INDIAN INSTITUTE OF ENGINEERING SCIENCE AND TECHNOLOGY, SHIBPUR

COURSE STRUCTURE AND SYLLABI FOR POSTGRADUATE PROGRAMMES

M.Tech PROGRAMMES

CIVIL ENGINEERING DEPARTMENT

FROM 2021 ONWARDS

JULY 2021

CONTENTS **PAGE NO.**

Specialization: Environmental Engineering

Course Structure

1st Semester

Sl. No	Course Name	Course code	Class Load/Week			Credit	Class load/ Week	Marks
			L	T	P			
1.	Course I: Chemistry for Environmental Engineering	CE 5110	3	0	0	3	3	100
2.	Course II: Biological Processes in Environmental Engineering	CE 5111	3	0	0	3	3	100
3.	Course III: Physico-Chemical Processes Water and Wastewater Treatment	CE 5112	3	0	0	3	3	100
4.	Course IV: (Dep. Elective)		3	0	0	3	3	100
5.	Course V: (Open Elective)		3	0	0	3	3	100
	Theory Sub-total		15	0	0	15	15	500
6.	Water Quality Analysis Lab	CE5180	0	0	3	2	3	100
7.	Physicochemical Process Lab	CE5181	0	0	3	2	3	100
8.	Biological Process Lab	CE5182	0	0	3	2	3	100
	Practical Sub-total		NIL	NIL	9	6	9	300
	1st Semester Total					21	24	800

2ndSemester

Sl. No	Course Name	Course code	Class Load/Week			Credit	Class load/ Week	Marks
			L	T	P			
1.	Course VI: Process and Hydraulic Design of Water and Wastewater Systems	CE5210	3	0	0	3	3	100
2.	Course VII: Air Pollution and Control	CE5211	3	0	0	3	3	100
3.	Course VIII: Solid and Hazardous Waste Management	CE5212	3	0	0	3	3	100
4.	Course IX (Dep. Elective)		3	0	0	3	3	100
5.	Course X (Open Elective)		3	0	0	3	3	100
	Theory Subtotal		10	1	0	15	15	500
6.	M. Tech Project Part - I (Term Paper)	CE5291	0	0	2	4	0	200
7.	Term Paper Seminar & Viva-voce	CE5292	0	0	0	2	0	100
	Practical Subtotal		0	0	0	6	0	300
	2nd Semester Total					21	17	800

3rdSemester

Sl. No	Course Name	Course code	Class Load/Week			Credit	Class load/ Week	Marks
			L	T	P			
1.	M. Tech Project Part - II (Progress Report)	CE6191	0	0	0	12	0	300
2.	Progress Report Seminar & Viva-voce	CE6192	0	0	0	6	3	100
	Total Credit		0	0	0	18	0	
	3rd Semester Total					18	0	400

4th Semester

Sl. No	Course Name	Course code	Class Load/Week			Credit	Class load/ Week	Marks
			L	T	P			
1.	M. Tech Project Part - III (Thesis)	CE6291	0	0	0	22	0	400
2.	Thesis seminar and viva voce	CE6292	0	0	0	8	0	200
	Total Credit		0	0	0	30	0	
	4th Semester Total					30	0	600

Course IV [Departmental elective]	**Course IX [Departmental elective]**
CE5145 Management of Rural Water Supply and Sanitation CE5146 Environmental Management and Legislation CE5147 Energy Evolution from Waste Material	CE5245Industrial Pollution Control CE 5246 Environmental Biotechnology CE 5247 Environmental Toxicology and Risk Assessment

1st Semester

CE5110 Chemistry for Environmental Engineering

Weekly Contact: 3-0-0 (L-T-S)
Full Marks: 100
Credits: 3

Course Objective: To provide students with the knowledge of chemical principles, atmospheric chemistryand working principle of multiple analytical instruments related to environmental engineering.

Course Outcome: At the end of the course, the students will be able to:

- Understand the fundamental chemical principles of environmental chemistry.
- Know different equilibria aspects of acid-base, solubility and oxidation-reduction.
- Learn the concept of thermodynamics.
- Get an overview of atmospheric and aerosol chemistry.
- Be acquainted with various sophisticated instruments used in environmental analysis.

Syllabus (Brief outline): Introduction, Basic Chemical Principles, Acid-Base Equilibria, Metal Complexation, Solubility Equilibria, Oxidation Reduction Equilibria, Thermodynamics, Atmospheric chemistry, Fundamentals of analytical instruments and Fundamentals of Process Kinetics and Reactor Analysis

Module No.	Course Module and Lesson Plan	Contact hours
1.	**Introduction:** Chemistry and Environmental Chemistry; The BuildingBlocks of Matter; Chemical Bonds and Compound Formation	2
2.	**Basic Chemical Principles**: General solubility rules for inorganic compounds; Concentration; Composite parameter; Chemical activity and ionic strength; Chemical equilibrium.	2
3.	**Acid-Base Equilibria:** Dissociation of water; Definition of acid and base; Acidity constant; Acid/base speciation as a function of pH; α plot; LogC-pH diagrams; Buffer and Hendersen-Hasselbalch equation	5
4.	**Metal Complexation:** Ligands; Equilibrium relationship in metal complexation; Complexation with H2O and OH-; K, β, and *K, *β notations; Cadmium hydroxide complexes and impact of chloride; Predominance area diagrams – Fe^{2+}/OH^-/Cl^-.	5
5.	**Solubility Equilibria:** Solubility product; Common ion effect; Effect of pH on solubility of metallic hydroxides; Effect of weak acid and bases; Effect of complexes; Equilibrium relationships and LogC – pH diagrams; Predominance area diagrams.	5
6.	**Oxidation Reduction Equilibria:** Definition of oxidation and reduction; Rules	5

	for determining oxidation number; Oxidation numbers (valences) of some important elements; Simple redox reactions; Balancing complex redox reactions; Redox half-cell reactions; Free energy of reaction; Electrochemical cell; pe, peo, and Eh (or EHo); Construction of log C-pe diagrams; pe-pH diagram (Pourbaix diagram).	
7.	**Thermodynamics:** Heat and work; Specific heat; Laws of Thermodynamics; Entropy; Internal energy and enthalpy; Other thermodynamic functions; The Gibbs function.	4
8.	**Atmospheric chemistry:** Stratospheric chemistry; Tropospheric chemistry and photochemical reactions; Acid rain formation; Aerosol chemistry	3
9.	**Fundamentals of analytical instruments:** Spectrophotometry - UV-VIS spectrophotometer, Atomicabsorption spectrophotometer; Chromatography – ion chromatography; gas chromatography and liquid chromatography; Flame photometer; TOC analyzer.	4
10.	**Fundamentals of Process Kinetics and Reactor Analysis:** Rate of reaction; Order of reaction; Enzymatic reaction, Reactors and its analysis.	4
	Total	**39**

Suggested Readings:

1. Clair Sawyer, Perry McCarty and Gene Parkin "CHEMISTRY FOR ENVIRONMENTAL ENGINEERING AND SCIENCE'' McGraw-Hill Publisher.
2. Stumm, W. and Morgan, J.J. "Aquatic Chemistry", John Willey and Sons. Inc.
3. Benefield, L.D., Judikins, J.F. and Weand, B.L. "Process Chemistry for Water and WastewaterTreatment" Prentice-Hall Inc**.**

CE5111 BIOLOGICAL PROCESSES IN WASTEWATER TREATMENT

Weekly Contact: 3-0-0 (L-T-S)

Full Marks: 100
Credits: 3

Course objective: To familiarize students about fundamentals of microbiology for wastewater treatment and to impart the basic idea of different biological methods for wastewater treatment.

Course outcome:

1. Students will be able to learn microbiology and bio-kinetics parameters.
2. Students will be able to know about different methods for biological wastewater treatment.
3. After completing the course, the students will be able todesign the biological processes.

Syllabus: Fundamentals of Biological Wastewater Treatment, Bacterial Growth and Energetics, Microbial Growth Kinetics, Suspended and Attached Growth Process, Biological Nitrification, Denitrification and Phosphorous Removal, Anaerobic Fermentation and Oxidation, Activated Sludge Process (ASP), Trickling and Bio-Filters

Module No.	Course Module and Lesson Plan	Contact hours
1.	**Fundamentals of Biological Wastewater Treatment**: Objectives and Scopes, Role of Microorganism, Suspended Growth Process, Attached Growth Process, Composition and Classification of microorganism, Carbon and Energy sources for microbial growth, Nutrients and other Growth requirements	5
2.	**Bacterial Growth and Energetics**: Bacterial Reproduction, Bacterial Growth pattern in batch culture, bacterial growth and biomass yield, Estimating biomass yield and oxygen requirement	4
3.	**Microbial Growth Kinetics:** Concept, Rate of utilization of soluble substrate, Rate of soluble substrate production from particulate organic matter, Kinetic co-efficients for substrate utilization and biomass growth, Rate of oxygen uptake, Net biomass yield and observed yield.	4
4	**Suspended and Attached Growth Process**: Biomass mass balance, Substrate mass balance, Mixed liquor solid concentration and solids production, observed yield, Design and operating parameters like (F/M) ratio, Specific substrate utilization rate, organic loading rate, Substrate flux in biofilm, Substrate mass balance for biofilm.	6
5	**Activated Sludge Process (ASP):** Basic concept, evolution requirements, Process design considerations, Food to microorganism ratio, volumetric organic loading rate, sludge production, oxygen requirements etc., sludge wasting, oxygen uptake rate, Complete-mix activated sludge process for BOD removal and nitrification, Sequencing Batch Reactor, Biological nitrogen removal by ASP, Biological phosphorous removal by ASP.	
6	**Trickling and Bio-Filters** Basic concept, classification and components, Process design considerations, Design of packing media, Combined BOD removal and nitrification, Biofilter Activated Sludge Process.	
7	**Anaerobic Fermentation and Oxidation:** Process description, Microbiology, Stoichiometry, Growth kinetics and Environmental factors of Anaerobic Fermentation, General design considerations of conventional Anaerobic digester, Anaerobic contact process, Anaerobic sequencing batch reactor and Anaerobic sludge blanket process.	
8	**Biological Nitrification, Denitrification and Phosphorous Removal**: Process description, Microbiology, Stoichiometry, Growth kinetics and Environmental factors of Nitrification; Process description, Microbiology, Stoichiometry, Growth kinetics and Environmental factors of Denitrification; Process description, Microbiology, Stoichiometry, Growth kinetics and Environmental factors of Phosphorous Removal	6
	TOTAL	**39**

Suggested Readings:

1. Metcalf & Eddy "Wastewater Engineering –Treatment and Reuse", Tata McGraw Hill Publishers.
2. Davis and Cornwel, "Introduction to Environmental Engineering", McGraw Hill Publishers
3. Peavy, Rowe and Tchobanoglous, "Environmental Engineering", McGraw Hill Publishers

CE5112 Physico-Chemical Processes in Water and Wastewater Treatment

Weekly Contact: 3-0-0 (L-T-S)
Full Marks: 100
Credits: 3

Course Objective: To provide students with the knowledge of different Physico-chemical processes related to water and wastewater treatment.

Course Outcome: At the end of the course, the students will be able to:

- Know different Physico-chemical processes related to water and wastewater treatment.
- Comprehend the modes of operation and engineering application of various Physico-chemical processes.
- Learn the design implementation of the Physico-chemical processes in water and wastewater treatment plant.

Syllabus (Brief outline): Coagulation and Flocculation, Sedimentation, Filtration, Chemical precipitation, Adsorption, Ion Exchange, Disinfection, Membrane processes, Aeration and gas transfer

Module No.	Course Module and Lesson Plan	Contact hours
1.	**Coagulation and Flocculation:** stability of colloids, destabilisation, transport of colloidal particles, design	5
2.	**Sedimentation:** discrete and flocculent suspensions, clarifier configuration, design, tube/plate settlers	4
3.	**Filtration:** configurations/classifications, mechanism, filter hydraulics and design of filter bed	5
4.	**Chemical precipitation:**basic principle, OH^-, CO_3^{2-} and S^- precipitation, water softening Applications	2
5.	**Adsorption:** mechanism, equilibria, kinetics, contacting systems and modes of operation, design	5
6.	**Ion Exchange:** exchange processes, exchange materials, equilibria, modes of operation and application, design	5
7.	**Disinfection:** pathogens and indicator organisms, disinfectants, disinfection processes, factors affecting disinfection	4
8.	**Membrane processes:** Membranes, Reverse osmosis, ultra-filtration, electrodialysis, principles and application	5
9.	**Aeration and gas transfer:** Gas transfer processes, systems, factors affecting the aeration and transfer rates	4

	Total	**39**

Suggested Readings:

1. Walter J Weber Jr. Physicochemical Processes for Water Quality Control, John Wiley and Sons
2. Davis and Cornwel, "Introduction to Environmental Engineering", McGraw Hill Publishers
3. Peavy, Rowe and Tchobanoglous, "Environmental Engineering", McGraw Hill Publishers

Departmental Electives (Course IV)

CE 5145 Management of Rural Water Supply and Sanitation

Weekly Contact: 3-0-0 (L-T-S)
Full Marks: 100
Credits: 3

Course Objective: To provide students with a basic understanding of rural water supply, treatment requirements, and liquid and solid waste management.

Course Outcome: At the end of the course, the students will be able to:

- Identify the sources of rural water supply
- Decide the methods of treatment requirements for rural water supply
- Learn about the management of night soil and liquid waste
- Get acquainted with different approaches of solid waste management

Syllabus (Brief outline): General Overview, Water Supply Quality aspects, Planning of water supply schemes in rural areas, Treatment of water for rural water supply, Disposal of Night Soil and Wastewater, Compact and simple wastewater treatment units, Disposal of Solid Wastes.

Module No.	Course Module and Lesson Plan	Contact hours
1.	**General Overview:** General Concept and scope of environmental sanitation in rural areas, Magnitude and problems of water supply and sanitation in rural areas in India, National policy.	5
2.	**Water Supply Quality aspects:** Specific impurities and their significance, Design population, Demand and variations	4
3.	**Planning of water supply schemes in rural areas**: Individual village and group schemes, Source of water supply: Springs, wells, infiltration wells, radial wells, infiltration galleries and surface water intake,Emergency water supply	6
4.	**Treatment of water for rural water supply:** Compact system: multi-bottom	6

	settler, horizontal roughing filter, slow sand filter, cloth filter, chlorine diffuse cartridges, pumps, pipe, materials, appurtenances and improved device for use in rural water supply schemes, Distribution system for rural water supply	
5.	**Disposal of Night Soil and Wastewater:** Various methods of collection and disposal of night soil, sanitary latrines, community latrines, septic tanks, soakage system, anaerobic filter, Imhoff tank.	6
6.	**Compact and simple wastewater treatment units:** stabilization ponds, revolving biological surfaces. Biogas Plants, Quantity of cow dung, required capacity and design	6
7.	**Disposal of Solid Wastes:** Composting, landfilling, incineration, recycling. Case studies.	6
	Total	**39**

Suggested Readings:

1. Rural Water Supply and Sanitation - Sanjay Gupta, VAYU Education of India
2. Rural Water Supply and Sanitation- Forest B. Wright, Kruger Publishing Company
3. Water Supply & Sanitary Engineering - G.S. Birdie & J.S. Birdie, Dhanpat Rai Publishing Co. Pvt. Ltd.
4. Textbook of Water Supply and Sanitary Engineering - S.K. Husain, Oxford & IBH Publishers

CE 5146 Environmental Management and Legislation

Weekly Contact: 3-0-0 (L-T-S)
Full Marks: 100
Credits: 3

Course Objective: To make students acquainted with various aspects of environmental management and legislation.

Course Outcome: At the end of the course, the students will be able to:

- Learn about resource management and biodiversity conservation.
- Know about pollution and control strategies.
- Become acquainted with waste management.
- Get the idea environmental health risk assessment.

Syllabus (Brief outline): Natural Resource Management and Biodiversity Conservation, Pollution and Pollution Control, Basics of Environmental Management, E-Waste and Radioactive Waste Management, Life Cycle Assessment, Environmental Impact Assessment and Audit, Environmental Risk Assessment, ISO 9000, 14000 Series and OHSAS 18001.

Module No.	Course Module and Lesson Plan	Contact hours
1.	**Natural Resource Management and Biodiversity Conservation:** Introduction, Three key concerns, Levels of Biodiversity, Evolution of biodiversity, Biodiversity in India, Value and uses of biodiversity	6
2.	**Pollution and Pollution Control:** Classification of pollutants, Causes of pollution, Air pollution, water pollution, Soil pollution, Noise pollution, Thermal pollution, Radioactive pollution, Global warming and climate changes, Ozone depletion, Eutrophication etc.	4
3.	**Basics of Environmental Management:** Definition, scope and importance, Dimensions and principles of environmental management, Drawbacks of conventional environmental management approaches,Integrated environmental management	4
4.	**E-Waste and Radioactive Waste Management:** Evolution and composition of E-wastes, E-waste management in India and abroad, Recycling, reuse and recovery of E-wastes, Treatment and disposal of E-wastes, Environmentally sound treatment of E-wastes, Classification of radioactive wastes, Management of radioactive wastes.	5
5.	**Life Cycle Assessment:** Introduction, Stages in Life Cycle Assessment, Life Cycle Assessment Procedures, Life Cycle of Industrial Products; LCA Framework, Streamlined Life Cycle Assessment, Benefit of Life Cycle Assessment.	5
6.	**Environmental Impact Assessment and Audit:** Introduction, Environmental Impact Assessment. EIA Practice in India, Elements of an EIA Report, Environmental Audit, Principal Elements of Environmental Audit, Components of Auditing, Environmental Audit Process, Environmental Audit (EA) Report, Waste Audit	5
7.	**Environmental Risk Assessment:** Introduction, Use of Risk Assessment in Environmental Management, Hazard andRisk, Process of Environmental Risk Assessment and Management, Risk Evaluation,Emission and Exposure Control, Risk Monitoring, Risk Communication, Advantagesand Disadvantages of Risk Assessment.	6
8.	**ISO 9000, 14000 Series and OHSAS 18001:** Introduction, EMS Certification, Emerging Trends in Management of EnvironmentalIssues, ISO 14000 Series, Guidelines for Auditing, Types of Audit, Risk AuditTechniques, Status of EMS in India, OHSAS 18001 Standard	4
	Total	**39**

Suggested Readings:

1. I.V Murali Krishna, ValliManickam and Anil Shah "Environmental Management : Science and Engineering for Industry",Elsevier Publishers.
2. M.M. Sulphey and M.M. Safeer"Introduction to Environment Management" PHI Learning Pvt. Ltd..
3. S.K. Agarwal "Environmental Management" APH Publishing

CE 5147 Energy Evolution from Waste Materials

Weekly Contact: 3-0-0 (L-T-S)
Full Marks: 100
Credits: 3

Course Objective: To provide students with a basic understanding of energy evolution from waste material.

Course Outcome: At the end of the course, the students will be able to:

- Get acquainted with the concept of waste to energy approach
- Know the composition and quantities of solid waste
- Know various technologies of waste to energy conversion
- Select the facility Site
- Getfamiliar with environmental legislation issues

Syllabus (Brief outline): Introduction and Overview, WTE Implementation Concepts, Solid waste Composition and Quantities, WTE Technologies, Selecting the Facility Site and Environmental Legislation Issues, Energy and Materials Markets, Procurement of WTE systems, Ownership and Financing of WTE facilities.

Module No.	Course Module and Lesson Plan	Contact hours
1.	**Introduction and Overview:**The growing solid waste disposal problem, The trends towards Waste to Energy (WTE), Climate change and WTE, Relevance and Importance of WTE, Concept of Chemical and Biological Conversion.	6
2.	**WTE Implementation Concepts:**Introduction, Developing the project team, Risk assessment, Implementation process, Implementation project scheduling, Implementation project costs, Public information programs	4
3.	**Solid waste Composition and Quantities:**Introduction, Types of solid waste, Solid waste quantities, Waste composition methodology, Waste sorting, Energy Potential of Solid Wastes.	4
4.	**WTE Technologies:**Introduction, Flow control mechanisms of solid wastes, Basic combustion system, Stages of combustion, Mass-burning, Modular combustion, Refuse derived fuel (RDF) systems, Fluidized bed systems, Anaerobic Digestion, Emerging waste conversion technologies.	5

5.	**Selecting the Facility Site and Environmental Legislation Issues:** Introduction, site selection process, Site screening process, Use of Geographic Information Systems (GIS) technology in sitting, Environmental Regulations for running the facility.	5
6.	**Energy and Materials Markets:** Introduction, Energy markets, Materials markets, Projected energy productionfrom a proposed WTE facility.	5
7.	**Procurement of WTE systems:** Introduction, Procurement approaches,Procedures for conducting the procurement process, Preparing the request for-proposals, Proposal evaluation, Negotiations process.	4
8.	**Ownership and Financing of WTE facilities:** Introduction, Ownership alternatives, Prerequisite to financing, Financingoptions, Private equity, Costs and facility operation, Initial capital equipment,Operating costs, Estimated annual debt service and annual operating costs,Equipment life and replacement, Zero tip fee for a developing nation	6
	Total	**39**

Suggested Readings:

1. Marc Rogoff and Francois Screve, "Waste-to-Energy – Technology and Project Implementation", Elsevier Publishers.
2. Tchobanoglous, Theisen and Vigil, "Integrated Solid Waste Management –Engineering Principle and Management Issues", McGraw Hill Publishers
3. Paul Breze "Energy from Waste" Elsevier Publishers.

CE 5180Water Quality Analysis Laboratory

Weekly Contact: 0-0-3 (L-T-P)
Full Marks: 100
Credits: 2

Course Objective: To provide `hand in experience how to analyse different water quality parameters and knowledge on operating principles of different water quality analysis equipments.

