *Energy from Biomass and Wastes*. Institute of Gas Technology, Chicago.
4. Kiang YH. 1981. *Waste Energy Utilization Technology*. Marcel Dekkar, New York, USA.
5. Rezaiyan J and Cheeremisinoff NP. 2005. *Gasification Technologies– A Primer for Engineers and Scientists*. CRC Press, Taylor and Francis group, New York, USA.
6. Tchobanoglous G and Elliassen HTR. 1978. *Solid Wastes*. McGraw Hill Book Company,New York, USA.
7. Wilson DG and Reinhold VN. 1977. *Hand Book of Solid Waste Management*. Van Nostrand Reinhold Company, New York.


**Course Outcomes**

At the end of the course, learners will be able

**CO1:** To address the energy conversion process for biomass for various outputs.

**CO2:** To describe the different stages of biomass combustion and describe advantages and disadvantages of different thermochemical processes.

**CO3:** To match weight loss at given temperatures to biomass components.

**CO4:** To describe different thermochemical processes and their solid, liquid, and gas product distributions.

**CO5:** To perform a mass balance on a thermochemical reactor.

**Mapping between Cos, POs and PSOs**

| CO | PO | | | | | | | | | | | | PSO | | |
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| CO3 | | | | | | | | | | | | | | | |
| CO4 | | | | | | | | | | | | | | | |
| CO5 | | | | | | | | | | | | | | | |

| Course code | Advances in Renewable Energy Systems |
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| **Course title** | **REE 603** |
| **Corse credit** | **3 (2+1)** |
| **Objective of Course** | 1. 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.<br>2. To design and analyzed the renewable energy systems and relevant technologies critically with economic feasibility.<br>3. To understand the difference between renewable and non-renewable energies and create awareness in understanding the types of renewable energy benefits of harvesting renewable energy<br>4. To understand the characteristics and operations of each type of renewable energy and aware of the importance of renewable energy generation. |
| **Course Content** | **Theory**<br>**: Unit**<br>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.<br>**Unit -II**<br>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.<br>**Unit III**<br>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.<br>**Unit IV**<br>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.<br>**Practicals:**<br>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 controlsystem, grid control devices. Design of wind mills, rotor design procedure, momentum theory and blade element theory. Wind mill installation and operation issues. |

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| **References:** | 1. Anderson EE. 1983. *Fundamentals of Solar Energy Conversion*. Addision Wesley publicationCompany, Boston, United State.<br>2. Kishore VVN. 2008. *Renewable Energy Engineering and Technology–A Knowledge Compendium*. TERI Press, New Delhi, India.<br>3. More HG and Maheshwari RC. *Wind Energy Utilization in India*. Technical BulletinNo.CIAE/82/38,CIAE, Bhopal.<br>4. Powar AG and Mohod AG. 2010. *Wind Energy Technology*. Jain Publication, New Delhi, India.<br>5. Rai GD. 1994. *Nonconventional Sources of Energy*. Khanna Publishers, New Delhi, India.<br>6. Rao S and Parulekar BB. 1994. *Energy Technology Nonconventional, Renewable andConventional*. Khanna Publishers, New Delhi, India.<br>7. Sitharthan R and Geethanjali M. 2014. *Wind Energy Utilization in India: A Review*. Middle-East Journal of Scientific Research, Pakistan.<br>8. Solanki CS. 2011. *Solar Photovoltaics: Fundamentals, Technologies and Applications*. PHILearning Private Limited, New Delhi, India.<br>9. Sukhatme SP and Nayak J. 2008. *Solar Energy: Principles of Thermal Collection and*<br>10. *Storage*. Tata McGraw Hill Publishing Company Limited, New Delhi, India. |
| **Course Outcomes** | At the end of the course, learners will be able<br>**CO1:** To understand of renewable energy systems, its components and interactions between the components. This includes all renewable energy technologies, different storage technologies, distribution grid, smart grid including sensors. Regulation and control, and both "stand alone" systems and large integrated distribution systems.<br>**CO2:** To understand national and international regulations and framework conditions for renewable energy systems. This also includes different price models and actions.<br>**CO3:** To profound knowledge in a special field such as solar energy, storage, smart grid. |

**Mapping between Cos, POs and PSOs**

| CO | PO | | | | | | | | | | | | PSO | | |
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| | 1 | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **1** | **2** | **3** |
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|---|---|
| **Course code** | **New Alternate Energy Systems** |
| **Course title** | **REE 604** |
| **Corse credit** | **3 (2+1)** |
| **Objective of Course** | 1. To acquaint various recent and emerging alternate fuels and their various applications for power generation.<br>2. To understand the various recent and emerging alternate energy sources and their utilization for meeting the increasing energy demand.<br>3. To impart the knowledge of basics of alternative fuels for IC engine and alternative drive systems for automobiles, principle of solar energy collection.<br>4. To impart the knowledge of methods of production of Bio gas, methanol, ethanol, SVO, Bio diesel and various aspects of electrical and Hybrid vehicles. |
| **Course Content** | **Theory**<br>**: Unit I**<br>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). Electrogas dynamics (EGD): Principles, types.<br>**Unit -II**<br>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.<br>**Unit III**<br>Geo-thermal energy system: Classification, binary cycle conversion, water fed heat pumps, electric generation, steam generation, steam field. Heat mining, Darcy's law, volcano related heatresources, sedimentary basins, hot dry rocks. **Unit IV**<br>Power generation through alternative sources. Environmental pollution: Measurements and control methods, instrumentation, pollution standards, social cost estimates, $CO_2$ reductionpotential, $CO_2$ sequestration.<br>**Practicals:**<br>Testing of electrolysis plant, photo electric plant, photo plant, design criteria of fuel cell. Design considerations for alternative energy systems. |

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| **References:** | 1.Culp JA. 1979. *Principles of Energy Conversion*. McGraw-Hill Book Company, London.<br>2.Appleby A C 1987. *Fuel Cells: Trends in Research and Application. Hemisphere, Washington*.<br>3.Blomen LJMJ and Mugerwa MN. 1993. *Fuel Cell System*. Plenum Press, New York, USA.<br>4.Thielhein KD. 1977. *Alternate Energy Sources.* International compendium, Hemi spherepublishing company, London. |
| **Course Outcomes** | At the end of the course, learners will be able<br>**CO1:** To design technology and system on renewable and carbon-neutral energy and to analyze energy economics and business model.<br>**CO2:**To formulate energy policy and planning, to develop interdisciplinary research in energy systems engineering and also to understand professional and ethical responsibility.<br>**CO3:** To describe need for alternative fuels for Internal combustion engine and alternative drive systems for automobiles, principle of solar energy collection, construction of photo voltaic cells, OTEC, MHD, etc.<br>**CO4:** To explain the various aspects of electrical and Hybrid vehicles. |

**Mapping between Cos, POs and PSOs**

| CO | PO | | | | | | | | | | | | PSO | | |
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| **CO4** | | | | | | | | | | | | | | | |

| Course code | Fuel and Combustion |
|---|---|
| Course title | REE 605 |
| Corse credit | 3 (2+1) |
| Objective of Course | 1.To acquaint depth knowledge about solid, liquid and gaseous fuels and their combustion kinematics.<br>2.To understand of different combustion technologies.<br>3.To design, estimate and critical analysis of various combustion techniques for efficient utilization of fuels. |
| Course Content | **Theory**<br>**: Unit**<br>Solid and liquid fuels: Type and availability, oxidation, hydrogenation of solid fuel and processingof solid fuels. Liquid Fuels: Processing, properties testing of liquid fuels and refining. Liquid fuels from other sources: Preparation and storage. Production technologies for solid and liquid fuel.<br>**Unit -II**<br>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 productiontechnologies.<br>**Unit III**<br>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.<br>**Unit IV**<br>Combustion of liquid fuels: Atomization, vapor concentration, droplet and ignition. Liquid fuel burners: Atomizing air burners, pressure jet atomizing burners, thin fluid burners, rotary atomizing burners.<br>**Unit V**<br>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.<br>**Practicals:**<br>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. |

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| **References:** | 1.Babu MKG and Subramanian KA. 2013. *Alternative Transportation Fuels: Utilization inCombustion Engines*. CRC Press, Boca Raton, Florida. 2.Glassman I. 1987. *Combustion*. Academic Press Inc. Orlando, Florida, USA.<br>3.Mukunda HS. 2011. *Understanding Clean Energy and Fuels from Biomass*. Wiley IndiaPublication, New Delhi, India.<br>4.Sarkar S. 1990. *Fuels and Combustion*. Orient Longmans, Bombay.<br>5.Speight JG and Loyalka SK. 2007. *Handbook of Alternative Fuel Technologies*. CRC Press,Boca Raton, Florida. |
| **Course Outcomes** | At the end of the course, learners will be able<br>**CO1:** To analyze fuel characteristics and combustion process.<br>**CO2:** To differentiate among different fuels combustion and capability of recognition different engine designs.<br>**CO3:** To analysis & discussion of the engine data and other system data (e.g. boiler, furnace, gasifier,etc.).<br>**CO4:** To apply fundamental aspects of combustion related problem and an understanding on the combustion appliances<br>**CO5:**To design technology and system on renewable and carbon-neutral energy and to analyze energy economics and business model. |

**Mapping between Cos, POs and PSOs**

| CO | PO | | | | | | | | | | | | PSO | | |
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| | 1 | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **1** | **2** | **3** |
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| **CO3** | | | | | | | | | | | | | | | |
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| **CO5** | | | | | | | | | | | | | | | |

| Course code | Advances in Biogas Technology |
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| Course title | REE 606 |
| Corse credit | 3 (2+1) |
| Objective of Course | 1. To understand advances in biogas technology and its mechanism in detail.<br>2. Toanalyze the case studies for understanding success and failures.<br>3. To facilitate the students in developing skills in the decision making process.<br>4. To analyse the various aspects of biogas energy management systems, carry out techno-economic feasibility for biogas plant.<br>5. To apply the knowledge in planning and operations of biogas energy system. |
| Course Content | **Theory**<br>**: Unit**<br>Worldwide review of anaerobic digesters, realistic potential- of biogas, analysis of biogas systemand proposed means for their prospects. Engineering design of biogas units for biogas productionfrom solid and liquid wastes.<br>**Unit -II**<br>Design parameters: Affecting and failure of biogas systems, structural behavior and conditions of fixed dome digesters, alternate construction- materials, gas holders for gas production in colder regions, heating, stirring etc.<br>**Unit III**<br>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.<br>**Unit IV**<br>Scrubbing, purification and compression of biogas. Scaling-up and standardization of biogas plant for power generation and heating. Advanced biofuels: Bio-CNG/ renewable natural gas (RNG) as vehicle fuel. Liquefaction of biogas.<br>**Practicals:**<br>Engineering design and analysis of biogas system. Development of kinetic equations. Biogas purification, compression and liquefaction. Industrial applications of biogas. |

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| **References:** | 1.Abbasi SA and Nipaney PC. 1993. *Modeling and Simulation of Biogas System Economies*.Ashish Publication House, New Delhi.<br>2.Abbasi T, Tauseef SM and Abbasi SA. 2012. *Biogas Energy*. Springer publications, New York, USA.<br>3.Chawala OP. 1986. *Advances in Biogas Technology*. ICAR, New Delhi. 4.Mittal KM. 1996. *Biogas Systems: Principles and A pplications*. New Age International Publication Limited, New Delhi.<br>5.Rohlich GA, Walbot V, Connar LJ, Golueke CG, Hinesly TD, Jones PH, Lapp HM, Loehr<br>6.RC, LueiHing C, Pfeffer JT, Prakasam TBS and Brown NL. 1977. *Methane Generation from Human Animals and Agril Wastes*. National Academy of Sciences, Washington. |
| **Course** | At the end of the course, learners will be able |
| **Outcomes** | **CO1:** To introduce the students to the role of biotechnology in waste products management<br>**CO2:** To learn about role of microbes in biodegradation, bioremediation and composting<br>**CO3:** To understand the treatment processes of waste water and also the knowledge of production of biogas.<br>**CO4:** To design different bio-digestion process for industrial as well as domestic use. |

**Mapping between Cos, POs and PSOs**

| **CO** | **PO** | | | | | | | | | | | | **PSO** | | |
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| | 1 | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **1** | **2** | **3** |
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|---|---|
| **Course code** | **Solid Waste and Waste Water Management** |
| **Course title** | **REE 607** |
| **Corse credit** | **3 (2+1)** |
| **Objective of Course** | 1. 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.<br>2. To estimate, characterize and design of solid waste conversion system.<br>3. To understand the energetic and kinetics of anaerobic treatment, sanitation land fill, pre-digestion of waste etc. |
| **Course Content** | **Theory**<br>**: Unit**<br>Solid waste: Sources, quality, classification and characteristics, collection and reduction at source,handling, storage, transportation and disposal methods.<br>**Unit -II**<br>Reactor for anaerobic digestion: Contact and filter digestion, homogenous and non-homogeneousreactors. Energetic and kinetics of anaerobic treatment.<br>**Unit III**<br>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.<br>**Unit IV**<br>Sanitation land fill, municipal and compost treatment. Predigestion of waste. Sensors, ICT and remote sensing technologies for waste management.<br>**Practicals:**<br>Design principles in waste treatment, equipment specification and instrumentation. Mathematical modelling of BOD and COD reduction rate, recovery by batch distillation. |
| **References:** | 1. Bridgwater AV and Mum-ford CJ. 1979. Waste Recycling and Pollution Control Handbook.<br>2. Van Nostrand Reinhold Company, New York.<br>3. Kreith F and Tchobanoglous G. 2002. Handbook of Solid Waste Management. McGraw Hill Book Company, New York.<br>4. Ramachandra TV. 2006. Management of Municipal Solid Waste. Capital Publication Company, New Delhi.<br>5. Tchobanoglous G, Theisenand H and Elliassen R. 1978. Solid Wastes. McGraw Hill Book Company, New York. |

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| **Course Outcomes** | At the end of the course, learners will be able<br>**CO1:** To apply the knowledge about the operation of waste to energy plants.<br>**CO2:** To analyze the various aspects of waste to energy plant.<br>**CO3:** To apply the knowledge in planning & operation of waste to energy plants.<br>**CO4:** To introduce the students to the role of biotechnology in waste products management. |

