Course Structure as per BSMA Committee, ICAR
M.Tech. in Agricultural Engineering

Particulars	Credit Requirement
(i) Course work	
Major courses	20
Minor courses	08
Supporting courses	06
Common courses	05
Seminar	01
(ii) Thesis Research	30
Total	**70**

Major courses (Requirement: 20 Credits): From the Discipline in which a student takes admission. Among the listed courses of different disciplines (Soil and Water Conservation Engineering, Processing and Food Engineering, Irrigation and Drainage Engineering, Farm Machinery and Power Engineering) the compulsory core courses are given *mark.

Minor courses (Requirement: 08 Credits): From the subjects closely related to a student's major subject to be taken from other related Departments such as Soil and Water Conservation, Agronomy, Horticulture, Soil Science, and Agricultural Economics of the School of Agricultural Sciences, NU, Medziphema.

Supporting courses (Requirement: 06 Credits): Relevant supporting courses will be taken from the Department of Agricultural Economics, School of Agricultural Sciences, NU, Medziphema, such as (Statistical Methods for Applied Science, Design of Experiments, Applied Regression Analysis etc.)

Common Courses (Requirement: 05 Credits)**:** The following courses **(one credit each)** will be offered to all students undergoing Master's degree programme. These subjects are common to all the PG programs of SAS.

Course Code	Course Title
PGS 501	Library and Information Services
PGS 502	Technical Writing and Communication Skills
PGS 503	Intellectual Property and its management in Agriculture
PGS 504	Basic Concepts in Laboratory Techniques
PGS 505	Agricultural Research, Research Ethics and Rural Development Programmes

Other Requirements

Course Code	Course Title	Credit Hours
AGE 591	Seminar	0+1
AGE 599	Thesis Research	0+30

M.Tech (Agricultural Engineering) in Soil and Water Conservation Engineering

Major Courses (Requirement: 20 Credits)

Course Code	Course Title	Credit Hours
*AGE 501	Advanced Soil and Water Conservation Engineering	2+1
*AGE 502	Applied Watershed Hydrology	2+1
AGE 503	Soil and Water Conservation Structures	2+1
AGE 504	Stochastic Hydrology	2+1
*AGE 505	Watershed Management and Modeling	2+1
AGE 506	Flow Through Porous Media	2+0
AGE 507	Remote Sensing and GIS for Land and Water Resource Management	2+1
AGE 508	Climate Change and Water Resources	3+0
AGE 509	Numerical Methods in Hydrology	2+0
AGE 510	Dryland Water Management Technologies	2+0

*Compulsory course

M.Tech (Agricultural Engineering) in Processing and Food Engineering

Major Courses (Requirement: 20 Credits)

Course Code	Course Title	Credit Hours
*AGE 521	Transport Phenomena in Food Processing	2+1
*AGE 522	Unit Operations in Food Process Engineering	2+1
*AGE 523	Field Crops Process Engineering	2+1
*AGE 524	Horticultural Crops Process Engineering	2+1
AGE 525	Storage Engineering and Handling of Agricultural Produce	2+1
AGE 526	Food Package Engineering	1+1
AGE 527	Instrumentation and Sensors in Food Processing	2+1
AGE 528	Application of Engineering Properties in Food Processing	2+1
AGE 529	Food Quality and Safety	2+1
AGE 530	Food Processing Technologies	2+1
AGE 531	Food Processing Equipment and Plant Design	1+1
AGE 532	Seed Process Engineering	1+1
AGE 533	Agri-Project Planning and Management	2+1
AGE 534	Farm Structures and Environmental Control	2+1
AGE 535	Dairy Product Processing	2+1
AGE 536	Processing of Meat, Poultry and Fish	2+1
AGE 537	Design of Aquacultural Structures	2+1
AGE 538	Thermal Environmental Engineering for Agricultural Processing	2+1

*Compulsory Courses

M.Tech (Agricultural Engineering) in Irrigation and Drainage Engineering

Major Courses (Requirement: 20 Credits)

Course Code	Course Title	Credits hours
AGE 541	Design of Surface Irrigation Systems	1+1
*AGE 542	Design of Farm Drainage Systems	2+1
AGE 543	Command Area Management	2+1
AGE 544	Water and Nutrient Management Under Protected Cultivation	2+1
*AGE 545	Design of Drip and Sprinkler Irrigation Systems	2+1
*AGE 546	Ground Water Engineering	2+1
AGE 547	Remote Sensing and GIS for Land and Water Resource Management	2+1
AGE 548	Waste Water Management and Utilization in Agriculture	2+1
AGE 549	Water Conveyance and Distribution	2+1
AGE 550	Minor Irrigation	2+1
AGE 551	Design of Pumps for Irrigation and Drainage	2+0
AGE 552	Crop Environmental Engineering	2+0
AGE 553	Water Resources Systems Engineering	2+1
AGE 554	Irrigation Economics, Planning and Management	2+0
AGE 555	Sensing and Automation in Irrigation Systems	3+0

*Compulsory course

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

Major Courses (Requirement: 20 Credits)

Course Code	Course Title	Credit Hours
AGE 561*	Soil Dynamics in Tillage and Traction	2+1
AGE 562*	Testing and Evaluation of Agricultural Equipment	2+1
AGE 563*	Ergonomics and Safety in Farm Operations	2+1
AGE 564	Design of Tractor systems	2+1
AGE 565	Design of Farm Machinery-I	2+1
AGE 566	Design of Farm Machinery-II	1+1
AGE 567*	Management of Farm Power and Machinery System	2+1
AGE 568	Principles of Automation and Control	2+1
AGE 569	Principles of Hydraulic and Pneumatic Systems	2+1
AGE 570	Applied Instrumentation in Farm Machinery	2+1
AGE 571	Systems Simulation and Computer Aided Problem Solving in Engineering	1+1
AGE 572	Computer Aided Design of Machinery	0+2
AGE 573	Advance Manufacturing Technologies	2+0
AGE 574	Machinery for Precision Agriculture	2+1
AGE 575	Machinery for Horticulture and Protected Agriculture	2+0

*Compulsory Course

Syllabus

M.Tech. (Agricultural Engineering) in Soil and Water Conservation Engineering

AGE 501: Advanced Soil and Water Conservation Engineering (2+1)

I. Theory

Unit I

Concept of probability in design of soil and water conservation structures. Probability and continuous frequency distribution. Fitting empirical distributions.

Unit II

Relevance of soil and water conservation in agriculture and in the river valley projects. Layout and planning of soil and water conservation measures. Software's for design of conservation structures.

Unit III

Productivity loss due to soil erosion. Water stress and water excess. Types and mechanics of soil erosion. Software's for soil loss estimation, WEAP, EPIC

Unit IV

Theories of sediment transport. Control of runoff and sediment loss. Sediment deposition process. Estimation of sediment load.

Unit V

Design of soil and water conservation structures: Check dams, gully plugs, gabion structures, earth dams, silt detention dams, farm ponds, etc., and the alternate use of the stored water for agriculture. Application of Remote Sensing and GIS in Soil and Water Conservation.

II. Practical

Assessment of erosive status of a watershed through field measurement or analysis of morphometric properties. Estimation of erosivity index of rainfall. Determination of soil physical properties: Texture, grain size distribution, Atterberg's limits, various moisture percentages. Locating best 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.

Reference book

- Garg SK. 1987. *Irrigation Engineering and Hydraulic Structures*. Khanna Publishers, New Delhi.
- Kirkby MJ and Morgan PPC (eds). 1980. *Soil Erosion*. John Wiley and Sons. New York, USA.
- Suresh R. 2016. *Soil and Water Conservation Engineering*. Standard Publishers and Distributors, Delhi.

AGE 502: Applied Watershed Hydrology (2+1)

I. Theory Unit I

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.

Unit II

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.

Unit III

Micro climate, estimation methods of evaporation. Advances and improvements in rational approach. SCS approach criticism and improvements.

Unit IV

Hydrological hazard functions. Methods of estimation of hydrologic parameters. Data transformation.

Unit V

Calibration and evaluation of hydrologic models. Computer simulation of hydrological process in small watersheds.

II. **Practical**

Delineation of watershed and study of watershed characteristics. Measurement of rainfall and runoff in a watershed and data analysis. Estimation of infiltration and runoff from a watershed. Analysis and derivation of various types of hydrographs. Flood routing. Reservoir sedimentation. Watershed model components. Visit to a watershed.

Reference book

- Haan CT. *Hydrologic Modeling of Small Watershed*.
- Singh VP. 2010. *Rainfall-Runoff Modeling* (Vol. I)—Prentice Hall, New York.
- Singh VP. 2010. *Environmental Hydrology*. Springer, New York.

AGE 503: Soil and Water Conservation Structures (2+1)

I. **Theory Unit I**

Design, planning and layout of soil and water conservation structures. Criteria of selection of appropriate structures as per soil, land use and climatic conditions.

Unit II

Design and construction of earthen dam, stability analysis of land slopes and soil mass including landslides.

Unit III

Hydrological and structural design including stress analysis. Hydraulic jump and energy dissipaters for soil conservation structures.

Unit IV

Seepage through dams, flow net and determination of uplift pressure in drop structures, design of energy dissipaters.

Unit V

Design of water harvesting structures, construction, maintenance and utilization of stored water. Mechanized construction techniques for soil and water conservation structures.

II. **Practical**

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.

Reference book

- Mahnot SC, Singh PK and Chaplot PC. 2011. *Soil and Water Conservation and Watershed Management*. Apex Publishing House, Udaipur.
- Murty VVN. 1988. *Land and Water Management Engineering.* Second Edition Kalyani Publishers, New Delhi.
- Singh Gurmel C, Venkataraman G, Sastri and Joshi BP. 1991. *Manual of Soil and Water conservation Practices*. Oxford and IBH Publishing Co. Pvt. Ltd, New Delhi. .
- Suresh R. 2006. *Soil and Water Conservation Engineering*. Fourth Edition Standard Publishers and Distributors, Delhi.
- Singh Raj Vir. 2003. *Watershed Management*. Second Edition, Yash Publishing, Bikaner.

AGE 504: Stochastic Hydrology (2+1)

I. **Theory**

Unit I

Hydrologic cycle, Systems concept, Hydrologic systems model. Classification of hydrologic models, Statistical, stochastic and deterministic approaches. Statistical characteristics of hydrological data, probability distribution of hydrologic variables. Deterministic and stochastic hydrology, Cause and effect analysis. Hydrologic time series analysis – nature, stationarity and ergodicity, components of time series, trend,

periodicity and stochastic parts, parameter estimation of probability distributions. Analysis of hydrologic extremes.

Unit II

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.