Course Outcome: At the end of the course, the students will be able to:

- Know about principles of analysis of different water quality parameters sampling and preservation
- Become familiar with analysis and reporting of data
- Development of standard curves and interpretation of result

Syllabus (Brief outline): Determination of different water quality parameters

Module No.	Course Module and Lesson Plan	Contact hours
1.	Determination of aluminium of an aqueous sample by Erichrome Cyanine R method	4
2	Determination of arsenic of an aqueous sample by SDDC method	4
3	Determination of chromium of an aqueous sample by SnCl2 colorimetric method	4
4	Determination of iron of an aqueous sample by phenantholine method	4
5	Determination of manganese of an aqueous sample by persulfate method	4
6	Determination of phosphate of an aqueous sample by colorimetric method	4
7	Determination of sulfate of an aqueous sample by turbidimetric method	4
8	Determination of metal contents of an aqueous sample by atomic absorption spectrophotometric method	4
9	Determination of pesticide by high performance liquid chromatography	4
10	Viva Voce	3
	Total	**39**

Suggested Readings:

1.Standard Methods for the Examination of water and Wastewater, APHA, AWWA,WEF.

CE 5181Physicochemical Process Laboratory

Weekly Contact: 0-0-3 (L-T-P)
Full Marks: 100
Credits: 2

Course Objective: To provide `hand in experience how to analyse different physical and chemical processes in water and wastewater treatment systems.

Course Outcome: At the end of the course, the students will be able to:

- Know about working principles and analysis of different physical and chemical unit operations carried out in water and wastewater treatment

Syllabus (Brief outline): Operation of different physical and chemical unit operation carried out in water and wastewater analysis

Module	Course Module and Lesson Plan	Contact

No.		hours
1.	Type-I settling column analysis of discrete suspensions	6
2	Type-II settling column analysis of flocculating particles	6
3	Design of sand filter bed with a given specification and calculation of head loss	6
4	Determination of optimum coagulant for removal of turbidity	4
5	Determination of chlorine dose for disinfection of surface water	4
6	Adsorption of phenol on activated carbon and isotherm analysis	6
7	Degradation study of organic compounds through oxidation process	4
8	Viva-voce	3
	Total	**39**

Suggested Readings:

1. Standard Methods for the Examination of water and Wastewater, APHA, AWWA,WEF.

CE 5182Biological Process Laboratory

Weekly Contact: 0-0-3 (L-T-P)
Full Marks: 100
Credits: 2

Course Objective: To provide `hand in experience how to analyse different wastewater quality parameters and in wastewater treatment systems.

Course Outcome: At the end of the course, the students will be able to:

- Know about working principles and analysis of different wastewater quality parameters in wastewater treatment process.

Syllabus (Brief outline): Determination of solids and Oxygen demanding constituents, Determination of biological parameters

Module No.	Course Module and Lesson Plan	Contact hours
1	Introductory lecture	3
2	Determination of solids in wastewater	6
3	Determination of biochemical oxygen demand of wastewater	6
4	Determination of chemical oxygen demand of wastewater	3

5	Determination total organic carbon of wastewater by TOC analyser	6
6	Determination of nitrate-nitrogen of an aqueous sample by UV spectrophotometric method	5
7	Determination of MLSS, MLVSS and SVI of a biological reactor	5
8	Viva-voce	4
	Total	**39**

Suggested Readings:

1.Standard Methods for the Examination of water and Wastewater, APHA, AWWA,WEF.

2nd Semester

CE 5245: Process and Hydraulic Design of Water and Wastewater Systems

Weekly Contact: 3-0-0 (L-T-S)

Full Marks: 100
Credits: 3

Course objective: To familiarize the students about various design aspects and considerations for water and wastewater treatment units, and to learn about the hydraulics of water and wastewater treatment plant and water distribution system and sewerage system.

Course outcome:

1. Students will be able to learn and design different unit processes for water and wastewater treatment
2. Students will be able to design intake structures, wells, water distribution system and sewerage system.
3. Students will be able to design the hydraulic profiles in water and wastewater treatment plants.

Syllabus: Estimation of water and wastewater flow, Hydraulics of wells, Hydraulics of water supply system, Hydraulics of sewer and its design, Design of unit operations and process, Water and wastewater treatment plant hydraulics.

Module No.	Course Module and Lesson Plan	**Contact hours**
1	**Estimation of water and wastewater flow:** Various types of water demand; Design Period; Population forecasting; Variation in rate of demand; Estimation of sewage quantity – rational method.	**3**
2	**Hydraulics of wells:** Geological formation - aquifer, aquitard,	**8**

	aquiclude and aquifuge; Storage Coefficient; Specific yield; Coefficient of permeability; Coefficient of transmissibility; Well Hydraulics – steady flow analysis and unsteady flow analysis; Unconfined steady flow into an infiltration gallery.	
3	**Hydraulics of water supply system:** Methods of distribution of water; Distribution reservoirs and its capacity; Layout of distribution system; Hydraulics of conduits – major and minor losses; Hazen-Williams formula; Darcy-Weisbach formula; Analysis of pipe network – Equivalent pipe method and Hardy Cross method.	**10**
4	**Hydraulics of sewer and its design:** Systems of sewerage and their lay-outs; Patterns of sewerage lay-out; Sewer materials; Type of flow; Flow friction formulae - Manning's formula; Design of circular sewers; Proportional hydraulic elements; Hydraulic elements of circular sewer running partially full; Design examples; Design guidelines.	**6**
5	**Design of unit operations and process:** Design of unit process/operations for water treatment and wastewater treatment units as per CPHEEO manual.	**8**
6	**Water and wastewater treatment plant hydraulics:** Hydraulic analysis of each of the units in water and wastewater treatment.	**4**
	Total	**39**

Suggested Readings:

1. Metcalf & Eddy "Wastewater Engineering –Treatment and Reuse", Tata McGraw Hill Publishers.
2. Davis andCornwel, "Introduction to Environmental Engineering", McGraw Hill Publishers
3. Peavy, Rowe and Tchobanoglous, "Environmental Engineering", McGraw Hill Publishers
4. Garg, S. K. "Environmental Engineering (Vol I & II)'', Khanna Publisher
5. CPHEEO manual on water supply and treatment and CPHEEO manual on sewerage and sewage treatment

CE 5211: Air Pollution and Control

Weekly Contact: 3-0-0 (L-T-S)
Full Marks: 100
Credits: 3

Course Objective: To familiarize students with air pollution and its control methods.

Course Outcome: At the end of the course, the students will be able to:

- Know about the fundamentals of air pollution, its sources, types and global impact.
- Learn about air pollution monitoring and analysis.
- Become familiar with National & International air emission standards and control laws.
- Learn about air pollution control methods.

Syllabus (Brief outline): Introduction, Air pollution monitoring and analysis, Air emission standards, Meteorology, Dispersion models, Air pollution control, Urban air pollution, Indoor air pollution and Global impacts of air pollution.

Module No.	Course Module and Lesson Plan	Contact hours
1.	Introduction to the course: Atmosphere Air pollution episodes	1
2.	Air pollution:sources, types, chemical transformation and effects on biosphere and environment.	3
3.	Air pollution monitoring and analysis	4
4.	National & International air emission standards; air pollution emission inventory; emission factor; airquality index; air pollution control laws	4
5.	Introduction to air pollution meteorology	4
6.	Air pollution dispersion, transportation, Air Quality Modelling: meteorological parameters, simple boxand Gaussian type model for point, area and line sources	6
7.	Air pollution control: SO_2, NO_2, particulates, Hydrocarbons.	7
8.	Urban air pollution, Vehicular air pollution, control	6
9.	Indoor air pollution	1
10.	Global effects of air pollution: Greenhouse effects, acid rain and ozone layer depletion; internationalagreements for mitigating global air pollution effects.	3
	Total	**39**

Suggested Readings:

1. Noel De Nevers Air Pollution Control Engineering, McGraw-Hill.
2. C. David Cooper and F.C. Alley Air Pollution Control – A Design Approach, MEDTECH.
3. Kenneth Wark, Cecil F. Warner, Wayne T Davis Air Pollution – Its Origin and Control, PEARSON

CE 5212 Solid and Hazardous Waste Management

Weekly Contact: 3-0-0 (L-T-S)
Full Marks: 100
Credits: 3

Course Objective: To provide the students with basic understanding about the generation of hazardous wastes, its minimization and treatment methods and management for its safe disposal.

Course Outcome: At the end of the course, the students will be able to:

- Understand the sources and composition of different solid and hazardous wastes
- Know about the different methods for waste treatment and management
- Acquire knowledge about the waste composition and treatment methods for specificindustries.
- Know about solid waste risk assessment, remedial measures and legal framework

Syllabus (Brief outline): Introduction, Ultimate Disposal of Municipal Solid Waste, Resource and Energy recovery form solid waste, Hazardous waste, Physical and chemical properties, Fate and contaminant transport, Quantitative risk assessment, remedial measures, Laws and environmental ethics, legal framework

Module No.	Course Module and Lesson Plan	Contact hours
1.	**Introduction:** Definition, Solid waste classification, Characteristics, Sources, -Solid waste management–Overviews of solid waste quantity, onsite handling and generation of solid waste; collection, Processing, storage, including segregation; Transfer and transport-route layout; Processing and Disposal.	6
2.	**Ultimate Disposal of Municipal Solid Waste**: Sanitary Landfill-criteria for landfill, landfill stability and operational procedure, gas and leachate control, Composting-aerobic and anaerobic, vermi-compost, Incineration; Biomedical Waste, e-waste management	6
3.	**Resource and Energy recovery form solid waste:** Processing and separation of components, recovery systems, system design and layout, energy recovery from aerobic and anaerobic digestion, incineration, combustion and energy recovery, gasification, pyrolysis, energy recovery system and system-efficiency	8
4.	**Hazardous waste:** Definition and episodes, Sources and types, Classification and testing-EP Toxicity Test, TCLP, Future endeavours.	5
5.	**Physical and chemical properties**: Solubility, Vapour pressure, diffusion, portioning: Octanol-water, soil-water, bio-concentration factor	4
6	**Fate and contaminant transport :** ground water flow and contaminant transport, factors affects groundwater contaminants transport, Hazardous waste removal mechanism and site remediation techniques	4
7	Quantitative risk assessment, remedial measures, Laws and environmental ethics, legal framework	6
	Total	**39**

Suggested Readings:

1.H.S.Peavy, D.R.Rowe and G. Tchobanoglous. Environmental Engineering. McGraw-Hill
2. M.D. LaGrega, P.L.Buckinghum, J.C. Evans and Environmental Resources Management, Hazardous Waste Management,McGraw-Hill
3. S.C. Bhatia. Environmental Pollution and Control in Chemical Process Industries, Khanna Publishers

Departmental Electives (Course IX)

CE 5210 Industrial Pollution Control

Weekly Contact: 3-0-0 (L-T-S)
Full Marks: 100
Credits: 3

Course Objective: To provide students with the knowledge of different industrial processes and pollution control.

Course Outcome: At the end of the course, the students will be able to:

- Know about water pollution and control
- Become familiar with air pollution and control
- Learn about management of hazardous waste

Syllabus (Brief outline): Water pollution control, Air Pollution Control and Hazardous Waste Management

Module No.	Course Module and Lesson Plan	Contact hours
1.	**Water pollution control:**Wastewater quality parameters; Effect of discharge of industrial wastewaters on streams, land and environment; importance and scope, problem involved in water treatment; Variation and quality of industrial wastewater; Indian Standards for discharge of treated wastewaters on land, into municipal sewer and natural watercourses;	4
2	**Sampling of wastewaters**–Wastewater survey, sampling and preservation, Representative samples, Grab and composite samples; Approach and minimization of waste generation;	4
3	**Treatment options**- equalization and proportioning, neutralization, floatation, physicochemical process applied in industrial wastewater treatment, Case studies.	6
4	Process flow diagrams, characteristics and treatment of various industrial wastewater: pulp and paper, textile, tannery, distillery, electroplating, refinery etc	8
5	**Air Pollution Control:** Sources of air pollution- - Stationary and mobile; Types of pollutant - gases and particulate; Effects of air pollution in regional and global scale; Air pollution episodes; Ambient and source standards, Gaseous and particulate control, stack monitoring, Case studies	6
6	**Hazardous Waste Management:**Definition and identification of hazardous wastes; sources and characteristics; Regulatory framework in India; Hazardous waste treatment technologies - physical, chemical and thermal treatment of hazardous waste; Hazardous waste landfills - site selection, design and operation – remediation of hazardous waste disposal sites, CPCB guidelines	8

7	**Biomedical waste:** Biomedical waste generation, location, land and cover area, equipment infrastructure, record, inventories, segregation, transport and treatment, CPCB Guide lines.	3
	Total	**39**

Suggested Readings:

1. Metcalf & Eddy "Wastewater Engineering –Treatment and Reuse", Tata McGraw Hill Publishers.
2. Davis and Cornwel, "Introduction to Environmental Engineering", McGraw Hill Publishers
3. Peavy, Rowe and Tchobanoglous, "Environmental Engineering", McGraw Hill Publishers

CE 5246 Environmental Biotechnology

Weekly Contact: 3-0-0 (L-T-S)
Full Marks: 100
Credits: 3

Course Objective: To provide the students with basic knowledge of environmental biotechnology.

Course Outcome: At the end of the course, the students will be able to:

- Know the fundamentals of microbiology.
- Learn about microbial and biofilm kinetics.
- Acquire knowledge on activated sludge and aerobic biofilm processes.
- Learn about nitrification and denitrification.
- Know how to remove Phosphorous.

Syllabus (Brief outline): Bacterial growth kinetics Microbial Ecology, bio film kinetics and reactor performance, design aspects of biological process, nutrient removal.

Module No.	Course Module and Lesson Plan	Contact hours
1.	**Basics of Microbiology:** The Cell, Taxonomy and Phylogeny, Eucarya, Biochemistry, Enzymes, energy Capture,Metabolism, DNA and RNA, Microbial Ecology	6
2.	**Microbial Kinetics:** Basic Rate Expressions, Basic Mass Balances, Mass Balances in Inert Biomass and Volatile solids, Soluble Microbial Products, Nutrients and Electron Accepter, Hydrolysis of Particulates and Polymeric Substrates, Inhibition, Other alternate Rate Expressions	4
3.	**Biofilm Kinetics:** Microbial Aggregation, The Idealized Biofilm, The steady-state Biofilm, The Steady-state Biofilm Solution, Average Biofilm SRT, Completely Mixed Biofilm Reactor, Trends in CMBR Performance, Normalized Surface Loading, Special-case BiofilmSolution.	4
4.	**The Activated Sludge Process:** Characteristics of Activated Sludge, Process Configuration, Design and Operating Criteria, Aeration System, Bulking and other Sludge Settling Problems, Activated Sludge Design and Analysis,	6

	Analysis and Design of Settlers.	
5.	**Aerobic Biofilm Processes:** Biofilm Process Considerations, Trickling Filters and Biological Towers, Rotating BiologicalContactors; Granular Media Filters, Fluidized-Bed and Circulating-Bed Biofilm Reactors;Hybrid Biofilm-Suspended Growth Processes.	5
6.	**Nitrification:**Biochemistry and Physiology of Nitrifying bacteria, common Process Considerations,Activated Sludge Nitrification – One Sludge Vs. Two Sludge, Biofilm Nitrification, HybridProcess, The Role of Input BOD: TKN Ratio, The ANAMMOX Process.	5
7.	**Denitrification**:Physiology of Denitrifying Bacteria, Tertiary Denitrification in Activated Sludge/BiofilmProcesses, One-sludge Denitrification – Basic and variations.	5
8.	**Phosphorous Removal:** Normal Phosphorous uptake into Biomass, Precipitation by Metal- Salts Addition,Enhanced Biological Phosphorous Removal.	4
	Total	**39**

Suggested Readings:

1. Rittmann and McCarty “Environmental Biotechnology-Principles and Applications”, McGraw Hill Publishers.
2. Daniel A Vallero “Environmental Biotechnology – A Biosystems Approach” Elsevier Publishers.
3. Pradipta Kumar Mohapatra “Text Book of Environmental Biotechnology” I.K. International Publishing House Pvt. Ltd.

CE 5247 Environmental Toxicology and Risk Assessment

Weekly Contact: 3-0-0 (L-T-S)
Full Marks: 100
Credits: 3

Course Objective: To provide students with knowledge of environmental toxicology and risk assessment. This course will discuss the statistical techniques for probabilistic exposure assessment with case studies.

Course Outcome: At the end of the course, the students will be able to:

- Know the fundamentals of environmental toxicology and risk assessment.
- Learn about exposure routes and toxicokintetics.
- Get familiar with the concepts of biomarkers, bio concentration factor, indicator species etc.
- Learn about Integrated exposure assessment with case studies.
- Get acquainted withPBPK Model.
- Learn the application of Monte Carlo simulations and other statistical techniques for probabilistic exposure assessment.

Syllabus (Brief outline): Introduction, Exposure routes, Toxicology/epidemiology, Integrated exposure assessment, PBPK Models, probabilistic exposure assessment, Risk Characterization, communication and decision making.

Module No.	Course Module and Lesson Plan	**Contact hours**
1.	Importance of environmental toxicology, dose-response relationship, hazard and risk	4
2.	Routes of exposure, Toxicokinetics, oral route, dermal route, inhalation route, distribution, elimination, absorption and bioavailability	5
3.	Toxicology/epidemiology–Biomarkers; Ecology Trophic levels, BCF (bio concentration factor), BCF modelling, indicator species	5
4.	Integrated exposure assessment – (case studies);	6
5.	Physiological-based Pharmokinetic (PBPK) Models;	7
6.	Application of statistical and Monte Carlo simulations for probabilistic exposure assessment	6
7.	Risk Characterization, communication and decision making	6
	Total	**39**

Suggested Readings:

1. Risk Assessment in Environmental Management by D. Kofi Asante-Duah, JOHN WILEY & SONS PUBLICATION
2. Quantitative Environmental Risk Analysis for Human Health by Robert A. Fjeld, Norman A. Eisenberg and Keith L. Compton, JOHN WILEY & SONS, INC., PUBLICATION

Specialization: Geotechnical Engineering

Course Structure

1st Semester

Sl. No	Course Name	Course code	Class Load/Week			Credit	Class load/ Week	Marks
			L	T	P			
1.	Course I: Advanced Soil Mechanics	CE 5104	3	0	0	3	3	100
2.	Course II: Foundation Engineering	CE 5105	3	0	0	3	3	100
3.	Course III: Dynamics of Soils and Machine Foundations	CE 5106	3	0	0	3	3	100
4.	Course IV: (Dept. Elective)		3	0	0	3	3	100
5.	Course V:(Open Elective)		3	0	0	3	3	100
	Theory Sub-total		15	0	0	15	15	500
6.	Advanced Geotechnical Engineering Laboratory	CE5174	0	0	3	2	3	100
7.	Geotechnical Model Laboratory	CE5175	0	0	3	2	3	100
8.	Mini Project on Advanced Geotechnical Engineering	CE5176	0	0	3	2	3	100
	Practical Sub-total		NIL	NIL	9	6	9	300
	1st Semester Total					21	24	800

2nd Semester

Sl. No	Course Name	Course code	Class Load/Week			Credit	Class load/ Week	Marks
			L	T	P			
1.	Course VI: Applied Geotechnical Engineering	CE5204	3	0	0	3	3	100
2.	Course VII: Analysis and Design of Special Foundations	CE5205	3	0	0	3	3	100
3.	Course VIII: Elasticity and Plasticity	CE5206	3	0	0	3	3	100
4.	Course IX (Dep. Elective)		3	0	0	3	3	100
5.	Course X (Open Elective)		3	0	0	3	3	100
	Theory Subtotal		15	0	0	15	15	500
6.	M. Tech thesis Part - I (Term Course)	CE5291	0	0	2	4	2	200
7.	Term Paper Seminar & Viva-voce	CE 5292	0	0	0	2	0	100
	Practical Subtotal		0	0	0	6	0	300
	2nd Semester Total					21	17	800

3rdSemester

Sl. No	Course Name	Course code	Class Load/Week			Credit	Class load/ Week	Marks
			L	T	P			
1.	M. Tech Thesis Part - II (Progress Report)	CE6191	0	0	0	12	0	300
2.	Progress Report Seminar & Viva-voce	CE6192	0	0	0	6	0	100
	Total Credit		0	0	0	18	0	
	3rd Semester Total					18	0	400

4thSemester

Sl. No	Course Name	Course code	Class Load/Week			Credit	Class load/ Week	Marks
			L	T	P			
1.	M. Tech Final Thesis	CE6291	0	0	0	22	0	400
2.	Thesis seminar and viva voce	CE6292	0	0	0	8	0	200
	Total Credit		0	0	0	30	0	
	4th Semester Total					30	0	600

Course IV [Departmental elective]	**Course IX [Departmental elective]**
CE5129 Ground improvement Techniques and applications	CE5229 Geotechnical Earthquake Engineering
CE5130 Rock mechanics	CE5230 Environmental Geotechnics
CE5131 Unsaturated soil mechanics	CE5231 Physical modelling in Geotechnics
CE5132 Soil Exploration and Geo-Instrumentation	CE5232 Offshore Geotechnics
CE5133Geomechanics in Soil-Structure Interaction	CE5233 Forensic Geotechnical Engineering
CE5134 Computational Geotechnics	CE5234 Tunnelling and Underground Space Technology
CE5135 Risk and Reliability in Geotechnical Engineering	

Semester: 1

CE 5104 Advanced Soil Mechanics

Weekly contact: 3-0-0 (L-T-S)
Full marks: 100
Credits: 3

Course Objective: The course intends to familiarize the students with structure and properties of clay mineral including their identification, methods of computing stress distribution in soils, concepts of soil compressibility and soil consolidation, shear strength of soil and earth pressure concepts.

Course Outcome: At the end of the course, the students will be able to:

- Understand the various factors governing the engineering behaviour of clayey soils
- Characterize stress-strain behaviour of soils, develop the stress paths, study the failure criteria and to evaluate the shear strength of soils
- Calculate stresses generated in soil mass due to imposed loads and external loads
- Calculate the compressibility parameters and settlement of soils
- Understand the principles of earth pressure theories

Syllabus: Clay mineralogy, soil - water interactions, index properties of soils in light of clay mineralogical structure, shear Strength of cohesive and cohesionless soils, stress-strain relationships, failure theories, stress path, compressibility, consolidation theories, , rheological models, earth Pressure theories, graphical methods.