Mapping between COs with POs and PSOs

**Please refer mapping of PO and PSO for the style of mapping.**

**Mapping between Cos, POs and PSOs**

| **CO** | **PO** | | | | | | | | | | | | **PSO** | | |
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| **CO2** | | | | | | | | | | | | | | | |
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|---|---|
| **Course code** | **Advanced Photovoltaic Power Generation** |
| **Course title** | **REE 608** |
| **Corse credit** | **2 (1+1)** |
| **Objective of Course** | 1. To develop a comprehensive technological understanding in solar PV system components.<br>2. To provide in depth understanding of design parameters to help design and simulate the performance of a solar PV power plant.<br>3. To pertain knowledge about design, planning, project implementation and operation of solar PV power generation.<br>4. Design and simulate a PV power plant using software tool, Plan, project implementation, operation and maintenance.<br>5. Carry out techno-economic environmental performance evaluation of a solar PV power plant. |
| **Course Content** | **Theory**<br>**: Unit I**<br>Semiconductors: Transport properties, junctions, dark and illumination<br>characteristics. Single junction and multi junction films. Solar PV concentrator cells and systems. Thin film solar cells: Nano, micro, and polycrystalline solar cells.<br>**Unit -II**<br>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.<br>**Unit III**<br>Space charge control, low pressure diode, MMPT, cesium converter, system considerations. Photo electro chemical cells and materials. Photo galvanic cells: Recent development.<br>**Unit IV**<br>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.<br>**Practicals:**<br>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 storageby PV panels. |

**References:**


1. Duffle JA and Beckman WA. 1991. *Solar Engineering of Thermal Processes*. John Wiley, NewJersey.
2. Fonash SJ. 1982. *Solar Cell Device Physics*. Academic Press, Cambridge, England.
3. Garg HP. 1990. *Advances in Solar Energy Technology*. Springer Publishing Company, Dordrecht,Netherland.
4. Green MA. 1981. *Solar Cells Operating Principles, Technology, and System Applications.* Prentice Hall, New Jersey.
5. Kreith F and Kreider JF. 1978. *Principles of Solar Engineering.* McGraw Hill, New York.
6. Luque A and Hegedus S. 2011. *Handbook of Photovoltaic Science and Engineering Education.* JohnWiley and Sons, New Jersey.
7. Solanki CS. 2011. *Solar Photovoltaic: Fundamentals, Technologies and Applications*. PHI Learning Private Limited, Delhi.
8. Sze SM and Kwok KN. 2007. *Physics of Semiconductor Devices*. John Wiley & Sons, New Jersey.
9. Veziroglu TN. 1977. *Alternative Energy Sources*. McGraw Hill, New York.


**Course Outcomes**

At the end of the course, learners will be able

**CO1:** To understand the physical principles of the photovoltaic (PV) solar cell and what are its sources of losses.

**CO2:** To know the electrical (current-voltage and power-voltage) characteristics of solar cell, panel or generator and how the environment parameters influence it.

**CO3:** To know the most important characteristics of the elements within a PV system, battery and charge controller, DC/DC converter, DC/AC converter (inverter) and loads.

**CO4:** To understand the role of solar energy in the context of regional and global energy system, its economic, social and environmental implications, and the impact of technology on a local and global context.

**Mapping between Cos, POs and PSOs**

| CO | PO | | | | | | | | | | | | PSO | | |
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|---|---|
| **Course code** | **Energy Planning, Management and Economics** |
| **Course title** | **REE 609** |
| **Corse credit** | **3 (3+0)** |
| **Objective of Course** | 1.To acquaint and equip with energy planning, management and economical evaluation for agricultural production system.<br>2.To quantify, analyze and forecast the demand and supply of different energy for agriculture production system.<br>3.To evaluate the techno economics of RET's use in industry and domestic purposes. |
| **Course Content** | **Theory**<br>**: Unit**<br>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.<br>**Unit -II**<br>Energy audit of production agriculture and rural living and scope of conservation. Identification of energy efficient machinery systems, energy losses and their management.<br>**Unit III**<br>Energy analysis techniques and methods: Energy balance, output and input ratio, resource utilization, conservation of energy sources. Energy conservation planning and practices.<br>**Unit IV**<br>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. |
| **References:** | 1.Fluck RC and Baird CD. 1984. *Agricultural Energetics*. AVI Publication, United State.<br>2.Kennedy WJ and Turner WC. 1984. *Energy Management*. Prentice Hall, New Jersey.<br>3.Pimental D. 1980. *Handbook of Energy Utilization in Agriculture*. CRC Press, Florida.<br>4.Rai GD. 1998. *Nonconventional Sources of Energy*.Khanna Publication, New Delhi.<br>5.Twindal JW and Wier AD. 1986. *RenewableEnergy Sources*. E & F N Spon, New York.<br>6.Verma SR, Mittal JP and Singh S. 1994. *Energy Management and Conservation in Agricultural Production and Food Processing*. USG Publication, Chicago. |

| **Course Outcomes** | At the end of the course, learners will be able<br>**CO1:** To understand the current energy scenario along with energy management and strategies<br>**CO2:** To take action on energy conservation techniques.<br>**CO3:** To acquire the knowledge of financial management<br>**CO4:** To analyze the data for energy monitoring and targeting. **CO5:** To analyse the techno economics of RETs'. |
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Mapping between COs with POs and PSOs

**Please refer mapping of PO and PSO for the style of mapping.**

**Mapping between Cos, POs and PSOs**

| **CO** | **PO** | | | | | | | | | | | | **PSO** | | |
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| **CO5** | | | | | | | | | | | | | | | |

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| **Course code** | **Renewable Energy for Industrial Application** |
| **Course title** | **REE 610** |
| **Corse credit** | **3 (2+1)** |
| **Objective of Course** | 1. To provide the knowledge regarding the energy consumption pattern in agro based industries, quantification techniques and identification of opportunities for renewable energy sources.<br>2. To acquaint with energy quantification techniques, design of system, economic evaluation and utilization of renewable energy sources for agro- industrial applications.<br>3. To keep the knowledge of current thoughts and newer technology options along with their advances in the field of the utilization of different types of renewable energy technology and wastes for energy production. |
| **Course Content** | **Theory**<br>**: Unit I**<br>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.<br>**Unit -II**<br>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 solararchitecture technology), solar furnace and solar greenhouse technology for high-tech cultivation. Solar photovoltaic technology for industrial power.<br>**Unit III**<br>Bio energy for industrial application: Quantification of industrial bio-waste, characterization, power generation through bio-methanation, gasification and dendro thermal power plant.<br>**Unit IV**<br>Wind energy: Aero generator of new era and national and international state of art in wind powergeneration. Other renewable energy sources: Magneto hydro dynamics, fuel cells technology andmicro-hydro energy technology.<br>**Practicals:**<br>Elucidation and energy consumption for unit operations in industry. Study of energy quantificationand 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. |

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| **References:** | 1. Duffie JA and Beakman WA. 2006. *Solar Energy Thermal Process*. John Wiley and Sons,NewYork.<br>2. Kumar S. 2011. *Energy Conservation Building User Code Guide.* Bureau of EnergyEfficiency,New Delhi.<br>3. Rathore NS, Kurchania AK and Panwar NL. 2007. *Non Conventional Energy Sources*.Himanshu Publications, Udaipur, Rajasthan.<br>4. Sayigh AAM. 2012. *Solar Energy Engineering*. Academic Press, New York.<br>5. Singh P, Kurchania AK, Rathore NS and Mathur AN. 2005. *Sustainable Development through Renewable Energy Sources*. Yash Publications, Bikaner, Rajasthan. Private Limited, Delhi. |
| **Course** | At the end of the course, learners will be able |
| **Outcomes** | **CO1:** To apply the knowledge about the operation of waste to energy plants. **CO2:** To analyze the various aspects of different RETs' and waste to energy plant.<br>**CO3:** To apply the knowledge in planning & operation of waste to energy plants. |

**Mapping between Cos, POs and PSOs**

| CO | PO | | | | | | | | | | | | PSO | | |
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| Course code | **Biofuel Technologies and Applications** |
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| **Course title** | **REE 611** |
| **Corse credit** | **2 (1+1)** |
| **Objective of Course** | 1. To acquaint recent biofuel production technologies and their applications.<br>2. To perform financial estimations of the biofuel projects.<br>3. To get insight of the various biofuel technologies.<br>4. To understand the bio-fuel production technologies with financial viability and applications of bio-fuel in different sector of development. |
| **Course Content** | **Theory**<br>**: Unit I**<br>Liquid biofuels: Non-edible oilseeds, oil extraction, pre-processing, characterization. World scenario: Liquid fuel challenges and some solutions. Liquid bio-fuel applications.<br>**Unit -II**<br>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, bio propanol.<br>**Unit III**<br>BioCNG: Biogas to green vehicle fuel, anaerobic digestion. Bio gas opportunities: Landfill gas, agricultural and industrial wastewater and additional sources of methane.<br>**Unit IV**<br>Biodiesel: Feedstock for biodiesel, manufacturing processes for biodiesel, value addition by utilization of by-products, environmental impacts of biodiesel, biodiesel from algae, biodiesel engines.<br>**Unit V**<br>Pyrolysis oil: Fast pyrolysis technologies, composition and issues of bio oil. Bio oil upgradationtechnologies.<br>**Practicals:**<br>Evaluation of liquid fuel system for heat and power generation and characterization of liquid fuel,trans-esterification process. Engine performance on biodiesel. Biogas engine system for transport vehicle. Bio oil production by pyrolysis. |

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| **References:** | 1. Boyle G. 2008. *Renewable Energy.* Atlantic Publishing Company, New Delhi.<br>2. Gonsalves JB. 2006. *An Assessment of the Biofuels Industry in* John *India.* Wiley & Sons,New Delhi.<br>3. Kishore VVN. 2008. *Renewable Energy Engineering and Technology–A KnowledgeCompendium. Education.* TERI Press, Delhi.<br>4. Klass D. 1998. *Biomass for Renewable Energy, Fuels, and Chemicals.* Entech International,Barrington, Illinois, USA.<br>5. Mitzlaff KV. 1988. *Engines for Biogas–Theory, Modification, Economic Operation.* Deutsches<br>6. Zentrum für Entwicklungs technologien–GATE, Germany. |
| **Course Outcomes** | At the end of the course, learners will be able<br>**CO1:** To characterize different biomass feedstocks based on its constituents and properties.<br>**CO2:** To understand and evaluate various biomass pretreatment and processing techniques in terms of their applicability for different biomass type for biomass conversion processes.<br>**CO3:** To understand the process of combustion, pyrolysis, gasification and liquefaction for production of value added bio-products, biogas, bio-CNG generation etc.<br>**CO4:** To understand basics of biofuels, their production technologies and applications in various energy utility routes. |

**Mapping between Cos, POs and PSOs**

| **CO** | **PO** | | | | | | | | | | | | **PSO** | | |
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|---|---|
| **Course code** | **Energy Modelling and Simulation** |
| **Course title** | **REE 612** |
| **Corse credit** | **2 (1+1)** |
| **Objective of Course** | 1. To provide in depth knowledge about various mathematical models, interdependence of energy, ecology and environment, energy modelling in the context of climate change.<br>2. To learn energy modelling of gasification, pyrolysis, biogas system, fermentation, biodiesel production system, solar and wind technologies etc.<br>3. To impart basic skill of model development and optimization in the field of energy.<br>4. To develop basic skill of development of energy system model and to enable learners to use system modeling as tool for optimization vis-à- vis decision making on energy related field problems. |
| **Course Content** | **Theory**<br>**: Unit I**<br>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.<br>**Unit -II**<br>Energy Modelling: Review of various energy sector models, energy demand analysis and forecasting, energy supply assessment and evaluation, energy demand, supply balancing, energymodelling in the context of climate change. **Unit III**<br>Model studies in gasification, pyrolysis, biogas, fermentation, biodiesel, solar, wind technologiesand heat transfer applications. Moving boundary models.<br>**Unit IV**<br>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.<br>**Practicals:**<br>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. |
| **References:** | 1.Desai A V 1990. *Energy Planning and Economics.* New Age International Publication Limited,New Delhi.<br>2.Munasinghe M and Meier P 1993. *Energy Policy Analysis and Modelling* (*Cambridge Energy and Environment Series*). Cambridge University Press, England. |

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| **Course Outcomes** | At the end of the course, learners will be able<br>**CO1:** To comprehend the basic principles of modelling and simulation of energy systems.<br>**CO2:** To demonstrate the ability to formulate, mathematically describe, numerically solve and analyse solar energy conversion processes, using advanced numerical tools such as CFD.<br>**CO3:** To demonstrate the ability to assess the technical and economic performance of PV units and their integration into the energy system.<br>**CO4:** To understand how to develop a model, and how to apply varies strategies for different parametric model.<br>**CO5:** To optimize the energy systems and to understand the working principles econometric modeling. |

Mapping between COs with POs and PSOs

**Please refer mapping of PO and PSO for the style of mapping.**

**Mapping between Cos, POs and PSOs**

| **CO** | **PO** | | | | | | | | | | | | **PSO** | | |
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| Course code | Doctoral Seminar-I |
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| Course title | REE 691 |
| Corse credit | 1 (0+1) |
| Objective of Course | 1. To prepare students to compete for a successful career in Renewable Energy Engineering profession through global education standards.<br>2. To enable the students to aptly apply their acquired knowledge in basic sciences and mathematics in solving Renewable Energy Engineering problems.<br>3. To produce skillful graduates to analyze, design and develop a system/component/ process for the required needs under the realistic constraints.<br>4. To train the students to approach ethically any multidisciplinary engineering challenges with economic, environmental and social contexts.<br>5. To create an awareness among the students about the need for life long learning to succeed in their professional career. |
| Course Content | - |
| References: | - |
| Course Outcomes | At the end of the course, learners will be able<br>**CO1:** To get the knowledge and to demonstrate the ability to identify, formulate and solve engineering problems.<br>**CO2:** To demonstrate the ability to design and conduct experiments, analyze and interpret data.<br>**CO3:** To visualize the ability and work on laboratory and multi-disciplinary tasks.<br>**CO4:** To demonstrate the skills to use modern engineering tools, software's and equipment to analyze problems.<br>**CO5:** To demonstrate the knowledge of professional, ethical responsibilities and in both verbal and written form and to develop confidence for self education and ability for life-long learning. |

Mapping between COs with POs and PSOs
**Please refer mapping of PO and PSO for the style of mapping.**