Unit III

Stochastic Process: Classification, stationary process. Time series: Classification, component of time series. Methods of investigation: Auto correlation coefficient, moving average process, auto regressive process, auto regressive moving average process, auto regressive integrated moving average process. Spectral analysis, analysis of multivariate hydrologic series.

Unit IV

Thomas Fiering model, Box Jenkins model. Model formulation: Parameter estimation, calibration and validation. Application to hydrologic data. Generation and forecasting. Regional flood frequency analysis. Transformations, Hypothesis testing.

Unit V

Modeling hydrologic uncertainty. First order Markov process, Markov chain, Data generation, Hydrologic time series analysis, Modelling of hydrologic time series.

II. **Practical**

To estimate various statistical parameters of the hydrologic variables, estimating missing data in historical series, various parameter estimation methods like method of moments, method of maximum likelihood, method of mixed moments, probability of weighted moments fitting discrete and continuous distribution functions to variables, application of transformation techniques to historical data for estimating variables at different return periods, determining correlation and regression coefficients, analyzing multivariate regression, 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.

Reference book

- Clarke RT. *Mathematical Models in Hydrology*. FAO Publication.
- Haan CT. 2002. *Statistical Methods in Hydrology.* Iowa State Press.
- Kotteguda NT. 1982. *Stochastic Water Resources Technology*. The Macmillan Press, New York.
- McCuen RH and Snyder WM. *Hydrological Modelling–Statistical Methods and Applications*. Prentice Hall Inc., New York.
- Yevjevich V *Stochastic Processes in Hydrology*. Water Resources Publications, Colorado.

AGE 505: Watershed Management and Modeling (2+1)

I. **Theory**

Unit I

Concept of watershed, its hydrological and geomorphological characteristics. Status of watershed management programs in India. Problems of desertification and degradation.

Unit II

Concept of watershed management and sustainability, participatory approach and operational watershed. Surveys, monitoring, reclamation and conservation of agricultural and forest watersheds, hill slopes and ravines.

Unit III

Watershed management research instrumentation and measurement, problem identification, simulation and synthesis. Rainfed farming and drought management. Modeling of flood and drought phenomenon.

Unit IV

Use of Remote Sensing and GIS in watershed management and modeling. Watershed modeling approaches, mathematical bases and structure of existing watershed models.

Unit V

Environmental impact assessment of watersheds. Quantitative evaluation of management techniques. National land use policy, legal and social aspects. Case studies of watershed management.

II. Practical

Selection and delineation of a watershed. Benchmark surveys. Preparation of watershed land use map. Preparation of watershed development proposal. Preparation of watershed evaluation and impact assessment report. Application of watershed models for evaluation of conservation treatments. Use of Remote Sensing and GIS in watershed management and modeling.

Reference book

- Punjab Agricultural University, Ludhiana.
- Dhruvanarayana VV, Sastry G and Patnaik US. *Watershed Management*. Publ. and Inf. Dv., ICAR, Krishi Anusandhan Bhavan, New Delhi.
- Singh RV. 2000. *Watershed Planning and Management*. Second Edition Yash Publishing House, Bikaner.
- Suresh R. 2017. *Watershed Planning and Management*. Standard Publication and Distribution, Delhi.
- Tideman EM. 1999. *Watershed Management* (*Guidelines for Indian Conditions*). Omega Scientific Publishers, New Delhi.

AGE 506: Flow Through Porous Media (2+0)

I. Theory

Unit I

Aquifer and fluid properties, forces holding water in soils, hydrodynamics in porous media and limitations of governing laws.

Unit II

Differential equations of saturated flow, initial and boundary conditions. Dupuit and Business approximations and linearization techniques.

Unit III

Stream functions, potential functions and flow net theory. Analysis of seepage from canals and ditches.

Unit IV

Unsaturated flow theory, Infiltration and capillary rise flux dynamics. Movement of groundwater in fractured and swelling porous media.

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.

Reference book

- Bears J. 1972. *Dynamics of Fluids in Porous Media*. American Elsevier Publishing Co. Inc. New York.Company.
- Collins RE. 1961. *Flow of Fluids through Porous Materials*. Reinhold publishing cooperation, New York.
- Core AT *Flow in Porous Media*.
- De Wiest Roger JM. 1969. *Flow through Porous Media*. Academic press, New York.
- Helmut K *Soil Physics*. pp. 7-79.
- Verruijt A. 1982. *Theory of Groundwater Flow*. 2nd Edn., Macmillan, London

AGE 507: GIS and Remote Sensing for Land and Water Resource Management (2+1)

I. Theory

Unit I

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.

Unit II

Satellite Data analysis: Visual interpretation, digital image processing, image pre- processing, image enhancement, image classification and data merging.

Unit III

Definition: Basic components of GIS, map projections and co-ordinate system, spatial data structure-raster, vector, spatial relationship, topology, geodatabase models, hierarchical network, relational, object-oriented models, integrated GIS database- common sources of error–data quality: Macro, micro and usage level components, meta data, Spatial data transfer standards.

Unit IV

Thematic mapping, 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.

Unit V

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.

II. Practical

Familiarization with the Remote sensing instruments and satellite imagery. Aerial Photograph and scale determination with stereoscope. Interpretation of satellite imageries and aerial photographs. Determination of Parallaxes in images. Introduction to digital image processing software and GIS software and their working principles. Generation of digital elevation model (DEM) for land and water resource management. Case studies on mapping, monitoring and management of natural resources using remote sensing and GIS.

Reference book

- Ian HS, Cornelius and Steve C. 2002. *An Introduction to Geographical Information Systems*. Pearson Education, New Delhi.
- James BC and Randolph HW. 2011. *Introduction to Remote Sensing*. The Guilford Press.
- Lilles TM and Kiefer RW. 2008. *Remote Sensing and Image Interpretation*. John Wiley and Sons.
- Paul Curran PJ. 1985. *Principles of Remote Sensing*. ELBS Publications.
- Rees WG. 2001. *Physical Principles of Remote Sensing*. Cambridge University Press.

AGE 508: Climate Change and Water Resources (3+0)

I. Theory

Unit I

The climate system: Definitions, climate, climate system, climate change.

Drivers of climate change, characteristics of climate system components: Greenhouse effect, carbon cycle, wind systems. Trade winds and the Hadley Cell, ozone hole in the stratosphere, El Nino, La Nina– ENSO, teleconnections.

Unit II

Impacts of climate change: Observed and projected**,** global and Indian scenario, observed changes and projected changes of IPCC: Impacts on water resources, NATCOM Report, impacts on sectoral vulnerabilities, SRES, different scenarios, climate change impacts on ET and irrigation demand.

Unit III

Tools for vulnerability assessment: Need for vulnerability assessment, steps for assessment, approaches for assessment. Models: Quantitative models, Economic models, impact matrix approach, Box models, Zero-dimensional models, Radioactive- convective models, Higher-dimension models, EMICs (Earth-system models of intermediate complexity), GCMs (global climate models or general circulation models), Sectoral models.

Unit IV

Adaptation and 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.

Unit V

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.

Case studies: Water resources assessment case studies: Ganga Damodar Project, Himalayan glacier studies, Ganga valley project. Adaptation strategies in assessment of water resources. Hydrological design practices and dam safety, operation policies for water resources projects. Flood management strategies, drought management strategies, temporal and spatial assessment of water for irrigation, land use and cropping pattern, coastal zone management strategies.

Reference book

- Majumdar PP and Nagesh KD. *Floods in a Changing Climate: Hydrological Modelling*. Cambride University Press, New York.
- Pathak H, Agarwal PK and Singh SD. *Mitigation in Agriculture: Methodology for Assessment and Application*. Division of Environmental Sciences, IARI New Delhi.
- Rao YS, Zhang TC Ojha, Gurjar BR, Tyagi RD, Kao CM (eds). *Climate Change Modelling, Mitigation, and Adaptation*. American Society of Civil Engineers.
- Srinivasa RK and Nagesh KD. *Impact of Climate Change on Water Resources with Modelling Techniques and Case Studies*. Springer publications, New York.
- Tamim Y and Caitlin AG. *Climate Change and Water Resources.* Springer Publication.

AGE 509: Numerical Methods in Hydrology (2+0)

I. Theory

Unit I

Review of finite difference operators. Concept of linear space and basis functions. Approximating from finite dimensional sub spaces.

Unit II

Variational and weighted residual methods. Langrange polynomials. Triangular and quadrilateral shape functions.

Unit III

Isoparametric elements and transformation of coordinates. Basis functions in three dimensions.

Unit IV

Galerkin finite element solution of Laplace, diffusion and dispersion-convection equations.

Unit V

Method of collocation, application in surface and sub surface hydrology.

Reference book

- Bear J and Verruijt A. 1987. *Modeling Groundwater Flow and Pollution*. 414 pp. Dordrecht, Boston.
- Carr JR. 1995. *Numerical Analysis for the Geological Sciences.* 592 pp. Prentice-Hall, Englewood Cliffs NJ.
- George H and Patricia W. 2000. *Numerical Methods in the Hydrological Sciences.* American Geophysical Union, Florida Avenue, NW.
- Gerald CF and Wheatley PO. 1999. *Applied Numerical Analysis*. 6th ed., 768 pp, Addison- Wesley, Reading, MA.
- Middleton GV. 2000. *Data Analysis in the Earth Sciences using MATLAB* 260 pp., Prentice Hall, Saddle River NJ.
- Wang HF and Anderson MP. 1982. *Introduction to Groundwater Modeling: Finite Difference and Finite Element Methods.* 237 pp, W.H. Freeman and Co., San Francisco.

AGE 510: Dryland Water Management Technologies (2+0)

I. Theory

Unit I

Drought severity assessment: Meteorological, hydrological and agricultural methods. Drought indices. GIS

based drought information system, drought vulnerability assessment and mapping using GIS. DPAP programme, drought monitoring constraints, limiting crop production in dry land areas. Types of drought, characterization of environment for water availability, crop planning for erratic and aberrant weather conditions.

Unit II

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.

Unit III

Land shaping and land development for soil moisture conservation. Improvement of tillage and soil management by implements and engineering practices. Soil and moisture conservation for rainfed lands through improved implements and engineering practices. Gel technology. *Ex-situ* measures: Water harvesting-micro catchments. Design of small water harvesting structures: Farm Ponds, percolation tanks their types and design, recycling of runoff water for crop productivity.

Unit IV

Crops and cropping practices related to soil and moisture conservation. Fertility management in dryland farming. Planning and development of watersheds from engineering view point. Case studies.

Unit V

Application of aerial photography in surveys and planning of watersheds for rainfed agriculture.
Use of Remote Sensing in soil moisture estimation.