Module No.	Course module and lesson plan	Contact hours
1.	**Clay mineralogy** -Introduction to clay mineralogy, structures and identification (XRD, DTA, TG) of clay minerals, inter-particle forces, soil - water interactions, index properties of soils in light of clay mineralogical structure.	6
2.	**Shear strength** -Shear Strength of cohesive and cohesionless soils, stress-strain relationships, failure theories, corrections, behaviour of soil and stress path.	10
3.	**Soil stresses**–Stresses in soil due to imposed loads and external loads.	5
4.	**Compressibility and consolidation** - One, two and three-dimensional consolidation theories, secondary consolidation, settlement of compressible soil layers, non-linear stress-strain curves and applications, rheological models.	9
5.	**Earth Pressure concepts -** Basic concepts of lateral pressure, determination of active and passive pressures, Rankine and Coulomb earth pressure theories, graphical methods, Culmann's Graphical Method, Rebhann's method, logarithmic spiral methods, friction circle method, consideration of surcharge, seepage, stratification, type of backfill, wall friction and adhesion.	9
	Total	**39**

Suggested Readings:

1. Terzaghi, K., "Theoretical Soil Mechanics", John Wiley.
2. Wood, D.M., "Soil Behaviour and Critical State Soil Mechanics", Cambridge University Press.
3. R. E. Grim, "Clay Mineralogy", McGraw – Hill Book Company Inc

4. J. K. Mitchell, "Fundamentals of Soil Behaviour", John Wiley.
5. Murthy V. N.S, "Textbook of Soil Mechanics and Foundation Engineering", CBS Publishers & Distributors.

CE 5105 Foundation Engineering

Weekly contact: 3-0-0 (L-T-S)
Full marks: 100
Credits: 3

Course Objective: To develop an understanding of the analysis and design of foundations. The course intends to familiarize the students with various types of foundation, design of shallow and deep foundation in homogeneous soils, layered soils and rock strata, load calculations, settlement calculations and design of foundation in sloping ground.

Course Outcome: At the end of the course, the students will be able to:

- Understand the concepts of bearing capacity and soil settlement
- Design, analyse and proportion shallow foundations in cohesionless and cohesive soils
- Design and analyse pile foundations and pile groups as per codal provision

Syllabus: Shallow foundation, bearing capacity and settlement calculations, foundation in sloping ground, types of pile foundation, vertical and lateral load carrying capacities of single pile, pile group, soil-pile interaction, settlement computation, testing of pile foundation.

Module No.	Course module and lesson plan	Contact hours
1	**Shallow foundation** -Types of **s**hallow foundation, bearing capacity of shallow foundation in homogeneous, layered and rock strata, related derivations, bearing capacity from in-situ tests, settlement calculations, foundation in sloping ground.	12
2	**Pile foundation**–Types and selection, installation and its effect, vertical and lateral load carrying capacities of single pile, soil-pile interaction, T-Z, Q-Z and P-Y curves, design problems.	10
3	**Design of pile group -**Load calculation of pile groups, forces in pile group, elastic and consolidation settlement computation,	8
4	**Testing of Pile Foundation -** Pile load test as per codal provision, dynamic pile load test, field tests for quality control.	9
	Total	**39**

Suggested Readings:

1. Bowles, J.W., "Analysis and Design of Foundations", 4th and 5th Ed., McGraw-Hill.
2. Das, B M., "Principles of Foundation Engineering", PWS Publishing, U.S.A, .
3. Salgado, R., "The Engineering of Foundations", McGraw Hill.
4. Peck, Hansen &Thornburn, "Foundation Engineering", Wiley Eastern Limited.
5. Poulos, H.G and Davis, E.H., "Pile foundation analysis and design", The University of Sydney.

CE 5106 Dynamics of Soils and Machine Foundations

Weekly contact: 3-0-0 (L-T-S)
Full marks: 100
Credits: 3

Course Objective: The course intends to acquaint the students with the fundamentals of vibration theory and dynamic soil properties, including free and forced vibrations, damped and undamped motion, degrees of freedom, wave propagation in elastic medium and evaluation of elastic soil constants. Further, the students will be familiarized with the design and construction aspects of machine foundations, response of block foundations and foundations for impact type machines, piles under different vibration modes and frame foundation.

Course Outcome: At the end of the course, the students will be able to:

- Understand the fundamentals of damped and undamped motion and the general theory of vibration
- Analyze the phenomenon of wave propagation in elastic medium
- Analyze and design machine foundations
- Understand the vibration isolation aspects associated with machine foundation design

Syllabus: Theory of vibration, degrees of freedom, transmissibility, principles of measuring instruments, dynamic soil properties, wave propagation in elastic medium, laboratory and field methods, machine foundations, foundations for impact type machines, dynamic response of embedded block foundation, piles under different vibration modes, frame foundation, vibration isolation.

Module No.	Course module and lesson plan	Contact hours
1	**Theory of vibration**- Free and forced vibrations, damped and undamped motion, single and multiple degrees of freedom, transmissibility, principles of measuring instruments.	12
2	**Dynamic soil properties**- Empirical and semi-empirical approaches to soil dynamics, wave propagation in elastic medium, elastic soil constants, laboratory and field methods, dynamic bearing capacity.	12
3	**Design of machine foundations**- Estimation of unbalanced forces, foundations for impact type machines, dynamic response of embedded block foundation, piles under different vibration modes, frame foundation, vibration isolation, construction aspects of machine foundations.	15
	Total	**39**

Suggested Readings:

1. Richart, F.E., Woods, R.D. and Hall, J.R., "Vibrations of soils and foundations", Prentice-Hall.
2. Prakash, S. and Puri V. K., "Foundations for Machines Analysis and Design", Wiley Series in Geotechnical Engineering
3. Major, A., "Vibration Analysis and Design of Foundations for Machines and Turbines", Collet's Holdings.
4. Das, B.M, and Ramana, G.V., "Principles of Soil Dynamics", Cengage Learning.
5. Swami Saran., "Soil Dynamics and Machine Foundations",Galgotia Pub. Pvt. Ltd.
6. Srinivasulu, P. and Vaidyanathan, C. V.,"Handbook of Machine Foundations", Tata McGraw Hill publishing company Ltd.

CE 5129 Ground Improvement Techniques and its application

Weekly contact: 3-0-0 (L-T-S)
Full marks: 100
Credits: 3

Course Objective: The course intends to familiarize the students with the basic understanding of soft soil and necessity of ground remediation, along with an overview of the ground improvement methods frequently adopted in the field, such as compaction, vibroflotation, grouting, nailing, blasting, admixture, preloading, drainage techniques, use of geosynthetics etc.

Course Outcome: At the end of the course, the students will be able to:

- Understand the various factors governing the engineering behaviour of soils and the suitability of soils for various geotechnical engineering applications.
- Analyze the engineering properties of soft soil
- Gain information on the various ground remediation methods adopted in the field and their applicability depending on soil type and prevalent site condition
- Understand the principle of reinforced earth and the application of geosynthetics in geotechnical design

Syllabus: Engineering properties of soft soil, soil stabilization, admixtures, stone column, preloading, PVDs, dynamic compaction, vibroflotation, dynamic consolidation, sand drains, soil nailing, anchors, blasting, grouting, engineering properties of geosynthetics, principle of reinforced earth walls, applications of geosynthetics in slope stability, embankment construction, retaining walls, landfills, field applications.

Module No.	Course module and lesson plan	Contact hours
1	**Soft soil**- Engineering properties of soft soil, compressible fills, expansive soils.	5
2	**Methods of Ground Improvement –** Soil stabilization, Admixtures, Stone column, Preloading, PVD, Dynamic Compaction, Vibroflotation, Dynamic Consolidation, Sand Drains, Soil Nailing, Anchors, Blasting, Grouting, Design Methods, Case Studies	18
3	**Design and application of Geosynthetics**– Types and functions of geosynthetics, engineering properties of geosynthetics, principle of reinforced earth walls, applications of geosynthetics in bearing capacity improvement, slope stability, retaining walls, embankments on soft soil, and pavements, filtration, drainage and seepage control with geosynthetics, geosynthetics in landfills, field applications and design	16
	Total	**39**

Suggested Readings:

1. Manfred R. Hausmann, “Engineering Principles of Ground Modification”, McGraw-Hill Pub, Co.
2. Jones, C.J.E.P., “Reinforcement and Soil Structures”, Butterworth Publications.
3. Koerner, R. M., “Designing with Geosynthetics”, Prentice Hall Inc.

CE 5132 Soil Exploration and Geo-Instrumentation

Weekly contact: 3-0-0 (L-T-S)
Full marks: 100
Credits: 3

Course Objective: To develop the basic knowledge about soil exploration and planning and design of soil exploration programme. The course will impart an idea about the choice of sampler, sampling of soils and rock in the field, and the methods of determining the engineering properties of soils. The course will familiarize the students with a basic understanding of the methods of geotechnical investigations and geo-instruments used in civil engineering design and constructions.

Course Outcome: At the end of the course, the students will be able to:

- Develop a basic idea about planning and design of subsurface exploration.
- Develop an idea about the types of sampler and sampling methods
- Acquire Sound knowledge regarding preparation of soil investigation report
- Develop idea about geo-instrumentation for monitoring structures during and post construction

Syllabus: Subsurface exploration, planning, drilling and sampling techniques, in-situ field tests and laboratory tests, report preparation and recommendations, Monitoring of performance of constructed facilities, geo-instrumentation during and post construction, investigation of failure mechanism.

Module No.	Course module and lesson plan	Contact hours
1	**Soil exploration**–Significance of project, specific subsurface exploration, planning, drilling and sampling techniques, in-situ field tests and laboratory tests to evaluate static and dynamic soil properties, report preparation and recommendations	25
2	**Geo-instrumentation-**Performance of constructed facilities, investigation of failure mechanism, geo-instrumentation for monitoring structures during and post construction, instrumentation for deformation and pore water pressure build-up study	14
	Total	**39**

Suggested Readings:

1. Arora, K.R. "Soil Mechanics and Foundation Engineering", Standard Publishers Distributers, New Delhi, India.
2. Murthy V. N.S, "Textbook of Soil Mechanics and Foundation Engineering", CBS Publishers & Distributors.
3. Hvorslev, M. J., "Subsurface exploration and sampling of soils for civil engineering purpose", edited by Waterways Experiment Station, Mississippi.

CE 5131 Unsaturated Soil Mechanics

Weekly contact: 3-0-0 (L-T-S)
Full marks: 100
Credits: 3

Course Objective: The course intends to convey the significance of unsaturated soil behaviour and the variables responsible for controlling the water retention capacity and hydraulic characteristics of unsaturated soils. The concept of matric suction, volumetric water content, SWCC, stress state variables and influence of the matric suction on soil shear strength will be discussed, along with basics of testing of unsaturated soils.

Course Outcome: At the end of the course, the students will be able to:

- Understand the hydraulic characteristics of different types of unsaturated soils
- Analyze the flow mechanisms through unsaturated soils
- Learn about the principle and measurement of soil suction
- Understand the stress state variables and shear strength of unsaturated soil
- Conduct testing of unsaturated soils

Syllabus: Genesis of unsaturated soils, principle and measurement of soil suction, total suction, matric suction, osmotic suction, state of stress, shear strength of unsaturated soil, deformation aspects, flow through unsaturated soils, soil-water characteristic curve, hydraulic conductivity function,testing of unsaturated soils.

Module No.	Course module and lesson plan	Contact hours
1	**Genesis of unsaturated soils**-Identification and classification of expansive and collapsing soils, introduction to phase properties and relations, air-water-solid interface, transient suction and moisture profiles.	6
2	**Soil suction**: Suction, principle and measurement of total suction, matric suction, osmotic suction, capillarity.	7
3	**State of stress, shear strength and deformation of soil**: Stress state variables, material variables, effective stress concepts for unsaturated soils, representation of net normal stress, axis translation technique, shear strength of unsaturated soil, extended Mohr-Coulomb criterion, measurement of pore air pressure and pore water pressure, triaxial tests, Hankel's pore water pressure parameters, influence of the matric suction on soil strength, Bishop's model for unsaturated soils.	10
4	**Flow through unsaturated soils**: Soil plasticity, soil-water interaction, diffused double layer, soil-water characteristic curve (SWCC), hysteresis in SWCC, permeability and hydraulic conductivity function, direct and indirect measurements of SWCC and hydraulic conductivity function.	10
5	**Testing of unsaturated soils**: Evaluation of swell pressure, swell potential, collapse potential and soil suction.	6
	Total	**39**

Suggested Readings:

1. Fredlund, D.G. and Rahardjo, H. "Soil Mechanics for Unsaturated Soils", Wiley Interscience Publications.

2. Blight, G.E. “Mechanics of Residual Soils”, Taylor & Francis Pub., 1997.
3. Nelson, J.D. and Miller, D.J. “Expansive soils-Problems and Practice in Foundation and Pavement Engineering”, Wiley-Interscience Pub.

CE 5130 Rock mechanics

Weekly contact: 3-0-0 (L-T-S)
Full marks: 100
Credits: 3

Course Objective: The course intends to provide sound knowledge in analyzing stability problems related to rocks. The course covers topics related to failure theories of rocks, application of elastic theory to rock design, propagation of cracks and the design of structures and tunnels in rocky strata.

Course Outcome: At the end of the course, the students will be able to:

- Classify rocks and learn about rock coring methods
- Gain an understanding of the strength and stress-strain response of rocks
- Analyze the effect of water and cracking on engineering property of rocks
- Design structures in rocks and learn about design principles of rock tunneling
- Adjudge stability of rock slopes

Syllabus: Rock classification and coring, rock strength, stress-strain relations, application of elastic theory to rock design, failure theories of rocks and propagation of cracks, Design theories and measurement methods, measurement of stresses in rock mass, various measuring devices, evaluation of properties of rocks in field, design of structures in rocks, design principles of rock tunneling, design principles and stability of rock slopes.

Module No.	Course module and lesson plan	Contact hours
1	**Rock classification and coring** - Composition of rocks, engineering classification of rocks and limitation, rock structures and Perespace in rock, rock coring methods.	8
2	**Rock strength and failure theories-**Elastic properties of rock, stress-strain relations, application of elastic theory to rock design, uniaxial and triaxial strength of rocks, failure theories of rocks and propagation of cracks.	10
3	**Design theories and measurement methods-** Griffith Crack Theory, water in rock, structural feature of massive rocks and their effects on engineering properties, measurement of stresses in rock mass, various measuring devices, evaluation of properties of rocks in field.	12
4	**Rock Tunneling**– Design of structures in rocks, design principles of rock tunneling, design principles and stability of rock slopes.	9
	Total	**39**

Suggested Readings:

1. “Engineering Rock Mechanics: An Introduction to the Principles”. Hudson J.A. and J.P. Harrison. Elsevier, Oxford
2. “Introduction to Rock Mechanics” by R.E.Goodman, John Wiley & Sons.

3. "Engineering in Rocks for Slopes, Foundation and Tunnels", Editor T.Ramamurthy, Prentice Hall India Pvt. Ltd.
4. Related codes and manuals from International Society of Rock Mechanics, ASTM and Bureau of Indian Standards.

CE 5133 Geomechanics in Soil-Structure Interaction

Weekly contact: 3-0-0 (L-T-S)
Full marks: 100
Credits: 3

Course Objective: The course intends to cover topics related to static soil-structure interaction, pile-soil interaction and dynamic soil-foundation interaction. Especial emphasis will be given in discussing elasto-plastic soil behaviour, pile-soil-pile interaction, estimation of shear modulus, damping ratio and linear equivalent & non-linear models, along with related applications.

Course Outcome: At the end of the course, the students will be able to:

- Gain an understanding of contact pressure distribution and static soil-structure interaction concepts
- Analyze engineering problems related to soil-pile interaction and pile-soil-pile interaction
- Understand the stress-strain behaviour of soils under cyclic load
- Analyze engineering problems related to dynamic soil-foundation interaction

Syllabus: Static soil-structure interaction, contact pressure distribution, elastic models, elasto-plastic soil behaviour, numerical analysis of beams and plates resting on elastic foundation, soil-pile interaction, pile-soil-pile interaction, dynamic soil-foundation interaction, stress-strain behaviour of soils under cyclic load, linear equivalent & non-linear models, related applications.

Module No.	Course module and lesson plan	Contact hours
1	**Static soil-structure interaction** – Contact pressure distribution, idealized soil-foundation and interface behaviour, elastic models, elasto-plastic soil behaviour, numerical analysis of beams and plates resting on elastic foundation.	12
2	**Pile-soil interaction –** Soil-pile interaction, pile-soil-pile interaction.	9
3	**Dynamic soil-foundation interaction** – Stress-strain behaviour of soils under cyclic load, estimation of shear modulus, modulus reduction curve, damping ratio, linear equivalent & non-linear models, related applications.	18
	Total	**39**

Suggested Readings:

1. Hetenyi, M. "Beams on Elastic Foundation", The University of Michigan Press, U.S.A.
2. Moore, P.J. "Analysis and Design of Foundations for vibrations", Oxford & IBH Pub. Co.
3. Das, B.M. "Fundamentals of soil dynamics", Elsevier, New York, U.S.A.
4. Selvadurai, A.P.S. "Elastic analysis of soil-foundation interaction", Elsevier Scientific Company Publishing, New York, U.S.A.
5. ShamsherPrakash. "Soil Dynamics", McGraw Hill book company.
6. D.D Barkan. "Dynamics of Bases and Foundations", McGraw Hill book company.

7. E.E. Richart et al. “Vibrations of soils and foundations”, Prentice Hall Inc.
8. Chowdhury, I., and Dasgupta, S. P. “Dynamics of Structure and Foundation”, Vol. 1 and Vol 2, CRC Press.

CE 5134 Computational Geotechnics

Weekly contact: 3-0-0 (L-T-S)
Full marks: 100
Credits: 3

Course Objective: The course intends to highlight the importance and application of numerical modelling in solving geotechnical engineeringrelated complex field problems.The course willfamiliarize the students with various computational methods and the constitutive modelling of soil response.

Course Outcome: At the end of the course, the students will be able to:

- Learn about the basics of numerical modelling techniques used in geotechnical engineering
- Familiarize themselves with various computational methods
- Learn about constitutive modelling of soil response and artificial neural networks
- Apply numerical methods for solving geotechnical engineering problems

Syllabus: Introduction to numerical modelling in geotechnical engineering, solution of nonlinear systems of equations, finite difference method, finite element method, discrete element method, boundary element method, constitutive modelling of soil response, artificial neural networks**,** application of numerical methods for solving geotechnical engineering problems.

Module No.	Course module and lesson plan	Contact hours
1	**Introduction** – Introduction to numerical modelling in geotechnical engineering, review of basic concepts.	6
2	**Computational methods**: Solution of nonlinear systems of equations, Finite difference method, Finite element method, Constitutive modelling of soil response.	21
3	**Applications**–Application of numerical methods for solving geotechnical engineering problems.	12
	Total	**39**

Suggested Readings:

1. Desai, C.S. and Christian, J.T. Eds. “Numerical Methods in Geotechnical Engineering”, McGraw-Hill.
2. Bathe, K.J., “Finite Element Procedures in Engineering Analysis”, Prentice-Hall, Englewood Cliffs, NJ.
3. Wood, D.M., “Soil Behavior and Critical State Soil Mechanics”, Cambridge University Press, New York.

CE 5135 Risk and Reliability in Geotechnical Engineering

Weekly contact: 3-0-0 (L-T-S)
Full marks: 100
Credits: 3

Course Objective: The objective of the course is to familiarize the students with uncertainties involved in geotechnical analysis and the fundamentals of probabilistic methods and reliability based analysis.The course will discuss the application of reliability based methods towards solving various geotechnical problems.

Course Outcome: At the end of the course, the students will be able to:

- Understand the sources and types of uncertainties associated with geotechnical analysis
- Apply probabilistic and reliability based analysis in geotechnical engineering design problems.
- Conduct reliability-based groundwater modelling, flow through earth dams, slope stability analysis, design of shallow and deep foundations and liquefaction analysis

Syllabus: Introduction, sources and types of uncertainties associated with geotechnical analysis, importance of probabilistic methods and reliability based analysis, review of probability and statistics, fundamentals of reliability analysis, Monte Carlo simulation, and application of reliability approach towards geotechnical problems.

Module No.	Course module and lesson plan	Contact hours
1	**Introduction**: Sources and types of uncertainties associated with geotechnical analysis, importance of probabilistic methods and reliability based analysis in geotechnical engineering.	5
2	**Review of probability and statistics**: Discrete and continuous random variables, parameter estimation, testing of hypothesis, regression analysis	6
3	**Fundamentals of reliability analysis**: First Order Second Moment (FOSM) method, First Order Reliability Method (FORM), Second Order Reliability Method (SORM), Monte Carlo simulation	12
4	**Application towards geotechnical problems**: Characterization of uncertainty in field measured and laboratory measured soil properties, uncertainty in interpretation techniques, spatial variability of soil properties, probabilistic groundwater modelling, flow through earth dams, probabilistic slope stability analysis, fundamentals of LRFD design methodology, reliability based design of shallow and deep foundations, reliability based liquefaction analysis.	16
	Total	**39**

Suggested Readings:

1. Ang, A.H.-S. and Tang, W.H. “Probability Concepts in Engineering Planning and Design”, Vol. 1 and Vol. 2, John Wiley, New York.
2. Nathabandu T. Kottegoda and Renzo Rosso “Statistics, Probability, and Reliability for Civil and Environmental Engineers”, McGraw-Hill International.
3. Baecher, G.B. and Christian, J.T. “Reliability and Statistics in Geotechnical Engineering”, John Wiley and Sons, London and New York.

CE 5174 Advanced Geotechnical Engineering Laboratory

Weekly contact: 0-0-3 (L-T-S)
Full marks: 100
Credits: 2

Course Objective: The course intends to impart the basic knowledge of soil mechanics required for characterization of soils through laboratory investigations and field testing. The course will acquaint the students with the art of evaluation of engineering properties of soils using routine and advanced testing methods, determination of dynamic soil properties through field testing, along with testing of geosynthetics.