**Mapping between Cos, POs and PSOs**

| CO | PO | | | | | | | | | | | | PSO | | |
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| Course code | **Doctoral Seminar-II** |
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| **Course title** | **REE 692** |
| **Corse credit** | **1 (0+1)** |
| **Objective of Course** | 1. To prepare students to compete for a successful career in Renewable Energy Engineering profession with multi-disciplinary aspects through global education standards.<br>2. To enable the students to aptly apply their acquired knowledge in basic sciences and mathematics in solving Renewable Energy Engineering with other discipline related problems.<br>3. To produce skillful graduates to analyze, design and develop a system/component/ process for the required needs under the realistic constraints.<br>4. To train the students to approach ethically any multidisciplinary engineering challenges with economic, environmental and social contexts.<br>5. To create an awareness among the students about the need for life long learning to succeed in their professional career. |
| **Course Content** | - |
| **References:** | - |
| **Course Outcomes** | At the end of the course, learners will be able<br>**CO1:** To get the knowledge and to demonstrate the ability to identify, formulate and solve engineering problems.<br>**CO2:** To demonstrate the ability to design and conduct experiments, analyze and interpret data.<br>**CO3:** To visualize the ability and work on laboratory and multi-disciplinary tasks.<br>**CO4:** To demonstrate the skills to use modern engineering tools, software's and equipment to analyze problems.<br>**CO5:** To demonstrate the knowledge of professional, ethical responsibilities and in both verbal and written form and to develop confidence for self education and ability for life-long learning. |

Mapping between COs with POs and PSOs
**Please refer mapping of PO and PSO for the style of mapping.**

**Mapping between Cos, POs and PSOs**

| **CO** | **PO** | | | | | | | | | | | | **PSO** | | |
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| Course code | Doctoral Research |
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| **Course title** | **REE 699** |
| **Corse credit** | **75 (0+75)** |
| **Objective of Course** | 1. To provide a comprehensive understanding of the concepts and methodologies for project identification, project preparation, project evaluation and project financing<br>2. To make the student understand the project cycle and their wide socio-economic and environmental impacts<br>3. To make the student learn how to evaluate a project in view of global concern about sustainable development of energy and environment projects |
| **Course Content** | - |
| **References:** | - |
| **Course Outcomes** | At the end of the course, learners will be able<br>**CO1:** To identify various practical issues related Renewable Energy Engineering and Environmental features of a project.<br>**CO2:** Laboratory/machine/ gadget development and field based study.<br>**CO3:** Small and comprehensive projects for renewable energy engineering development and sustainability.<br>**CO4:** To develop a project with suitable technology/systems and global environmental impacts as well as energy saving.<br>**CO5:** To carry out techno-economic evaluation of Renewable Energy Engineering projects compared with other conventional systems as well as environmental considerations. |

**Mapping between Cos, POs and PSOs**

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| **Course code** | SWCE 501 |
| **Course title** | Advanced Soil and Water Conservation Engineering |
| **Corse credit** | 2+1 |
| **Objective of Course** | 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. |
| Course Content | Theory<br>Unit- I<br>Concept of probability in design of soil and water conservation structures. Discrete and continuous frequency distribution. Fitting probability distributions.<br>Unit-II<br>Relevance of soil and water conservation in agriculture and in the river valley projects. Layout and planning of soil and water conservation measures. Software's for design of conservation structures.<br>Unit-III<br>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<br>Unit-IV<br>Theories of sediment transport. Control of runoff and sediment loss. Sediment deposition process. Estimation of sediment load.<br>Unit-V<br>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. Application of Remote Sensing and GIS in Soil and Water Conservation.<br><br>Practical<br>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 possible sites of soil and water conservation structures on the basis of map features and erosivity status. Estimation of costs of soil and water conservation measures. |
| References: | • Garg SK. 1987. Irrigation Engineering and Hydraulic Structures. Khanna Publishers, New Delhi<br>• Kirkby MJ and Morgan PPC (eds). 1980. Soil Erosion. John Wiley and Sons. New York, USA<br>• Suresh R. 2016. Soil and Water Conservation Engineering. Standard Publishers and Distributors, Delhi. |
| Course Outcomes | CO1: Apply principles of probability and statistics to optimize the design of conservation structures. |

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| | CO2: Analyze the impact of soil and water conservation on agricultural productivity and environmental sustainability.<br>CO3: Evaluate soil erosion risks and water stress/excess issues using relevant software and field data.<br>CO4: Design and implement effective soil and water conservation strategies based on technical knowledge and site-specific conditions.<br>CO5: Utilize Remote Sensing and GIS technologies for soil erosion monitoring and resource management. |

**Mapping between Cos, POs and PSOs**

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| **Course code** | SWCE 502 |
| **Course title** | Applied Watershed Hydrology |
| **Corse credit** | 2+1 |
| **Objective of Course** | 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. |
| Course Content | Theory<br>Unit-I<br>Hydrology in water resources planning, rainfall, surface runoff and sub-surface runoff as components of hydrologic cycle. Runoff phenomena, relationship between precipitation and runoff. Stream flow measurement and analysis of data in detail.<br>Unit-II<br>Synthetic unit hydrograph. Recent advances in analysis of hydrologic data and flow from small watersheds. Methods of runoff estimation from small watersheds. Use of IUH and various methods of estimation. Runoff estimation models: SCS, CN software. Advances and improvements in rational approach. SCS approach criticism and improvements.<br>Unit-III<br>Micro climate, estimation methods of evaporation and evapotranspiration. Molecular and eddy transport of water, eddy diffusion, mixing, zero plane displacement, microclimate near the ground.<br>Unit-IV<br>Hydrological hazard functions. Methods of estimation of hydrologic parameters. Data transformation.<br>Unit-V<br>Calibration and evaluation of hydrologic models. Computer simulation of hydrological process in small watersheds.<br><br>Practical:<br>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. |
| References: | • Andy D. Ward, Stanley W. Trimble, Suzette R. Burckhard, John G. Lyon. 2015 Environmental Hydrology CRC Press.<br>• Haan CT, Johnson HP and Brakensiek DL. 1982. Hydrologic Modeling of Small Watershed, ASAE Monograph No. 5, American Society of Agricultural Engineers, Michigan.<br>• Singh V P 1988. Hydrologic Systems: Rainfall-Runoff Modeling (Vol.I) – Prentice Hall, New York.<br>• Singh VP. 1995. Environmental Hydrology. Springer, New York. |

| Course Outcomes | At the end of the course, learners will be able<br>CO1: Integrate hydrological principles into water resource planning and decision-making.<br>CO2: Analyze and interpret hydrological data to understand watershed dynamics.<br>CO3: Design and implement effective streamflow monitoring and analysis systems.<br>CO4: Apply appropriate methods to estimate runoff and predict water availability for small watersheds.<br>CO5: Utilize advanced hydrological models and software tools for accurate water resource assessment. |
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**Mapping between Cos, POs and PSOs**

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| **Course code** | SWCE 503 |
| **Course title** | Soil and Water Conservation Structures |
| **Corse credit** | 2+1 |
| **Objective of Course** | To acquaint students with the planning and design of soil and water conservation structures, their stability checks and mechanized soil conservation techniques. |
| Course Content | Theory<br>Unit-I<br>Design, planning and layout of soil and water conservation structures. Criteria of selection of appropriate structures as per soil, land use and climatic conditions.<br>Unit-II<br>Design and construction of earthen dam, stability analysis of land slopes and soil mass including landslides.<br>Unit-III<br>Hydrological and structural design including stress analysis. Hydraulic jump and energy dissipaters for soil conservation structures.<br>Unit-IV<br>Seepage through dams, flow net and determination of uplift pressure in drop structures, design of energy dissipaters.<br>Unit-V<br>Design of water harvesting structures, construction, maintenance and utilization of stored water. Mechanized construction techniques for soil and water conservation structures.<br><br>Practical<br>Numerical approach on probability distribution functions. 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. |
| References: | • Mahnot, SC Singh PK and Chaplot PC. 2011. Soil and Water Conservation and Watershed Management. APEX publishing house, Udaipur.<br>• Murty VVN, Jha MK. 1988. Land and Water Management Engineering. Second Edition Kalyani Publishers, New Delhi.<br>• Singh Gurmel C, Venkataraman G, Sastri and B.P. Joshi 1991. Manual of Soil & Water conservation Practices. Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi.<br>• Singh PK. 2000. Watershed Management (Design and Practice). e-media publications, Udaipur.<br>• Singh Raj Vir. 2003. Watershed Management. Second Edition, Yash Publishing, Bikaner.<br>• Suresh R. 2006. Soil and Water Conservation Engineering. |

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| | Fourth Edition Standard Publishers and Distributors, Delhi. |
| Course Outcomes | At the end of the course, learners will be able<br>CO1: Apply technical knowledge to design and implement customized soil and water conservation solutions.<br>CO2: Analyze and assess the stability of slopes and design safe and sustainable earth dams.<br>CO3: Integrate hydrological and structural principles in the design of efficient and durable conservation structures.<br>CO4: Analyze seepage and uplift pressure in hydraulic structures and design appropriate mitigation strategies.<br>CO5: Design, implement, and maintain water harvesting structures, evaluating their effectiveness and exploring advanced construction methods. |

**Mapping between Cos, POs and PSOs**

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| **Course code** | SWCE 504 |
| **Course title** | Stochastic Hydrology |
| **Corse credit** | 2+1 |
| **Objective of Course** | To acquaint students about the stochastic processes in hydrology including statistical characteristics of hydrological time series data, modeling hydrologic uncertainty and analysis of multivariate hydrologic series, |
| Course Content | Theory<br>Unit-I<br>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, parameter estimation of probability distributions. Analysis of hydrologic extremes.<br><br>Unit-II<br>Multivariate 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.<br><br>Unit-III<br>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 multivariate hydrologic series.<br><br>Unit-IV<br>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.<br><br>Unit-V<br>Modeling hydrologic uncertainty. First order Markov process, Markov chain, Data generation, Hydrologic time series analysis, Modelling of hydrologic time series.<br><br>Practical<br>To estimate various statistical parameters of the hydrologic variables, estimating missing data in historical series, various parameter estimation methods like method of moments, method |

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| | 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, autocorrelation 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. |
| References: | • Clarke RT. Mathematical Models in Hydrology. FAO Publication.<br>• Haan CT. 2002. Statistical Methods in Hydrology. Iowa State Press.<br>• Kotteguda N.T. 1982. Stochastic Water Resources Technology. The Macmillan Press, New York.<br>• McCuen RH and Snyder WM. Hydrological Modelling–Statistical Methods and Applications. Prentice Hall Inc. New York.<br>• Yevjevich V Stochastic Processes in Hydrology. Water Resources Publications, Colorado. |
| Course Outcomes | At the end of the course, learners will be able<br>CO1: Explain and apply different hydrologic modeling approaches to analyze and represent real-world hydrological systems.<br>CO2: Analyze and interpret hydrological data using statistical methods, including probability distributions and extreme value analysis.<br>CO3: Utilize time series analysis techniques to decompose and understand the dynamics of hydrological data.<br>CO4: Develop and calibrate hydrological models for simulation, forecasting, and regional flood frequency analysis.<br>CO5: Assess and quantify uncertainties in hydrological data and models, and employ appropriate mitigation strategies. |

**Mapping between Cos, POs and PSOs**

| CO | PO | | | | | | | | | | | | PSO | | |
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| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 |
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| **Course code** | SWCE 505 |
| **Course title** | Watershed Management and Modeling |
| **Corse credit** | 2+1 |
| **Objective of Course** | 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 |
| Course Content | Theory<br>Unit-I<br>Concept of watershed, its hydrological and geomorphological characteristics. Status of watershed management programs in India. Problems of desertification and degradation.<br>Unit-II<br>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.<br>Unit-III<br>Watershed management research instrumentation and measurement, problem identification, simulation and synthesis. Rainfed farming and drought management. Modeling of flood and drought phenomenon.<br>Unit-IV<br>Use of Remote Sensing and GIS in watershed management and modeling. Watershed modeling approaches, mathematical bases and structure of existing watershed models.<br>Unit-V<br>Environmental impact assessment of watersheds. Quantitative evaluation of management techniques. National land use policy, legal and social aspects. Case studies of watershed management.<br><br>Practical<br>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. |
| References: | • Dhaliwal GS, Hansra BS and Ladhar SS. 1993. Wetlands, their Conservation and Management.<br>Punjab Agricultural University, Ludhiana.<br>• Dhruvanarayana VV, Sastry G and Patnaik US. Watershed Management. Publ. and Inf. Dv., ICAR, Krishi Anusandhan Bhavan, New Delhi.<br>• Singh RV. 2000. Watershed Planning and Management. Second Edition Yash Publishing House, Bikaner.<br>• Suresh R. 2017. Watershed Planning and Management. Standard Publication and Distribution, Delhi |

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| | • Tideman EM 1999. Watershed Management (Guidelines for Indian Conditions). Omega Scientific Publishers, New Delhi. |
| Course Outcomes | At the end of the course, learners will be able<br>CO1: Analyze and interpret data to characterize watersheds and assess the need for management interventions.<br>CO2: Design and implement participatory watershed management plans that consider environmental, social, and economic factors.<br>CO3: Utilize research methods and instrumentation to collect and analyze data, identify critical issues, and develop evidence-based solutions.<br>CO4: Apply Remote Sensing and GIS tools to map, monitor, and model watershed processes for informed decision-making.<br>CO5: Evaluate the environmental, economic, and social impacts of watershed management practices and propose sustainable strategies for improvement. |

**Mapping between Cos, POs and PSOs**

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| **Course code** | SWCE 506 |
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| **Course title** | Flow Through Porous Media |
| **Corse credit** | 2+0 |
| **Objective of Course** | To provide comprehensive knowledge to the students in aquifer and fluid properties, unsaturated flow theory and movement of groundwater in fractured and swelling porous media. |
| Course Content | Theory<br>Unit-I<br>Aquifer and fluid properties, forces holding water in soils, hydrodynamics in porous media and<br><br>limitations of governing laws.<br>Unit-II<br>Differential equations of saturated flow, initial and boundary conditions. Dupuit and Business approximations and linearization techniques.<br>Unit-III<br>Stream functions, potential functions and flow net theory. Analysis of seepage from canals and ditches.<br>Unit-IV<br>Unsaturated flow theory, Infiltration and capillary rise flux dynamics. Movement of groundwater in fractured and swelling porous media.<br>Unit-V<br>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. |
| References: | • Bear J and Arnold V Modeling Groundwater Flow and Pollution. D. Reidel Publishing Company<br>• Bears J. 1972. Dynamics of Fluids in Porous Media. American Elsevier Publishing Co. Inc. New York.<br>• Collins RE. 1961. Flow of Fluids through Porous Materials. Reinhold publishing cooperation, New York.<br>• De Wiest Roger JM. 1969. Flow through Porous Media. Academic press, New York.<br>• Dullien FAL. 1979. Porous Media: Fluid Transport and Pore Structure, Academic Press.<br>• Harr, M.E. (1962) Groundwater and Seepage. McGraw-Hill Book Company, New York.<br>• Helmut Kohnke. 1968. Soil Physics. McGraw-Hill Book Co, New York.<br>• Scheidegger AE. 1974. The Physics of Flow through Porous Media, University of Toronto Press.<br>• Verruijt A. 1982. Theory of Groundwater Flow. 2nd Edn., |