Reference book

- Das NR. 2007. *Tillage and Crop Production*. Scientific Publishers.
- Dhopte AM. 2002. *Agro Technology for Dryland Farming*. Scientific Publ.
- Gupta US. 1995. *Production and Improvements of Crops for Drylands.* Oxford & IBH
- Singh RP. 1988. *Improved Agronomic Practices for Dryland Crops*. CRIDA.
- Singh RP. 2005. *Sustainable Development of Dryland Agriculture in India*. Scientific Publ.
- Singh RV. 2003. *Watershed Planning and Management*. Second Edition. Yash Publishing House, Bikaner.
- Singh SD. 1998. *Arid Land Irrigation and Ecological Management.* Scientific Publishers.

Syllabus

M.Tech (Agricultural Engineering) in Processing and Food Engineering

AGE 521: Transport Phenomena in Food Processing (2+1)

I. Theory

Unit I

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

Unit II

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

Unit III

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

Unit IV

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

II. Practical

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

Reference book

- Bird, Stewart, Lightfoot 2442. *Transport Phenomena*, John Wiley & Sons.
- Bodh Raj 2412. *Introduction to Transport Phenomena*, PHI.
- Christie J. 1993. *Transport Process and Unit Operations*. Prentice-Hall of India Private Limited, New Delhi ISBN 4-13-445253-X.
- Coulson JM and Richardson JF. 1999. *Chemical Engineering*. Vol. II, IV.Pergamon Press.
- Earle RL. 1985. *Unit Operations in Food Processing*. Pergamon Press.
- Holman JP 1992. Heat Transfer. McGraw Hill.
- Jorge Welti-Chanes, Jorge F and Velez-Ruiz 2442. *Transport Phenomena in Food Processing*. CRC Press ISBN: 9781566769938 Geankoplis.
- McCabe WL and Smith JC 1999. *Unit Operations of Chemical Engineering*. McGraw Hill.
- Plawsky, Joel L 2414. *Transport Phenomena Fundamentals*, CRC Press, ISBN: 978-1-4665- 5535-8,1466555351.

AGE 522: Unit Operations in Food Process Engineering (2+1)

I. Theory

Unit I

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

Unit II

Drying and dehydration: Psychrometry, theories of drying, EMC, equipment for drying of solid, pastes and liquid foods. Evaporation: Components, heat and mass balance in single and multiple effect evaporators,

equipment and applications, steam economy. Thermal processing: Blanching, pasteurization and sterilization, death rate kinetics, process time calculations, sterilization equipment.

Unit III

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

Unit IV

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

Unit V

Size reduction: Principles of size reduction, size reduction laws. Size reduction equipment: Jaw crusher, gyratory crusher, roller mill, hammer mill.

II. Practical

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

Reference book

- Berk. 2418. Food Process Engineering and Technology, Academic Press, ISBN: 978-4-12-812418-7
- Brennan JG, Butters JR, Cowell ND and Lilly AEI. 1994. Food Engineering Operations. Elsevier.
- Fellows P 1988. Food Processing Technology: Principle and Practice. VCH Publ.
- McCabe WL and Smith JC. 1999. Unit Operations of Chemical Engineering. McGraw Hill.
- Sahay KM and Singh KK. 1994. Unit Operation of Agricultural Processing. Vikas Publ. House.
- Singh RP and Heldman DR. 1993. Introduction to Food Engineering. Academic Press.
- Smith. 2411. Introduction to Food Process Engineering, Springer.
- Toledo. 2447. Fundamentals of Food Process Engineering, Springer.
- Varzakas. 2415. Food Engineering Handbook, CRC press.

AGE 523: Field Crops Process Engineering (2+1)

I. Theory

Unit I

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.

Unit II

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

Unit III

Dal mills, handling and storage of by-products and their utilization. Storage of milled products. Expeller and solvent extraction processing. Assessment of processed product quality.

Unit IV

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

Reference book

- Asiedu JJ. 1994. *Processing Tropical Crops*. ELBS/MacMillan.
- Chakraverty A. 1995. *Post-Harvest Technology of Cereals, Pulses and Oilseeds.* Oxford and IBH.

· Golob 2442. *Crop Post-Harvest: Science and Technology* Vol. 1, Wiley-Blackwell.
· Hodges 2444. *Crop post-harvest: science and technology* Vol. 2, Wiley-Blackwell.
· Morris Lieberman. 1983. *Post-Harvest Physiology and Crop Preservation*. Plenum Press.
· Pandey PH. 1994. *Principles of Agricultural Processing*. Kalyani.
· Pillaiyar P. 1988. *Rice - Post Production Manual.* Wiley Eastern.
· Sahay KM and Singh KK. 1994. *Unit Operations in Agricultural Processing*. Vikas Publ. House.

AGE 524: Horticultural Crops Process Engineering (2+1)

I. Theory

Unit I

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

Unit II

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

Unit III

Cold storage of fruits and vegetables, controlled atmosphere and modified atmosphere packaging of fruits and vegetables, quality deterioration and storage.

Unit IV

Dehydration of fruits and vegetables, methods, osmotic dehydration, foam mat drying, freeze drying, microwave heating, applications, radiation preservation of fruits and vegetables, irradiation sources.

Unit V

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

II. Practical

Determination of size, shape, density, area-volume-mass relationship of fruits and vegetables, sugar-acid ratio of fruits, evaluation of washer, grader and packaging methods, experiments on drying of fruits and vegetables, controlled atmosphere storage and quality evaluation. Student's capability to mill and process (value added products) all kinds of horticultural crops as per requirement of food industries.

Reference book

· Bhatti S and Varma U. 1995. *Fruit and Vegetable Processing*. CBS.
· Cruesss WV. 2444. *Commercial Fruit and Vegetable Products*. Agrobios Publisher.
· Danthy ME. 1997. *Fruit and Vegetable Processing*. International Book Publisher.
· Simson. 2416. *Post-Harvest Technology of Horticultural crops.* AAP.
· Singh. 2418. *Advances in Post-Harvest Technologies of Vegetable Crops*. AAP.
· Srivastava RP and Kumar S. 1994. *Fruit and Vegetable Preservation*. Principles and Practices. International Book Distr.
· Thompson AK. 1996. *Post Harvest Technology of Fruits and Vegetables*. Blackwell.
· Verma LR and Joshi VK. 2444. *Post Harvest Technology of Fruits and Vegetables*. Vols. I-II. Indus Publisher.

AGE 525: Storage Engineering and Handling of Agricultural Produce (2+1)

I. Theory Unit I

Storage of grains, biochemical changes during storage, production, distribution and storage capacity estimate models, storage capacity models, ecology, storage factors affecting losses, storage requirements.

Unit II

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

Unit III

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

Unit IV

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

II. Practical

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

Reference book

- Boumans. 1985. *Grain Handling and Storage*. Elsevier.
- FAO. 1984. *Design and Operation of Cold Stores in Developing Countries*. FAO.
- Golob. 2442. *Crop Post-Harvest: Science and Technology*. Vol 1 Wiley-blackwell.
- Hall CW. 1974. *Handling and Storage of Food Grains in Tropical and Sub-Tropical Areas*. FAO Publisher Oxford & IBH.
- Henderson S and Perry SM. 1976. *Agricultural Process Engineering*. 5th Ed. AVI Publisher.
- Hodges 2444. *Crop Post-Harvest: Science and Technology*. Vol 2, Wiley-blackwell.
- Ripp BE. 1984. *Controlled Atmosphere and Fumigation in Grain Storage*. Elsevier.
- Shefelt RL and Prussi SE. 1992. *Post Harvest Handling – A System Approach*. Academic Press.
- Vijayaraghavan S 1993. *Grain Storage Engineering and Technology*. Batra Book Service.

AGE 526: Food Package Engineering (1+1)

I. Theory

Unit I

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

Unit II

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.

Unit III

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.

Unit IV

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.

II. Practical

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

Reference book

- Crosby NT. 1981. *Food Packaging Materials*. Applied Science Publisher.
- Frank A. 1992. *A Handbook of Food Packaging*. Springer.
- Mahadeviah M and Gowramma RV. 1996. *Food Packaging Materials*. Tata McGraw
- Hill.Palling SJ. 1984. *Developments in Food Packaging*. Applied Science Publisher.
- Robertson GL. 2413. *Food Packaging - Principles and Practice*. 3rd Ed Taylor & Francis.
- Sacharow S and Grittin RC. 1984. *Principles of Food Packaging*. AVI Publisher.

AGE 527: Instrumentation and Sensors in Food Processing (2+1)

I. Theory

Unit I

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

Unit II

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

Unit III

Temperature measurement using bi-metals, thermisters, thermocouples, humidity measurement, manometers. Flow transducer, positive displacement, venturimeter, Rotameter, Drag force, hot wire anemometer.

Unit IV

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

II. Practical

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

Reference book

- Doebelin EO. 1994. *Measurement Systems Applications and Design*. Tata McGraw Hill.
- Erika KR and Brimelow JB. 2441. *Instrumentation and Sensors for the Food Industry*. CRC Woodhead.
- Nakra BC and Chaudhary KK. 2444. *Instrumentation Measurement and Analysis*. Tata McGraw Hill.
- Mukhopadhyay. 2414. *Novel Sensors for Food Inspection: Modelling, Fabrication and Experimentation*. Springer.
- Mukhopadhyay SC. 2417. *Sensors for Everyday Life*. Springer.
- Paré JRJ and Bélanger JMR. 1997. *Instrumental Methods in Food Analysis*. Elsevier Academic Press.

AGE 528: Application of Engineering Properties in Food Processing (2+1)

I. Theory

Unit I

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

Unit II

Contact stresses between bodies, Hertz problems, firmness and hardness, mechanical damage, 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.

Unit III

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

Unit IV

Application of engineering properties in design and operation of agricultural equipment and structures.

II. Practical

Experiments for the determination of physical properties like length, breadth, thickness, surface area, bulk density, porosity, true density, coefficient of friction, angle of repose and colour for various food grains, fruits, vegetables, spices and processed foods, aerodynamic properties like terminal velocity, lift and drag force for

food grains, thermal properties like thermal conductivity, thermal diffusivity and specific heat. Rheological properties: firmness and hardness of grain, fruits and stalk, electrical properties like dielectric constant, dielectric loss factor, loss tangent and A.C. conductivity of various food materials.

Reference book

- Ludger F and Teixeira AA. 2447. *Food Physics Physical Properties - Measurement and Application.* Springer.
- Mohesenin NN. 1984. *Thermal Properties of Foods and Agricultural Materials*. Gordon and Breach Science Publisher.
- Mohesenin NN. 1984. *Physical Properties of Plant and Animal Materials*. Gordon & Breach Science Publisher.
- Peleg M and Bagelay EB. 1983. *Physical Properties of Foods*. AVI Publisher.
- Peter B. 2447. *The Chemical Physics of Food*. Wiley-Blackwell.
- Rao MA and Rizvi SSH. 1986. *Engineering Properties of Foods*. Marcel Dekker.
- Singhal OP and Samuel DVK. 2443. *Engineering Properties of Biological Materials*. Saroj Prakasan.
- Sitkei. 1986. *Mechanics of Agricultural Materials*. Elsevier.