Course Outcome: At the end of the course, the students will be able to:

- Identify and characterize soils through laboratory investigations
- Conduct testing of geosynthetics in the laboratory for determination of physical property, strength, stiffness and drainage potential
- Determine the dynamic soil properties through field testing

Syllabus: Recapitulation of routine soil tests including specific gravity, sieve analysis, hydrometer analysis, Atterberg limits, relative density, compaction test, field density evaluation, CBR, permeability test, consolidation test, direct shear test, triaxial test, testing of geosynthetics, determination of dynamic soil properties through field testing, SASW test.

Module No.	Course module and lesson plan	Contact hours
1	**Recapitulation of routine soil tests –** Specific gravity, sieve analysis, hydrometer analysis, Atterberg limits, relative density, compaction test, field density evaluation, CBR.	9
2	Permeability test, consolidation test, direct shear test, Triaxial test (UU, CU)	12
3	**Testing of geosynthetics** – Thickness, AOS, permittivity, transmissivity, wide-width tensile test, narrow-width tensile strength, CBR push-through.	12
4	Determination of dynamic soil properties through field testing, SASW.	6
	Total	**39**

Suggested Readings:

1. Bolton, M.D. “A Guide to Soil Mechanics”, Cambridge University Press.
2. Lambe, T.W. and Whitman, R.V., “Soil Mechanics”, Wiley Eastern Limited.
3. Koerner, R. M., “Designing with Geosynthetics”, Prentice Hall Inc.
4. Related codes and manuals from ASTM and Bureau of Indian Standards.

CE 5175 Geotechnical Model Testing Laboratory

Weekly contact: 0-0-3 (L-T-S)
Full marks: 100
Credits: 2

Course Objective: The objective of the course is to introduce the fundamentals of physical modelling concepts used in geotechnical engineering, including the importance of adopting relevant scaling laws and conducting dimensional analysis. Model testing of different types of foundation will be conducted in the laboratory as a part of this course.

Course Outcome: At the end of the course, the students will be able to:

- Conduct scaling and proportioning of prototype structures
- Understand the importance of dimensional analysis and experimental design methodologies
- Undertake fabrication and testing of models including shallow footing, pile foundation, pile-raft testing, stone column installation and testing, pile-integrity testing etc.

Syllabus: Introduction, experimental design methodologies, scaling and proportioning of prototype structures, dimensional analysis, fabrication and testing of models, testing of shallow footing, pile foundation, pile-raft testing, stone column installation and testing, pile-integrity testing.

Module No.	Course module and lesson plan	Contact hours
1	**Introduction-** Basic concepts of physical experimental design methodologies modelling in geotechnical engineering, scaling and proportioning of prototype structures, dimensional analysis, Buckingham's π- theorem, Rayleigh method etc.	12
2	**Model testing of foundation**- Fabrication and testing of models including shallow footing, pile foundation, pile-raft testing.	18
3	Stone column installation and testing, pile-integrity testing.	9
	Total	**39**

Suggested Readings:

1. Bowles, J.W., "Analysis and Design of Foundations", 4th and 5th Ed., McGraw-Hill.
2. Taylor, D.W., "Fundamentals of Soil Mechanics", John Wiley.
3. Som, N.N and Das, S.C., "Theory and Practice of Foundation Design", Prentice Hall of India Pvt. Ltd., New Delhi.
4. Related codes and manuals from ASTM and Bureau of Indian Standards.

CE 5176 Advanced Geotechnical Engineering Project

Weekly contact: 0-0-3 (L-T-S)
Full marks: 100
Credits: 2

Course Objective: The course intends to help the students develop an understanding of design, analysis and proportioning of different complex foundation types adopted in the field, including machine foundations designed to sustain dynamic loads, Buoyancy raft, Piled-Raft and Braced Excavation. Further, application of geotechnical engineering softwares in solving field problems will be demonstrated through the course.

Course Outcome: At the end of the course, the students will be able to:

- Design, analyse and proportion machine foundations
- Design and analyse Buoyancy Raft and Piled-Raft Foundation
- Design and analyse Braced Excavation systems
- Solve engineering problems using commercially available geotechnical engineering softwares

Syllabus: Assignments on Machine Foundation based on concepts of soil dynamics, Assignment on Buoyancy raft and Piled-Raft Foundation, Assignment on Braced Excavation, Assignment on demonstration of geotechnical engineering software.

Module No.	Course module and lesson plan	Contact hours
1	**Assignment 1: Soil Dynamics**- Assignments on Machine Foundation	12
2	**Assignment 2: Special Foundation**- Assignment on Buoyancy raft and Piled-Raft Foundation	6
3	**Assignment 3:** Assignment on Braced Excavation	9
4	**Assignment 4:** Assignment on demonstration of Geotechnical Engineering software.	12
	Total	**39**

Suggested Readings:

1. Kramer, S.L., "Geotechnical Earthquake Engineering", Pearson Education.
2. Major, A.,"Vibration Analysis and Design of Foundations for Machines and Turbines", Collets.
3. Bowles, J.W., "Foundation Analysis and Design", 5th Edn., McGraw-Hill.
4. Lambe, T.W. and Whitman, R.V., "Soil Mechanics", Wiley Eastern Ltd.,
5. Terzagi, K., Perck, R. B., and Mesri, G., "Soil Mechanics in Engineering Practice", John Wiley and Sons Inc.

Semester 2

CE 5204 Applied Geotechnical Engineering

Weekly contact: 3-0-0 (L-T-S)
Full marks: 100
Credits: 3

Course Objective: The course intends to familiarize the students with fundamentals of flow process through porous media under three-dimensional condition, considering transient flow and flow through anisotropic and non-homogeneous medium. Additionally, concepts related to the stability of slopes and buried structures, design principles of retaining walls and design of sheet pile system will be undertaken as a part of this course.

Course Outcome: At the end of the course, the students will be able to:

- Understand the flow through porous media under anisotropic and non-homogeneous medium
- Analyse the stability of slopes and buried structures
- Apply the principles of earth pressure theories to retaining walls
- Conduct analysis and design of sheet pile and braced excavations

Syllabus: Flow through porous media,Laplace equations of fluid flow for 1D, 2D and 3D seepage, flow nets, transient flow, flow through anisotropic and non-homogeneous medium, slope stability and buried structures,arching effects, Marston's load theory, minimum cover, pipe floatation, earth pressure concepts, design principles of retaining walls, sheet pile wall, braced excavation.

Module No.	Course module and lesson plan	Contact hours
1	**Flow through porous media**–Permeability and seepage forces, capillarity, effective stress during seepage, Laplace equations of fluid flow for 1D, 2D and 3D seepage, flow nets, transient flow, flow through anisotropic and non-homogeneous medium, confined and unconfined seepage.	12
2	**Slope stability and buried structures**- Effective stress and total stress analysis, sudden drawdown condition, stabilization of marginally stable slopes, arching effects, buried structures, Marston's load theory, minimum cover, pipe floatation.	8
3	**Retaining Wall -** Uses, types, stability analysis and design principles of retaining walls, backfill drainage, settlement and tilting.	9
4	**Sheet pile wall, Braced excavation**–Types, application, analysis and design of sheet pile.	10
	Total	**39**

Suggested Readings:

1. Terzaghi, K., and Peck, R. B. "Soil Mechanics in Engineering Practices", A Wiley International Edition
2. Harr, M. E., "Groundwater and Seepage", McGRAW – Hill Book Company.
3. Taylor, D.W., "Fundamentals of Soil Mechanics", John Wiley.
4. Bolton, M.D., "A guide to soil mechanics", Cambridge University Press.
5. Winterkorn, H. F., and Fang, H. "Foundation Engineering Handbook", Galgotia Book Source
6. Murthy V. N.S, "Textbook of Soil Mechanics and Foundation Engineering", CBS Publishers & Distributors.

CE 5205 Analysis and Design of Special Foundations

Weekly contact: 3-0-0 (L-T-S)
Full marks: 100
Credits: 3

Course Objective: The course intends to acquaint the students with soil-structure interaction problems and contact pressure distribution. The course modules will include design and proportioning of piled-raft foundation, design of pile caps, design of piers and well foundation, design of foundations for bracing systems and cellular cofferdams and foundation for offshore geotechnical structures.

Course Outcome: At the end of the course, the students will be able to:

- Understand contact pressure distribution below rigid and flexible footing
- Design, analyse and proportion raft foundation and soil-structure interaction problems.
- Design and analyse well foundations, braced cuts and cellular cofferdams
- Design and analyse foundations for offshore structures

Syllabus: Shallow foundation, beams and plates on elastic foundation, contact pressure distribution, rigid and flexible footing, raft foundation, soil-structure interaction problems, piled-raft foundation, design of pile caps, response of piles under dynamic loads, design of piers and well foundations, braced excavations, stability of vertical cuts, cellular cofferdams in rock and in deep soil, foundations for offshore structures.

Module No.	Course module and lesson plan	Contact hours
1	**Shallow foundation** -Beams and plates on elastic foundation, contact pressure distribution below rigid and flexible footing, raft foundation, soil-structure interaction problems.	8
2	**Deep foundation –** Piled-raft foundation, design of pile caps, response of piles under dynamic loads, field applications and design problems.	10
3	**Design of piers and well foundations –** Basic concept, design principle, field applications and design problems	5
4	**Braced cuts and Cofferdams**- Braced excavations and stability of vertical cuts, braced and cellular cofferdams, uses, types, components, stability, piping and heaving. Stability of cellular cofferdams, cellular cofferdams in rock and in deep soils.	10
5	**Foundations for offshore structures-** Types, design methodology and applications.	6
	Total	**39**

Suggested Readings:

1. Bowles, J.W., "Analysis and Design of Foundations", 4th and 5th Ed., McGraw-Hill.
2. Das, B M., "Principles of Foundation Engineering", PWS Publishing, U.S.A.
3. Salgado, R., "The Engineering of Foundations", McGraw Hill.
4. Peck, Hansen &Thornburn, "Foundation Engineering", Wiley Eastern Limited.

CE 5206 Elasticity and Plasticity

Weekly contact: 3-0-0 (L-T-S)
Full marks: 100
Credits: 3

Course Objective: The course intends to acquaint the students withconcepts of elasticity and plasticity, including basics of principal stresses and strains, invariants, octahedral stress and strain, associative and non-associative flow rules, advanced hardening and softening models, along with fundamentals of viscoelasticity and constitutive modelling in geotechnical engineering.

Course Outcome: At the end of the course, the students will be able to:

- Understand the basics of elasticity theory, and solve related problems in Cartesian coordinate and Polar coordinate system.
- Understand the plasticity theory and behaviour of rigid-perfectly plastic solids and elastic-plastic boundary value problems.
- Understand the basics of viscoelasticity and constitutive modelling used in geotechnical engineering

Syllabus: Elasticity, equilibrium, compatibility for 2D and 3D cases, principal stresses and strains, invariants, octahedral stress and strain, plasticity, associative and non-associative flow rules, advanced hardening and softening models, problems in rigid-perfectly plastic solids, boundary value problems, viscoelasticity and constitutive modelling in geotechnical engineering.

Module No.	Course module and lesson plan	Contact hours
1	**Elasticity** – Elasticity, stresses and strains, equilibrium, compatibility for 2D and 3D cases, principal stresses and strains, invariants, octahedral stress and strain, related problems in Cartesian and Polar coordinate system.	20
2	**Plasticity**- Plasticity, associative and non-associative flow rules, advanced hardening and softening models, problems in rigid-perfectly plastic solids, selected rigid-perfectly plastic boundary value problems and elastic-plastic boundary value problems.	11
3	Viscoelasticity and constitutive modelling in geotechnical engineering.	8
	Total	**39**

Suggested Readings:

1. Timoshenko S. P. And Goodier , J. N., .,"Theory of Elasticity", McGraw Hill Book Company
2. Chakrabarty, J.,"Theory of Plasticity", Butterworth.
3. Calladine, C.R., "Plasticity for Engineers", Woodhead.
4. Lubliner J., "Plasticity Theory", Dover.

CE 5229 Geotechnical Earthquake Engineering

Weekly contact: 3-0-0 (L-T-S)
Full marks: 100
Credits: 3

Course Objective: The objective of this course is to familiarize the students with concepts of geotechnical earthquake engineering. The course involves an overview of global seismicity, plate tectonics, wave propagation concepts, source-site attenuation relationships and seismic hazard assessment, followed by seismic design of various geotechnical structures**.**

Course Outcome: At the end of the course, the students will be able to:

- Understand earthquake hazards and learn about measures to estimate future seismic hazard
- Quantify and interpret seismic data
- Conduct seismic hazard estimation and to predict liquefaction potential
- Design various geotechnical structures subjected to earthquake load, including shallow and deep foundations, reinforced soil wall, slopes, ground anchors, waterfront retaining structures, tailing dams.

Syllabus: Introduction, fundamental concepts of earthquake engineering pertaining to geotechnical problems, principles of earthquake, instrumentation, engineering seismology and tectonics, faults, wave propagation, dynamic soil properties, attenuation relationships, liquefaction, evaluation of liquefaction hazard and mitigation, seismic hazard analysis, seismic design of various geotechnical structures, codal provisions.

Module No.	Course module and lesson plan	Contact hours
1	**Introduction** – Fundamental concepts of earthquake engineering pertaining to geotechnical problems, principles of earthquake, seismic zonation map, measurement of earthquakes, instrumentation, engineering seismology and tectonics, faults, wave propagation, prediction ofwave velocities in homogeneous and layered medium, dynamic soil properties, interpretation of seismic data, attenuation relationships, related field tests, laboratory test and model tests	12
2	**Liquefaction -** Introduction to liquefaction phenomena, effects of liquefaction, flow liquefaction and cyclic mobility, factors influencing liquefaction susceptibility, evaluation of liquefaction hazard through field investigation techniques (SPT, CPT and SASW), reduction of liquefaction potential	8
3	**Seismic hazard analysis**- Identification of earthquake sources, Probabilistic Seismic hazard analysis (PSHA) and Deterministic Seismic hazard analysis (DSHA), Uncertainty in computation of seismic hazards, Microzonation and site response analysis.	9
4	**Seismic design of various geotechnical structures**- Shallow and deep foundations, reinforced soil wall, slopes, ground anchors, waterfront retaining structures, tailing dam etc. subjected to earthquake load, codal provisions.	10
	Total	**39**

Suggested Readings:

1. Steven L. Kramer, “Geotechnical Earthquake Engineering”, Prentice Hall Inc.
2. Robert W. Day, “Geotechnical Earthquake Engineering Handbook”, McGraw Hill, New York.

3. IkuoTowhata, “Geotechnical Earthquake Engineering”, Springer-Verlag Heidelberg.
4. Shamsher Prakash, “Soil Dynamics”, McGraw-Hill Book Company.
5. MilutinSrbulov, “Geotechnical Earthquake Engineering: Simplified Analyses with Case Studies and Examples”, Springer-Verlag.
6. IS 1893, Indian Standard Criteria for earthquake resistant Design of Structures

CE 5230 Environmental Geotechnics

Weekly contact: 3-0-0 (L-T-S)
Full marks: 100
Credits: 3

Course Objective: The course intends students to develop a knowledge of the effect of contaminants on engineering properties of soil. The course will enable the students to identify the different remedial methods of contaminated soils and waste utilization methods. The course covers detailed design procedure of liner, cover, cut off walls, leachate collection system and removal system.

Course Outcome: At the end of the course, the students will be able to:

- Develop the basic knowledge of the sources, production and classification of wastes
- Understand the engineering properties of contaminated soils and mechanism of contaminant transport
- Develop the skills to mitigate the problems of contaminant transport through soil.
- Sound knowledge regarding design aspects of liner, cover, cut off walls.
- Develop concepts of waste utilization for sustainable development

Syllabus: Introduction, sources, production and classification of wastes, environmental laws and regulations, soil pollution, contaminant transport, mathematical modelling and applications, waste disposal facilities, design of various landfill components such as liners, covers, leachate collection and removal systems, gas generation and management, ground water monitoring, end uses of landfill sites, slurry walls, remediation technologies, sustainable development and reuse potential of waste materials.

Module No.	Course module and lesson plan	Contact hours
1	**Introduction** – Sources, production and classification of wastes, environmental laws and regulations.	5
2	**Soil pollution**– Physical, chemical and biological interactions in soil.	3
3	**Contaminant transport**- Processes, mathematical modelling and applications.	10
4	**Waste disposal facilities**–Estimation of landfill quantities, landfill site location, design of various landfill components such as liners, covers, leachate collection and removal systems, gas generation and management, ground water monitoring, end uses of landfill sites, slurry walls.	10
5	**Remediation technologies**– Introduction, Soil Washing, Soil Vapor Extraction, Bioremediation, Chemical Treatment, Vitrification, Phytoremediation, Solidification and Stabilization, Risk Assessment approaches	7
6	**Sustainable development:** Reuse potential of waste materials, Case Studies	4
	Total	**39**

Suggested Readings:

1. Sharma, H.D., and Lewis, P.L., "Waste Containment systems, waste stabilization and landfill, John Wiley & Sons, Inc., Hoboken, New Jersey.
2. Oweis, I.S., and Khera, R.P., "Geotechnology of waste management", Butterworths.
3. Yong, R.N., "Contaminated soils, pollutant fate and mitigation", CRC Press.
4. Rowe, R. Kerry, Quigley, Robert M., Brachman, Richard W. I., and Booker, John R., "Barrier Systems for Waste Disposal Facilities", Spon Press, Taylor & Francis Group, London.
5. Tchobanoglous, G., Theisen, H. and Vigil, S.A., "Integrated Solid Waste Management - Engineering Principles and Management Issues," McGraw Hill.
6. Daniel, D. E., "Geotechnical Practice for Waste Disposal", Chapman and Hall, London.

CE 5231 Physical modelling in Geotechnics

Weekly contact: 3-0-0 (L-T-S)
Full marks: 100
Credits: 3

Course Objective: The course intends to acquaint the students with different physical modelling techniques, and the relative advantages and disadvantages of various modelling methodologies. The course modules will include dimensional analysis, scaling laws and scale effects in geotechnical physical modelling. Especial emphasis will be given on sophisticated modelling tools used in geotechnical engineering, namely, the applications of shake table testing and centrifuge model testing conducted at enhanced gravity levels.

Course Outcome: At the end of the course, the students will be able to:

- Understand the basics of modeling, and different types of physical modelling techniques
- Calculate model dimensions for prototype structures
- Quantify the scale effects and errors involved in physical modelling
- Extrapolate model response to prototype field behaviour
- Understand the relevance and application of shake table testing and geotechnical centrifuge modelling

Syllabus: Introduction, physical modelling methods, dimensional analysis, full scale testing, laboratory small-scale testing, shake table testing, geotechnical centrifuge modelling, advantages, scaling laws, scale effects and errors in rotational acceleration field, modelling of models, applications in geotechnical engineering.

Module No.	Course module and lesson plan	Contact hours
1	**Introduction** – Physical modelling methods, field trials, full scale testing, laboratory small-scale testing, centrifuge modelling, relative merits and demerits, dimensional analysis.	6
2	**Shake table testing -** Introduction toshake table testing, relevant applications	3
3	**Geotechnical centrifuge modelling** –Basic Principle, advantages, high gravity (*N*g) modelling concept, scaling laws, scale effects and errors in rotational acceleration field, modelling of models, beam centrifuge, drum centrifuge, existing geotechnical centrifuges and their specifications.	20
4	**Relevance of centrifuge modelling -** Applications in landfill engineering, testing of reinforced earth structures, stability of slopes, disaster mitigation,	10

	ground improvement, blasting, tunneling etc.	
	Total	**39**

Suggested Readings:

1. Taylor R.N,"Centrifuges in modelling: principles and scale effects",Geotechnical Centrifuge Technology, R. N. Taylor, (Eds.), Blackie Academic and Professional, Glasgow, U.K
2. Schofield, A. N., 1980, "Cambridge geotechnical centrifuge operations," *Géotechnique*, 30(3), 227-268.
3. Relevant articles in the journal of Physical Modelling in Geotechnics.

CE 5232 Offshore Geotechnics

Weekly contact: 3-0-0 (L-T-S)
Full marks: 100
Credits: 3

Course Objective: The course intends to enable the students develop a sound knowledge about the origin, state of in-situ stresses and classification of marine deposits. The students will get familiarized with different aspects of offshore geotechnical investigations and seafloor stability. The coarse modules will also include details about construction, installation and instrumentation of gravity platforms in offshore environment, with special focus on offshore pile foundations.

Course Outcome: At the end of the course, the students will be able to:

- Characterize marine deposits
- Calculate the geotechnical properties of offshore deposits from in-situ testing and laboratory test data
- Design offshore structures including offshore pile foundations
- Calculate the stability of structures resting on the seafloor

Syllabus: Origin and classification of marine sediments, in-situ state of stress, offshore geotechnical investigations, in-situ testing techniques, laboratory testing, construction, installation and instrumentation of foundations for offshore gravity structures, stability analysis, deformation analysis, types of offshore piles, axial load capacity, deformation analysis, lateral loading, dynamic response, seafloor instability, mechanisms of slope instability under gravity forces and wave forces, installation and stability of submarine pipelines.

Module No.	Course Module and Lesson Plan	Contact hours
1	**Nature of marine soils**- Origin, classification and distribution of marine sediments, in-situ stress state in marine deposits, inorganic clay deposits, calcareous sediments, siliceous sediments.	5
2	**Offshore Geotechnical Investigations**- Phases of the investigation, geophysical survey, drilling and sampling procedures, in-situ testing techniques, laboratory testing.	6
3	**Foundations for Offshore Gravity Structures** - Construction, installation, instrumentation of gravity platforms, stability analysis, deformation analysis based on elastic theory, piping and erosion. Design of suction piles for offshore	12

	structure.	
4	**Offshore Pile Foundations**- Types of offshore piles, temporary support of piled structures, dynamic analysis of pile driving, axial load capacity, axial deformation analysis, lateral loading, dynamic response.	10
5	**Seafloor Stability**- Causes of seafloor instability, geological features of submarine slides, mechanisms of slope instability under gravity forces and wave forces, installation and stability of submarine pipelines.	6
	Total	**39**

Suggested Readings:

1. "Marine Geotechnics" – H.G. Poulos, Prentice Hall Inc.
2. "Construction of marine and offshore structures" – Ben C Gerwick, jr., CRC Press, Taylor and Francis Group.
3. "Seabed Reconnaissance and Offshore Soil Mechanics (for the installation of petroleum structures)" – Pierre LE Tirant (1979), Gulf Pubs. Company, Texas.
4. "Port Engineering planning, construction, maintenance and security" – George P Tsinker, John Wiley & Sons, Inc.