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| | Macmillan, London. |
| Course Outcomes | At the end of the course, learners will be able<br>CO1: Apply principles of fluid mechanics and porous media physics to predict groundwater behavior.<br>CO2: Formulate and solve differential equations for saturated groundwater flow under various conditions.<br>CO3: Utilize flow net analysis and potential functions to design and evaluate hydraulic structures.<br>CO4: Analyze unsaturated flow processes and their role in infiltration, soil moisture dynamics, and contaminant transport.<br>CO5: Apply theoretical knowledge of groundwater flow and dispersion to solve practical engineering problems related to drainage, dam stability, |

**Mapping between Cos, POs and PSOs**

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| **Course code** | SWCE 507 |
| **Course title** | GIS and Remote Sensing for Land and Water Resource Management |
| **Corse credit** | 2+1 |
| **Objective of 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. |
| Course Content | Theory<br>Unit-I<br>Physics of remote sensing, electromagnetic 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 and others, Indian Space Programme.<br>Unit-II<br>Satellite Data analysis: Visual interpretation, digital image processing, image pre-processing, image enhancement, image classification and data merging.<br>Unit-III<br>Definition: 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.<br>Unit-IV<br>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. Analytical Hierarchy Process, Object oriented GIS–AM/FM/ GIS, Web Based GIS.<br>Unit-V<br>Spatial data sources: 4M GIS approach water resources system, Thematic maps, rainfall runoff modelling, groundwater modelling, water quality modelling and flood inundation mapping and modelling. Drought monitoring, cropping pattern change analysis, performance evaluation of irrigation commands. Site selection for artificial recharge, reservoir sedimentation.<br><br>Practical<br>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 |

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| | 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. |
| References: | • Ian HS, Cornelius and Steve C. 2002. An Introduction to Geographical Information Systems. Pearson Education. New Delhi.<br>• James BC and Randolph HW. 2011. Introduction to Remote Sensing. The Guilford Press.<br>• Lilles TM and Kiefer RW. 2008. Remote Sensing and Image Interpretation. John Wiley and Sons.<br>• Paul Curran PJ. 1985. Principles of Remote Sensing. ELBS Publications.<br>• Rees WG. 2001. Physical Principles of Remote Sensing. Cambridge University Press. |
| Course Outcomes | At the end of the course, learners will be able<br>CO1: Apply the principles of remote sensing to understand the interactions between electromagnetic radiation and Earth's surface features.<br>CO2: Analyze and interpret satellite imagery using visual and digital image processing techniques to extract relevant information.<br>CO3: Implement GIS concepts and tools to create and manage spatial data, including maps, vectors, and rasters.<br>CO4: Utilize GIS functionalities for thematic mapping, measurements, spatial analysis, and modeling of various environmental phenomena.<br>CO5: Apply remote sensing and GIS technologies to solve |

**Mapping between Cos, POs and PSOs**

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| **Course code** | SWCE 508 |
| **Course title** | Climate Change and Water Resources |
| **Corse credit** | 3+0 |
| **Objective of Course** | 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 |
| Course Content | Theory<br>Unit-I<br>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.<br>Unit-II<br>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.<br>Unit-III<br>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.<br>Unit-IV<br>Adaptation and mitigation water: Related adaptation to climate change in the fields of ecosystems and biodiversity, agriculture and food security, land use and forestry, human health, water supply and sanitation, infrastructure and economy (insurance, tourism, industry and transportation), Adaptation, vulnerability and sustainable development.<br>Unit-V<br>Sector specific mitigation: Carbon dioxide capture and storage (CCS), bio-energy crops, biomass electricity, hydropower, geothermal energy, energy use in buildings, land-use change and management, cropland management, afforestation and reforestation. Potential water resource conflicts between adaptation and mitigation. Implications for policy and sustainable development.<br><br>Case studies: Water resources assessment case studies: Ganga Damodar Project, Himalayan glacier studies, Ganga valley project. Adaptation strategies in assessment of water resources. |

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| | 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. |
| References: | • Srinivasa RK and Nagesh KD. Impact of Climate Change on Water Resources with Modelling Techniques and Case Studies. Springer publications, New York.<br>• Rao YS, Zhang TC Ojha, Gurjar BR, Tyagi RD, Kao CM (eds). Climate Change Modelling, Mitigation, and Adaptation. American Society of Civil Engineers.<br>• Tamim Y and Caitlin AG. Climate Change and Water Resources. Springer Publication.<br>• Majumdar PP and Nagesh KD. Floods in a Changing Climate: Hydrological Modelling. Cambridge University Press, New York.<br>• Pathak H, Agarwal PK and Singh SD. Mitigation in Agriculture: Methodology for Assessment and Application. Division of Environmental Sciences, IARI New Delhi. |
| Course Outcomes | At the end of the course, learners will be able<br>CO1: Explain the dynamics of the climate system, the factors driving climate change, and its characteristics.<br>CO2: Assess the impacts of climate change on water resources, considering both global and Indian scenarios.<br>CO3: Utilize and critically evaluate different tools and models for climate vulnerability assessment in the water sector.<br>CO4: Develop and analyze adaptation and mitigation strategies for water resources management in the face of climate change.<br>CO5: Apply climate change knowledge to real-world water resource management issues through case studies. |

**Mapping between Cos, POs and PSOs**

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| **Course code** | SWCE 509 |
| **Course title** | Numerical Methods in Hydrology |
| **Corse credit** | 2+0 |
| **Objective of Course** | To acquaint students about the concept of linear space, triangular and quadrilateral shape functions, isoparametric elements and transformation of coordinates. |
| Course Content | Theory<br>Unit-I<br>Review of finite difference operators. Concept of linear space and basis functions. Approximating from finite dimensional sub spaces.<br>Unit-II<br>Variational and weighted residual methods. Langrange polynomials. Triangular and quadrilateral shape functions.<br>Unit-III<br>Isoparametric elements and transformation of coordinates. Basis functions in three dimensions.<br>Unit-IV<br>Galerkin finite element solution of Laplace, diffusion and dispersion-convection equations.<br>Unit-V<br>Method of collocation, application in surface and sub surface hydrology. |
| References: | • Bear J and Verruijt A. 1987. Modeling Groundwater Flow and Pollution. 414pp. Dordrecht, Boston.<br>• Carr JR. 1995. Numerical Analysis for the Geological Sciences. 592pp. Prentice-Hall, Englewood Cliffs NJ.<br>• George H and Patricia W. 2000. Numerical Methods in the Hydrological Sciences. American Geophysical Union, Florida Avenue, N.W<br>• Gerald CF. and Wheatley PO. 1999. Applied Numerical Analysis. 6th ed., 768 pp., Addison-Wesley, Reading, MA.<br>• Middleton GV. 2000. Data Analysis in the Earth Sciences using MATLAB 260pp., Prentice Hall, Saddle River NJ.<br>• Wang HF and Anderson MP. 1982. Introduction to Groundwater Modeling: Finite Difference and Finite Element Methods. 237pp., W.H. Freeman and Co., San Francisco. |
| Course Outcomes | At the end of the course, learners will be able<br>CO1: Apply finite difference operators effectively in numerical simulations.<br>CO2: Design and implement finite element solutions using appropriate linear spaces and basis functions.<br>CO3: Utilize variational and weighted residual methods for accurate solution of engineering problems.<br>CO4: Analyze and implement isoparametric elements and |

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| | coordinate transformations in three-dimensional finite element applications.<br>CO5: Solve Laplace, diffusion, and dispersion-convection equations in hydrological systems using the Galerkin finite element method. |

**Mapping between Cos, POs and PSOs**

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| **Course code** | SWCE 510 |
| **Course title** | Dryland Water Management Technologies |
| **Corse credit** | 2+0 |
| **Objective of Course** | 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. |
| Course Content | Theory<br>Unit-I<br>Drought severity assessment: Meteorological, hydrological and agricultural methods. Drought indices. GIS based drought information system, drought vulnerability assessment and mapping using GIS. DPAP programme, 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.<br>Unit-II<br>Stress physiology and crop resistance to drought, adaptation of crop plants to drought, drought management strategies. Preparation of appropriate crop plans for dry land areas. Mid contingent plan for aberrant weather conditions.<br>Unit- III<br>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.<br>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.<br>Unit-IV<br>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.<br>Unit-V<br>Application of aerial photography in surveys and planning of watersheds for rainfed agriculture. Use of Remote Sensing in soil moisture estimation. |
| References: | • Das NR. 2007. Tillage and Crop Production. Scientific Publishers.<br>• Dhopte AM. 2002. Agro Technology for Dryland Farming. Scientific Publ.<br>• Gupta US. 1995. Production and Improvements of Crops for Drylands. Oxford & IBH<br>• Singh RP. 1988. Improved Agronomic Practices for Dryland Crops. CRIDA. |

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| | • Singh RP. 2005. Sustainable Development of Dryland Agriculture in India. Scientific Publ.<br>• Singh RV. 2003. Watershed Planning and Management. Second Edition. Yash Publishing House, Bikaner.<br>• Singh SD. 1998. Arid Land Irrigation and Ecological Management. Scientific Publishers. |
| Course Outcomes | At the end of the course, learners will be able<br>CO1: Apply and interpret different drought indices and GIS-based information systems to evaluate drought severity and vulnerability.<br>CO2: Explain the physiological mechanisms of drought stress in crops and propose strategies for enhancing drought resistance and adapting cropping practices.<br>CO3: Design and implement land shaping, tillage, and soil moisture conservation practices suitable for dryland agriculture.<br>CO4: Design and construct efficient ex-situ water harvesting structures like farm ponds and percolation tanks to optimize water use for crop production.<br>CO5: Utilize aerial photography and remote sensing techniques for soil moisture estimation and planning of rainfed agricultural watersheds. |

**Mapping between Cos, POs and PSOs**

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|---|---|
| **Course code** | SWCE 601 |
| **Course title** | Advances in Hydrology |
| **Corse credit** | 2+1 |
| **Objective of Course** | To provide comprehensive knowledge to the students about hydrologic models, flood frequency analysis and formulation of statistical models. |
| Course Content | Theory<br>Unit-I<br>Hydrologic models, processes and systems. Uncertainty in hydrological events. Statistical homogeneity.<br>Unit-II<br>Probabilistic concept. Frequency analysis. Probability distribution of hydrological variables. Confidence intervals and hypothesis testing.<br>Unit-III<br>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.<br>Unit-IV<br>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.<br>Unit-V<br>Formulation of various steps involved in formulation of statistical models and their application in hydrology.<br><br>Practical<br>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 modeling. |
| References: | • Garg SK 1987. Hydrology and Water Resources Engineering. Khanna Publications.<br>• Hann CT. Advanced Statistical Methods in Hydrology. Oxford Publications House New Delhi<br>• Linseley RK Jr, Kohler MA and Paulhus JLH. 1975. Applied Hydrology. McGraw Hill.<br>• Maity R. 2018. Statistical Methods in Hydrology and Hydro-climatology. Springer, New York<br>• Mutreja KN. 1986. Applied Hydrology. Tata McGraw Hill.<br>• Ramesh SV Teegavarapu, Salas JD and Stedinger JR. 2019. Statistical Analysis of Hydrologic Variables: Methods and Applications, ASCE Publication 1801 Alexander Bell Drive Reston, VA |

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| | • Singh VP. 1988. Hydrologic Systems: Rainfall-Runoff Modeling (Vol.I) – Prentice Hall, New York. |
| Course Outcomes | CO1: Analyze the characteristics and uncertainties of hydrological models, processes, and systems.<br>CO2: Apply probabilistic concepts and frequency analysis to assess flood risks and predict extreme events in hydrology.<br>CO3: Develop and evaluate statistical models for hydrological time series using techniques like linear regression, correlation analysis, and time series analysis.<br>CO4: Utilize stochastic models and understand the importance of Markov processes in simulating and generating random hydrological data.<br>CO5: Formulate and apply statistical models to real-world hydrological problems using software like SPSS and other relevant tools. |

**Mapping between Cos, POs and PSOs**

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| **Course code** | SWCE 602 |
| **Course title** | Soil and Water Systems Simulation and Modeling |
| **Corse credit** | 2+1 |
| **Objective of Course** | To acquaint students about the rainfall-runoff models, sediment model, overland and channel flow simulation and decision support systems using simulation models. |
| Course Content | Theory<br>Unit-I<br>Models and their classification, simulation procedure. Rainfall-runoff models. Infiltration models, evapo-transpiration models, structure of a water balance model.<br>Unit-II<br>Overland and channel flow simulation. Modeling approaches and parameters. Stream flow statistics. Surface water storage requirements.<br>Unit-III<br>Flood control storage capacity and total reservoir capacity. Surface water allocations. Palaeo- channels. Ground water models.<br>Unit-IV<br>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.<br>Unit-V<br>Stanford watershed model and input data requirements of various hydrologic modeling systems. Soil water assessment tool (SWAT). Groundwater modeling and solute transport.<br><br>Practical<br>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 modeling system. Soil water management model. Soil water assessment tool (SWAT). Catchments simulation hydrology model. Stream flow model and use of dimensionless unit hydrograph. Generalized groundwater models. |
| References: | • Biswas AK. 1976. Systems Approach to Water Management. McGraw Hill.<br>• Cox DR and Mille HD. 1965. The Theory of Stochastic Processes. John Wiley & Sons.<br>• Eagleson PS. 1970. Dynamic Hydrology. Mc Graw Hill.<br>• Himmel Blau DM and Bischoff KB. 1968. Process Analysis and Simulation Deterministic Systems. John Wiley & Sons.<br>• Linsley RK, Kohler MA and Paulhus JLH. 1949. Applied Hydrology. Mc Graw Hill.<br>• Schwar RS and Friedland B. 1965. Linear Systems. Mc Graw Hill. |

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| | • Ven Te Chow, David R Maidment and Mays LW. 1998. Applied Hydrology. McGraw Hill. |
| Course Outcomes | CO1: Understand and classify different hydrological models, including rainfall-runoff, infiltration, evapotranspiration, and water balance models, and learn their simulation procedures.<br>CO2: Analyze overland and channel flow using various modeling approaches and parameters, and calculate streamflow statistics and surface water storage requirements.<br>CO3: Design and assess flood control storage capacity, total reservoir capacity, and surface water allocations, considering paleohydrological data and groundwater modeling.<br>CO4: Develop and implement nodal network models within a general systems framework, accounting for irregular boundaries and applying decision support systems and Monte Carlo simulations for water management.<br>CO5: Utilize specific hydrological modeling software like Stanford Watershed Model (SWM), SWAT, and groundwater models to solve real-world water resource problems, understanding their input data requirements. |