AGE 529: Food Quality and Safety (2+1)

I. Theory

Unit I

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

Unit II

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

Unit III

Process equipment and machinery auditing, consideration of risk, environmental consideration, mechanical quality control.

Unit IV

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

Unit V

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

II. Practical

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

Reference book

- Herschdoerfer, SM. 1984. *Quality Control in the Food Industry*. Vol. 1 Academic Press.
- Herschdoerfer SM. 2412. *Quality Control in the Food Industry*. Vol. 2 Elsevier Science.
- Hubbard MR. 2443. *Statistical Quality Control for the Food Iindustry*. Springer.
- Mahadeviah M and Gowramma R V. 1996. *Food Packaging Materials*. Tata McGraw Hill.
- Mehmet M. 2411. *Biosensors in Food Processing, Safety, and Quality Control*. CRC Press.
- Palling SJ. 1984. *Developments in Food Packaging*. Applied Science Publisher.
- Sacharow S and Grittin RC. 1984. *Principles of Food Packaging*. AVI Publisher.
- Yanbo H, Whittaker AD and Lacey RE. 2441. *Automation for Food Engineering*. Food Quality Quantization and Process Control-CRC Press.

AGE 530: Food Processing Technologies (2+1)

I. Theory

Unit I

Mixing and homogenization; Principles of solid and liquid mixing, types of mixers for solids, liquid and pastes

homogenization. Emulsification: Principles and equipments.

Unit II

Novel dehydration technologies; Osmotic dehydration, foam mat drying, puff drying, freeze drying, microwave drying, dehumidified air drying. Extrusion: Theory, equipment, applications.

Unit III

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

Unit IV

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

Unit V

Food plant hygiene; Cleaning, sterilizing, waste disposal methods, Food processing plant utilities, steam requirements in food processing, HACCP in food processing industries.

II. Practical

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

Reference book

- Brennan JG, Butters JR, Cowell ND and Lilly AEI 1994. *Food Engineering Operations*. Elsevier.
- Earle RL. 1985. *Unit Operations in Food Processing*. Pergamon Press.
- Fellows P. 1988. *Food Processing Technology: Principle and Practice*. VCH Publisher.
- Geankoplis JC. 1999. *Transport Process and Unit Operations*. Allyn & Bacon.
- Gould GW. 1996. *New Methods of Food Preservation*. Blackie Academic & Professional.
- Heldman DR and Lund BD. 1992. *Hand Book of Food Engineering*. Marcel Dekker.
- McCabe WL and Smith JC. 1999. *Unit Operations of Chemical Engineering*. McGraw Hill.
- Sahay KM and Singh KK. 1994. *Unit Operation of Agricultural Processing*. Vikas Publ. House.
- Singh RP 1991. *Fundamentals of Food Process Engineering*. AVI Publisher.
- Singh RP and Heldman DR 1993. *Introduction to Food Engineering*. Academic Press.

AGE 531: Food Processing Equipment and Plant Design (1+1)

I. Theory

Unit I

Design considerations of processing agricultural and food products.

Unit II

Design of machinery for drying, milling, separation, grinding, mixing, evaporation, condensation, membrane separation.

Unit III

Human factors in design, selection of materials of construction and standard component, design standards and testing standards. Plant design concepts and general design considerations: Plant location, location factors and their interaction with plant location, location theory models, and computer aided selection of the location.
Feasibility analysis and preparation of feasibility report; Plant size, factors affecting plant size and their interactions, estimation of break-even and economic plant size. Product and process design, process selection, process flow charts, computer aided development of flow charts.

Unit IV

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

II. Practical

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

Reference book

- Antonio LG and Gustavo VBC. 2445. *Food Plant Design*. CRC Press.
- Couper. 2412. *Chemical Process Equipment*. Selection and Design Elsevier.
- George S and Athanasios EK. 2415. *Handbook of Food Processing Equipment*. Springer.
- Lloyd EB and Edwin HY. 1959. *Process Equipment Design*. Wiley-Interscience.
- Michael MC. 2413. *Food Plant Sanitation: Design, Maintenance, and Good Manufacturing Practices.* CRC Press.

AGE 532: Seed Process Engineering (1+1)

I. Theory

Unit I

Processing of different seeds and their engineering properties, principles and importance of seed processing.

Unit II

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

Unit III

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

Unit IV

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

II. Practical

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

Reference book

- Babasaheb. 2444. *Seeds Handbook: Processing and Storage.* CRC.
- Gregg *et al*. 1974. *Seed Processing*. NSC.
- Guar. 2412. *A Handbook of Seed Processing and Marketing* Agrobios.
- Henderson S and Perry S M. 1976. *Agricultural Process Engineering*. 5th Ed. AVI Publisher.
- Mathad. 2417. *Seed Processing: A Practical Approach.* NIPA.
- Sahay KM and Singh KK. 1994. *Unit Operation of Agricultural Processing*. Vikas Publisher House.
- Vaugha. 1968. *Seed Processing and Handling* .https://www.mcia.msstate.edu/pdf/seed- processing-and-handling_1.pdf.

AGE 533: Agri-Project Planning and Management (2+1)

I. Theory

Unit I

Project development, market survey and time motion analysis.

Unit II

Selection of equipment, technology option, techno-economic feasibility and processing in production catchment.

Unit III

Product and process design, PERT, CPM, transport model, simplex, linear and dynamic programming, operation log book. Material balance and efficiency analysis, performance testing, performance indices, energy requirement and consumption. Marketing of agricultural products, market positioning.

Unit IV

BIS/FSSAI/ISO standards/ guidelines on best practices, equipment and their design and operation for handling, processing and storage of food/feed.

II. Practical

Preparation of project and feasibility report. Salient features, design and layout of different food processing units; MSME, large processing unit. Record keeping related to production, finance and marketing. Techno-economic feasibility and SWOT analysis for Start-ups.

Reference book

- Ahmed T. 1997. *Dairy Plant Engineering and Management*. 4th Ed. Kitab Mahal.
- Albert L. 2417. *Project Management, Planning and Control.*
- Anandajayasekeram P. 2444. *Agricultural Project Planning and Analysis.*

AGE 534: Farm Structures and Environmental Control (2+1)

I. Theory

Unit I

Farmstead planning, survey and data collection for information bank. Analysis of data, Lay outs. Cost estimation and appraisal. Project development; Time, motion and input analysis, flow charts and drawings and case studies.

Unit II

Farm structures (farmstead, livestock, poultry, storage godowns, farm machinery storage, biogas, green house, net house etc), their design, constructional details and design of low-cost structures. Heating, ventilating and exhaust systems, air distribution and air cleaning, combustion of fuels and equipment.

Unit III

Drying and dehumidification system, air-water contact operations and evaporation, process and product air conditioning, energy efficient environmental control practices. Rural electrification, households electric wiring, rural water supply and sanitation.

Unit IV

Instruments and measurements: Codes and standards.

II. Practical

Calculation of heating and cooling load, design calculation of moisture condensation in agricultural buildings, study of moisture migration behaviour in storage bins, design aspect of green house, net house, septic tank, grain storage structures, cold storage.

Reference book

- Albright LD. 1994. *Environmental Control for Animals and Plants.* ASAE Textbooks.
- Esmay ML and Dixon JE. 1986. *Environmental Control for Agricultural Buildings*. The AVI Corp.
- Gaudy AF and Gaudy ET. 1988. *Elements of Bioenvironmental Engineering*. Engineering Press.
- Moore FF. 1994. *Environmental Control Systems: Heating, Cooling, Lighting*. Chapman and Hall.
- Threlkeld JL. 1974. *Thermal Environmental Engineering*. Prentice Hall.

AGE 535: Dairy Product Processing (2+1)

I. Theory

Unit I

Procurement, transportation and processing of market milk, cleaning and sanitization of dairy equipment. Special milks such as flavoured, sterilized, recombined and reconstituted toned and double toned.

Unit II

Condensed milk: Methods of manufacture and related equipment, evaluation of condensed and evaporated milk. Dried milk: Definition, methods of manufacture of skim 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.

Unit III

Ice cream: Methods of manufacture and related equipment, defects in ice cream, technology of softy manufacture. Cheese: Methods of manufacture, cheddar, Gouda, cottage and processed cheese, defects in cheese.

Unit IV

Indigenous milk products: Method of manufacture of *yoghurt, dahi, khoa, burfi, kalakand, gulabjamun, rosogolla, srikhand, chhana, paneer, ghee, lassi*etc. Probiotic milk product.

II. Practical

Estimation and fat and SNF in milk. Operation of LTLT and HTST Pasteurization. Preparation of special milks.Cream separation and standardization of milk. Preparation and evaluation of table butter, ice-cream, cheese and indigenous milk product such as *khoa, chhana, paneer, ghee, rosogolla, gulabjamun, shrikhand, lassi, burfi,* etc. Visit to dairy plants.

Reference book

- Adnan T. 2449. *Dairy Powders and Concentrated Products* (*Society of Dairy Technology*). Wiley-Blackwell.
- Adnan T. 2446. *Probiotic Dairy Products* (*Society of Dairy Technology series*). Wiley- Blackwell.
- Britz. 2448. *Advanced Dairy Science and Technology*. Blackwell Publisher: Blackwell Publisher Professional.
- De. 2441. *Outlines of Diary Technology*. Oxford.
- Hui YH. 1992. *Dairy Science and Technology Handbook.* Vol. I, II and III Wiley.
- Spreer E. 2417. *Milk and Dairy Product Technology*. Taylor and Francis.
- Walstra P, Jan TM, Wouters and Geurts TJ. 2446. *Dairy Science and Technology*. CRC, Taylor and Francis.

AGE 536: Processing of Meat, Poultry and Fish (2+1)

I. Theory

Unit I

Meat: Genetic engineering of farm animals for better meat quality, automation for the modern slaughterhouse, hot-boning of meat, new spectroscopic techniques for online monitoring of meat quality, real-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.

Unit II

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 waste.

Unit III

Fish and seafood: Fresh fish handling and chill storage, modified atmospheric packaging of seafoods, fish odours and flavours, assessment of freshness of fish and seafoods, traditional dried and salted fish products, proteolysed fish products, minced fish technology, retort pouch processing technology, irradiation and microwave in fish handling and processing, advanced freezing technology for fish storage, high pressure processing of seafoods, value addition of freshwater and aqua cultured fish products, application of enzymes in fish processing and quality control, toxins, pollutants and contaminants in fish and seafoods.