CE 5233 Forensic Geotechnical Engineering

Weekly contact: 3-0-0 (L-T-S)
Full marks: 100
Credits: 3

Course Objective: The course will enable the students to understand the need for forensic investigation in geotechnical engineering, along with various engineering aspects and legal aspects associated with it. The methods used for predicting the causes of failure for different geotechnical structures based on post failure investigation will be discussed as a part of this course.

Course Outcome: At the end of the course, the students will be able to:

- Plan geotechnical investigations required for forensic examination
- Understand the engineering and legal issues related to forensic investigation
- Predict the cause of failure of a geotechnical structure based on post failure geotechnical investigation

Syllabus: Introduction, forensic engineer, types of damage, planning and investigation methodology, development of failure, hypothesis, back analysis, legal issues, reliability aspects, performance evaluation, analysis of field case studies, case histories related to settlement of structures, lateral movement, backfill settlements, expansive soil, slope failures and landslides, slope softening and creep, trench collapses, dam failures, foundation failure due to earthquakes, erosion, groundwater and moisture problems, retaining structure failures pavement failures, failures in soil reinforcement and geosynthetics, development of codal provisions and performance based analysis procedures.

Module No.	Course Module and Lesson Plan	Contact hours
1	**Introduction** - Definition of a forensic engineer, types of damage, planning the investigation, investigation methodology, and collection of data.	8

2	**Distress Characterization**– Development of failure, hypothesis, diagnostic tests, back analysis, technical shortcomings, legal issues, reliability aspects, observation method of performance evaluation.	11
3	**Analysis of field case studies**- Case histories related to settlement of structures, lateral movement, backfill settlements, causes due to soil types such as collapsible soil, expansive soil, soluble soils, slope failures and landslides, debris flow, slope softening and creep, trench collapses, dam failures, foundation failure due to earthquakes, erosion, deterioration, tree roots, groundwater and moisture problems, retaining failures problems, pavement failures and issues, failures in soil reinforcement and geosynthetics, development of codal provisions and performance based analysis procedures.	20
	Total	**39**

Suggested Readings:

1. Bolton M , "A Guide to Soil Mechanics", Universities Press.
2. Robert W. Day ,"Forensic Geotechnical and Foundation Engineering", Second Edition, McGraw-Hill Companies, Inc.
3. Rao, V.V.S. and SivakumarBabu, G.L., "Forensic Geotechnical Engineering", Springer Nature.

CE 5234 Tunneling and Underground Space Technology

Weekly contact: 3-0-0 (L-T-S)
Full marks: 100
Credits: 3

Course Objective: The course intends to convey the significance of geo-investigation, geo-instrumentation and design methodologies for construction of underground structures. Especial emphasis will be given in discussing the planning, modelling, monitoring and construction methodology of underground structures, safety and comfort aspects associated with underground space, and the effects of tunnelling on superstructures.

Course Outcome: At the end of the course, the students will be able to:

- Plan geotechnical investigation for underground construction
- Design underground structures in soils and rocks
- Account for safety aspects associated with planning of underground infrastructures
- Design schemes for monitoring underground structures with geo-instrumentation
- Adjudge the effects of tunnelling on superstructures and design principles of tunnels in rock

Syllabus (Brief outline): Planning, development and operation of underground space, safety and comfort, geo-investigation, drainage and dewatering, geomechanical analysis, effects of tunnelling on superstructures, modelling, design, construction and monitoring methodology of underground structures, underground earth-sheltered structures, pipelines, ducts, and cables, basic design principles of tunnels in rock, related applications.

Module No.	Course Module and Lesson Plan	Contact hours

1	**Introduction**– Planning, development and operation of underground space, safety and comfort, human-space interaction, geo-investigation, drainage and dewatering, geomechanical analysis, effects of tunnelling on superstructures.	10
2	**Underground structures**– Modelling, design and construction methodology, Monitoring and maintenance aspects of underground structures by employing geo-instrumentation, underground earth-sheltered structures, underground pipelines, ducts, and cables. Micro-tunneling, and other forms of trenchless technologies.	22
3	**Rock tunneling**–Basic design principles of tunnels in rock, applications.	7
	Total	**39**

Suggested Readings:

1. Hudson J.A. and J.P. Harrison, "Engineering Rock Mechanics: an Introduction to the Principles", Elsevier, Oxford.
2. "Tunnelling and Underground Space Technology", International tunneling association, Pergamon Press,
3. "Engineering in Rocks for Slopes, Foundation and Tunnels", Editor T.Ramamurthy, Prentice Hall India Pvt. Ltd.
4. Hvorslev, M. J., "Subsurface exploration and sampling of soils for civil engineering purpose", edited by Waterways Experiment Station, Mississippi.
5. Swami Saran, "Analysis and Design of Substructures: Limit state design", Oxford and IBH Publishing Co. Pvt. Ltd.

Specialization: Transportation Engineering

Course Structure

1st Semester

Sl. No	Course Name	Course code	Class Load/Week			Credit	Class load/ Week	Marks
			L	T	P			
1.	CourseI: Pavement Engineering I	CE 5107	3	0	0	3	3	100
2.	CourseII: Traffic System Analysis	CE 5108	3	0	0	3	3	100
3.	Course III: Urban Transportation Planning	CE 5109	3	0	0	3	3	100
4.	Course IV: (Dep. Elective)		3	0	0	3	3	100
5.	Course V: (Open Elective)		3	0	0	3	3	100
	Theory Sub-total		15	0	0	15	15	500
6.	Pavement Material Laboratory	CE5177	0	0	3	2	3	100
7.	Traffic System Laboratory	CE5178	0	0	3	2	3	100
8.	Software Application in Transportation Engineering	CE5179	0	0	3	2	3	100
	Practical Sub-total		NIL	NIL	9	6	9	300
	1st Semester Total					21	24	800

2nd Semester

Sl. No	Course Name	Course code	Class Load/Week			Credit	Class load/ Week	Marks
			L	T	P			
1.	Course VI: Pavement Engineering II	CE5207	3	0	0	3	3	100
2.	Course VII: Traffic System Design and Management	CE5208	3	0	0	3	3	100
3.	Course VIII: Transport Economics and Project Evaluation	CE5209	3	0	0	3	3	100
4.	Course IX (Dep. Elective)		3	0	0	3	3	100
5.	CourseX (Open Elective)		3	0	0	3	3	100

	Theory Subtotal		15	0	0	15	15	500
6.	M. Tech Project Part - I (Term Paper)	CE5291	0	0	2	4	0	200
7.	Term Paper Seminar & Viva-voce	CE5292	0	0	0	2	0	100
	Practical Subtotal		0	0	0	6	0	300
	2nd Semester Total					21	17	800

3rd Semester

Sl. No	Course Name	Course code	Class Load/Week			Credit	Class load/ Week	Marks
			L	T	P			
1.	M. Tech Project Part - II (Progress Report)	CE6191	0	0	0	12	0	300
2.	Progress Report Seminar & Viva-voce	CE6192	0	0	0	6	3	100
	Total Credit		0	0	0	18	0	
	3rdSemester Total					18	0	400

4th Semester

Sl. No	Course Name	Course code	Class Load/Week			Credit	Class load/ Week	Marks
			L	T	P			
1.	M. Tech Project Part - III (Thesis)	CE6291	0	0	0	22	0	400
2.	Thesis seminar and viva voce	CE6292	0	0	0	8	0	200
	Total Credit		0	0	0	30	0	
	4thSemester Total					30	0	600

Course IV [Departmental elective]	**Course IX [Departmental elective]**
CE5137 Geometric Design and Road Safety CE5138 Optimization in Transportation Engineering CE5139 Geospatial Techniques in Transportation CE5140 Airport Planning and Design	CE5237 Pavement Evaluation and Asset Management CE5238 Advanced Pavement Materials and Design CE5239 Intelligent Transportation Systems CE5241Transportation Network Analysis

1st Semester

CE 5107Pavement Engineering I

Weekly Contact: 3-0-0 (L-T-S)

Full Marks: 100 **Credits: 3**

Course Objective: To assess the knowledge on the recoverable or elastic deformation of the pavement within the permissible limits so that the pavement can sustain a large number of repeated load applications during the design life, without resulting in structural damages in the pavement layers. This course also highlighted about the various design methods along with their reliability and serviceability concept.

Course Outcome: At the end of the course, the students will be able to:

- Know about the quality of materials to be used in the flexible pavement layers
- Know about the various design parameters and methods
- Know about the failure criteria, reliability concept and serviceability Concept,
- Know about the incorporation various alternative materials for construction of flexible pavements

Syllabus (Brief outline): Pavement Types, Structural Elements of Pavement, Quality of the materials used in construction of flexible pavements. Analysis and design of flexible pavements by using various methods. Assessment of failure criterion of the flexible along with reliability and serviceability concept. Roll of various alternative materials in flexible pavements.

Module No.	Course Module and Lesson Plan	Contact hours
1.	Pavement Types, Structural Elements of Pavement. Road Aggregates, Properties of Aggregates, Binding Materials, Types of Bituminous Road Binders, Emulsions, Rheology of Bituminous Binders, visco-elastic, rutting and fatigue properties of bituminous mixtures.	6
2.	Factors Affecting Design of Pavements – traffic and material characterization	6
3.	Analysis of flexible pavements using different analytical methods, Multi layered Pavement Analysis	5
4.	Philosophy of design of flexible pavements, failure criteria, reliability concept, Pavement Serviceability Concept,	3
5.	Design of Flexible pavements as per IRC, AASTHO and other methods, comparison of different pavement design approaches	16
6.	New materials in flexible pavement	3
	TOTAL	**39**

Suggested Readings:

1. E.J.Yoder, M.W.Witczak “Principles of pavement design”, Wiley Publications.
2. Y.H.Huang, “Pavement analysis and design”, Pearson Education India.
3. R B Mallick& T Ei-Korchi, “ Pavement Engineering Principles and Practice”; CRC Press
4. R.Srinivasa Kumar, “Pavement Design”, Universities Press.
5. P.Chakraborty, A.Das, “Principles of transportation engineering”, PHI Learning Pvt. Ltd.

CE 5108Traffic System Analysis

Weekly Contact: 3-0-0 (L-T-S)

Full Marks: 100
Credits: 3

Course Objective:

- To introduce fundamental knowledge of traffic system engineering
- To know the traffic flow characteristics, and Traffic Flow theories
- To study various traffic surveys, traffic operation and control.

Course Outcome: At the end of the course, the students will be able to

- Identify traffic stream characteristics
- Understand the application traffic studies, their analysis and their interpretation
- Assess level of services of roadway facilities
- Understand the important application of various traffic simulation models

Syllabus (Brief outline): Traffic Flow Characteristics, Traffic Flow parameters and their interrelationship; Traffic studies, survey and analysis; Traffic flow theories; Capacity and LOS for uninterrupted flow application; Traffic flow simulation.

Module No.	Course Module and Lesson Plan	Contact hours
1.	Traffic Flow Characteristics, Traffic Flow parameters and their interrelationship,	6
2.	Traffic Studies and Surveys. Data Analysis, Application of statistical methods.	6
3.	Different traffic flow theories	9
4.	Capacity for Uninterrupted Flow, Factors Affecting Capacity, Level of service, Capacity analysis as per US-HCM and Indo-HCM.	12
5.	Traffic flowSimulation	6
	TOTAL	**39**

Suggested Readings:

1. William R. Mcshane and Roger P. Roess, “Traffic Engineering”, Pearson
2. May, A.D., “Fundamentals of Traffic Flow”, Prentice Hall, Inc.
3. Kadiyali, L.R., “Traffic Engineering and Transport Planning”, Khanna Publishers
4. C JotinKhisty and B Kent Lall, “Transportation Engineering” Prentice-Hall of India
5. C. S. Papacostas& P. D. Prevedouros, ‘Transportation Engineering & Planning’; Prentice-Hall India

CE 5109Urban Transportation Planning

Weekly Contact: 3-0-0 (L-T-S)

Full Marks: 100 **Credits: 3**

Course Objective: To provide the students with a basic understanding of urban transportation problems, planning methodologies, analysis techniques and infrastructure systems. The course also intends to impart basic knowledge on public transportation systems planning, for example, multimodal transportation,transit planningand sustainable transportation systems.

Course Outcome: Students will gain a theoretical and applied understanding of transportation systems planning in this course. The course learning outcomes are:

- Understand the need for urban transportation planning
- Define study area, traffic analysis zones, coding
- Undertake various urban transportation planning surveys
- Develop travel demand model and forecasting over a range of horizons
- Plan mass transit facilities and integrated public transportation

Syllabus (Brief outline): Introduction and scope; definition and basic principles; transportation problems; conventional transportation planning process; travel demand modelling and forecasting; study area delineation; zoning; UTP survey; trip generation modelling; trip distribution modeling; modal split modelling; traffic assignment; mass transport management measures; integration of public transportation modes; case studies; transportation logistics

Module No.	Course Module and Lesson Plan	Contact hours
1.	Introduction and scope; Definition and basic principles; Transportation problems; Types of models; Planning methodologies	2
2.	Conventional transportation planning process; Travel demand modelling and forecasting; Study area delineation; Zoning; UTP survey	4
3.	Trip Generation modeling – variables influencing a trip generation, Regression Analysis and Category Analysis	6
4.	Trip distribution Modeling – factors governing the trip distribution, Growth factor Method, Gravity Model, Intervening opportunity and Competing	7

	opportunity Models	
5.	Modal Split Modeling – factors influencing Mode choice aggregate and disaggregate models, logit and probit analysis	5
6.	Traffic assignment – Transportation networks, Minimum Path Algorithms, Assignment methods: All or Nothing assignment, Capacity restrained assignment and Multipath assignment, Route choice behaviour.	7
7.	Mass Transport Management Measures; Integration of Public Transportation Modes; Public transport Infrastructure; Case Studies	4
8.	Transportation logistics –concepts of business logistics, road freight transport, city logistics, logistics information system, uncertainty issues	4
	TOTAL	**39**

Suggested Readings:

1. Papacostas C.S. and Prevedouros, P.D., Transportation Engineering & Planning, PHI, New Delhi,
2. Hutchinson, B.G., Principles of Urban Transport Systems Planning, McGraw Hill, New York,.
3. Thomas, R., Traffic Assignment Techniques, Avebury Technical, Aldershot,.
4. AdibKanafani, "Transportation Demand Analysis", McGraw Hill Inc,.
5. Vukan R. Vuchic, "Urban Transit – Operations, Planning and Economics", John Willey and Sons, Inc.

Departmental Electives (Course IV)

CE 5137Geometric Design and Road Safety

Weekly Contact: 3-0-0 (L-T-S)

Full Marks: 100 **Credits: 3**

Course Objective: To provide the students an advanced knowledge about elements of highway geometry, highway alignment, roadway intersections and interchanges, and to introduce and inform them about the road accidents and their scientific study so as to overall improve the road safety.

Course Outcome: At the end of the course, the students will be able to:

- Design horizontal and vertical curves as per IRC and AASHTO, and define various sight distances and their requirements
- Understand the elements of geometric design, driver behaviour and road classification thereof.
- Apply various intersection and interchange designs to a particular conflict point with known traffic and geometric conditions.
- Understand factors causing accidents, their prevention, conduct a scientific post-crash study and know about road safety auditing

Syllabus(Brief outline): Geometric design elements, sight distances, horizontal and vertical geometric design, highway elements, intersections, interchanges and their design, traffic accident analysis, safety and auditing.

Module No.	Course Module and Lesson Plan	Contact hours
1.	Various geometric design elements, vehicular characteristics, drivers' characteristic including vision, terrain wise road classification, gradient consideration, sight distances.	6
2.	Design of horizontal and vertical alignment as per IRC and AASTHO methods, design consideration of sight distances and cross-sectional elements, Design of horizontal and vertical curves, coordination of curves and performances, underpass, access control, drainage consideration.	9
3.	Intersection and interchange design: Types of intersections, design of at grade intersections, channelization and auxiliary lanes, conflict points management, rotary design, Interchanges, types of interchanges, ramp design, acceleration and deceleration lanes, innovative intersections.	12
4.	Causes and types of accidents, accident studies, crash estimation, accident analysis, black spot analysis, enforcement measures, education measures, road safety audit	12
	TOTAL	**39**

Suggested Readings:

1. AASHTO A Policy on Geometric Design of Highway and Streets.
2. Geometric Design of Roads Handbook 1st Edition by Keith M. Wolhuter. CRC Press (Taylor and Francis group).
3. IRC 38 : Design of Horizontal Curves For Highways and design Tables, Indian Roads Congress
4. IRC SP 23: Vertical Curves for Highways. Indian Roads Congress
5. IRC SP 88: Manual on Road Safety Audit. Indian Roads Congress

CE 5138 Optimization in Transportation Engineering

Weekly Contact: 3-0-0 (L-T-S)

Full Marks: 100 **Credits: 3**

Course Objective: To provide the students with a basic understanding of analytical techniques and applications in Transportation Engineering.The course also intends to impart basic knowledge on data

analysis, for example, elementary statistical and probability theories and distributions, regression and correlation analysis.

Course Outcome: Students will gain a theoretical and applied understanding of analytical techniques for evaluating transportation systems. The course learning outcomes are:

- Understand the elementary statistical and probability theories and distributions
- Understand the regression analysis, linear programming, dynamic programming
- Ascertain appropriate optimization techniques for transportation networks
- Ability to analyse model outcomes to make better decisions to improve system performance
- Apply different techniques to traffic and transportation problems

Syllabus (Brief outline): Collection and presentation of data, elementary statistical and probability theories and distributions, tests of hypothesis; Regression and correlation analysis; Linear programming, dynamic programming, transportation models; Analysis of network flows; Techniques related to transportation system analysis with an introduction to Genetic Algorithm, Fuzzy System, ANN, clustering technique; Application of different Techniques to Traffic and Transportation Problems.

Module No.	Course Module and Lesson Plan	Contact hours
1.	Collection and presentation of data, elementary statistical and probability theories and distributions, tests of hypothesis	9
2.	Regression and correlation analysis	6
3.	Linear programming, dynamic programming, transportation models	6
4.	Analysis of network flows	6
5.	Techniques related to transportation system analysis with introduction to Genetic Algorithm, Fuzzy System, ANN, clustering technique	6
6.	Application of different Techniques to Traffic and Transportation Problems.	6
	TOTAL	**39**

Suggested Readings:

1. Norman R. Draper, Harry Smith, “Applied Regression Analysis”, Wiley, New York
2. Mokhtar S. Bazaraa, John J. Jarvis, Hanif D. Sherali, “Linear Programming and Network Flows”, Wiley, New York
3. Brian S. Everitt, Sabine Landau, Morven Leese, Daniel Stahl, “Cluster Analysis” Wiley, New York
4. Papacostas C.S. and Prevedouros, P.D., Transportation Engineering & Planning, PHI, New Delhi,
5. Thomas, R., Traffic Assignment Techniques, Avebury Technical, Aldershot,.

CE 5139 Geospatial Techniques in Transportation

Weekly Contact: 3-0-0 (L-T-S)

Full Marks: 100 **Credits: 3**

Course Objective: To provide the students with a basic understanding of theories of geographic information systems and applications in transportation engineering. The course also intends to impart basic knowledge on image analysis, for example, image processing, georeferencing and projections, digitization, image classification and rectification, camera calibration techniques in traffic data collection.

Course Outcome: Students will gain a theoretical and applied understanding ofgeospatial techniques in transportation. The course learning outcomes are:

- Understand the basics of remote sensing, data acquisition and interpretation technology
- Apply image processing, georeferencing, camera calibration techniques in traffic data collection
- Ascertain appropriate modeling techniques foranalysing spatial and non-spatial data
- Understand working configuration of GPS- Satellite, various GPS surveying methods
- Ability to apply spatial techniques in transportation

Syllabus (Brief outline): Introduction and basics of remote sensing, data acquisition and interpretation technology, types of remote sensing, digital system data format enhancement and classification; Introduction to image processing, maps and map scales, georeferencing and projections, digitization, image classification and rectification, camera calibration techniques in traffic data collection; Definition and components of GIS, spatial and non-spatial data, DBMS, GIS data model, raster and vector data structures and spatial analysis of each one in detail, DTM, DEM and DSM; Introduction to GPS, geodesy and components, working configuration of GPS- Satellite, geometry, space configuration, satellite ranging and errors; various GPS surveying methods- Lidar, DGPS, GNSS, aerial drones; Application of spatial techniques in transportation

Module No.	Course Module and Lesson Plan	Contact hours
1.	Introduction and basics of remote sensing, data acquisition and interpretation technology, types of remote sensing, digital system data format enhancement and classification.	9
2.	Introduction to image processing, maps and map scales, georeferencing and projections, digitization, image classification and rectification, camera calibration techniques in traffic data collection.	6
3.	Definition and components of GIS, spatial and non-spatial data, DBMS, GIS data model, raster and vector data structures and spatial analysis of each one in detail, DTM, DEM and DSM.	9

4.	Introduction to GPS, geodesy and components, working configuration of GPS-Satellite, geometry, space configuration, satellite ranging and errors; various GPS surveying methods- Lidar, DGPS, GNSS, aerial drones.	8
5.	Application of spatial techniques in transportation	7
	TOTAL	**39**

Suggested Readings:

1. Joseph G., Fundamentals of Remote Sensing, University Press
2. Burrough P.A. and Rachel A. McDonell, Principles of Geographical Information Systems Third Edition. Oxford Publication
3. Jensen, J.R.. Remote Sensing of the Environment an Earth Resource Perspective, Pearson Education, Delhi.
4. Campbell, J.B. Introduction to Remote Sensing, Taylor & Francis, London.
5.