**Mapping between Cos, POs and PSOs**

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| **Course code** | SWCE 603 |
| **Course title** | Reservoir Operation and River Basin Modeling |
| **Corse credit** | 2+1 |
| **Objective of Course** | 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. |
| Course Content | Theory<br>Unit-I<br>Water resources system analysis: Techniques, concept, objectives and applications.<br>Unit-II<br>Identification and evaluation of water management plans. Demand analysis, policy formulation. Water resources planning objectives. Water resources planning under uncertainty.<br>Unit-III<br>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.<br>Unit-IV<br>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.<br>Unit-V<br>Stochastic river basin modeling: Single reservoir design and operation, multisite river basin models, stochastic linear programming operation models.<br><br>Practical<br>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. |
| References: | • Chaturvedi MC. 1984. System Approach to Water Resources Planning and Management.<br>• Loucks DP et al. 1980. Water Resources System Planning and Analysis. Prentice Hall, NJ.<br>• Major DC and Lenton RL. 1979. Applied Water Resources System Planning. Prentice Hall Inc. New Jersey. |
| Course Outcomes | CO1: Apply various techniques for water resources system analysis, understanding its concepts, objectives, and diverse applications. |

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| | CO2: Identify and evaluate water management plans through demand analysis, policy formulation, and consideration of uncertainties in planning.<br>CO3: Master the theories and principles of Integrated River Basin Management (IRBM) processes and phases, analyzing the functions of river basins and human impacts, with a focus on Indian basins and case studies.<br>CO4: Utilize statistical methods, decision support systems, and deterministic river basin models for streamflow estimation, reservoir storage management, mass diagram analysis, peak flow analysis, and single/multi-reservoir operation models.<br>CO5: Implement stochastic river basin modeling approaches for single reservoir design and operation, multisite basin models, and stochastic linear programming operation models, applying these models to real-world river basin problems. |

**Mapping between Cos, POs and PSOs**

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| **Course code** | SWCE 604 |
| **Course title** | Modeling Soil Erosion Processes and Sedimentation |
| **Corse credit** | 2+1 |
| **Objective of Course** | To acquaint students about the concept of modeling upland erosion, reservoir sedimentation and sediment yield models for estimation of soil erosion. |
| Course Content | Theory<br>Unit-I<br>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.<br>Unit-II<br>Modeling upland erosion and component processes. Modes of transport and transport capacity concept and computation. Channel erosion. Erosion and sediment yield measurement and estimates.<br>Unit-III<br>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.<br>Unit-IV<br>Calibration and testing of models. Universal soil loss equation, its modification and revisions. Stochastic and dynamic sediment yield models.<br>Unit-V<br>Evaluation of erosion control measures. Computer models used for hydrologic and/or watershed modeling.<br><br>Practical<br>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. |
| References: | • Garde RJ and Ranga Raju KG. 1977. Mechanics of Sediment Transport and Alluvial Stream Problems. Wiley Eastern Ltd.<br>• Morgan RPC (Ed. DA Davison). 1986. Soil Erosion and Conservation. ELBS.<br>• Longman USDA .1969. A Manual on Conservation of Soil and Water. Oxford & IBH.<br>• Tripathi RP and Singh HP. 1993. Soil Erosion and Conservation. Publisher- New Age International New Delhi. |
| Course Outcomes | CO1: Understand the mechanics of soil erosion within small watersheds, including overland flow theory, sediment transport processes, and deposition mechanisms.<br>CO2: Analyze and model upland erosion using various |

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| | approaches, focusing on transport modes, transport capacity, and channel erosion. Assess erosion and sediment yield through measurements and estimation techniques.<br>CO3: Apply knowledge of sediment properties and critical forces to reservoir sedimentation surveys and computations, understanding the classification and mathematical bases of sediment yield models.<br>CO4: Calibrate and test sediment yield models, including the Universal Soil Loss Equation and its modifications, recognizing the role of stochastic and dynamic models.<br>CO5: Evaluate the effectiveness of erosion control measures and utilize computer models for hydrologic and watershed modeling to address soil erosion challenges. |

**Mapping between Cos, POs and PSOs**

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| **Course code** | SWCE 605 |
| **Course title** | Waste Water Treatment and Utilization |
| **Corse credit** | 3+0 |
| **Objective of Course** | To acquaint students about types of waste water and the various treatment measures alongwith the utilization of waste water in agriculture and other sectors. |
| Course Content | Theory<br>Unit-I<br>Types of waste water, causes of pollution, analysis of pollutants in the waste effluents, Biological wastewater 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.<br>Unit-II<br>Sewerage system: Domestic wastewater characteristics, flow equalization, population equivalent, treatment flow chart. Primary, secondary and tertiary treatment of domestic wastewater. Downstream wastewater treatment for reuse and recycle. Need for downstream processing. Guidelines for wastewater recycling. Small and package plants for wastewater treatment.<br>Unit-III<br>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.<br>Unit-IV<br>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.<br>Unit-V<br>Biofilm process: Trickling filter, biotower, 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.<br><br>Practical<br>Study on physical, chemical and biological parameters of wastewater. Determination of EC and pH of wastewater Determination of BOD of wastewater. Determination of COD of |

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| | wastewater. Determination of TSS and TDS of wastewater. Determination RSC of wastewater. Determination of e-coli in the wastewater .On field demonstration of wastewater use for the irrigation. Determination of nutrient (N, P and K) concentration in wastewater. Field demonstration of impact of waste water on eco-system and human health. Study on various wastewater treatment methods. Study on effect of wastewater on contamination of ground water. Visit of village pond treatment nearby area. Visit of sewerage treatment plant nearby area. |
| References: | • Metcalf and Eddy 2003. Wastewater Engineering. 4th Ed., McGraw Hill.<br>• Droste RL. 1997. Theory and Practice of Water and Wastewater Treatment. John Wiley.<br>• Qasim SR. 1999. Wastewater Treatment Plants – Planning, Design and Operation. CRC Press, Florida.<br>• Ramalho RS. Wastewater Treatment. Wiley. |
| Course Outcomes | CO1: Understand the characteristics of wastewater, causes of pollution, analysis of pollutants, and biological treatment principles, including microbiology, biochemistry, kinetics, and reactor analysis.<br>CO2: Analyze and design sewerage systems, including domestic wastewater characteristics, treatment flow charts, primary, secondary, and tertiary treatment processes, and downstream processing for reuse and recycle.<br>CO3: Master the Activated Sludge Process (ASP) in detail, covering substrate utilization, kinetics, process description, design, performance evaluation, trouble shooting, and nitrogen removal mechanisms.<br>CO4: Design and operate ASP for nutrient removal, understanding F/M ratio, mean cell residence time, oxygen requirements, biological and chemical phosphorus removal, sedimentation, and advanced variations like SBR, oxidation ditch, and membrane bioreactors.<br>CO5: Analyze and apply biofilm processes like trickling filter, biotower, and RBC, and stabilization ponds, including their design, operation, and maintenance. Explore anaerobic processes, sludge treatment, and utilization of treated wastewater in agriculture and other sectors. |

**Mapping between Cos, POs and PSOs**

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| **Course code** | SWCE 606 |
| **Course title** | Hydro-Chemical Modeling |
| **Corse credit** | 2+0 |
| **Objective of Course** | To provide comprehensive knowledge to the students about hydrodynamics of flow through porous media and development of analytical, statistical and numerical models. |
| Course Content | Theory<br>Unit-I<br>Review of hydrodynamics in flow through porous media. Miscible displacement, physical processes.<br>Unit-II<br>Breakthrough curves and mathematical models for miscible displacement. Hydrodynamic dispersion convection equations and its solutions.<br>Unit-III<br>Statistical models for dispersion. Gaseous (CO2 and O2) diffusion equation.<br>Unit-IV<br>Heat flow through soil by conduction. Concept of adsorption in solute transport.<br>Unit-V<br>Analytical and numerical models of contaminant transport in unsaturated soil profile and groundwater aquifers. |
| References: | • Larry W Mays 1996. Water Resources Handbook. Mc Graw Hill.<br>• Metcalf and Eddey 1994. Wastewater Treatment Engineering and Reuse. John Wiley.<br>• Soli J Arceivala 1998. Wastewater Treatment for Pollution Control. Tata Mc Graw-Hill. |
| Course Outcomes | CO1: Apply fundamental principles of hydrodynamics to understand flow through porous media and the physical processes involved in miscible displacement of fluids.<br>CO2: Analyze breakthrough curves and develop mathematical models to predict the behavior of miscible displacement, including the use of hydrodynamic dispersion-convection equations and their solutions.<br>CO3: Employ statistical models to assess dispersion in porous media and solve the gaseous diffusion equation for CO2 and O2 transport.<br>CO4: Understand and apply the concept of adsorption in solute transport, analyzing its influence on contaminant movement.<br>CO5: Implement analytical and numerical models to simulate contaminant transport in unsaturated soil profiles and groundwater aquifers, enabling the prediction of contaminant spread and potential remediation strategies. |

**Please refer mapping of PO and PSO for the style of mapping.**

**Mapping between Cos, POs and PSOs**

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| **Course code** | **CSE 501** |
| **Course title** | **Big Data Analytics** |
| **Corse credit** | **3 (2+1)** |
| **Objective of Course** | 1. To understand principles of analyzing and mining big data<br>2. to use simple tools to extract useful information from big data sets |
| Course Content | Unit I<br><br>Data analysis, data matrix attributes. Data: Algebraic and geometric view, probabilistic view.<br><br>Unit II<br><br>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.<br><br>Unit III<br><br>Data mining models and methods, correlation, association rules, k-means, clustering understanding of concept, preparation and modeling.<br><br>Unit IV<br><br>Discriminant analysis, linear regression, logistic regression, understanding, preparation and modeling.<br><br>Unit V<br><br>Decision trees, neural networks, understanding, preparation and modeling.<br><br>**Practical**<br><br>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. |
| References: | ▪ Dr Matthew North Data Mining for the Masses A Global Text Project Book ISBN: 0615684378ISBN-13: 978-0615684376.<br>▪ Mohammed J Z, Troy and Wagner M Jr. Data Mining and |

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| | Analysis: Fundamental Concepts and Algorithms. Universidade Federal de Minas Gerais, Brazil. Cambridge University Press ISBN 978-0-521-76633-3 Hardback |
| Course Outcomes | At the end of the course, learners will be able<br>**CO1**: Capability to understand the principles behind analysis of big data<br>**CO2**:apply the same using simple tools |

**Mapping between Cos, POs and PSOs**

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| **Course code** | **CSE 502** |
| **Course title** | **Artificial Intelligence** |
| **Corse credit** | **3 (2+1)** |
| **Objective of Course** | 1. To introduce students with techniques and capabilities of artificial intelligence (AI)<br>2. To enable student to do simple exercises of AI |
| Course Content | **Theory**<br>**Unit I**<br>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.<br>**Unit II**<br>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.<br>**Unit III**<br>Problem solving using AI, search techniques, breadth first search, depth first search, depth limited search, bidirectional |

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| | search, heuristic search, problems and examples. Knowledge representation, frames, methods and demons, correlations, decision trees, fuzzy trees.<br><br>**Unit IV**<br><br>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.<br><br>**Unit V**<br><br>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.<br><br>**Practical**<br><br>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. |
| References: | ▪ 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.<br>▪ Ivan Bratko, Prolog Programming for Artificial Intelligence.<br>▪ Warwick K. 2012. Artificial Intelligence: The Basics ISBN: 978-0-415-56482-3 (hbk). |
| Course Outcomes | At the end of the course, learners will be able<br>**CO1**: Ability to understand and apply principles of AI in solving simple problems<br>**CO2**: to enable them to get insight into working of AI based systems. |

**Mapping between Cos, POs and PSOs**

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| **Course code** | **CSE 503** |
| **Course title** | **Neuro-Fuzzy Application in Engineering** |
| **Corse credit** | **3 (2+1)** |
| **Objective of Course** | 1. To learn the basic concept of neural network models and fuzzy logic based models<br>2. apply fuzzy reasoning and fuzzy inference to solve various agricultural engineering problems |
| Course Content | **Theory**<br><br>**Unit I**<br><br>Basic concepts of neural networks and fuzzy logic, differences between conventional computing and neuro-fuzzy computing, characteristics of neuro-fuzzy computing.<br><br>**Unit II**<br><br>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 reasoning and modelling in engineering problems.<br><br>**Unit III**<br><br>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.<br><br>**Unit IV**<br><br>Neuro–fuzzy modelling: Neuro-fuzzy inference systems, neuro-fuzzy control.<br><br>**Unit V**<br><br>Applications of neuro-fuzzy computing: Time series analysis and modelling, remote sensing, environmental modelling.<br><br>**Practical**<br><br>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 |

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| | 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. |
| References: | ▪ Jang, JS R, Sun C Tand Mizutan E 1997. Neuro-Fuzzy and Soft Computing. Prentice Hall<br>▪ Simon Haykin NJ. 1994. Neural Networks. A Comprehensive Foundation. McMillan College Publishing Company.<br>▪ Klir George J and Forger TA. 1995. Fuzzy Sets, Uncertainty and Information. Prentice Hall of India, Pvt. Ltd, New Delhi.<br>▪ Kosko B. 1997. Neural Networks and Fuzzy Systems. Prentice Hall of India Pvt. Ltd, New Delhi.<br>▪ Rao V and Rao H. 1996. C++ Neural Networks and Fuzzy Logic. BPB Publications, New Delhi. |
| Course Outcomes | At the end of the course, learners will be able<br>**CO1**: The students will be able to have the basic concept of neural network models and fuzzy logic-based models<br>**CO2**: The students will be in a position to apply fuzzy reasoning and fuzzy inference for various problems of agricultural engineering.<br>**CO3:** They will also learn to develop different types of neural network models. |

**Mapping between Cos, POs and PSOs**

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| **Course code** | **CSE 504** |
| **Course title** | **Soft Computing Techniques in Engineering** |
| **Corse credit** | **3 (2+1)** |
| **Objective of Course** | 1. To learn the basic concepts of soft computing techniques like neural networks, genetic algorithms and fuzzy systems.<br>2. To apply these techniques for real time problem solving. |
| Course Content | **Theory**<br><br>**Unit I**<br><br>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 preprocessing: Scaling, Fourier transformation, principle component analysis and wavelet transformations.<br><br>**Unit II**<br><br>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.<br><br>**Unit III**<br><br>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.<br><br>**Unit IV**<br><br>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.<br><br>**Unit V**<br><br>Fuzzy modeling and control schemes for nonlinear systems. |