Unit IV

Milk: Physical, chemical and nutritional properties of milk components, improvements in the pasteurization

and sterilization of milk. Flavour generation in dairy products, controlling texture of fermented dairy products, functional dairy products, on-line measurement of product quality in dairy processing, high pressure processing of milk products, novel separation technologies to produce dairy ingredients, new technologies to increase shelf-life of dairy products, genetic engineering of milk proteins, production and utilization of functional milk proteins, methods of improving nutritional quality of milk, significance of milk fat in dairy products, chromatographic, spectrometric, ultrasound and other techniques for analysis of milk lipids.

II. Practical

Analysis of fresh and processed meat, fish, poultry and milk products, preservation of fresh meat and fish, processing and production of different products from fresh meat, fish and milk, shelflife studies on different meat, fish and milk products. Visit to processing plants.

Reference book

- Chooksey MK. 2443. *Fish Processing and Product Development*. CIFE, Kochi.
- Chooksey MK and Basu S. 2443. *Practical Manual on Fish Processing and Quality Control.* CIFE, Kochi.
- Hall GM. 1997. *Fish Processing Technology*. Blabie Academic and Professional.
- Lawrie RS. 1985. *Developments in Meat Sciences*. Vol III Applied Science Publishers.
- Mead GC. 1989. *Processing of Poultry*. Elsevier.
- Pearson AM and Tauber FW. 1984. *Processed Meats*. AVI Publishers.
- Stadelman WJ and Cotterill OJ. 1984. *Egg Science and Technology*. AVI Publishers.

AGE 537: Design of Aquacultural Structures (2+1)

I. Theory

Unit I

Inland fish farming and associated considerations.

Unit II

Fish physiology and micro-climatic considerations. Site selection for aquaculture structures.

Unit III

Design of dykes, sluice, channels etc. Aeration and feeding systems: Design of fish rearing structures, hatcheries, containers for live fish, fingerlings, fish seeds.

Unit IV

Aquaculture in recirculatory systems, oxygen and aeration, sterilization and disinfection. Recirculation of water: Reuse systems, water exchange, design of re- use systems, Inlet and outlet structures and water treatment plants.

II. Practical

Aeration and feeding systems of fish ponds, fish farming structures, water treatment plants, containers for live fish. Design of re-use systems. Inlet and outlet structures.

Reference book

- FAO. 1983. *Inland Aquaculture Engineering*. ISBN 92-5-142168-6.

AGE 538: Thermal Environmental Engineering for Agricultural Processing (2+1)

I. Theory

Unit I

Requirements of temperature and moisture in food preservation, processing, storage, animal and plant production systems, human comfort etc.

Unit II

Thermodynamic properties of moist air, psychrometric chart, psychrometric processes and applications. Mass transfer and evaporation of water from free surfaces, theory of psychrometer, direct contact transfer processes between moist air and water-air washer, cooling tower, heating and cooling of moist air by extended surface coils, dehumidification using moisture absorbing materials. Solar irradiations on structures, calculation of heating and cooling loads in buildings/ storage structures.

Unit III

Design of air conditioning systems, air distribution and duct design, air flow pattern and control, equipment, components and controls. Instruments for measurement and control of temperature and moisture.

Unit IV

Thermal insulation materials for environmental control systems, applications of environmental control in green house, dairy industry, potato storage etc.

Reference book

- *Perry's Chemical Engineers' Handbook*, Section 12. (2447).
- Threlkald JL. *Thermal Environmental Engineering*, Pearson.

Syllabus

M.Tech. (Agricultural Engineering) in Irrigation and Drainage Engineering

AGE 541 - Design of Surface Irrigation Systems (1+1)

I. **Theory Unit I**

Climate and irrigation water requirement. Irrigation principles, losses, conveyance, distribution, application and water budgeting. Estimation techniques of effective rainfall. Irrigation software: CROPWAT, AQUACROP.

Unit II

Farm irrigation systems. Irrigation efficiencies. Economic feasibility. Irrigation water quality and salinity management techniques. Design of water conveyance, control and distribution systems.

Unit III

Hydraulics: Design and operation of border, check basin, 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.

Unit IV

Basic water management concepts and objectives. Alternative irrigation scheduling techniques. Integrated approach to irrigation water management.

II. **Practical**

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.

Reference book

- Finkel HJ. 1983. *Handbook of Irrigation Technology*. Vols. I-II, CRC Press.
- James LG. 1988. *Principles of Farm Irrigation System Design*. John Wiley and Sons, New York, USA.
- Karmeli D, Peri G and Todes M. 1985. *Irrigation Systems: Design and Operation*. Oxford University Press.
- Michael AM. 2008. *Irrigation Theory and Practices*. Vikas Publishing House Pvt. Ltd, New Delhi.
- Pillsbury AF. 1972. *Sprinkler Irrigation*. FAO Agricultural Development Paper No. 88, FAO.
- Rydzewski. 1987. *Irrigation Development Planning*. John Wiley and Sons.
- Sivanappan RK 1987. *Sprinkler Irrigation*. Oxford and IBH.
- Sivanappan RK, Padmakumari O and Kumar V. 1987. *Drip Irrigation*. Keerthy Publ, House.

AGE 542- Design of Farm Drainage Systems (2+1)

I. **Theory**

II. **Unit I**

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.

Unit II

Concept of critical water table depth for waterlogged soil and crop growth. Drainage investigations and drainage characteristics of various soils. Methods of drainage system and drainage coefficient.

Unit III

Theories and applications of surface and subsurface drainage. Planning, design and installation of surface and subsurface drainage systems for waterlogged and saline soils. Theories and design of vertical drainage, horizontal subsurface drainage and multiple well point system. Drainage materials.

Unit IV

Steady and unsteady state drainage equations for layered and non-layered soils. Principle and applications of Hooghoudt, Kirkham, Earnst, Glover Dumm, Kraijenhoff-van-de-leur equations. Drainage for salinity control.

Unit V

Salt balance, leaching requirement and management practices under drained conditions. Disposal of drainage effluents. Case study for reclamation of salt affected waterlogged areas.

III. Practical

Measurement of in-situ hydraulic conductivity. Estimation of drainage coefficient and leaching requirements. Delineation of waterlogged areas through isobar, isobath and topographic maps. Design of surface and subsurface drainage systems. Design of filter and envelop materials.

Reference book

- Bhattacharaya AK and Michael AM. 2003. *Land Drainage*. Vikas Publ.
- Clande Ayres and Daniel Scoates AE. 1989. *Level Drainage and Reclamation*. Mc.Graw Hill.
- Luthin JN. 1978. *Drainage Engineering*. Wiley Eastern.
- Ritzema HP (Ed.) 1994. *Drainage Principles and Applications*. ILRI
- Roe CE. 1966. *Engineering for Agricultural Drainage*. McGraw Hill.
- Schilfgaarde Jan Van (Editor). 1974. *Drainage for Agriculture*. Monograph No. 17. American Society of Agronomy Madison, Wisconsin, USA.

AGE 543Command Area Management (2+1)

I. Theory

Unit I

Concept of command area development as an integrated approach. Command area project formulation, major, medium and minor projects. Command areas in India, command area activities and their prioritization. Source of budget for CAD works. Structure of command area development, organization, role and responsibilities of CADA.

Unit II

Laser based land grading survey and levelling in command areas. Design of lined and unlined canals. Diversion head works and canal head regulators, cross drainage works, canal falls, canal breaches. Design of On Farm Water Distribution Network, operation and maintenance of canal.

Unit III

Assessment and appraisal of water availability in command areas. Water management problems in command areas and their possible remedies. Duty of water, its determination and factors affecting it. Methods of improving duty of canal water. Feasibility of drip irrigation in irrigated command areas.

Unit IV

Single and multi-objective command area planning for the better management and allocation of irrigation water. Conjunctive use of canal water and groundwater. Real time canal irrigation scheduling.

Unit V

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.

II. Practical

Study of canal, tank and tube well in a command area. Study of design and operational parameters of a command area. Study of water balance in a command. Study the impact of command area project on crop yield and environment. Conflict resolution through PRA exercise. Diagnostic analysis of the problems of command area through PRA and field observations. Analysis of equity in water distribution. Considerations for preparation of roistering schedules. Study of the functioning of irrigation cooperatives/water user's associations. Preparation of command area development plan.

Reference book

- Jos´eLiria Montanes. 2006. *Design, Construction, Regulation and Maintenance*. Taylor and Francis Publication.
- Modi PN. *Irrigation Water Resources and Water Power Engineering*. Standard Publishers.
- Singh VP. 2014. *Entropy Theory in Hydraulic Engineering: An Introduction*. ASCE Press.
- Sharma SK. *Irrigation Water Resources and Water Power Engineering*. Standard Publishers.
- Swamee PK and Chahar BR. *Design of Canals*. Springer Publications.

AGE 544: Water and Nutrient Management under Protected Cultivation (2+1)

I. Theory

Unit I

Significance of soilless culture in agriculture. Functions of the root system. Response of root growth to local nutrient concentrations. Interactions between environmental conditions and form of N nutrition.

Unit I

Roots as source and sink for organic compounds and plant hormones. Physical and chemical properties of soilless media.

Unit II

Water content and water potential in soilless media. Water movement in soilless media. Uptake of water by plants in soilless media and water availability.

Unit III

Production technology for vegetables under protected conditions in soil and soilless media. Automation for climate control in protected structures. Thermal modeling of greenhouse environment for protected cultivation.

II. Practical

Filter types and its selection criteria. Design and installation of drip irrigation system for vegetables and orchards. Irrigation and fertigation scheduling for vegetables and horticultural. Study of different types of sensors, relay and control mechanism for controlled irrigation and fertigation. Design of automated system for irrigation and fertigation. Design and installation of different protected structures as per the guidelines of NHM. Design and fabrication of soilless medium for crop/ flower production. Economical evaluation of automated irrigation system and soilless medium for crop/flower production.

Reference book

- Howard M Resh. *Hydroponic Food Production*. CRC Press, New York.
- Michael Raviv and Heinrich J Lieth 2014. *Soilless Culture*. CRC Press.
- Meier Schwarz. *Soilless Culture Management*. Springer publications, New York.

AGE 545: Design of Drip and Sprinkler Irrigation Systems (2+1)

I. Theory

Unit I

Suitability of sprinkler and drip irrigation systems under Indian conditions. Basic hydraulics of sprinkler and micro irrigation system.

Unit II

Pipe flow analysis. Friction losses and pressure variation. Flow in nozzles and emitters.

Unit III

Design and evaluation of sprinkler and micro irrigation systems in relation to source, soil, climate and topographical conditions.

Unit IV

Selection of pipe size, pumps and power units. Layout, distribution, efficiency and economics.