CE 5140Airport Planning and Design

Weekly Contact: 3-0-0 (L-T-S)

Full Marks: 100
Credits: 3

Course Objective:

- Provides a basic understanding on Airport Systems Planning and Operation
- To impart knowledge about planning and designing of various components of airport system
- To learn about geometric design of various structural components of airport system
- To learn about structural design of airport pavements
- To make them learn the importance of airport drainage

Course Outcome: At the end of the course, the students will be able to:

- Apply the concept of airport planning and demand forecasting
- Design of airport components and airfield pavements
- Design the components of airport terminal and airport drainage system

Syllabus (Brief outline): Air Transport structure and organization, aircraft characteristics; Forecasting air travel demand trend; Airport configuration and planning, airport capacity; Geometric design of landing area, design of runway, and design of taxiway; Planning and design of terminal area, airport markings, airport lightning; Airport access system planning; design of airport pavement, airport drainage

Module No.	Course Module and Lesson Plan	Contact hours
1.	Air Transport structure and organization, the challenges and the issues, airport technology, aircraft characteristics related to airport design,	6
2.	Forecasting air travel demand trend	3
3.	Airport planning, airport configuration, airport capacity	6
4.	Geometric design of landing area, design of runway, design of taxiway	9
5.	Planning and design of terminal area, airport markings, airport lightning	6
6.	Airport access system planning	3
7.	Structural design of airport pavement, airport drainage	6
	TOTAL	**39**

Suggested Readings:

1. Robert Horonjeff and Francis X. McKelvey, "Planning & Design of Airports, McGraw Hill, Inc
2. S. K. Khanna, M. G. Arora and S. S. Jain, "Airport Planning & Design", NemChand and Bros.
3. V Kumar and S Chandra, "Air Transportation Planning and Design" Galgotia Publishers
4. Ashford, N. and Wright, P. H., "Airport Engineering", John Wiley & Sons,
5. ICAO, "Aerodrome Design Manual", International Civil Aviation Organization, Montreal, Canada

CE 5177 Pavement Material Laboratory

Weekly Contact: 3-0-0 (L-T-S)

Full Marks: 100 **Credits: 2**

Course Objective: To examine the suitability of the materials for preparing bituminous mixes required for construction of flexible pavements and to determine the optimum bitumen content of the bituminous mix.

Course Outcome: At the end of the course, the students will be able to:

- Understand the grade and quality of the paving bitumen
- Understand the quality of the aggregates to be used for bituminous mixes
- Determine the optimum bitumen content for the bituminous mix
- Evaluate the condition of the pavement

Syllabus (Brief outline): Test of aggregates and bitumen;Bituminous Mix Design-Marshall Method; Evaluation of pavement condition.

Module No.	Course Module and Lesson Plan	Contact hours
1.	Test of aggregates and bitumen	12
2.	Bituminous Mix Design	12
3.	Evaluation of pavement condition	12
4.	Assessment	3
	TOTAL	**39**

Suggested Readings:

1. E.J.Yoder, M.W.Witczak "Principles of pavement design", Wiley Publications.
2. Y.H.Huang, "Pavement analysis and design", Pearson Education India.
3. R B Mallick& T Ei-Korchi, " Pavement Engineering Principles and Practice"; CRC Press
4. R.Srinivasa Kumar, "Pavement Design", Universities Press.
5. P.Chakraborty, A.Das, "Principles of transportation engineering", PHI Learning Pvt. Ltd.

CE 5178Traffic System Laboratory

Weekly Contact: 3-0-0 (L-T-S)

Full Marks: 100
Credits: 2

Course Objective: Provides clear understanding on conducting various types of traffic surveys data collection, analysis, inference and presentation

Course Outcome: At the end of the course, the students will be able to:

- Understand how to conduct various types of traffic surveys involving data collection, its analysis, inference and way of presentation by writing a study report

Syllabus (Brief outline):

Traffic Surveys: traffic data collection by video-photographic method, Volume count, Speed study including spot speed, Parking study, Intersection turning movements, Speed and Delay study, Moving observer survey, Traffic noise measurement, Road lighting, User perception surveys, Origin-Destination (O-D) Surveys, Roadside and Household interviews.

Module No.	Course Module and Lesson Plan	Contact hours
1.	Traffic Data Collection	12
2.	Decoding of Video Data	12
3.	Analysis of Data	12
4.	Assessment and Survey report writing	3
	TOTAL	**39**

Suggested Readings:

1. William R. Mcshane and Roger P. Roess, "Traffic Engineering", Pearson
2. May, A.D., "Fundamentals of Traffic Flow", Prentice Hall, Inc.
3. Kadiyali, L.R., "Traffic Engineering and Transport Planning", Khanna Publishers
4. C JotinKhisty and B Kent Lall, "Transportation Engineering" Prentice-Hall of India
5. C. S. Papacostas& P. D. Prevedouros, 'Transportation Engineering & Planning'; Prentice-Hall India

CE 5179Software Application in Transportation Engineering

Weekly Contact: 3-0-0 (L-T-S)

Full Marks: 100 **Credits: 2**

Course Objective: To impart the knowledge of various software used for modelling, calculating and designing elements in transportation engineering, and providing hands-on training of these software to the students.

Course Outcome: At the end of the course, the students will be able to:

- Get acquainted with various transportation engineering software pertaining to traffic simulation, pavement design, Highway alignment design and transportation planning.
- Generate scenarios and design elements of transportation engineering based on the learned software and apply them to solve day-to-day problems in transportation engineering.

Syllabus: Simulation and modeling; Design and maintenance of pavement; Highway design; Travel demand and transit modeling

Module No.	Course Module and Lesson Plan	Contact hours
1.	Simulation and modeling – software demonstration for traffic flow modeling, intersection modeling, driver behaviour study	9
2.	Design and maintenance of pavement – demonstration of pavement design and maintenance management system software	9
3.	Highway design – demonstration of software of highway alignment design, drainage	9
4.	Travel demand and transit modeling – demonstration of software applications for travel demand, transit systems and network modeling	9
5.	Practical problem-solving assignments and assessment	3
	TOTAL	**39**

Suggested Readings:

1. Traffic Flow Dynamics: Data, Models and Simulation. Martin Treiber. Springer publication.
2. *Software related to pavement design:* https://www.dot.state.mn.us/materials/pvmtdesign/software.html

2nd Semester

CE 5207Pavement Engineering II

Weekly Contact: 3-0-0 (L-T-S)

Full Marks: 100 **Credits: 3**

Course Objective: To access the knowledge on the design of rigid pavement by evaluating the stresses that are likely to develop due tothe application of the anticipated wheel loadsand the climate condition in the region. The objective of this study is also extended to evaluate the failure criterion of the rigid pavements and the necessity of roadway drainage.

Course Outcome: At the end of the course, the students will be able to:

- Know about the various types of rigid pavements and their properties
- Know about stress behaviour under repeated loading and environmental condition
- Know the various design methods of rigid pavements
- Know about the applicability of joints in the rigid pavements
- Know about the utility of alternative materials and drainages in the rigid pavements

Syllabus (Brief outline): Types Concrete Pavement, their properties and mix design;Stresses in Rigid Pavements, Behaviour of Rigid Pavement under Repeated Loading, Rigid Pavement Joints; various Design methods of Rigid Pavement. Utilization of alternative materials in the rigid pavement and roadway drainage;High performance pavement.

Module No.	Course Module and Lesson Plan	Contact hours
1.	Concrete Pavement Types, Properties of Concrete, Concrete Mix Design for Rigid Pavement	6
2.	Stresses in Rigid Pavements, Behaviour of Rigid Pavement under Repeated Load, Rigid Pavement Joints	6
3.	Design of Rigid Pavement as per IRC, AASTHO, PCA and other Methods.	12
4.	Reinforced Concrete Pavement, Continuously Reinforced Concrete Pavement, Roller Compacted Concrete, High Volume Flyash Concrete, Concrete Pavement for low volume roads	6
5.	Soil Stabilized Roads, High performance pavement	6
6.	Roadway Drainage	3
	TOTAL	**39**

Suggested Readings:

1. E.J.Yoder, M.W.Witczak "Principles of pavement design", Wiley Publications.
2. Y.H.Huang, "Pavement analysis and design", Pearson Education India.
3. R B Mallick& T Ei-Korchi, " Pavement Engineering Principles and Practice"; CRC Press
4. R.Srinivasa Kumar, "Pavement Design", Universities Press.
5. P.Chakraborty, A.Das, "Principles of transportation engineering", PHI Learning Pvt. Ltd.

CE 5208 Traffic System Design and Management

Weekly Contact: 3-0-0 (L-T-S)

Full Marks: 100
Credits: 3

Course Objective:

- Provides a basic understanding on transportation problems, theirdesign, operation and management
- To study the performance of various transportation systems, design of traffic signal
- To make the students learn to deal with traffic issues including traffic safety, operation and control.

Course Outcome: At the end of the course, the students will be able to:

- Understand the basic principles of design and management of transportation systems
- Design of traffic signal, operations and maintenance of transportation facilities
- Assess level of services of roadway facilities, controls and terminal facilities of transportation system
- Understand the fundamental principles of design and application of traffic safety

Syllabus (Brief outline): Characteristics of traffic problems, traffic congestion, forecasting of future traffic; Traffic control system, analysis and design of signalized intersection, synchronized signal system; Pedestrian transportation system; Traffic operation, planning and management; Parking facilities; Traffic sign, marking road safety design; Highway traffic system design, design of toll booth system

Module No.	Course Module and Lesson Plan	Contact hours
1.	Characteristics of traffic problems, traffic congestion, forecasting of future traffic	6
2.	Traffic control system, signalized intersection, saturation flow, capacity of signalized intersection, design of signalized intersections, synchronized signal system	12
3.	Pedestrian transportation, design of pedestrian facilities	3
4.	Traffic operation, circulation planning, traffic management of large cities, traffic calming facilities	6
5.	Parking studies, parking design, terminal design	6
6.	Road signs, markings and design of other safety appurtenant	3
7.	Traffic system design of highways and expressways, design of toll booth system	3
	TOTAL	**39**

Suggested Readings:

1. William R. Mcshane and Roger P. Roess, "Traffic Engineering", Pearson
2. May, A.D., "Fundamentals of Traffic Flow", Prentice Hall, Inc.
3. C JotinKhisty and B Kent Lall, "Transportation Engineering" Prentice-Hall of India
4. C. S. Papacostas& P. D. Prevedouros, 'Transportation Engineering & Planning'; Prentice-Hall India
5. F. L. Mannering, W. P. Kilareski, & S. S. Washburn, 'Principles of Highway Engineering and Traffic Analysis'; Willey India

CE 5209Transport Economics and Project Evaluation

Weekly Contact: 3-0-0 (L-T-S)

Full Marks: 100
Credits: 3

Course Objective: To provide the students with a basic understanding of transport economics and project evaluation approches.The course also intends to impart basic knowledge on various approaches for strategic analysis, for example, congestion cost and congestion pricing system, pricing strategies, impacts of transport infrastructure.

Course Outcome: Students will gain a theoretical and applied understanding of transport economics and project evaluation in this course. The course learning outcomes are:

- Understand the basic concepts of transport economics
- Performeconomiccost-benefit analysis

- Learn application of muti criteria decision making process in transport project planning and evaluation
- Evaluate transportation systemsaccounting for congestion pricing, the pricing structure of services
- Understand impacts of transport infrastructure

Syllabus (Brief outline): Basic concept of transport economics, demand, supply, elasticity, elements of engineering economics, costs ; Economic and financial appraisal of projects, financial and economic cost benefit analysis, vehicle operating cost, travel time valuation, accident cost; Techniques in transport Project Evaluation, Application of Muti Criteria Decision Making Process in Project Planning and evaluation; Alternative means and methods of transport project development, Pricing strategies and pricing structure of transport services, Congestion cost; Impact of transport infrastructure, environmental impact, energy impact.

Module No.	Course Module and Lesson Plan	Contact hours
1.	Basic concept of transport economics, demand, supply, elasticity, elements of engineering economics, costs	6
2.	Economic and financial appraisal of projects, financial and economic cost benefit analysis, vehicle operating cost, travel time valuation, accident cost	9
3.	Techniques in transport Project Evaluation, Application of Muti Criteria Decision Making Process in Project Planning and evaluation;	12
4.	Alternative means and methods of transport project development, Pricing strategies and pricing structure of transport services, Congestion cost	6
5.	Impact of transport infrastructure, environmental impact, energy impact,	6
	TOTAL	**39**

Suggested Readings:

1. VineyMaitri, P. K. Sarkar, “Theory & Application Economics In Highway & Transport Planning”, Standard Publishers Distributors
2. Kumares C. Sinha, Samuel Labi, “Transportation Decision Making- Principles of Project Evaluation and Programming” Wiley
3. IRC SP 30: Economic Evaluation of Highway Projects in India. Indian Roads Congress

Departmental Electives (Course IX)

CE 5237Pavement Evaluation and Asset Management

Weekly Contact: 3-0-0 (L-T-S)

Full Marks: 100
Credits: 3

Course Objective: To create an ability within the students, to apply various pavement evaluation, rehabilitation and maintenance techniques to a pavement through its life cycle, in order to optimize and allocate the cost, assets and quality of the pavement. The students are expected to develop skills to manage pavements in efficient way by means of cost analysis, maintenance and other strategies.

Course Outcome: At the end of the course, the students will be able to:

- Learn the various distresses occurring in pavements
- Get an insight into the rehabilitation, maintenance techniques used on the site, and know its importance
- Learn about the performance and life cycle cost analysis of a pavement, and learn to develop an asset management system for pavement repair/ rehabilitation in theory, and using software.
- Know about the various quality control and assurances used in roadway construction.

Syllabus(Brief outline): Pavement distresses, evaluation, rehabilitation, repair and maintenance, pavement performance management, asset management and quality control in road construction.

Module No.	Course Module and Lesson Plan	Contact hours
1.	Pavement Distress, Pavement Evaluation Techniques	6
2.	Pavement Rehabilitation, Strengthening of pavement, Overlay Design, Maintenance of Unpaved and Paved Roads,	6
3.	Pavement Performance Management, Concept of Life Cycle Cost of Pavement, Selection of Cost Effective Pavement Type	6
4.	Concepts of Asset Management, Components for Asset Management, Total Highway Asset Management System, resource allocation, optimization, and decision analysis	12
5.	Software application in pavement evaluation	6
6.	Quality Control and Assurance in Roadway Construction	3
	TOTAL	**39**

Suggested Readings:

1. AASHTO Guidelines for Pavement Management Systems. American Association of State Highway and Transportation Officials, Washington, D.C.
2. Haas, R., Hudson, W.R., and Zaniewski, J., Modern Pavement Management. Krieger Publishing Co., Malabar, FL
3. R.Srinivasa Kumar, “Pavement Design”, Universities Press.

4. IRC:115, “Guidelines for structural evaluation and strengthening of flexible road pavements using Falling Weight Deflectometer (FWD) technique”, Indian Roads Congress.

CE 5238 Advanced Pavement Materials and Design

Weekly Contact: 3-0-0 (L-T-S)

Full Marks: 100
Credits: 3

Course Objective: To impart the knowledge of Advanced Pavement Engineering by topics such as dynamic behaviour of sub-grade, novel construction materials and the analysis of road materials, damage assessment, modern pavements such as concrete blocks, composite pavement, displacement-based analysis of pavement and subgrade, and road stability.

Course Outcome: At the end of the course, the students will be able to:

- Know about various pavement material characterization, non-conventional fillers and bitumen modifiers.
- Learn the damage analysis of rigid and flexible pavements, distresses, and construction of concrete vlock pavements and composite pavements.
- Analyse the pavement, by calculation of stresses and displacements based on theory of elasticity
- Conduct stability analysis of roadbeds.

Syllabus (Brief outline): Characterization of pavement materials, analysis of road materials, distresses in concrete pavements and analysis, stresses and displacement in pavements, stability analysis of roadbeds, variability in pavement materials, concrete block pavements.

Module No.	Course Module and Lesson Plan	Contact hours
1.	Characterization of pavement materials – Dynamic behavior of Sub-grade Soil, Polymer Modified Bitumen (PMB), Reclaimed Asphalt Pavement (RAP) materials, Non-conventional fillers (rice husk ash, fly ash, pond ash, hydrated lime, cement).	10
2.	Design and analysis of road materials –Moisture damage analysis of HMA, Design of emulsified mixes.	6
3.	Cemented materials and cement concrete-Distress and deformation analysis of paving concrete by destructive and non-destructive test methods.	5
4.	Construction procedure of Concrete Block Pavement (CBP), theory of composite pavements.	4
5.	Stresses and displacements due to embankment type of loading based on Theory of elasticity.	2
6.	Variability in pavement materials including soil subgrade -statistical applications in pavement analysis.	4

7.	Advanced methods of stability analysis of road beds- embankments and cut sections, hilly terrains.	8
	TOTAL	**39**

Suggested Readings:

1. E.J.Yoder, M.W.Witczak "Principles of pavement design", Wiley Publications.
2. Y.H.Huang, "Pavement analysis and design", Pearson Education India.
3. R B Mallick& T Ei-Korchi, " Pavement Engineering Principles and Practice"; CRC Press
4. Ministry of Road Transport & Highways (MORTH), "Specification for road and bridge works", IRC.
5. IRC:37-2018, "Tentative guidelines for the design of flexible pavements", Indian Roads Congress.

CE 5239Intelligent Transportation Systems

Weekly Contact: 3-0-0 (L-T-S)

Full Marks: 100 **Credits: 3**

Course Objective: To introduce intelligent systems for smarter transportation, including real-time traffic data collection and processing, control and management systems, fare collection systems etc.,for efficient and safe operations traffic in urban corridors. Also, the course intends to impart knowledge on the strategic launching of projects through the evaluation of existing schemes.

Course Outcome: At the end of the course, the students will be able to:

- Understand ITS and its benefits, methods of real-time traffic data collection
- Apply IoT in transportation –transport systems management, monitoring system, remote Area Surveillance
- Apply ITS forefficientand safe operations trafficin urban corridors
- Evaluateschemes for implementation of ITS oriented projects

Syllabus(Brief outline): Concept of Intelligent Transportation Systems (ITS), history and benefits, traffic data collection and analysis techniques, Internet of things in transportation and communication technique, application of ITS for various transportation components, evaluation and planning using ITS, launching of an ITS project and provision at governmental levels.

Module No.	Course Module and Lesson Plan	Contact hours
1.	Introduction to Intelligent Transportation Systems (ITS) – definition, objectives of ITS, context and concepts, history, benefits of ITS	3
2.	ITS traffic Data collection techniques – video data collection, automatic vehicle location, automatic vehicle identification, data from vehicle detectors and	6

	sensors, analysis of data.	
3.	Internet of Things in transportation – Function of ITS components, Systems architecture, vehicle to vehicle and infrastructure (V2V and V2I) communication systems and its applications- ATMS, ATIS, APTS, AVCS, Connected vehicles, Traffic Management Centres.	7
4.	Application of ITS –Electronic payment systems, Enforcement techniques, collision avoidance systems, Transportation demand management, Routing of emergency vehicles, Feedback ramp metering, Introduction of ITS in rail transport.	8
5.	ITS for safesustainable mobility–Estimation of emissions from in-use vehicles, information managementon pollution, congestion and mobility levels, emergency management	3
6.	Evaluation, planning and financing using ITS – Evaluation for planning approaches, Cost-Benefit ratio, usage of traffic flow theory concept, Conception and implementation of ITS, Public, private and PPP models for implementation of ITS.	6
7.	Launching of ITS – Guidelines and stages in launching of ITS at the project level and program level, Need of nationwide program for ITS, strategic plan development, Provision of ITS in urban development missions of India.	6
	TOTAL	**39**

Suggested Readings:

1. M A Chowdhary and A Sadek. Fundamentals of Intelligent Transportation systems planning. Artech House Inc..
2. Bob Williams. Intelligent transportation systems standards. Artech House, London
3. ITS Hand Book 2000: Recommendations for World Road Association (PIARC) by Kan Paul Chen, John Miles.
4. P K Sarkar and A K Jain “Intelligent Transport Systems”, PHI Learning Private Limited

CE 5241:Transportation Network Analysis

Weekly Contact: 3-0-0 (L-T-S)

Full Marks: 100
Credits: 3

Course Objective: To provide the students with a basic understanding of theories and applications of transportation network demand and supply models and simulation techniques.The course also intends to impart basic knowledge on analytical and simulation-based network assignment models, for example, incremental assignment, iterative assignment, multipath/probabilistic assignment.The emphasis in this course is on practical applications and analysis of algorithms.

Course Outcome: Students will gain a theoretical and applied understanding of transportation network analysis in this course. The course learning outcomes are:

- Understand the models for each stage of the four-step travel demand model
- Apply the travel demand assessment procedures to a sample transportation network
- Ascertain appropriate optimization techniques for transportation networks
- Understand different transportation network management policies such as congestion pricing
- Ability to analyse model outcomes to make better decisions to improve system performance

Syllabus (Brief outline): Transportation system analysis; Fundamentals of network models; Preliminaries of optimization; Transportation network problems; Network trip assignment; Other transportation networks; Network improvements

Module No.	Course Module and Lesson Plan	Contact hours
1.	**Transportation system analysis:** concepts/ components /data requirements – network representation – sequential travel forecasting procedure– link performance function– demand-performance equilibrium	5
2.	**Fundamentals of network models:** graphical representation –network attributes – connectivity, constraint, tree, path– minimum spanning tree –Euler tours and paths	7
3.	**Preliminaries of optimization:** basics of linear programming – shortest path problem– nonlinear programs –nonlinear complementarity problem –variational inequality problem	6
4.	**Transportation network problems:** Hitchcock transportation problem – trans-shipment problems –network optimization algorithms – minimum path algorithms	7
5.	**Network trip assignment:** all-or-nothing –capacity restraint assignment –incremental assignment –iterative assignment –multipath/probabilistic assignment –sensitivity analysis	7
6.	**Other transportation networks: s**upply chain network –transit network –ride-sharing network –multimodal networks	5
7.	**Network improvements:**resiliency –bottlenecks –performance measures	2
	TOTAL	**39**

Suggested Readings:

1. Sheffi, Y., Urban Transportation Networks: Equilibrium Analysis with Mathematical Programming Methods, Prentice-Hall, Inc., Englewood Cliffs, New Jersey.
2. Ahuja, R.K., Magnanti, T.L. and Orlin, J.B., Network Flows: Theory, Algorithms and Applications. Prentice-Hall Inc.
3. Patriksson M., The Traffic Assignment Problem: Models and Methods. Utrecht, The Netherlands.
4. Ortuzar J.D., &Willumsen L.G., Modelling Transport, Wiley.
5. Bell, M.G.H., and Iida, Y., Transportation Network Analysis, John Wiley & Sons.