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| | 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.<br><br>**Practical**<br><br>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. |
| References: | ▪ David EG. Genetic Algorithms.<br>▪ Rajasekaran S and Vijayalakshmi Pai GA. 2017.Neural Networks, Fuzzy Logic and Genetic Algorithm, Synthesis and Applications. PHI Learning Pvt. Ltd.<br>▪ Ross TJ. 1997. Fuzzy Logic with Fuzzy Applications. McGraw Hill Inc.<br>▪ Simon H. 2003. Neural Networks: A Comprehensive Foundation. Pearson Edition.<br>▪ Sivanandam SN and Deepa SN. 2011. Principles of Soft Computing. Wiley India Pvt. Ltd., 2nd Edition.<br>▪ Sivanandam SN and Deepa SN. 2013. Principles of Soft Computing. Wiley India. |
| Course Outcomes | At the end of the course, learners will be able<br>**CO1**: To enable students to apply modern engineering techniques which are useful for solving nonlinear and complex functions.<br>**CO2:** To develop application of different soft computing techniques like genetic algorithms, fuzzy logic, neural networks and their combination to real world problems. |

**Mapping between Cos, POs and PSOs**

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| **Course code** | **CSE 505** |
| **Course title** | **Database Management System** |
| **Corse credit** | **3 (2+1)** |
| **Objective of Course** | 1. To understand the basic concept of database system technologies<br>2. To learn security and backup/recovery issues of Relational database model.<br>3. To learn usage of database functions and SQL concepts |
| Course Content | **Theory**<br>Unit I<br>Database system - Operational Data, Characteristics of database approach, architecture.<br>Unit II<br>Overview of DBMS; Data associations - Entities, Attributes and Associations, Relationship among Entities, Representation of Associations and Relationship, Data Model classification.<br>Unit III<br>Entity Relationship model; Relational Data Structure- Relations, Domains and Attributes, Relational Algebra and Operations, Retrieval Operations.<br>Unit IV<br>Relational Database Design - Anomalies in a Database, Normalization Theory, and Normal forms; Query processing.<br>Unit V<br>Distributed Databases- concepts, architecture, design; Structured Query Language (SQL) - Data Definition Language (DDL), Data Manipulation Language (DML).<br>Unit VI<br>PL/SQL - Stored procedure, Database triggers; Relational Data Base Management Package.<br>**Practical:**<br>E-R diagram construction; SQL - Command Syntax, Data types, DDL Statements, DML Statements, integrity constraints; Triggers, creating stored procedures/functions; Normalization of database and Case study on a database design and implementation. |

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| References: | ▪ Date C.J. 2000. Introduction to Database System. Addison Wesley.<br>▪ Desai B.C. 2000. Introduction to Database Systems. Galgotia Publ.<br>▪ Elmasri and Navathe. 2006. Fundamentals of Database Systems. 4th Ed. Addison Wesley.<br>▪ Garcia-Molina H., Ullman J.D. and Widom J. 2013. Database Systems: The Complete Book. Prentice Hall.<br>▪ Rob P. and Coronel C. 2006. Database Systems: Design, implementation and Management. 7th Ed. Thomson Learning.<br>▪ Silberschartz A, Korth H.F. and Sudarshan S. 1997. Database Systems Concepts. Tata McGraw Hill. |
| Course Outcomes | At the end of the course, learners will be able<br>**CO1:** explain the concepts of database<br>**CO2:** perform security and backup/recovery issues in RDBMS.<br>**CO3:** perform database operations and expertise in SQL. |

**Mapping between Cos, POs and PSOs**

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| **CO2** | | | | | | | | | | | | | | | |
| **CO3** | | | | | | | | | | | | | | | |
| **CO4** | | | | | | | | | | | | | | | |
| **CO5** | | | | | | | | | | | | | | | |

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| **Course code** | **CSE 506** |
| **Course title** | **Digital Image Processing** |
| **Corse credit** | **3 (2+1)** |
| **Objective of Course** | 1. To understand basic of digital image processing.<br>2. To learn visual perception, image formation, spatial transformations, image enhancement, color image representation and processing, edge detection, image segmentation and morphological image processing |
| Course Content | **Theory**<br><br>**Unit I** |

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| | 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.<br><br>**Unit II**<br><br>Image enhancement in the spatial domain, basic gray level transformations, histogram processing, basics of spatial filtering, smoothing spatial filters, sharpening spatial filters.<br><br>**Unit III**<br><br>Color image processing, color fundamentals, color models, pseudo color image processing, basics of full-color image processing, color transformations, smoothing and sharpening, color segmentation.<br><br>**Unit IV**<br><br>Image segmentation, detection of discontinuities, edge linking and boundary detection, thresholding, region-based segmentation, segmentation by morphological watersheds.<br><br>**Unit V**<br><br>Morphological image processing, dilation and erosion, opening and closing, extensions to gray-scale images.<br><br>**Practical**<br><br>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. |
| References: | ▪ Jayaraman S, Esakkirajan S and Veerakumar T. Digital Image Processing. Tata McGraw Hill Publication.<br>▪ Rafael CG and Richard EW. Digital Image Processing. Third Edition, Pearson Education.<br>▪ Sridhar S. Digital Image Processing. Oxford University Press |
| Course Outcomes | At the end of the course, learners will be able<br>**CO1:** explain the concepts of digital image processing<br>**CO2:** perform algorithms underlying a range of tasks including acquisition, formation, enhancement, segmentation and representation. |
| **Mapping between Cos, POs and PSOs** | |

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| **Course code** | **CSE 507** |
| **Course title** | **Process Control System** |
| **Corse credit** | **3 (2+1)** |
| **Objective of Course** | 1. To learn the principles behind systems for industrial automation and control especially with respect to electronically implemented systems |
| Course Content | **Unit I**<br><br>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.<br><br>**Unit II**<br><br>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.<br><br>**Unit III**<br><br>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.<br><br>**Unit IV**<br><br>Control systems: Electric drives, introduction, energy saving with adjustable speed drives stepper motors, principles, |

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| | construction and drives. DC motor drives: Introduction to DC-DC converters, adjustable speed drives. Induction motor drives: Introduction, characteristics, adjustable speed drives. Synchronous motor drivemotor principles, adjustable speed and servo drives.<br><br>**Unit V**<br><br>Networking of sensors, actuators and controllers, the fieldbus, the fieldbus communication protocol, introduction to production control systems.<br><br>**Practical**<br><br>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. |
| References: | ▪ https://nptel.ac.in/downloads/108105063/<br>▪ Manesis S and Nikolakopoulos G. 2018. Introduction to Industrial Automation. 1st Edition, CRC Press. Textbook-ISBN 9781498705400-CAT#K24766 |
| Course Outcomes | At the end of the course, learners will be able<br>**CO1:** Understanding of the principles behind implementation of systems for automation and control. |

**Mapping between Cos, POs and PSOs**

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| **Course code** | **CE 501** |
| **Course title** | **Dimensional Analysis and Similitude** |
| **Course credit** | **2+0** |
| **Objective of Course** | 1. Grasp the fundamentals of dimensional analysis methods like Rayleigh's method and Buckingham-Pi theorem, applying them across diverse applications.<br>2. Acquire knowledge of model studies, dimensionless numbers (Reynolds, Froude, etc.), scale effects, and their significance in modeling.<br>3. Develop proficiency in understanding similitude laws, force ratios, and their application in physical models, specifically for nonlinear problem-solving.<br>4. Apply mathematical modeling principles, including model formulation, steady-state and dynamic simulations, and analysis of design variables. |
| Course Content | **Theory :**<br><br>**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.<br><br>**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.<br><br>**Unit III :**Similitude: Types of similarities (geometric-kinematic and dynamic similarity), force ratios,similarity laws. Model analysis: Physical models. Similarity methods for nonlinear problem typesof models, Scale effect. Numerical problems on Reynolds's and Froude's Model.<br><br>**Unit IV:** Use and scope of mathematical modelling, Principles of model formulation, Role and importanceof steady-state and dynamic simulation, Classification of models,<br>Model building, Modelling difficulties, Degree-of-freedom analysis, Selection of design |

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| | variables. |
| References: | **Suggested Reading**<br>• Barenblatt GI. 1987. Dimensional Analysis. Gordon and Breach Science, New York.<br>• Langhar HL. 1951. Dimensional Analysis and the Theory of Models. Wiley, New York.<br>• Murphy G. 1950. Similitude in Engineering. The Ronald Press Company, New York.<br>• Zohuri Bahman. Dimensional Analysis and Self-Similarity Methods for Engineers and<br>• Scientists. Springer Publications, New York |
| Course Outcomes | CO1: Demonstrate mastery in applying dimensional analysis methods like Rayleigh's and Buckingham-Pi theorem across diverse applications.<br><br>CO2: Exhibit proficiency in comprehending model studies, dimensionless numbers, and their relevance in modeling various scenarios.<br><br>CO3: Apply similitude concepts effectively, employing force ratios and similarity laws for problem-solving in physical models.<br><br>CO4: Demonstrate practical application of mathematical modeling principles, simulation significance, and handling complexities in diverse scenarios**.** |

**Mapping between Cos, POs and PSOs**

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| **CO2** | | | | | | - | - | - | - | - | | | | | |
| **CO3** | | | | - | - | - | - | - | - | - | | | | | |
| **CO4** | | | | | - | - | - | - | - | - | | | | | |

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| **Course code** | **CE 502** |
| **Course title** | **Water Quality and Pollution Control** |
| **Course credit** | **2+1** |
| **Objective of Course** | 1. Comprehend the physical and chemical properties of water, including major ions, suspended solids, EC, and pH, and their impact on water quality.<br>2. Develop skills in conducting water quality investigations, |

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| | encompassing sampling, data collection, analysis, and interpretation using field kits, samplers, and software packages.<br>3. Acquire knowledge about sources and types of pollution, BOD-DO relationships, non-point source pollution, and various water treatment technologies.<br>**4.** Understand multiple uses of water, water reclamation techniques, and the principles behind low-cost wastewater treatment methods and desalination**.** |
| Course Content | **Theory**<br><br>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.<br><br>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 wetland Agricultural Engineering: Soil and Water Conservation Engineering<br><br>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.<br><br>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.<br><br>Unit V : Determination of pH, total solids, dissolved and |

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| | 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.<br><br>**Practicals:**<br><br>1. Determination of pH, total solids, dissolved and suspended solids<br>2. Determination of chlorides, sulphates, turbidity<br>3. Dissolved oxygen, hardness<br>4. Preparation of water quality map of watershed in GIS environment<br>**5.** Visit of water polluted site of nearby area |
| References: | Suggested Reaadings<br>• Abbasi T and Abbasi SA. Water Quality Indices. Elsevier Publications, New York.<br>• Chin and David A. 2006. Water Quality Engineering in Natural Systems. Wiley – Interscience. Claude E. Boyd. Water Quality an Introduction. Springer Publications.<br>• 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.<br>• Thomann RV and Mueller JA. 1987. Principles of Surface Water Quality Modelling and Control. Harper and Row Publishers.<br>• Wesley W, Wallender PE and Kenneth K. Tanji, Sc.D. Agricultural Salinity Assessment and Management. ASCE Press |
| Course Outcomes | **CO1:** Demonstrate a comprehensive understanding of water quality parameters and their impact on environmental health.<br><br>**CO2:** Exhibit proficiency in assessing water quality parameters like pH, solids, chlorides, turbidity, and dissolved oxygen, and utilize GIS for water quality mapping.<br><br>**CO3:** Apply knowledge of pollution sources and treatment technologies in addressing and controlling water pollution. |

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| | **CO4:** Apply principles of water reclamation, reuse, and treatment to effectively utilize poor-quality water resource |
| **Mapping between Cos, POs and PSOs** | |

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| **Course code** | **CE 510** |
| **Course title** | **Experimental Stress Analysis** |
| **Course credit** | **2+1** |
| **Objective of Course** | 1. Develop a deep comprehension of stress-strain connections, encompassing Generalized Hooke's Law and its practical implications in diverse material analyses.<br>2. Attain adeptness across a spectrum of strain measurement methods, including diverse strain gauge applications, rosette analysis, and specialized temperature-based measurements.<br>3. Acquire expertise in employing sophisticated methods for strain analysis such as photoelasticity, brittle coating, Moiré's technique, and grid analysis for accurate stress evaluations.<br>4. Apply theoretical knowledge to solve genuine engineering challenges, selecting and utilizing appropriate strain analysis techniques in practical situations. |
| Course Content | **Theory**<br>Unit I: Strain and stress – strain relationship. Generalized Hook’s Law. Strain Gauges Mechanical, optical, electrical, acoustical and pneumatic etc and their use.<br><br>UNIT II: Different types of electrical resistance strain gauges. Semi-conductor strain gauges. Rosette analysis. Strain gauge circuits. Strain measurements at high temperatures.<br><br>Unit III: Two dimensional and three-dimensional photo-elastic method of strain analysis. Bifringent coatings and |

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| | scattered light in photoelasticity.<br><br>Unit IV: Brittle coating methods. Moiré's method of strain analysis. Grid method of strain analysis. Photo elastic strain gauges.<br><br>**Practicals:**<br><br>1. Cementing of an electrical resistance strain gage on a structural member<br>2. To find the gage factor for a resistance type strain gage.<br>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.<br>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.<br>5. Deter mine the tension produced in a circular shaft by using strain gages cemented perpendicular to each other.<br>6. Determine the bending moment produced in a circular shaft by using a rectangular shaft<br>7. To align the circular polariscope<br>8. Study the plane polariscope and circular polariscope with different light field arrangements.<br>9. Study of Moiré fringe apparatus and its applications in analysis of structures.<br>10. Calibrate the photoelastic material by use of rectangular beam under pure bending. |
| References: | Suggested Reading<br>• Srinath LS, Raghavan MR, Lingaiah K, Gargesha G, Pant B and Ramachandra K. *Experimental Stress Analysis*, McGraw-Hill.<br>• Dally JW and Riley WF. *Experimental Stress Analysis*, McGraw-Hill.<br>• Singh S. *Experimental Stress Analysis*, Khanna Publishers. |
| Course Outcomes | **CO1:** Demonstrate an in-depth comprehension of stress-strain dynamics, proficiently applying Generalized Hooke's Law for material analysis and structural assessments.<br>**CO2:** Display advanced skills in employing varied strain measurement tools, especially semiconductor gauges, rosette analysis, and high-temperature strain assessments. |

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| | **CO3:** Showcase mastery in utilizing intricate strain analysis approaches like photoelasticity, brittle coating, Moiré's method, and grid analysis within practical engineering settings.<br>**CO4:** Demonstrate practical application of diverse strain analysis techniques to effectively resolve engineering problems, adapting techniques based on specific contextual needs. |