Unit V

Fertigation through sprinkler and micro irrigation systems. Fertigation techniques involved in drip and sprinkler irrigation systems.

II. Practical

Design of drip and sprinkler irrigation system. Calculation of total head. Determination of uniformity of sprinkler discharge at the field. Numerical on the hydraulics of dripper. Calculation of different types of efficiencies of installed drip system. Calculation of cost benefits of drip and sprinkler irrigation systems.

Reference book

- Jensen ME. (Editor). 1983. *Design and Operation of Farm Irrigation Systems*. ASAE, Monograph No. 3. USA.
- James LG. 1988. *Principles of Farm Irrigation System Design.* John Wiley and Sons, New York, USA.
- Michael AM. 2006. *Irrigation Theory and Practice*. Vikas Publ. New Delhi.
- Withers Bruce and Vipond Stanley. 1974. *Irrigation: Design and Practice.* B.T. Batsford Ltd, London.
- Sivanappan RK. 1987. *Sprinkler Irrigation*. Oxford and IBH Publishing Co. New Delhi

AGE 546: Ground Water Engineering (2+1)

I. Theory

Unit I

Water resources of India. Occurrence, storage and movement of groundwater in alluvial and hard rock formations. Principles of groundwater flow. Interaction between surface water and groundwater.

Unit II

Natural and artificial groundwater recharge. Conjunctive use of surface and groundwater. Groundwater balance. Fluctuation of water table beneath a recharge site. Delineation of groundwater potential zones using RS and GIS, MODFLOW equation.

Unit III

Derivation of hydraulics of fully and partially penetrating wells in confined, leaky and unconfined aquifers. Flow net analysis.

Unit IV

Analysis of multi aquifers. Flow analysis in interfering wells. Pumping tests for estimation of aquifer parameters. Wells near recharge and impermeable boundaries. Skimming well technology.

Unit V

Design of well field. Salt water intrusion in inland and coastal aquifers. Application of groundwater models for groundwater management. Calibration and validation of models.

II. Practical

Water table contour maps and determination of groundwater flow. Estimation of aquifer characteristics. Problems on non-leaky and leaky aquifers. Analysis of pumping test data. Computation of interference of wells. Groundwater computer simulation models.

Reference book

- Boonstra J and de Ridder NA. 1981. *Numerical Modeling of Groundwater Basins*. ILRI.
- Demenico PA. 1972. *Concept and Models in Groundwater Hydrology*. McGraw Hill.
- Huisman L 1972. *Ground Water Recovery*. Mac Millan.
- Jat ML and SR Bhakar 2008. *Ground Water Hydrology*. Agro-tech Publishing Academy. Udaipur.
- Polubarinova Kochina P Ya. 1962. *Theory of Ground Water Movement*. Princeton Univ. Press.
- Raghunath HM 1992. *Ground Water*. Wiley Eastern.
- Todd DK 1997. *Ground Water Hydrology*. Wiley Eastern.

AGE547: GIS and Remote Sensing for Land and Water Resource Management (2+1)

I. Theory

Unit I

Physics of remote sensing. Electromagnetic radiation (EMR), interaction of EMR with atmosphere, earth surface, soil, water and vegetation. Remote sensing platforms: Monitoring atmosphere, land and water resources: LANDSAT, SPOT, ERS, IKONOS and others. Indian Space Programme.

Unit II

Satellite data analysis. Visual interpretation. Digital image processing. Image pre- processing. Image enhancement. Image classification. Data merging.

Unit III

Basic components of GIS. Map projections and co-ordinate system. Spatial data structure: Raster, vector. Spatial relationship. Topology. Geodatabase models: Hierarchical, network, relational, object-oriented

models. Integrated GIS database. Common sources of error. Data quality: Macro, micro and Usage level components, Meta data. Spatial data transfer standards.

Unit IV

Thematic mapping. Measurement in GIS: Length, perimeter and areas. Query analysis. Reclassification, Buffering and Neighbourhood functions. Map overlay: Vector and raster overlay. Interpolation and network analysis. Digital elevation modelling. Analytical Hierarchy Process. Object oriented GIS, AM/FM/GIS and Web Based GIS.

Unit V

Spatial data sources. 4M 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.

II. Practical

Familiarization with the remote sensing instruments and satellite imagery. Aerial Photograph and scale determination with stereoscope. Interpretation of satellite imagery and aerial photograph. Determination of Parallaxes in images. Introduction to digital image processing software and GIS software and their working principles. Generation of digital elevation model (DEM) for land and water resource management. Case studies on mapping, monitoring and management of natural resources using remote sensing and GIS.

Reference book

- Charles Elach and Jakob van Zyl. 2006. *Introduction to the Physics and Techniques of Remote Sensing*. John Wiley & Sons publications.
- Ian Heywood Sarah, Cornelius and Steve Carver. 2002. *An Introduction to Geographical Information Systems.* Pearson Education. New Delhi.
- James B Campbell and Randolph H Wynne. 2011. *Introduction to Remote Sensing*. The Guilford Press.
- Lillesand TM and Kiefer RW. 2008. *Remote Sensing and Image Interpretation*. John Wiely and Sons.
- Paul Curran PJ. 1985. *Principles of Remote Sensing*. ELBS Publications.
- Rees WG. 2001. *Physical Principles of Remote Sensing*. Cambridge University Press.

AGE 548: Waste Water Management and Utilization in Agriculture (2+1)

I. Theory

Unit I

Status of wastewater in India. Sources of contamination and characterization of urban and rural wastewater for irrigation. Water quality: Physical, chemical and biological parameters of wastewater.

Water quality requirement: Potable water standards, wastewater effluent standards, water quality indices. Irrigation water quality standards and guidelines for their restricted and unrestricted uses. Selection of appropriate forestry trees, fruits, vegetables, oilseeds and food grain crop for wastewater utilization.

Unit II

Control measures for preventing soil and other surface/groundwater source contamination. Different types of wastewater, pollutants and contaminants. Impact of wastewater on ecosystem, eutrophication, biomagnification, water borne diseases.

Unit III

Wastewater treatment methods: Physical, chemical and biological. General water treatments: Wastewater recycling, constructed wetlands, reed bed system. Carbon foot prints of wastewater reuse. Environmental standards.

Unit IV

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.

II. Practical

Measurement of water quality indices in the lab. Field demonstration of impact of waste water on eco-system and human health. Waste water treatment methods and effect of waste water in contamination of ground

water. Visit of waste water treatment plant near by area.

Reference book

- Charis Michel Galanakis. *Sustainable Water and Wastewater Processing.* Elsevier Publication, Amsterdam.
- Sean X Liu. 2014. *Food and Agricultural Wastewater Utilization and Treatment*. Wileu Blackwell New York.
- Shirish H, Sonawane Y, Pydi Setty T, Bala Narsaiah and S Srinu Naik. 2017. *Innovative Technologies for the Treatment of Industrial Wastewater: A Sustainable Approach*. CRC Press.
- Stuetz Richard. *Principles of Water and Wastewater Treatment Processes* (*Water and Wastewater Process Technologies*). IWA Publishing.

AGE 549: Water Conveyance and Distribution (2+1)

I. Theory

Unit I

Channel characteristics. Prismatic and non-prismatic channel. Steady, unsteady, uniform and non-uniform flow. Open channel and their properties. Energy and momentum, critical flow computation and application. Basic Concepts of free surface flow, classification of flow, velocity and pressure distribution.

Unit II

Uniform flow, conservation laws and specific energy. Application of momentum and energy equation. Channel transition. Study of critical flow, uniform flow, gradually varied flow, rapid varied flow, spatially varied flow and unsteady flow and their computations.

Unit III

Energy dissipation. Flow control structures and flow measurement. Theories and methods of open channel design.

Unit IV

Sediment transport in channels. Regime flow theories. Tractive force theory. Design of stable channels.

Unit V

Basic principles of pipe flow, pipe flow problems and equivalent pipe. Principles of network synthesis. Pipe network analysis. Water transmission lines. Cost considerations: Single-Input source. Branched systems: Single-Input source. Looped Systems: Multi-Input source. Branched systems: Multi-Input source, Looped systems. Decomposition of a large water system and optimal zone size.

II. Practical

Computation and use of geometrical and hydraulic elements of open channel. Use of flow measuring devices and methods and their limitations. Examination of velocity distribution and calculation of energy and momentum coefficients. Solution of channel design problems. Appraisal of flow control and distribution structures. Analysis and computation of flow profiles.

Reference book

- Chaudhry MH. 1993. *Open Channel Flow*. Prentice-Hall, NJ.
- Chow VT. 1979. *Open Channel Hydraulics*. McGraw Hill Inc. N York.
- French RH. 1986. *Open Channel Hydraulics*. McGraw Hill Pub Co., N York
- Henderson FM. 1966. *Open Channel Flow*. Macmillan Co. New York.
- Prabhata K Swamee and Ashok K Sharma. *Design of Water Supply Pipe Networks*. John Wiley New York.
- Subramanya K. 2008. *Flow in Open Channels*. Tata McGraw Hill Pub.
- Terry Sturm. 2011. *Open Channel Hydraulics.* Tata McGraw Hill Pub.

AGE 550: Minor Irrigation (2+1)

I.Theory

Unit I

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.

Unit II

Evaporation and seepage control. Groundwater development methods and their scope. Groundwater extraction

devices and methods. Aquifer characteristic and their evaluation. Wells in alluvial and rocky aquifers.

Unit III

Well interference, spacing and multiple well point system for controlled groundwater pumping. Safe yield from wells. Augmentation of well yield through pumping and recovery time management.

Unit IV

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.

Unit V

Conjunctive use of surface and groundwater. Legislation for groundwater development and management. Groundwater recharge and its use.

I. **Practical**

Measurement of seepage loss from reservoirs. Estimation of inflow to surface reservoir. Measurement of evaporation loss from surface reservoirs. Pumping test and determination of aquifer parameters. Establishment of draw down-discharge characteristic. Well log analysis and deciding on length and placement of strainers. Computation of well interference and deciding on well spacing. Estimation of irrigation for given discharge from well. Estimating pumping cost for irrigation. Analysis of ground water quality. Problems on well design.

Reference book

- Garg SK. 1987. *Irrigation Engineering and Hydraulic Structures*. Khanna Publisher, Delhi.
- Garg SK. 1987. *Hydrology and Water Resource Engineering.* Khanna Publishers, Delhi.
- Michael AM. 2006. *Irrigation Theory and Practice.* Vikas Publications, New Delhi.
- Sharma RK. 1987. *Hydrology and Water Resources Engineering*. Dhanpat Rai and Sons, New Delhi.
- Subramanian K. 1993. *Engineering Hydrology*. Tata Mc-Graw-Hill Co. New Delhi.