Specialization: Structural Engineering

Course Structure

1st Semester

Sl. No	Course Name	Course code	Class Load/Week			Credit	Class load/ Week	Marks
			L	T	P			
1.	Course I: Advanced Solid Mechanics	CE 5101	3	0	0	3	3	100
2.	Course II: Computational Methods in Structural Analysis	CE 5102	3	0	0	3	3	100
3.	Course III: Design of special reinforced Concrete Structures	CE 5103	3	0	0	3	3	100
4.	Course IV: (Dep. Elective)		3	0	0	3	3	100
5.	Course V: (Open Elective)		3	0	0	3	3	100
	Theory Sub-total		15	0	0	15	15	500
6.	Advanced Structural Engineering Laboratory	CE 5171	0	0	3	2	3	100
7.	Structural Analysis and Design Software Laboratory	CE 5172	0	0	3	2	3	100
8.	Mini Project	CE 5173	0	0	3	2	3	100
	Practical Sub-total		NIL	NIL	9	6	9	300
	1st Semester Total					21	24	800

2nd Semester

Sl. No	Course Name	Course code	Class Load/Week			Credit	Class load/ Week	Marks
			L	T	P			
1.	Course VI: Advanced Structural Mechanics	CE 5201	3	0	0	3	3	100
2.	Course VII: Structural Dynamics	CE 5202	3	0	0	3	3	100
3.	Course VIII: Design and Behavior of Metal Structures	CE 5203	3	0	0	3	3	100
4.	Course IX (Dep. Elective)		3	0	0	3	3	100
5.	Course X (Open Elective)		3	0	0	3	3	100
	Theory Subtotal		10	1	0	15	15	500
6.	M. Tech Project Part - I (Term Paper)	CE 5291	0	0	2	4	2	200
7.	Term Paper Seminar & Viva-voce	CE 5292	0	0	0	2	0	100
	Practical Subtotal		0	0	0	6	0	300
	2nd Semester Total					21	17	800

3rd Semester

Sl. No	Course Name	Course code	Class Load/Week			Credit	Class load/ Week	Marks
			L	T	P			
1.	M. Tech Project Part - II (Progress Report)	CE 6191	0	0	0	12	0	300
2.	Progress Report Seminar & Viva-voce	CE 6192	0	0	0	6	3	100
	Total Credit		0	0	0	18	0	
	3rd Semester Total					18	0	400

4th Semester

Sl. No	Course Name	Course code	Class Load/Week			Credit	Class load/ Week	Marks
			L	T	P			
1.	M. Tech Project Part - III (Thesis)	CE 6291	0	0	0	22	0	400
2.	Thesis seminar and viva voce	CE 6292	0	0	0	8	0	200
	Total Credit		0	0	0	30	0	
	4th Semester Total					30	0	600

Course IV [Departmental elective]	**Course IX [Departmental elective]**
CE 5121 Structural Optimization	CE 5221 Reliability Analysis of Structures
CE 5122 Prestressed Concrete Structures	CE 5222 Offshore Structures
CE 5123 Advanced Concrete Technology	CE 5223 Structures under Extreme Events
CE 5124 Experimental Methods in Structural Engineering	CE 5224 Bridge Engineering
CE 5125 Non-linear Structural Mechanics	CE 5225 Tall Structures
CE 5126 Soil Structure Interaction	CE 5226 Composite Materials and Structures
	CE 5227 Condition Assessment and Retrofitting of Structures
	CE 5228 Structural Vibration Control

1st Semester

CE 5101: Advanced Solid Mechanics

Weekly Contact: 3-0-0 (L-T-S)

Full Marks: 100 **Credits: 3**

Course Objective:

The objective of the course is to make the students aware of the limitations of the theory they have learned at any undergraduate level solid mechanics course and equip them with analytical methods of solving advanced solid mechanics problems. Another objective is to introduce the failure theories in greater detail useful in industry along with certain concepts of continuum mechanics which are beneficial for research in material modelling.

Course Outcome: At the end of the course, the students will be able to:

- Understand the concept of stress and strain as tensorial entities
- Understand the concepts of principal stress and strain
- Formulate and solve classical problems of elasto-static analysis
- Apply the theories of failure to practical problems of engineering analysis
- Understand the basic concept of plasticity, flow rules and hardening law
- Understand the theory and application of viscosity and viscoelasticity

Syllabus (Brief outline): Stress and strain as tensor, Cartesian and polar coordinate systems of elasto-static analysis. Theories of failure and introduction to plasticity and viscoelasticity.

Module No.	Course Module and Lesson Plan	Contact hours
1.	Analysis of stress, principal stress, Airy's stress function	6
2.	Analysis of strain, strain invariant, principal strain	3
3.	Generalized Hooke's law, axisymmetric problem, plane, stress, plane strain, Elasticity problem as a boundary value problem, Two and three dimensional elasto-static problems in cartesian and cylindrical co-ordinates	9
4.	Tensor analysis, concept of linear transformation, invariants	3
5.	Deformation gradient, Eulerian, and Lagrangian description of motion	4

6.	Large displacements and large strains; Hyper- elastic models	4
7.	Theory of one-dimensional plasticity, incremental theory of plasticity, yield law, flow rule, hardening laws,	6
8.	Theory and application of viscosity and viscoelasticity	4
	Total =	**39**

Suggested Readings:

6. L S Srinath," Advanced Mechanics of solids", Tata McGraw-Hill Publishing Company Ltd.
7. Applied Mechanics of Solids: A F Bower, link: http://solidmechanics.org/
8. Kelly, PA. Mechanics "*Lecture Notes: An introduction to Solid Mechanics*." Available from http://homepages.engineering.auckland.ac.nz/~pkel015/SolidMechanicsBooks/index.html

CE5102 Computational Methods in Structural Analysis

Weekly Contact: 3-0-0 (L-T-S)

Full Marks: 100 **Credits: 3**

Course Objective: The basic objective of the course is to provide the ability to develop mathematical models for various structural engineering problems like truss, beam, frame, plate, shell and axisymmetric elements by applying the concept of solid mechanics and to impart a thorough understanding of the fundamental theories of finite difference, finite element and finite strip methods. The course covers isoparametric finite element formulation and application to structural dynamics, stability, stress analysis etc.

Course Outcome: At the end of the course, the students will be able to:

- develop mathematical models for various structural engineering problems using finite difference method
- apply finite element method to one, two and three dimensional complicated structural systems.
- gain knowledge on basics of coding for structural analysis
- use FEM based software packages for various structural engineering problems like linear and nonlinear static analysis, dynamics, buckling, stress and failure analysis etc.
- Use finite strip method and boundary element method for simple structural engineering problems

Syllabus (Brief outline): Variational principles, Finite difference method, Finite element method, Finite strip method and Boundary element method

Module No.	Course Module and Lesson Plan	Contact hours
1	Introduction: Overview of various numerical and computational methods of structural Analysis	1
2	Finite Element Method Overview: One dimensional element (truss, frame, beam)	6
3	Basic Equations of Solid Mechanics - Review of equilibrium conditions, strain-displacement relations, stress - strain relations	2
2	Principle of Virtual work & Stationary potential energy and Variational methods.	4
4	Element properties and displacement models of rectangular, triangular and isoparametric elements for two dimensional modeling of structures and application to truss and frame, static and dynamic analysis of beam, torsion of circular shaft, buckling of column, static and dynamic analysis of plates and shells	12
5	Three dimensional elements and axisymmetric problems	4
6	Finite difference method: Analysis of structural engineering problems	6
7	Introduction to Finite strip method, Boundary element method	4

Suggested Readings:

1. Concept and application of Finite element analysis, R D Cook, D S Malkus, M E Plesha, Wiley

2. Finite element method and its basis and fundamental, O C Zienkiewicz R L Taylor and J Z Zhu, Elsevier.

3. Finite element Procedures, Bathe, Prentice Hall

4. A first Course in the Finite Element Method, Logan, D. L., Thomson

5. Matrix and Finite element analyses of Structures, Madhujit Mukhopadhyay, Ane Books Pvt. Ltd

6. Numerical Methods, S B Rao and C K Santha, Universities Press

CE 5103 Design of special reinforced concrete structures

Weekly Contact: 3-0-0 (L-T-S)

Full Marks: 100 **Credits: 3**

Course Objective: Students should have an overview of design philosophy of special reinforced concrete structures. They should understand the methods of design calculations with proper loading of various industrial and special structures. Detailing of reinforcement placement is also to be learned considering both safety and economy. They should be acquainted about the guidelines prescribed in the relevant IS codes.

Course Outcome: At the end of the course, the students will be able to:

- Design R.C. underground tanks and Overhead tanks
- Design Raft foundation
- Design Flat slab
- Design Deep Beams
- Design R.C. Silos and Bunkers
- Design R.C. Chimneys

Syllabus (Brief outline): Strip and Raft foundation, R.C. underground tanks, Waffle slab, Flat slab and Grid, Deep Beams, R.C. Overhead tanks with supporting structures and foundation, Silos and Bunkers with supporting structure, R.C. pipes and Chimneys

Module No.	Course Module and Lesson Plan	Contact hours
1.	Overview of design philosophy	4
2.	Strip and Raft foundation	4
3.	R.C. underground tanks	3
4.	Waffle slab, Flat slab and Grid	4
5.	Deep Beams	3
6.	R.C. Overhead tanks with supporting structures and foundation	6
7.	Silos and Bunkers with supporting structure	4
8.	R.C. pipes and Chimneys	4
	Total =	**39**

Suggested Readings:

- Reinforced Concrete Structures by R. Park and T. Paulay
- Advanced Reinforced Concrete Design, Prentice Hall of India,C. K Wang, C.G. Salmon
- 'Handbook of Concrete Engineering', Mark Fintel, V.N.R. Co., New York.
- Handbook on Civil Engg. by Merritt, Gaylord, Kemp etc.
- Design of Reinforced Concrete Structures by N. Subramanian
- Design of Reinforced Concrete Structures by Vazirani and Ratwani
- Relevant latest editions of I.S. Codes of practices.

Departmental Electives (Course IV)

CE 5121: Structural Optimization

Weekly Contact: 3-0-0 (L-T-S)

Full Marks: 100 **Credits: 3**

Course Objective: To understand the basic concepts of optimization, appreciate the intricacies involved in the formulation of the optimization problem and learn a variety of optimization algorithms and techniques and the suitability of their application to different optimization problems.

Course Outcome: At the end of the course, the students will be able to:

- Formulate structural optimization problems.
- Solve optimization problems through both classical and modern optimization techniques.
- Identify the appropriate optimization method for the solution of a real-world structural optimization problem.
- Have a knowledge of various optimization toolkits and assess the computational effort involved in them.

Syllabus (Brief outline): Formulation of an optimization problem, classical optimization techniques, linear programming, nonlinear programming, evolutionary optimization and other modern optimization techniques.

Module No.	Course Module and Lesson Plan	Contact hours
1	Introduction: Formulation of Structural Optimization problems: Design variables - Objective function - constraints.	3
2	Classical optimization techniques for unconstrained and	7

	constrained optimization problems, Lagrange multiplier technique and Kuhn-Tucker conditions	
3	Linear programming problems, Simplex method	6
4	Nonlinear unconstrained optimization problems – region elimination methods, gradient based methods, direct search methods	8
5	Constrained optimization problems: direct and indirect methods	7
6	Introduction to Genetic Algorithm, Dynamic Programming and other specialized optimization techniques	8
7	Applications	
	TOTAL	**39**

Suggested Readings:

1. S.S. Rao, Optimization, Theory and Applications, 2nd Edition, Wiley Eastern Ltd., New Delhi.
2. J.S. Arora, Introduction to Optimum Design, McGraw-Hill Book Company, New York.
3. K. Deb, Optimization for Engineering Design, Algorithms and Examples, PHI.
4. A.J. Morris (Editor), Foundations of Structural Optimization - A Unified Approach; John Wiley and Sons, Chichester.

CE 5122 Prestressed Concrete Structures

Weekly Contact: 3-0-0 (L-T-S)

Full Marks: 100 **Credits: 3**

Course Objective: To impart adequate knowledge on philosophy, analysis and design of prestress concrete structures.

Course Outcome: To be conversant in handling the design of prestressed concrete structures in practice.

Syllabus (Brief outline): Advantages of PSC over RCC, Materials and Methods of Prestressing, Analysis of Prestress, Complete limit state design procedure for statically determinate PSC girders using IS code of practice, Introduction to major international codes of practice on PSC.

Module No.	Course Module and Lesson Plan	Contact hours
1	Philosophy of prestress analysis	3
2	Materials for prestressed concrete construction	3
3	Technique of mechanical prestressing	6
4	Losses in prestress	6
5	Design for flexure, shear and servicebility	6
6	End zone design	6
7	Prestress analysis of statically indeterminate structures	6
8	Introduction to major international codes of practice	3
	TOTAL	**39**

Suggested Readings:

1) Design of Prestressed Concrete structure by Lin

2) Design of Prestressed Concrete by Krishna Raju

3) Design of Prestressed Concrete by Mallik & Gupta

CE 5123 Advanced concrete science and technology

Weekly Contact: 3-0-0 (L-T-S)

Full Marks: 100 **Credits: 3**

Course Objective: Students should have an overview about Concrete science & technology– its past, present and future. They should understand the basic mechanism of hydration of cement with and without use of admixtures. Properties and mix proportioning of special concrete are also to be learned considering the important aspects of sustainability and durability of concrete. They should be acquainted about the guidelines prescribed in the relevant IS codes.

Course Outcome: At the end of the course, the students will be able to:

- understand about hydration of cement with and without use of admixtures
- understand the use of special cementitious systems
- design the mix proportioning of special concrete
- understand about sustainability and durability of concrete.
- understand about microstructure of concrete

Syllabus (Brief outline): Hydration of cement, Different models of hydrated cement gel, Mechanism, application and specification of admixtures, Special cementitious systems, Concrete - environment interaction, Properties and mix proportioning of special concrete, Sustainability and Durability of concrete, Microstructure of Concrete.

Module No.	Course Module and Lesson Plan	Contact hours
1.	Concrete: Past, Present and Future	**3**
2.	Hydration of cement, Different models of hydrated cement gel.	**3**
3.	Mechanism, application and specification of chemical admixtures, mineral admixtures and other cement replacement materials	**3**
4.	Special cementitious systems, viz., Phosphate cement, Magnesium oxychloride cement, Rediset cement, Macro-Defect-Free cement, etc.	**6**
5.	Concrete - environment interaction; Marine concrete; Resistance of concrete to Fire and influence of temperature; Extreme weather concreting (Hot weather and Cold weather concreting).	**6**
6.	Properties and mix proportioning of fly ash concrete, silica fume concrete, fibre reinforced concrete, sprayed concrete, high performance concrete, self-compacting concrete and polymers in concrete	**6**

7.	Special concrete: Lightweight and foam concrete, Porous concrete, Nano-concrete, Translucent concrete, Bacterial concrete, Lunar concrete, Geopolymer concrete, Corrosion resistant concrete, etc.	**6**
8.	Sustainability and Durability of concrete.	**3**
9.	Microstructure of Concrete	**3**
	Total =	**39**

Suggested Readings:

1. A.M.Neville, "Properties of Concrete", Addison Wesley Longman Limited
2. A.M.Neville, J.J. Brooks "Concrete Technology", Pearson Education India.
3. P.K.Mehta, J.J. Monteiro, "Concrete – Microstructures and Properties".
4. M.S. Shetty, "Concrete Technology (Theory and Practice)", S. Chand Publishers .
5. M.L. Gambhir, "Concrete Technology", Tata McGraw-Hill Education.
6. A.R. Santhakumar, "Concrete Technology", Oxford University Press
7. Sydney Mindess, "Concrete".
8. Lea's Chemistry of Concrete.
9. Relevant latest editions of I.S. Codes of practices.

CE 5124 Experimental methods in structural engineering

Weekly Contact: 3-0-0 (L-T-S)

Full Marks: 100 **Credits: 3**

Course Objective:

To learn fundamentals of experimental methods in structural analysis that includes Test planning, design and implementation, Instrumentation, data acquisition, interpretation, statistical analysis, error and uncertainty quantification of experimental results

Course Outcome: At the end of the course, the students will be able to:

- Planning of Experimental palming and its implementation
- Applications of model building and analysis

- Use of various types of sensors for displacement, velocity, acceleration, pressure, loads, strains etc.
- Fundamental of data acquisition and related software to analyse static and dynamic test data
- NDT of concrete and steel
- Statistical analysis of experimental results to understand error and uncertainty in experimental outcome

Syllabus (Brief outline): Theories of similarities, dimensional analysis Model and analogies: uses and applications of models, Test planning, design and implementation, Instrumentation, Sensors and data acquisition, Non-destructive testing. Interpretation of experimental results.

Module No.	Course Module and Lesson Plan	Contact hours
1	Introduction: theories of similarities, dimensional analysis, Buckingham's Pi theorem, scale factors and dynamic similitude; Model and analogies: uses and applications of models: types of model investigation, indirect and direct models, elastic and inelastic models (steel, concrete and masonry), size effects;	8
2	Test planning, design and implementation: testing sequence and experimental plan, loading systems, devices, actuators and their control;	4
3	Instrumentation: mechanical, electrical, optical and acoustic methods of measurement of static and dynamic quantities. various types of sensors for displacement, velocity, acceleration, pressure, loads, strains, full-field measurements;	10
4	Data acquisition system and data processing: analog systems, digital systems using personal computers, dynamic measurement, numerical and graphical data processing and archiving;	4
5	Non-destructive testing. In-situ tests. short term and long term methods.	9
6	Interpretation of experimental results. Statistical analysis, error and uncertainty in experiment, measurement systems, accuracy in models and reliability of results;	4
	TOTAL	**39**

Suggested Readings:

1. Experimental Stress Analysis by James W. Dally and William F. Riley, McGraw-Hill Education
2. Experimental Stress Analysis by L.S. Srinath, M.R. Raghavan, K. Lingaiah, G. Gargesa, B. Pant, and K. Ramachandra, Tata Mc Graw Hill.
3. Non-Destructive Testing and Evaluation of Civil Engineering Structures edited by: Jean-Paul Balayssac Vincent Garnier , Elsv. Sc.
4. Vibration Monitoring, Testing, and Instrumentation Edited by Clarence W. de Silva, CRC Press Taylor & Francis Group.

CE 5125 Non-linear Structural Mechanics

Weekly Contact: 3-0-0 (L-T-S)

Full Marks: 100 **Credits: 3**

Course Objective: The primary objective of the course is to familiarize the students to structural problems where linearity between disturbance and response doesn't hold. Subsequently, the course seeks to aid the students to analyse and solve such non-linear problems

Course Outcome: At the end of the course, the students will be able to:

- Formulate and solve analytically geometrically non-linear one-dimensional problems
- Determine critical buckling loads of continuous beams and portal frames
- Formulate and solve one dimensional elasto-plastic problems involving hardening
- Formulate and solve metal and concrete plasticity problems

Syllabus (Brief outline): 'Elastica', pushover analysis, incremental plasticity, elasto-plastic deflection of beams.

Module No.	Description of Course Module	No. of lectures
1.	Large deflection of elastic beams: the 'elastica theory'	3
2.	The analysis of elastic instability and second order effects including pushover analysis	12
3.	Theory of one-dimensional plasticity, incremental theory of plasticity, yield law, flow rule, hardening laws.	10
4.	Elasto-plastic beam analysis and numerical solution	4
5.	Metal and concrete plasticity, limit analysis	10
	Total =	**39**

Suggested Readings:

1. Devdas Menon," Advanced Structural Analysis",
2. S P Timoshenko, J M Gere,"Theory of elastic stability", McGraw-Hill Edition
3. J Chakrabarty, "Theory of Plasticity", Elsevier Butterworth-Heinen

CE 5126 Soil-structure interaction

Weekly Contact: 3-0-0 (L-T-S)

Full Marks: 100 **Credits: 3**

Course Objective: The objective of the course is to familiarize a student to the mutual influencing nature of soil and structure and ways to analyse and design such structures.

Course Outcome: At the end of the course, the students will be able to:

- Formulate soil pressure on structures
- Solve statical problems of elasticity and elasto-plasticity involving soil-structure interaction
- Learn to use design codes for design and analysis of soil-structure interaction problems like retaining wall, etc.
- Formulate solution procedure of advanced dynamical problems

Syllabus (Brief outline): Contact pressure idealization, beams on elastic foundation, dynamic and static analysis geotechnical structures.

Module No.	Course Module and Lesson Plan	Contact hours
1.	Contact pressure distribution, idealized soil-foundation and interface behavior	4
2.	Elastic models, elastic-plastic soil behavior	4
3.	Analysis of beams, columns and plates resting on elastic and visco-elastic foundations.	12
4.	Dynamic earth pressures, force and displacement-based analysis	4
5.	Pseudo-static and pseudo-dynamic analysis, design codes,	4

6.	Dynamic analysis of geotechnical structures including retaining wall,	5
7.	Soil slope, railway subgrade and ballast using mass-spring-dashpot model.	6
	Total =	**39**

Suggested Readings:

1. Hetenyi, M. Beams on Elastic Foundation. The University of Michigan Press, U.S.A.
2. Das, B.M. Fundamentals of soil dynamics. Elsevier, New York, U.S.A.
3. Selvadurai, A.P.S. Elastic analysis of soil-foundation interaction. Elsevier Scientific Company Publishing, New York, U.S.A.
4. D.D Barkan. Dynamics of Bases and Foundations. McGraw Hill book Company.
5. E.E. Richart et al. Vibrations of soils and foundations. Prentice Hall Inc.