**Mapping between Cos, POs and PSOs**

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| CO4 | | | | - | | | - | | - | - | - | - | | | |

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| **Course code** | **ME 501** |
| **Course title** | **Mechatronics and Robotics in Agriculture** |
| **Corse credit** | **2 (2+0)** |
| **Objective of Course** | **Objective**<br><br>1.To acquaint and equip the students with important terminologies of mechatronics<br><br>2. To acquaint and equip with knowledge of interface and control<br><br>3. To introduce concepts behind designing mechatronic<br><br>4. To introduce application of mechatronics, automation in agriculture |
| Course Content | **Unit I**<br><br>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.<br><br>**Unit II**<br><br>System interfacing, instrumentation, and control systems. Input /output signals of a mechatronic system, signal conditioning, microprocessor control, microprocessor numerical control, microprocessor input/output control.<br><br>**Unit III**<br><br>Microprocessor based controllers and microelectronics: Introduction to microelectronics, digital logic, overview of control computers, microprocessors and microcontrollers, programmable logic controllers, digital communications.<br><br>**Unit IV**<br><br>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.<br><br>**Unit V**<br><br>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 aerobots in agriculture. |

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| References: | Alciatore DG and Histand MB. 2002. Introduction to Mechatronics and Measurement System.McGraw Hill Pvt Limited, New Delhi.<br><br>Robert HB. 2002. Mechatronic Hand Book. CRC Press.<br><br>Shakhatreh and Fareed. 2011. The Basics of Robotics. Lahti University of Applied Sciences Machine and Production Technology. |
| Course Outcomes | At the end of the course, learners will be able.<br>agricultural machinery that is and<br><br>**CO1:** Ability to understand mechatronics.<br><br>**CO2:** To understand on concepts of mechatronics.<br><br>**CO3:** Apply, execute and control automation in agriculture machines.<br><br>**CO4:** ability to use robotic machinery in agriculture. |

**Mapping between Cos, POs and PSOs**

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| **Course code** | **ME 502** |
| **Course title** | **Refrigeration Systems** |
| **Corse credit** | **3 (2+1)** |
| **Objective of Course** | 1. To explain the working of Carnot, Brayton, and aircraft refrigeration systems<br><br>2. To acquire the skills required to understand VCRS and its working terminologies.<br><br>3. To acquire the skills required to understand VARS and its working terminologies.<br><br>4. To analyses, and design different refrigeration processes and components |

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| Course Content | **Unit I**<br><br>Reversed Carnot cycle, Carnot, Brayton, and aircraft refrigeration systems.<br><br>**Unit II**<br><br>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.<br><br>**Unit III**<br><br>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.<br><br>**Unit IV**<br><br>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.<br><br>**Practical**<br><br>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 applicationof 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 COPof Cascade Refrigeration System, Visit to cold storage plants. |
| References: | Ahmadul A. Refrigeration and Air Conditioning. PHI India.<br>Arora CP. Refrigeration and Air Conditioning. McGraw-Hill India Publishing Ltd.<br>Arora R. Refrigeration and Air Conditioning. Prentice Hall of India.<br>Crouse and Anglin. Automobile Air Conditioning. McGraw Hill Publications.<br>Dossat RJ. Principles of Refrigeration. Pearson Education.<br>Jordon and Prister. Refrigeration and Air Conditioning. Prentice Hall of India Pvt. Ltd.<br>Prasad M. Refrigeration and Air Conditioning. New Age International Publisher.<br>Stocker WF and Jones JW. Refrigeration and Air Conditioning. McGraw-Hill. |

| Course Outcomes | At the end of the course, learners will be able.<br>**CO1**: Able to analyses air refrigeration cycles.<br>**CO2**: Able to understand the working principals VCRS<br>**CO3:** Able to understand VARS.<br>**CO4:** Perform thermodynamic analysis of absorption, steam jet, thermoelectric and vortex tube refrigeration systems |
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**Mapping between Cos, POs and PSOs**

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| **Course code** | **ME 503** |
| **Course title** | **MECHANISM ANALYSIS AND SYNTHESIS** |
| **Corse credit** | **3 (2+1)** |
| **Objective of Course** | **Objective**<br>1. The objective of the course is to understand the analysis and synthesis of mechanisms<br>2. To learn the graphical and analytical techniques commonly used in the synthesis of mechanisms using computer aided analysis.<br>3.To study gear and their motion analysis<br>4.To study various power transmission drives, gear trains, Cam design, and cam profile |
| Course Content | **UNIT I**<br>Kinematics of mechanisms, analysis and synthesis, mobility, systematic of mechanisms, deriving other mechanisms from linkages, Relative motion, instantaneous centre method, Kennedy's theorem. Graphical and analytical methods of kinematic analysis.<br>**UNIT II**<br>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, Feuerstein's method, Loop closure equations based on complex variable approach,<br>**UNIT III**<br>Gears and their motion-Analysis and Synthesis of epicyclic gear trains<br>**UNIT IV**<br>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 followers.<br>**Practical**<br>Graphical solutions of mechanisms relating to velocity and acceleration. |
| References: | Erdman A, Sandor G and Kota S. 2001. Mechanism Design: Analysis and Synthesis Pearson India Pvt Ltd, New Delhi.<br>Sandor GI, Erdman AG. 1984. Advanced Mechanism Design: Analysis and |

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| | Synthesis Pearson. Facsimile edition.<br>Ballaney PL. 2003. Theory of Machines. - Khanna Publishers, New Delhi.<br>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. |
| Course Outcomes | At the end of the course, learners will be able.<br>**CO1:** Able to design mechanisms for better accuracy and productivity.<br>**CO2:** Get familiar with design process of the mechanisms for functional requirements using computer interface.<br>**CO3:** Apply the concept of gear design and profile.<br>**CO4:** Solve the problems of drives, gear trains, generation of cam profile. |

**Mapping between Cos, POs and PSOs**

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| **Course code** | **ME-504** |
| **Course title** | **Vibration** |
| **Corse credit** | **3 + 0** |
| **Objective of Course** | 1. To understand the principles of vibration control.<br>2. To acquire skill of analyse balancing techniques for rotating and reciprocating masses.<br>3. To develop the ability to design effective vibration control systems.<br>4. To understand application of numerical and analytical methods.<br>5. To gain practical skills in implementing vibration control systems and balancing techniques in real-world |

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| Course Content | **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.<br><br>**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.<br><br>**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.<br><br>**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.<br><br>**Unit V:** Vibration of lumped parameter systems and continuous systems. Lagrange equations. Vibration measuring instruments, Vibrometer, velocity pickups, Accelerometer, and frequency measuring instruments. Applications of vibrations. Vibration control, balancing of rotating and reciprocating machines, design of vibration isolators. |
| References: | 1. V.P. Singh.2014. Mechanical Vibrations. Dhanpat Rai and Company, New Delhi<br>2. Rao S S. 2010.Mechanical Vibrations. Pearson Education, Delhi<br>3. Srinivas P.1983. Mechanical Vibration Analysis. Tata McGraw Hill Company Limited,New Delhi<br>4. Daniel J Inman.2013. Engineering Vibration. Prentice Hall, New Jersey |
| Course Outcomes | At the end of the course, learners will be able<br>**CO1**: **Comprehensive Understanding:** Students will develop a comprehensive understanding of the principles and factors influencing vibrations in mechanical systems, enabling them to identify and address vibration-related challenges in engineering applications.<br>**CO2**: **Balancing Proficiency:** Graduates will acquire the skills necessary to analyse and implement advanced balancing techniques for both rotating and reciprocating masses, ensuring efficient and stable operation of machinery.<br>**CO3: Effective Design Skills:** Students will be able to design vibration control systems by integrating knowledge of damping mechanisms, isolators, and absorbers, demonstrating proficiency in creating solutions that minimize undesired vibrations in |

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| | practical engineering scenarios.<br>**CO4: Analytical Competence:** Graduates will demonstrate proficiency in utilizing numerical and analytical methods to assess and predict the vibrational behaviour of mechanical systems, enabling them to make informed decisions in the design and implementation of vibration control strategies.<br>**CO5: Practical Implementation:** Students will gain hands-on experience in implementing vibration control systems and balancing techniques in real-world applications, showcasing their ability to translate theoretical knowledge into practical solutions while considering the specific constraints and requirements of diverse mechanical systems. |

**Mapping between Cos, POs and PSOs**

| CO | PO | | | | | | | | | | | | PSO | | |
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| | 1 | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **1** | **2** | **3** |
| **CO1** | | | | | | | | | | | | | | | |
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| **CO4** | | | | | | | | | | | | | | | |
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| **Course code** | ME-507 |
| **Course title** | Fatigue Design |
| **Corse credit** | 2+1 |
| **Objective of Course** | 1. To develop a thorough understanding of fatigue design considerations for mechanical components.<br>2. To develop understanding related to analysis of fatigue causes in brittle and ductile materials.<br>3. To explore the mechanisms of crack initiation and propagation in materials subjected to cyclic loading.<br>4. To gain insights into fracture mechanics |
| Course Content | **Unit I** Theories of failure, maximum normal stress, maximum shear stress and distortion energy theory, failure of ductile |

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| | materials, failure of brittle materials.<br><br>**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.<br><br>**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.<br><br>**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 design of common machine component. |
| References: | 1. Lessells, J.M. 1955. Strength and resistance of metals. John Wiley & sons, Michigan.<br>2. T.L. Anderson. 2005. Fracture Mechanics Fundamentals and Applications. CRC press, BocaRaton.<br>3. Bhandari V.B.2019. Design of Machine Elements. McGraw Hill Education Pvt Ltd, New Delhi.<br>4. Peterson, R.E. 1953 Stress Concentration Design Factors. John Wiley & Sons, New York.<br>5. Meguid, S.A.1989 Engineering Fracture Mechanics. John Wiley & Sons, New York<br>6. Kare Hellan.1985. Introduction to Fracture Mechanics. Mc Graw Hill Book Co, New York. |
| Course Outcomes | At the end of the course, learners will be able<br>**CO1**: **Applied Fatigue Design Expertise:** Graduates will be equipped with the knowledge and skills to apply fatigue design principles effectively, ensuring mechanical components are designed for optimal durability and reliability in real-world applications.<br>**CO2**: **Differential Analysis of Fatigue Causes:** Students will demonstrate the ability to differentiate and analyse the causes of fatigue in brittle and ductile materials, enhancing their capacity to diagnose potential vulnerabilities in diverse engineering materials.<br>**CO3: Effective Prediction and Mitigation:** Graduates will be proficient in predicting and mitigating fatigue failures by understanding the mechanisms of crack initiation and propagation, leading to improved structural integrity and |

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| | longevity of mechanical components.<br>**CO4: Advanced Fracture Prevention Strategies:** Students will develop expertise in fracture mechanics, allowing them to design and implement advanced strategies to prevent catastrophic failure due to fatigue, contributing to safer and more reliable engineering practices. |

**Mapping between Cos, POs and PSOs**

| CO | PO | | | | | | | | | | | | PSO | | |
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| | 1 | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **1** | **2** | **3** |
| **CO1** | | | | | | | | | | | | | | | |
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| **Course code** | **ME-515** |
| **Course title** | **Computer Aided Design** |
| **Corse credit** | **2+1** |
| **Objective of Course** | 1. Acquire a comprehensive understanding and develop proficiency in computer-aided design (CAD).<br>2. To gain in-depth knowledge and practical skills in 2D drawing.<br>3. To explore and master advanced 3D modelling techniques.<br>4. To understand the application of finite element analysis (FEA) for optimal product design. |
| Course Content | **Unit I:** Introduction to computer aided design, scope of computer aided machine design, design process and design environments. Geometric modelling and interactive graphic, engineering analysis, design review and automated drafting, modelling, viewing.<br><br>**Unit II:** 3-D solid modelling, boundary representation, constructive solid geometry, feature based modelling. Computer aided analysis and synthesis of common mechanical components, a bar, a beam and a shaft, comparison with analytical results.<br><br>**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. |

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| References: | 1. Mikell P. Groover, Emory W. Zimmers.2000 CAD/CAM Computer Aided Design and Manufacturing, PHI.<br>2. Zeid Ibraham.1991. CAD/CAM - Theory and Practice, Tata McGraw Hill, New Delhi.<br>3. Chandandeep Grewal & Kuldeep Sareen.2007. CAD/CAM Theory and Concepts. S.Chand, New Delhi.<br>4. P.N Rao.2010. CAD/CAM. Tata McGraw Hill, New Delhi. |
| Course Outcomes | At the end of the course, learners will be able<br>**CO1**: **CAD Proficiency:** Graduates will demonstrate proficiency in computer-aided design, showcasing the ability to create accurate and detailed engineering representations using both 2D drawing and 3D modelling tools.<br>**CO2**: **Precision in 2D Drawing:** Students will exhibit precision in 2D drawing, producing detailed engineering drawings that adhere to industry standards, facilitating effective communication and collaboration in the design and manufacturing processes.<br>**CO3: Advanced 3D Modelling Skills:** Graduates will possess advanced skills in 3D modelling, enabling them to create intricate and realistic virtual models that enhance their ability to conceptualize and communicate complex engineering designs in three dimensions.<br>**CO4: Expertise in Finite Element Analysis (FEA):** Students will demonstrate expertise in applying finite element analysis techniques to optimize product designs, ensuring graduates can assess and enhance the structural integrity and performance of engineering solutions through simulation and analysis. |

**Mapping between Cos, POs and PSOs**

| **CO** | **PO** | | | | | | | | | | | | **PSO** | | |
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| | 1 | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **1** | **2** | **3** |
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| **Course code** | **MATH 501** |
| **Course title** | **Finite Element Methods** |
| **Corse credit** | **2+1** |
| **Objective of Course** | 1. To introduce the concepts of Mathematical Modelling of Engineering Problems.<br>2. To appreciate the use of FEM to a range of Engineering Problems<br>3. To learn basic principles of finite element analysis procedure.<br>4. To learn the theory and characteristics of finite elements that represent engineering structures.<br>5. To learn and apply finite element solutions to structural, thermal, dynamic problem to develop the knowledge and skills needed to effectively evaluate finite element analyses. |
| Course Content | **Unit I**<br><br>Introduction. Historical background, Stress equilibrium, boundary condition, stress strain<br><br>relation, potential energy and equilibrium. Rayleigh-Ritz method. Galerkin method.<br><br>**Unit II**<br><br>coordinates and shape functions, potential energy approach, element stiffness matrix, Galerkin approach, assembly of global stiffness matrix. The finite element equation, boundary conditions.<br><br>**Unit III**<br><br>Trusses: Two dimensional problems, modeling by constant strain triangle, two dimensional iso-parametric elements, the four-node quadrilateral.<br><br>**Unit IV**<br><br>Scalar field problems, steady state heat transfer, torsion, potential flow, seepage and fluid flow index, dynamic analysis, principles. |
| Course Outcomes | **CO1:** Upon completion of this course, the students can able to understand different mathematical Techniques used in FEM analysis and<br><br>**CO2:** Understand the concepts of Nodes and elements.<br><br>**CO3**: Understand use of FEA in Structural and thermal problem.<br><br>**CO4**: Understand the application of FEA in heat transfer problem.<br><br>**CO5**: Learn how to do analysis learn the various concepts and |