AGE 551: Design of Pumps for Irrigation and Drainage (2+0)

I. **Theory**

Unit I

Basic hydraulic design of centrifugal pump. Net positive suction head and cavitation, vapour pressure, water hammering problem in centrifugal pump.

Unit II

Principles and design of pumping systems for agricultural drainage. Selection and performance of characteristics of vertical turbine pump, submersible pump and axial flow pump.

Unit III

Multiple well point system and their design. Energy requirement in groundwater pumping.

Unit IV

Non-conventional energy sources for pumping, wind mills, micro turbines, solar pumps. Hydraulic ram: Selection and design criteria. Solar photovoltaic system.

Unit V

Design of pumping station. Techno-economic evaluation. Efficient pumping system operation, flow control strategies and conservation measures for pumping systems.

Reference book

- Bansal RK. 1990. *A Text Book of Fluid Mechanics and Hydraulic Machines*. Laxmi Publications, New Delhi.
- Church AH and Jagdish Lal. 1973. *Centrifugal Pumps and Blowers*. Metropolitan Book Co. Pvt. Ltd. Delhi.
- Luthin JN. 1966. *Drainage Engineering*. Wiley and Sons. New York, USA.
- Michael AM and Khepar SD. 1989. *Water Wells and Pump Engineering*. Tata McGraw Hill Publishing Co., New Delhi.

AGE 552: Crop Environmental Engineering (2+0)

I. **Theory**

Unit I

Principles of heat, mass and momentum transport. Transport of radiant energy, radiation environment, micro climatology of radiation. Micrometeorology: Turbulent transfer profiles and fluxes. Interpretation of flux measurement. Laws of electromagnetic radiation, its measurement and estimation.

Unit II

Profile balance of heat, mass and momentum in and above crop communities. Climatic changes and plant response to environmental stresses. Measurement and estimation of potential evapotranspiration on point and regional scale.

Unit III

Root anatomy, water flow in roots and root density models (microscopic and macroscopic). Stem anatomy and pressure volume curves. Methods of measuring water status in plants. Estimating ET using three temperature model and MODIS algorithm. Soil–Plant–Atmosphere system: Basic properties. Dynamics of water movement. ET-yield relations.

Unit IV

Principles of optimal scheduling of irrigation and seasonal allocation of limiting water supplies using LP and DP. Seasonal and dated production functions. Crop yield modelling and condition assessment. Instrumentation and techniques for monitoring plant environments.Design and operation of controlled environment facilities and their instrumentation. Climatic changes and plant response to environmental stresses. Evapotranspiration models.

Reference book

- Abtew W and Melese A. 2017. *Evaporation and Evapotranspiration: Measurements and Estimations*. Springer Publications.
- Campbell GS and Norman JM. *An Introduction to Environmental Biophysics*. Springer Publication New York.
- Ghildyal BP and Tripathy RP. 1987. *Fundamental of Soil Physics.* Wiley Eastern.
- Monteith JL and Unsworth MH. *Principles of Environmental Physics*. Elsevier, Amsterdam.
- Slatyor O P 1967. *Plant Water Relationship*. Academic Press.
- Yang Y. *Evapotranspiration over Heterogeneous surfaces: Models and Applications.* Springer Publications.

AGE 553: Water Resources Systems Engineering (2+1)

I. **Theory Unit I**

Concepts and significance of optimization in water resources management. Model development in water management. Objective functions, deterministic and stochastic inputs.

Unit II

Soil plant atmosphere system. Problem formulation. Mathematical programming techniques: Linear programming, simplex method.

Unit III

Non-linear programming, quadratic programming, integer programming. Transportation problem and solution procedure. Geometric programming and dynamic programming.

Unit IV

Application of optimization techniques for water resources planning. Conjunctive use of water resources. Crop production functions and irrigation optimization.

Unit V

Multi objective water resources planning. Critical path method. Programme evaluation and review technique. Economic models. Project evaluation and discounting methods.

II. **Practical**

Assessment of water resources. Problems related to water allocation in agriculture under single and multiple cropping system. Use of computer software for linear and dynamic programming. Introduction to the use of other programming methods. Sensitivity analysis of different alternatives of water resources development and

allocation. Analysis of water demand and supply. Analysis of Competitive demands for water by various sectors of development. Benefits and cost of water resources development.

Reference book

- Larry WM. 1996. *Water Resources Handbook*. Mc-Graw-Hill.
- Loucks DP *et al*. 1981. *Water Resources System Planning and Analysis*. Prentice Hall.
- Rao SS. 1978. *Optimization Theory and Application*. Wiley Eastern.
- Wallander WW and Bos M. 1990. *Water Resource System Planning and Management*.

AGE 554: Irrigation Economics Planning and Management (2+0)

I. Theory Unit I

Economic analysis. Problems in project selection. Methods and approaches to water pricing. Criteria for investment and pricing in irrigation projects. Social benefits, problems and causes of under-utilization. Mathematics of economic analysis. Cost allocation, separable and non-separable costs. Discounting factors and techniques. Determination of benefits, cost and benefit analysis. Project evaluation. Limitations of benefit-cost analysis. Dynamics of project analysis.

Unit II

Role of financial analysis. Distinctions from economic analysis. Financial feasibility and analysis. Impact of public policies on regulation and allocation of irrigation water. Relative economic efficiency of alternative irrigation water management models. Irrigation system improvement by simulation and optimization to enhance irrigation water use efficiency.

Unit III

Indian agriculture, main problems, population, government policies, systems, organizing agriculture production. Farm Management: Definition, importance, scope, relation with other sciences and its characteristics.

Unit IV

Socio-economic survey. Importance of such survey in planning, implementation and evaluation of project performance. Planning of socio-economic survey, types of data sets to be collected, preparing the questionnaires form, schedules sampling, editing and scrutinizing of secondary data, classification and analysis of data.

Unit V

Role of farm management principles in decision making for irrigated agriculture. Decision making process, assessing risk and uncertainty in planning.

Reference book

- Heady, Early Orel, Hexem R and Roger W. 1978. *Water Production Functions for Irrigated Agriculture*.
- James Douglas and Lee Rober R. 1995. *Economics of Water Resource Planning*. Tata Mcgraw- Hill Publication Company Ltd, Bombay, New Delhi.
- Joshi SS and TR Kapoor. 2001. *Fundamentals of Farm Business Management*. Kalyani Publishers, Ludhiana.
- *Management of Water Project-Decision Making and Investment Appraisal*. Oxford Publication Co.
- Sharma VK. 1985. *Water Resource Planning and Management*. Himalaya Publication House, New Delhi.

AGE 555: Sensing and Automation in Irrigation Systems (3+0)

I. Theory

Unit I

Sensing and sensors. Sensor classifications. Wireless sensor networks. History of wireless sensor networks (WSN). Communication in a WSN. Important design constraints of a WSN like Energy, self-management, wireless networking, decentralized management, design constraints, security etc.

Unit II

Node architecture. Sensing subsystem. Analog-to-Digital converter. The processor subsystem, architectural overview, microcontroller, digital signal processor, application-specific integrated circuit, field programmable gate array (FPGA).

Unit III

Communication interfaces, serial peripheral interface, inter-integrated circuit, the IMote node architecture, The XYZ node architecture, the Hogthrob node architecture.

Unit -IV

Applications in surface irrigation automation, automation based on volume, time, fertigation scheduling, water logging, salinity, oxygen diffusion systems, etc.

Reference book

- Cauligi S Raghavendra, Krishna M Sivalingam and Taieb Znati. *Wireless Sensor Networks*. Springer.
- Edgar H, Callaway Jr. and Edgar H Callaway. *Wireless Sensor Networks: Architectures and Protocols*.
- Holger Karl and Andreas Willig. *Protocols and Architectures for Wireless Sensor Networks.* John Wiley & Sons.
- Waltenegus Dargie and Christian Poellabauer. *Fundamentals of Wireless Sensor Networks:* Theory and Practice. A John Wiley and Sons, Ltd, Publication.

Syllabus

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

AGE 561 : Soil Dynamics in Tillage and Traction (2+1)

I. Theory

Unit I

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

Unit II

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

Unit III

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

Unit IV

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

II. Practical

Measurements of soil shear strength by in-situ shear box apparatus and soil friction by friction plate. Measuring cone penetrometer resistance and working out tractive 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.

Reference book

- Gill WR and Van den Berg GE. 1968. *Soil Dynamics in Tillage and Traction*.
- Handbook 316, *Agricultural Research Service*, US Department of Agriculture, Washington DC, 1968.
- John BL, Paul KT, David WS and Makoto H. 2012. *Tractors and their Power Units.* 4th Edition. Springer Science & Business Media, ISBN: 81-239 0501-7, ASAE ISBN: 0-929355-72-5.
- Koolen AJ and Kuipers H. 1983. *Agricultural Soil Mechanics.* Springer-Verlag ISBN 13:978- 3-642-69012-9.
- McKyes E. 1989. *Agricultural Engineering Soil Mechanics*, Elsevier science publishers B.V., P.O. Box 211, 1000 AE Amsterdam, the Netherlands.
- McKyes E. 2016. *Soil Cutting and Tillage: Vol 7*. Developments in Agricultural Engineering Elsevier R Science Publisher SBV.

AGE 562: Testing and Evaluation of Agriculture Equipment (2+1)

I. Theory

Unit I

Importance and significance of testing and types of testing. Test equipment, usage and limitations. Test procedures and various test codes: National and International.

Unit II

Laboratory and field testing of tillage and sowing machinery: Sub-soiler, laser land leveler, mould board Plough, disc plough, rotavator, cultivator, disc harrow, seed cum fertilizer drill and planter.

Unit III

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

Unit IV

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

Unit V

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

II. **Practical**

Laboratory and field testing of selected farm equipment: Tillage, sowing and planting. Material testing of critical components. Accelerated testing of fast wearing components.

Reference book

- Barger E L, Liljedahl J B and McKibben E C. 1967. *Tractors and their Power Units*. Eastern Wiley 4th Edition.
- *Indian Standard Codes for Agricultural Implements*. Published by BIS, New Delhi.
- Inns F M. 1986. *Selection, Testing and Evaluation of Agricultural Machines and Equipment*. FAO Service Bull. No.115.
- Mehta M L, Verma S R, Rajan P and Singh S K 2019. *Testing and Evaluation of Agricultural Machinery*. Daya Publishing House, Delhi.
- *Nebraska Tractor Test Code for Testing Tractor*, Nebraska, USA.
- Smith D W, Sims B G and O'Neill D H 2001. *Testing and Evaluation of Agricultural Machinery and Equipment -Principle and Practice*. FAO Agricultural Services Bull. 110.

AGE 563: Ergonomics and Safety in Farm Operations (2+1)

I. **Theory**

Unit I

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

Unit II

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

Unit III

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

Unit IV

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

Unit V

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

II. **Practical**

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

Reference book

- Bridger R S 2009. *Introduction to Ergonomics*. CRC Press, Boca Rotan, USA
- Sanders M S and McCormick E J 2000. *Human Factors in Engineering and Design*. McGraw Hill. 7th edition
- Astrand P, Rodahl K, Dahl H A and Stromme S B 2003. *Textbook of Work Physiology - Physiological Basis of Exercise*. McGraw Hill.
- Gite L P 2009. *Anthropometric and Strength Data of Indian Agricultural Workers for Farm Equipment Design*. Central Institute of Agricultural Engineering, Bhopal.
- Gite L P, Agrawal K N, Mehta C R, Potdar R R and Narwariya B S. 2019. *Handbook of Ergonomical Design of Agricultural Tools, Equipment and work Places*. Jain Brothers, New Delhi.

AGE 564: Design of Tractor Systems (2+1)

I. **Theory**

Unit I

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

Unit II

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

Unit III

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

Unit IV

Mechanics of tractor stability. Computer aided design and its application in farm tractors.

II. **Practical**

Engine design calculations, transmission component design calculations. Extensive practices on the computer aided design packages.

Reference book

- Barger EL Liljedahl JB and McKibben EC. 1967. *Tractors and their Power Units*. Wiley Eastern Pvt. Ltd.
- Macmillan RH. 2002. *The Mechanics of Tractor – Implement Performance and Worked Example.* University of Melbourne, Australia.
- Sharma PC and Agarwal DK. 2000. *Machine Design*. S K Kataria and Sons, Delhi.

AGE 565 : Design of Farm Machinery-I (2+1)

I. **Theory**

Unit I

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

Unit II

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

Unit III

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

Unit IV

Methods of sowing and planting: Machines, agronomic specifications. Sowing inter- tilled crop. Grain

hoppers: Seed metering mechanism, furrow openers and seed tubes. Machines for fertilizer application: Discs type broadcasters. Organic fertilizer application: Properties of organic manure, spreading machines. Liquid fertilizer distributors. Planting and transplanting: Paddy transplanters, potato planters.

II. **Practical**

Design of mould board working surface; Coulter, frog, share, jointer, mould board plough. Trailed, semi mounted and mounted ploughs. Design of disc plough, disc harrow, peg tooth harrow, cultivators, sweeps. Design of rotary tiller. Design of traction and transport devices.

Design of seed drills; Metering mechanism, hopper, furrow opener. Fertilizer spreader, liquid fertilizer applicators and design of its sub systems. Design of paddy transplanters and potato planters.

Reference book

- Bernacki C, Haman J and Kanafajski Cz. 1972. *Agricultural Machines Theory and Construction.* Vol.I. U.S. Dept. of Commerce, National Technical Information Service, Springfield, Virginia 22151.
- Bosoi ES, Verniaev OV, Smirnov II and Sultan-Shakh EG. 1990. *Theory, Construction and Calculations of Agricultural Machinery - Vol. I.* Oxonian Press Pvt. Ltd. No.56, Connaught Circle, New Delhi.
- Gill R and Vanden Berg GE. 2013. *Soil Dynamics in Tillage and Traction*. Scientific Publishers (India) ISBN-10: 8172338031.
- Yatsuk EP 1981. *Rotary Soil Working Machines Construction, Calculation and Design.* American Publishing Co. Pvt. Ltd, New Delhi.

AGE 566 : Design of Farm Machinery-II (1+1)

I. **Theory Unit I**

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

Unit II

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

Unit III

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

Unit IV

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

Unit V

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

II. **Practical**

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

Reference book

- Bernacki C, Haman J and Kanafajski Cz 1972. *Agricultural Machines Theory and Construction*. Vol-I. U.S.

Department of Commerce, National Technical Information Service, Springfield, Virginia22151.
- Bindra, OS and Singh H. 1971. *Pesticides Application Equipments*. Oxford & IBH Publishing Co., New Delhi.
- Bosoi ES, Verniaev OV, Smirnov II and Sultan-Shakh EG. 1987. C*onstruction and Calculations of Agricultural Machinery - Vol.II.* Oxonian Press Pvt. Ltd. New Delhi.
- Miu P. 2016. *Combine Harvesters Modeling and Design*. CRC Press, Boca Raton, USA ISBN 13:978-1-4822-8237-5
- Thornhill EW and Matthews GA. 1995. *Pesticide Application Equipment for Use in Agriculture* Vol II. Mechanically powered equipment FAO Rome.

AGE 567: Management of Farm Power and Machinery System (2+1)

I. Theory

Unit I

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

Unit II

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

Unit III

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

Unit IV

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

II. Practical

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.

Reference book

- Carveille LA. 1980. *Selecting Farm Machinery*. Louisiana Cooperative Extn. Services Publication.
- Culpin C. 1996. *Profitable Farm Mechanization*. Lock Wood and Sons, London.
- FAO. 1990. *Agricultural Engineering in Development: Selection of Mechanization Inputs.* FAO, Agri service Bulletin.
- Hunt D. 1979. *Farm Power and Machinery Management.* Iowa State University Press, USA.
- Kapoor VK. 2012. *Operation Research: Concepts, Problems and Solutions.* Sultan Chand and Sons, India.

AGE 568: Principles of Automation and Control (2+1)

I. Theory

Unit I

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

Unit II

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

Introduction to CNC machines.

Unit III

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

Unit IV

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

Unit V

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

II. **Practical**

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

Reference book

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

AGE 569 - Principles of Hydraulic and Pneumatic Systems (2+1)

I. **Theory**

Unit I

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

Unit II

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

Unit III

Actuators, types, design of linear actuator and rotary actuators. Hydraulic rams, gear motors, piston motors and their performance characteristics. Hose, filters, reservoirs, types of circuits, intensifier, accumulator, valves. Valve types: Direction control, deceleration, flow, pressure control, check valve and their working etc.

Unit IV

Hydraulic circuit design. Applications in farm power and machinery: Tractor, combine, farm machinery systems, hydrostatic system etc.

Unit V

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

II. **Practical**

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

Reference book

- Anthony E. 2003. *Fluid Power with Applications*. Pearsons Education (Singapore) Pvt. Ltd.
- Krutz G. 1984. *Design of Agricultural Machines*. John Wiley and Sons.
- Majumdar S R. 2003. *Oil Hydraulics Systems: Principles and Maintenance*. Tata McGraw Hill Co.

· Merritt HE. 1991. *Hydraulic Control System*. John Wiley and Sons Inc.

AGE 570: Applied Instrumentation in Farm Machinery (2+1)

I. Theory

Unit I

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.

Unit II

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.

Unit III

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

Unit IV

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.

II. Practical

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

Reference book

· Ambrosius EE. 1966. *Mechanical Measurement and Instruments*. The Ronald Press Company.
· Doeblin EO. 2004. *Measurement System- Application and Design*. Tata McGrawHill
· Nakra BC and Choudhary KK. 1985. *Instrumentation, Measurement and Analysis*.2nd Edition Tata McGraw Hill.
· Nachtigal CL (Editor). 1990. *Instrumentation and Control. Fundamentals and Application*. Wiley Series in Mechanical Engineering.
· Oliver FJ. 1971. *Practical Instrumentation Transducers*. Hayden book company Inc.

AGE 571: Systems Simulation and Computer Aided Problem Solving in Engineering (1+1)

I. Theory

Unit I

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

Unit II

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

Unit III

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

Unit IV

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

II. Practical

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

Reference book

- Balagurusamy E. 2000. *Numerical Methods.*Tata McGraw Hill Publishing Company limited, New Delhi.
- Chapra SC and Canale RP. 1994. *Introduction to Computing for Engineers*. 2nd Edition McGraw Hill International Edition, New York.
- Dent JB and Blackie MJ. 1979. *System Simulation in Agriculture.* Applied Science Publishers Ltd., London.
- Law AM. 2015. *Simulation Modeling and Analysis.* McGraw Hill International Edition, New York.
- Schilling RJ and Harries SL. 2002. *Applied Numerical Methods for Engineers Using MATLAB and C.*Thomson Asia Pvt. Ltd. Singapore.
- Veerarajan T and Ramachnadran T. 2004. *Numerical Methods with Programmes in C and C++*. Tata McGraw Hill Publishing company limited, New Delhi.

AGE 572: Computer Aided Design of Machinery (0+2)

I. Practical

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

Reference book

- Jankowski G and Doyle R. 2007. *SolidWorks® For Dummies®*, 2nd Edition, Published by Wiley Publishing, Inc. ISBN: 978-0-470-12978-4
- Shih R H. 2014. *AutoCAD 2014 Tutorial-First Level: 2D Fundamentals*. SDC Publications

AGE 573: Advanced Manufacturing Technologies (2+1)

I. Theory

Unit I

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

Unit II

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

Unit III

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

Unit IV

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

Unit V

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

II. **Practical**

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

Reference book

Begeman ML, Ostwald PF and Amstead BH. 1979. *Manufacturing Processes: SI Version*. John Wiley and Sons. 7th Edition.

- Chapman PAJ. 1996. *Workshop Technology*, Part III. CBS Publisher and distributors Pvt Ltd. 3rd Edition international Edition.
- Gupta RB. 2017. *Production Technology*, Vol I - Production Process. Satya Prakashan, New Delhi.
- Hoyos L. 2010. *Fundamentals of Tool Design*. American Society of Tool and Manufacturer Engineers. Sixth Edition.
- Jain RK. 1994. *Production Technology: A Textbook for Engineering Students*. Khanna Publishers, New Delhi.
- Polukin P, Gringerg B, Kantenik S, Zhadan V and Vasilye D. *Metal Process Engineering*, MIR Publishers Moscow.

Ltd. 3rd Edition international Edition.

- Gupta RB. 2017. *Production Technology*, Vol I - Production Process. Satya Prakashan, New Delhi.
- Hoyos L. 2010. *Fundamentals of Tool Design*. American Society of Tool and Manufacturer Engineers. Sixth Edition.
- Jain RK. 1994. *Production Technology: A Textbook for Engineering Students*. Khanna Publishers, New Delhi.

.Polukin P, Gringerg B, Kantenik S, Zhadan V and Vasilye D. *Metal Process Engineering*,

AGE 574: Machinery for Precision Agriculture (2+1)

I. **Theory**

Unit I

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

Unit II

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

Unit III

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

Unit IV

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

Unit V

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

II. **Practical**

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

Reference book

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

AGE 575: Machinery for Horticulture and Protected Agriculture (2+0)

I. **Theory**

Unit I

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

Unit II

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

Unit III

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

Unit IV

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

Unit V

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

Reference book

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