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| | types of analysis CO6 Learn finite element modelling techniques. |

**Mapping between Cos, POs and PSOs**

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| **Course code** | **MATH 502** |
| **Course title** | **Numerical Methods for Engineers** |
| **Corse credit** | **2+1** |
| **Objective of Course** | 1. To expose students to various numerical methods for solving algebraic equations, ordinary and partial differential equations.<br>2. Find the solution of linear systems by using Direct methods, Matrix inversion method, Gaussian elimination methods, Gauss-Jordan Method, Method of factorization, Solution of Tridiagonal Systems.<br>3. Find the solution of ordinary differential equation of first order by Euler, Taylor and Runge-Kutta methods.<br>4. Find the derivatives using Newton's forward difference formula, Newton's backward difference formula, Derivatives using central difference formulae, Stirling's interpolation formula, Newton's divided difference formula, Maximum and minimum values of a tabulated function. |
| Course Content | **Unit I**<br>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.<br>**Unit II**<br>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 |

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| | Method of weighted residuals and orthogonal collocation and Galerkin technique to solve BVP in ODEs<br>**Unit III**<br>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.<br>**Unit IV**<br>Finite difference formulae: Forward and backward differences, Richardson's extrapolation, interpolation formulae, polynomial forms, linear interpolation, Lagrange interpolation polynomial, Newton interpolation polynomial<br>**Unit V**<br>Solution of Partial Differential Equations: Classification of PDEs (Parabolic, elliptical and hyperbolic equation), Elliptical equations, standard five point's 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 |
| Course Outcomes | **CO1:** Ability to solve algebraic equations, ordinary and partial differential equations coming across in Agricultural Engineering problems using various numerical methods.<br>**CO2:** Ability to use latest software's towards numerical problems.<br>**CO3:** Implement numerical methods for a variety of multidisciplinary applications and a variety of numerical algorithms using appropriate technology.<br>**CO4:** Compare different methods in numerical analysis with accuracy and efficiency of solution.<br>**CO5:** Apply appropriate numerical methods to solve the problem with most accuracy. |

**Mapping between Cos, POs and PSOs**

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| **CO3** | | | | | | | | | | | | | | | |
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| **Course code** | **MATH 506** |
| **Course title** | **Numerical Analysis** |
| **Corse credit** | **2+1** |
| **Objective of Course** | 1. To expose students to various numerical methods for solving algebraic equations, ordinary and partial differential equations.<br>2. Find the solution of algebraic and transcendental equations by bisection, secant and Newton-Raphson's Methods<br>3. Find the solution of ordinary differential equation of first order by Euler, Taylor and Runge-Kutta methods.<br>4. 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. |
| Course Content | **Unit I**<br>Computational errors, absolute and relative errors, difference operators, divided differences, interpolating polynomials using finite differences, Hermite interpolation, piecewise and spline interpolation, bivariate interpolation.<br>**Unit II**<br>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.<br>**Unit III**<br>Numerical differentiation based on interpolation, finite differences and undetermined coefficients. Numerical integration using methods based on interpolation and undetermined coefficients.<br>**Unit IV**<br>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 |

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| | method, iterative techniques, inverse of a matrix, computation of eigen values and eigen vectors. |
| Course Outcomes | **CO1:** Ability to solve algebraic equations, ordinary and partial differential equations coming across in Agricultural Engineering problems using various numerical methods.<br><br>**CO2:** Ability to use latest software's towards numerical problems.<br><br>**CO3:** Implement numerical methods for a variety of multidisciplinary applications and a variety of numerical algorithms using appropriate technology.<br><br>**CO4:** Compare different methods in numerical analysis with accuracy and efficiency of solution.<br><br>**CO5:** Apply appropriate numerical methods to solve the problem with most accuracy. |

**Mapping between Cos, POs and PSOs**

| **CO** | **PO** | | | | | | | | | | | | **PSO** | | |
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|---|---|
| **Course code** | **MATH 507** |
| **Course title** | **Numerical Methods for Ordinary and Partial Differential Equations** |
| **Corse credit** | **2+1** |
| **Objective of Course** | 1. To provide understanding and application of basic numerical techniques for evaluation and approximation of ordinary and partial differential equations.<br>2. Students will be able to apply the concepts and methods described in the syllabus.<br>3. They will be able to solve problems using the differential equation |

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| Course Content | **Unit I**<br>Interpolation, Approximation, least square and uniform approximation.<br>**Unit II**<br>Numerical differentiation and integration, Numerical solution of ordinary differential equations<br>by single step and multi-step methods<br>**Unit III**<br>Various difference schemes for solutions of partial differential equations of parabolic, elliptic and hyperbolic types<br>**Unit IV**<br>Solution of differential equations by finite element methods |
| Course Outcomes | **CO1:** Study solutions to partial differential equations using numerical methods.<br>**CO2:** Discretise partial differential equations via the finite difference method.<br>**CO3:** Discretise weak form partial differential equations via the finite element method.<br>**CO4:** Understand the principles of discretisation consistency, stability, and accuracy.<br>**CO5:** Discretise weak form partial differential equations via the finite element method |

**Mapping between Cos, POs and PSOs**

| CO | PO | | | | | | | | | | | | PSO | | |
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| **Course code** | STAT 501 |
| **Course title** | Statistical Methods for Research Workers |
| **Corse credit** | **2+1** |
| **Objective of Course** | 1.To expose students to various statistical techniques<br>2. Analysis of statistical data and interpretation of results |
| Course Content | **Unit I**<br>Probability and probability distributions. Principle of least squares. Linear and non-linear, regression. Multiple regressions. Correlation analysis. Selection of variables. Validation of models. Sampling techniques. Determination of sample size. Sampling distribution of mean and proportion.<br>**Unit II**<br>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.<br>**Unit III**<br>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 ways ANOVA by ranks. Kendall's Coefficient of concordance.<br>**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. Nonparametric tests. |
| References: | Anderson T W 1958. An Introduction to Multivariate Statistical Analysis. John Wiley.<br>•Dillon W R and Goldstein M. 1984. Multivariate Analysis - Methods and Applications. John Wiley.<br>•Electronic Statistics Text Book: http://www.statsoft.com/textbook/stathome.html<br>•Goon A M, Gupta M K and Dasgupta B. 1977. An Outline of Statistical Theory. Vol. I. The World Press.<br>• Goon A M, Gupta M K and Dasgupta B. 1983. Fundamentals of Statistics. Vol. I. The World Press.<br>•Hoel P G. 1971. Introduction to Mathematical Statistics. John Wiley.<br>•Hogg R V and Craig T T. 1978. Introduction to Mathematical Statistics. Macmillan.<br>•Montgomery and Runger 2014. Applied Statistics and Probability for Engineers. John Wiley<br>•Morrison D F. 1976. Multivariate Statistical Methods. McGraw Hill.<br>•Siegel S, Johan N and Casellan Jr. 1956. Non-parametric Tests for Behaviour Sciences. John Wiley |
| Course Outcomes | **CO1:** To understand the different concept of statistical techniques |

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| | **CO2:** To get exposure to various statistical techniques for analysis of data and interpretation of results |

**Mapping between Cos, POs and PSOs**

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| **Course code** | STAT 502 |
| **Course title** | Experimental Design |
| **Corse credit** | 1+1 |
| **Objective of Course** | 1. To acquaint and equip the students with the basic principles of theory of designs<br>2. To analysis of experiments. |
| Course Content | Unit I<br>Basic principles of experimental designs. Uniformity trials. Completely randomized design, randomized block design and latin square designs. Multiple comparison tests.<br>Unit II<br>Missing plot techniques. Analysis of covariance. Factorial experiments: 22, 23and 32. Split plot design. Strip plot design. Factorial in split plot design.<br>Unit III<br>Crossover designs. Balanced incomplete block design. Response surface designs. Groups of experiments.<br>**Practical**<br>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. |
| References: | • Cochran WG and Cox GM 1957. Experimental Designs. 2nd Ed. John Wiley.<br>• Dean AM and Voss D 1999. Design and Analysis of Experiments. Springer.<br>• Design Resources Server: www.iasri.res.in/design.<br>• Examination of Theory and Practice. John Wiley.<br>• Federer WT 1985. Experimental Designs. MacMillan.<br>• Fisher RA 1953. Design and Analysis of Experiments. Oliver & Boyd.<br>• Montogomery 2013. Design and analysis of experiments. John Wiley & Sons.<br>• Nigam AK and Gupta V K 1979. Handbook on Analysis of Agricultural Experiments. |

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| | IASRI Publ.<br>• Pearce SC 1983. The Agricultural Field Experiment: A Statistical Examination of Theory and Practice. John Wiley & Sons |
| Course Outcomes | **CO1:** To understand the concept of experimental designs<br>**CO2:** To enhance student's capability to apply experimental designs, analysis and interpretation of experimental results |
| **Mapping between Cos, POs and PSOs** | |

| **CO** | **PO** | | | | | | | | | | | | **PSO** | | |
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| **Course code** | PGS – 502 |
| **Course title** | TECHNICAL WRITING AND COMMUNICATIONS SKILLS |
| **Corse credit** | 0+1 |
| **Objective of Course** | 1. Objective To equip the students/scholars with skills to write dissertations, research papers, etc.<br>2. To equip the students/ scholars with skills to communicate<br>3. Articulate in English (verbal as well as writing). |
| Course Content | Practical Technical Writing – Various forms of scientific writings- theses, technical papers, reviews, manuals, etc; Various parts of thesis and research communications (title page, authorship contents page, preface, introduction, review of literature, material and methods, experimental results and discussion); Writing of abstracts, summaries, précis, citations etc.; commonly used abbreviations in the theses and research communications; illustrations, photographs and drawings with suitable captions; pagination, numbering of tables and illustrations; Writing of numbers and dates in scientific write-ups; Editing and proof-reading; Writing of a review article. Communication Skills - Grammar (Tenses, parts of speech, clauses, punctuation marks); Error analysis (Common errors); Concord; Collocation; Phonetic symbols and transcription; Accentual pattern: Weak forms in connected speech: Participation in group discussion: Facing an interview; presentation of scientific papers |
| References: | **1.** Chicago Manual of Style. 14th Ed. 1996. Prentice Hall of India.<br>2. Collins' Cobuild English Dictionary. 1995.<br>3. Harper Collins. Gordon HM & Walter JA. 1970. Technical Writing. 3rd Ed.<br>4. Holt, Rinehart & Winston. Hornby AS. 2000. Comp. Oxford Advanced Learner's Dictionary of Current English. 6th Ed. |

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| | Oxford University Press.<br>5. James HS. 1994. Handbook for Technical Writing. NTC Business Books.<br>6. Joseph G. 2000. MLA Handbook for Writers of Research Papers. 5th Ed. Affiliated East- West Press.<br>7. Mohan K. 2005. Speaking English Effectively. MacMillan India.<br>8. Richard WS. 1969. Technical Writing.<br>9. Barnes & Noble. Robert C. (Ed.). 2005. Spoken English: Flourish Your Language.Restructured and Revised Syllabi of Post-Graduate Programme -2022<br>10. Abhishek. Sethi J & Dhamija PV. 2004. Course in Phonetics and Spoken English. 2nd Ed. Prentice Hall of India.<br>11. Wren PC & Martin H. 2006. High School English Grammar and Composition. S. Chand & Co |
| Course Outcomes | **CO1:** To write dissertations, research papers, etc.<br>**CO2:** To effectively communicate and articulate orally in English Communications.<br>**CO3:** To effectively communicate and articulate in written English Communications |

**Mapping between Cos, POs and PSOs**

| **CO** | **PO** | | | | | | | | | | | | **PSO** | | |
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| **Course code** | PGS – 504 |
| **Course title** | BASIC CONCEPTS IN LABORATORY TECHNIQUES |
| **Corse credit** | 0+1 |
| **Objective of Course** | 1. To develop understanding for lab instruments.<br>2. To develop skill in operation of available lab instruments.<br>3. To develop basic laboratory skills and the techniques<br>4. To develop pre experiment preparation. |
| Course Content | • Safety measures while in Lab;<br>• Handling of chemical substances;<br>• Use of burettes, pipettes, measuring cylinders, flasks, separatory funnel, condensers, micropipettes and vaccupets;Restructured and Revised Syllabi of Post-Graduate Programme -2022<br>• Washing, drying and sterilization of glassware;<br>• Drying of solvents/ chemicals; |

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|---|---|
| | their dilution;<br>• Handling techniques of solutions;<br>• Preparation of different agro-chemical doses in field and pot applications;<br>• Preparation of solutions of acids;<br>• Neutralization of acid and bases;<br>• Preparation of buffers of different strengths and pH values;<br>• Use and handling of microscope, laminar flow, vacuum pumps, viscometer, thermometer, magnetic stirrer, micro-ovens, incubators, sand bath, water bath, oil bath;<br>• Electric wiring and earthing;<br>• Preparation of media and methods of sterilization;<br>• Seed viability testing, testing of pollen viability;<br>• Tissue culture of crop plants;<br>• Description of flowering plants in botanical terms in relation to taxonomy. |
| References: | 1. Furr AK. 2000. CRC Hand Book of Laboratory Safety. CRC Press.<br>2. Gabb MH and Latchem WE. 1968. A Handbook of Laboratory Solutions. Chemical Publ. Co |
| Course Outcomes | **CO1:** Understand the different types of apparatus to be used in laboratory and how to calibrate them.<br>**CO2:** These skills play a significant role in order to perform various experiments and to run various tests.<br>**CO3:** Basic laboratory skills are the techniques required for conducting experiments. These include pouring, measuring, filtration, and using gas burners and glassware.<br>**CO4:**Prepare different media and solutions |

**Mapping between Cos, POs and PSOs**

| **CO** | **PO** | | | | | | | | | | | | **PSO** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **1** | **2** | **3** |
| **CO1** | | | | | | | | | | | | | | | |
| **CO2** | | | | | | | | | | | | | | | |
| **CO3** | | | | | | | | | | | | | | | |
| **CO4** | | | | | | | | | | | | | | | |