CE 5171 Advanced Structural Engineering Laboratory

Weekly Contact: 0-0-03(L-T-S)

Full Marks: 100 **Credits: 2**

Course Objective: To equip the students with advanced non-destructive testing methods, vibration testing methods for assessment of structural health conditions

Course Outcome: At the end of the course, the students will be able to:

- use non-destructive testing instruments in site for assessing structural health conditions
- perform basic vibration testing on structural models
- develop a basic knowledge on various set ups and technologies for conducting experimentation for research and industrial projects

- **Syllabus (Brief outline):** NDT of steel and concrete structures, vibration testing, strain measurement

Module No.	Course Module and Lesson Plan	Contact hours

1	Mix, design, non-destructive and destructive testing of concrete	15
2	Non-destructive Evaluation of rebars in concrete	3
3	Non-destructive Testing of Steel	6
4	Vibration Testing	6
5	Measurement of Strain	6
	Viva	3
	TOTAL	**39**

Suggested Readings:

1. T P Ganesan, Model analysis of structure, University Press.
2. L.S. Srinath, M.R. Raghavan, K. Lingaiah, G. Gargesa, B. Pant, and K. Ramachandra, Experimental Stress Analysis, Tata Mc Graw Hill.
3. https://www.bksv.com/en/knowledge/training/online-training, Bruel & Kjar Inc.

CE 5172: Structural Analysis and Design Software Laboratory

Weekly Contact: 0-0-3 (L-T-S)

Full Marks: 100 **Credits: 2**

Course Objective: The course objective is to familiarize a student with various computational methods to solve the structural engineering problems. Specially, the course will help the students to understand the analysis and design of different structural components using available software.

Course Outcome: At the end of the course, the students will be able to:

- Express a structural analysis problem into computer implementable form.
- Solve numerical problems with at least one popular tool like MATLAB or Python.
- Solve classical two-dimensional linear elastic solid mechanics problems using a commercial software
- Analysis and design of structures by readily available software.
- Conversant as practising structural designer

Syllabus (Brief outline): The Structural Analysis with computer programming, Finite element analysis using available commercial software, Analysis and Design of structures using available Software.

Module No.	Course Module and Lesson Plan	Contact hours
1.	Structural Analysis with computer programming: Introduction to MATLAB/Python for solving numerical problems, solution of second-order differential equations experienced in structural mechanics	15
2.	Introduction to finite element method using available commercial software to solve one- and two-dimensional linear elastic boundary value problems of solid mechanics.	06
3.	Application of available Structural Analysis and Design Software to solve various problem in connection with core subjects	18
	Total =	**39**

Suggested Readings:

1. Latest editions of IS:456, IS:800, IS:1893(1), IS:13920, IS:3370(1, 2, 4), IS:4995(1, 2) and IS:1343.
2. Bungale S. Taranath, "Structural Analysis and Design of Tall Buildings", Mc-Graw Hill.
3. Duggal, S.K., "Limit State Design of Steel Structures", Tata McGraw Hill.
4. Wolfgang Schueller, "High Rise Building Structures", Wiley.
5. Subramanian, N., "Design of Steel Structures (Limit States Method)".

CE 5173 Mini Project

Weekly contact: 0-0-3 (L-T-S)

Full marks: 100
Credits: 2

Course Objective:

To complete a small project on analysis and design of special structures

Course Outcome:

- Understand to analyse and or design a special structure.
- Learn to present the entire work in a report form.
- Learn to make a presentation of his work done before the supervisor

Syllabus (Brief outline):

Small Group projects on analysis and design of special structures

2nd Semester

CE 5201 Advanced Structural Mechanics

Weekly Contact: 3-0-0 (L-T-S)

Full Marks: 100 **Credits: 3**

Course Objective: The objective of the course is to equip the students with analytical and computational tools to solve advanced problems of structural Mechanics

Course Outcome: At the end of the course, the students will be able to:

- solve torsion problems with non-circular cross-sections
- formulate stability analysis of columns, beams, and two-dimensional portal frames
- determine critical buckling load of columns, beam-columns, continuous beams, and portal frames
- understand the behaviour of plates and shells and analyse plates and shells using analytical as well as numerical techniques to solve two dimensional structural engineering problems and ability to construct the mathematical models of real life structural systems.

Syllabus (Brief outline): Analysis of non-circular prismatic bars under torsion, membrane analogy for torsion of thin sections. Concept of stability analysis using force, energy and dynamics using simple structural member. Critical load determination of columns, beams-columns, continuous beams and frames under axial load. Analytical and numerical techniques of analysis of plates and shells.

Module No.	Course Module and Lesson Plan	Contact hours
1.	Concept of stability, static, dynamic and energy criterion of stability; Buckling; Snap through and post-buckling; Stability of columns and beams; Introduction to inelastic buckling; Beam-columns; Stability of frames	11
2.	Torsion of general prismatic bars, Membrane analogy; Thin-walled tubes	12
3.	Governing differential equations of thin rectangular plates with various boundary conditions and loading conditions. Bending of long thin rectangular plate to a cylindrical surface, Navier's Solution, Levy's solutions, Kirchhoff plate theory, Shear deformation theories, Introduction to orthotropic plates, Numerical methods for solution of plates,	10
4.	General shell geometry, classifications, stress resultants, equilibrium equation, Membrane theory Shells, Classical bending theories of cylindrical shells such as approximate analysis of cylindrical shells, Numerical methods for shell analysis	6

	Total =	**39**

Suggested Readings:

1. S P Timoshenko, J M Gere,"Theory of elastic stability", McGraw-Hill Edition
2. S P Timoshenko, S W Kreiger,"Theory of plates and shells", Tata McGraw-Hill Edition
3. L S Srinath," Advanced Mechanics of solids", Tata McGraw-Hill Publishing Company Ltd.
4. Thin shell structures, J N Bandyopadhyay, New Aage International publisher

CE 5202 Structural Dynamics

Weekly Contact: 3-0-0 (L-T-S)

Full Marks: 100 **Credits: 3**

Course Objective: To learn the basic concepts of structural dynamics, understand mathematical modelling of different types of structures through the use of simplifying assumptions and to learn the dynamic analysis of structures to various types of excitations through analytical and computational techniques.

Course Outcome: At the end of the course, the students will be able to:

- Carry out proper structural idealization for structural dynamic analysis.
- Evaluate the dynamic properties of structures.
- Obtain the response of discrete and simple continuous systems under various dynamic loading.
- Interpret the theoretical results for application in practical problems.

Syllabus (Brief outline): Basic concepts, free and forced vibration analysis of single and multi-degree-of-freedom systems, vibration transmissibility, response spectrum, modal analysis, continuous systems, dynamic analysis by finite element method, introduction to random vibration.

Module No.	Course Module and Lesson Plan	Contact hours
1	Introduction, nature and types of dynamic loading, modelling aspects, methods of formulation of the equation of motion	2
2	Free vibration response of un damped and viscously damped single-degree-of-freedom systems	2
3	Forced vibration response of viscously damped single-degree-of-freedom	8

	systems under harmonic, periodic, impulsive and arbitrary dynamic loading; vibration measuring instruments, vibration transmissibility and isolation, response spectrum – basic principles, numerical evaluation of dynamic response	
4	Multi-degree-of-freedom systems - shear building idealization, natural vibration frequencies and mode shapes, normalization of modes, orthogonality of modes; damping in structures – classical and non-classical damping, estimation of modal damping ratios; forced motion of shear building – modal superposition method, response to base motion	10
5	Dynamics of distributed parameter systems – rods (axial vibrations), beams (shear, axial and axial-shear-flexural vibrations)	4
6	Dynamic analysis of structures using finite element method	8
7	Introduction to random vibration	5
	TOTAL	**39**

Suggested Readings:

1. R.W. Clough and J. Penzien, Dynamics of Structures, McGraw-Hill.
2. L. Meirovitch, Elements of Vibration Analysis, McGraw-Hill.
3. Douglas Thorby, Structural Dynamics and Vibration in Practice, Elsevier
4. Roy R. Craig, Jr., Structural Dynamics: An introduction to Computer Methods, John Wiley and Sons.
5. Mario Paz and William Leigh, Structural Dynamics, Springer.

CE 5203 Design and Behavior of Metal Structures

Weekly Contact: 3-0-0 (L-T-S)

Full Marks: 100 **Credits: 3**

Course Objective: To equip the students with analysis and design methodologies of metal-made structures, modern design practices and an in-depth perspective about behaviour of metal structures

Course Outcome: At the end of the course, the students will be able to:

- get familiar with modern design practices, such as reticulated plate, shell, cable supported structures, LRFD approach
- get critical in-sight about behaviour of metal-made structures like various modes of buckling, semi-rigid connection behaviour, plastic behaviour, etc

- develop column strength curves considering residual stress, initial crookedness, shear deformation, etc
- familiar with earthquake resistant design of metal structures

Syllabus (Brief outline): Design of reticulated plate, shell, cable supported structures, LRFD approach; column strength curves considering residual stress, initial crookedness, shear deformation, earthquake resistant design of metal structures, Aluminium structures, cold formed steel structure, semirigid connection

Sl. No.	Topic	No. of classes/ Semester
1	Mechanical properties of metals, hysteresis, ductility; Concept of plastic, compact, semi-compact and slender sections, residual stresses	3
2	Member design: effect of local buckling, elastic and inelastic buckling, buckling of lattice column, Buckling and post-buckling strength of plate elements, Torsional buckling, P-Δ effect, Design for fatigue, design and detailing for earthquake loads	10
3	Connection design: High strength friction grip (HSFG) bolted connections, Welding methods and non-destructive testing (NDT), Semi-rigid and rigid beam to column connections	7
4	Design of light gauge steel structural members	5
5	Design of Aluminum Structure	5
6	Behavior of reticulated plate, shell and cable supported roof system	6
7	Introduction of LRFD steel design	3
	TOTAL	**39**

Suggested Readings:

1. C.G. Salmon and J. E. Johnson, Steel structures: Design and Behavior, HarperCollins Publishing.
2. N. Subramanian, Design of Steel Structures, Oxford Univ Press.
3. N. S. Trahir and D. A. Nethercot, The Behaviour and Design of Steel Structures to EC3, Taylor and Francis.
4. S. P. Timoshenko and J. M. Gere, Theory of Elastic Stability, Mc-Graw Hill Book Company, New York.
5. W. T. Segui, LRFD Steel Design, Cengage Learning.

Departmental Electives (Course IX)

CE 5221 Reliability Analysis of Structures

Weekly Contact: 3-0-0 (L-T-S)

Full Marks: 100 **Credits: 3**

Course Objective:

To learn various reliability analysis techniques to asses safety of structures under uncertainty. Also, to get introductory knowledge on design under uncertainty and time dependent reliability analysis.

Course Outcome: At the end of the course, the students will be able to:

- Model loads and resistance parameters in probabilistic framework
- Apply FORM and SORM method to solve structural reliability analysis problem
- Apply Monte Carlo simulation for uncertainty quantification and recallability analysis of structures
- Use of Metamodeling technique in Monte Carlo simulation framework
- Get basic concept of design under uncertainty, system reliability, time dependent reliability analysis

Syllabus (Brief outline): Basic statistics and probability theory, concept of structural reliability, probabilistic models for loads and resistance parameters, Second moment based Structural reliability methods, Simulation methods for structural safety, Variance reduction techniques, Importance sampling, Application of metamodeling approaches in reliability analysis, Application of reliability in design, partial safety factors and code calibration, Introduction to: reliability of structural systems, reliability based and robust design optimization, time variant reliability analysis

Module No.	Course Module and Lesson Plan	Contact hours
1	Introduction to the concept of structural reliability, basic statistics and probability theory, probabilistic models for loads and resistance parameters	6
2	Structural reliability methods: FORM and SORM, Hasofer-Lind and Rackwitz-Fiessler methods, application to structural engineering problems	8
3	Simulation methods for structural safety, Variance reduction techniques, Importance sampling	4
4	Application of metamodeling approaches in reliability analysis	4
5	Reliability based design-determination of partial safety factors,	4

	code calibration	
6	Reliability of structural systems	5
7	Introduction to Reliability based and robust design optimization,	4
8	Introduction to time variant reliability analysis	4
	TOTAL	**39**

Suggested Readings:

1. A Haldar & S Mahadevan, Reliability Assessment Using Stochastic Finite Element Analysis, John-Wiely& Sons Inc., New York, USA.
2. A S Nowak & K R Collins, Reliability of Structures, CRC press.
3. H O Madsen, S Krenk and N C Lind, Methods of Structural Safety, Prentice-Hall, Inc,Englewood Cliffs, USA.
4. R.E. Melchers, Structural Reliability Analysis and Prediction, Ellis Horwood, Chisester, England.
5. Palle Thoft Cristensen and Y. Murotsu, Applications of Structural Systems Reliability Theory, Springer-Verlag, Berlin.

CE 5222 Offshore Structures

Weekly Contact: 3-0-0(L-T-S)

Full Marks: 100 **Credits: 3**

Course Objective: To make the students familiar with various offshore structure, and enable them to analyse and design offshore structures; basic knowledge about maintenance and inspection of offshore structures

Course Outcome: At the end of the course, the students will be able to:

- assess loads on offshore structure and understand applicability of various wave load models
- understand analysis and design methodologies of offshore structure, codal stipulations
- have an idea about the various aspects of inspection, maintenance and operation of offshore structures

Syllabus (Brief outline): offshore structure types, operations, assessment of loads, wave load modelling, analysis and design of offshore structure, codal stipulations, inspection and maintenance

Module No.	Course Module and Lesson Plan	Contact hours
1	Loads and structural forms of different types of offshore structures	7
2	Modeling of wave load, Morrison equation, static and stochastic wave modelling approaches	7
3	Dynamic analysis of single and multi-degree of freedom offshore structure, soil pile interaction	10
4	Design principles of various components of offshore structures, Codal provisions	10
5	Maintenance, inspection and operation of offshore structure, prevention of corrosion	5
	TOTAL	**39**

Suggested Readings:

1. Brebbia C.A. and Walker, 'Dynamic Analysis of Offshore Structures', Newnes Butterworth, London.
2. Chakraborti, S., 'Handbook of Offshore Engineering', 2 volume set, Elsevier Science.
3. Ochi, M. K., 'Ocean Waves, The Stochastic Approach', Cambridge University Press.
4. API RP-2A, American Petroleum Institute (API) Codes of Practices (latest versions), series 2: offshore structures API.
5. DNV-OS-C101,Design of offshore steel structures, General (LRFD method) DET NORSKE VERITAS.

CE 5223 Structures under Extreme Events

Weekly contact: 3-0-0 (L-T-S)

Full Marks: 100

Credits: 3

Course Objective:

To learn (i) modelling and response of analysis of structures under various extreme loading e.g., earthquake, wind blast, wave, fire, etc., (ii) materials modelling under extreme load and (iii) performance and energy-based design approach under extreme loads

Course Outcome: At the end of the course, the students will be able to:

- Model various extreme loads typically faced by structures e.g., earthquake, wind, wave, blast, fire, etc.
- To analyse structures under such loads

- Apply common software for analysing structures under various extreme loads
- Understand the importance of specialty of material modelling in case of extreme loading
- Know the concept of performance based and energy- based approach of designing structures under extreme load.

Syllabus (Brief outline): Overview of various Extreme Loading on structure, modelling and response of analysis of Structures under various Extreme Loading e.g., earthquake, wind blast, wave, fire, etc., materials model under extreme loading, Concept of performance and energy-based design approach under extreme loads, multi-hazard analysis

Module No.	Course Module and Lesson Plan	Contact hours
1	Introduction and overview of various extreme loading on structure	3
2	Extreme load modelling and response of structures under earthquake and tsunami	8
3	Extreme Load Modelling and Response of Structures under wind including cyclone and tornado,	6
4	Extreme Load Modelling and Response of Structures under blast	4
5	Extreme Load Modelling and Response of Structures under wave	4
6	Extreme Load Modelling and Response of Structures under fire.	4
7	Materials Model under extreme loading	4
8	Performance based design approach under extreme loads, Introduction to multi hazard analysis	6
	TOTAL	**39**

Suggested Readings:

1. A J. Kappos (ed), Dynamic Loading and design of structures, Taylor and Francis.
2. N. C. Nigam and S Narayanan, Applications of Random Vibrations, Narosa
3. A.K. Chopra, Dynamics of Structures – Theory and Applications to Earthquake Engineering, Prentice Hall.

CE 5224 Bridge Engineering

Weekly contact: 3-0-0 (L-T-S)

Full Marks: 100
Credits: 3

Course Objective: To impart adequate knowledge on analysis and design of standard bridge structures.

Course Outcome: To be conversant in handing the structural design of a bridge project in practice as per Indian standard.

Syllabus (Brief outline): Terminology and definitions, Complete planning requirements, Analysis and design of superstructure and substructures for standard bridges, Analysis of special type bridges, Fundamentals of construction methods, Introduction to major international codes. Introduction to world's magnificent bridges.

Module No.	Course Module and Lesson Plan	Contact hours
1	Definition, classification and components of bridges	3
2	Site selection, investigation and planning of bridge projects	3
3	Hydraulic design of bridges	3
4	Superstructure - Solid slab and Slab-girder deck analysis	6
5	Substructure and Well Foundation analysis	6
6	Introduction to analysis of balanced cantilever, arch, cable stayed and suspension bridges	6
7	Introduction to major international code of practice	3
8	Introduction to methods of bridge construction	6
9	Introduction to world's pioneer bridges.	3
	TOTAL	**39**

Suggested Readings:

1. Design and construction of highway bridges by K. S. Rakshit
2. Essentials of Bridge Engineering by D. J. Victor
3. Design of Bridges by N. K. Raju
4. Bridge Engineering by S. Ponnuswamy

CE 5225 Tall Structures

Weekly Contact: 3-0-0 (L-T-S)

Full Marks: 100 **Credits: 3**

Course Objective: To provide the students with a basic understanding of design philosophies and the fundamentals of tall structures. This will help them to understand the analysis and design of different structural components of tall structures like rigid frames, braced frames, in-filled frames, coupled shear walls, tubular, cores etc. The Performance-based design philosophy is also introduced to enrich the students.

Course Outcome: At the end of the course, the students will be able to:

- Understand the basic characteristics and behaviour of structural systems of tall structures and also the different structural forms.
- Understand the concept of analysis of tall structures like towers, chimneys etc.
- Learn the importance of symmetry and regularity in plan and elevation
- Design and detailing of various structural elements like beam-column joints, shear walls etc. using Performance-based design concept
- Perform the Stability analysis of tall buildings under various methods due to different loads.
- Design the foundation for typical tall structures.

Syllabus (Brief outline): The concept of high-rise structures and the behaviour of various structural systems, Analysis of multi-storey frames, Design philosophy and detailing of various structural, Performance-based design, Stability of Tall Structures, Design of foundation of tall structures

Module No.	Course Module and Lesson Plan	Contact hours
1.	Introduction to high rise structures, Behavior of Various Structural Systems: Factors affecting growth, Height and structural form; High rise behavior, Rigid frames, braced frames, in-filled frames, shear walls, coupled shear walls, wall-frames, tubular, cores, Futigger-braced and hybrid mega system.	8
2.	Analysis of multi-storey frames, Chimneys, Towers under gravity and lateral loads.	6
3.	Importance of symmetry and regularity in plan, and regularity in elevation.	6
4.	Design and detailing of various members and beam-column joints, shear walls and coupled shear walls for ductility. The capacity design principle. Performance based design philosophy	7
5.	Stability of Tall Buildings: Overall buckling analysis of frames, wall frames, approximate methods, second order effects of gravity of loading, P-Delta analysis, Transnational, Torsional instability, out of plum effects.	6
6.	Design of foundation of tall structures	6
	Total =	**39**

Suggested Readings:

1. Bungale S. Taranath, "Structural Analysis and Design of Tall Buildings", Mc-Graw Hill.
2. Bryan S. Smith and Alex Coull, "Tall Building Structures", Wiley India.
3. Wolfgang Schueller, "High Rise Building Structures", Wiley.
4. U.H.Varyani, "Structural Design of Multi-storeyed Buildings", 2nd Ed., South Asian Publishers, New Delhi.

CE 5226 Composite Materials and Structures

Weekly contact: 3-0-0 (L-T-S)

Full Marks: 100
Credits: 3

Course Objective: The main objective of the course is to introduce students to advanced composite materials and their applications, development of fundamental relationships for predicting the mechanical and hygrothermal response of multi layered materials and structures, develop micromechanical and macromechanical relationships for lamina and laminated materials with emphasis on continuous filament to introduce material, structural, and strength optimization to design laminated composite materials using FEM based software packages.

Course Outcome: At the end of the course, the students will be able to:

- apply knowledge of Advanced solid mechanics and Mathematics for solving lightweight structures
- fabrication of composite materials and conduct experiments, as well as to analyze and interpret data
- identify, formulate, and solve engineering problems
- expose with broader aspect of structural engineering in interdisciplinary fields
- use software packages for analysing FRP composite materials and structures for lightweight requirement in structures

Syllabus (Brief outline): Mechanics of multilayered materials, Micro and macro-mechanical behaviour of laminates, bending, dynamic, stability and failure analysis of FRP structures, Numerical methods of analysis of composite structures

Module No.	Course Module and Lesson Plan	Contact hours
1	Introduction: Fibre reinforced composite materials; Application of composite materials in Engineering fields; Fabrication techniques of FRP composites	6
2	Mechanics of layered orthotropic materials, lamina (layer) and laminates	6
3	Micromechanical behaviour of a lamina	3
4	Macro-mechanical analysis of laminates: Analysis of laminated plates; Shear deformation theories applied to laminated panels	9
5	Failure analysis and design of FRP composite structures	6
6	Numerical Modelling of composite structures	3
7	Introduction to steel concrete composite	6
	TOTAL	**39**

Suggested Readings:

1. Mechanics of Composite Materials, R M Jones
2. Composite materials, M. Mukhopadhyay

CE 5227 Condition Assessment and Retrofitting of Structures

Weekly Contact: 3-0-0 (L-T-S)

Full Marks: 100 **Credits: 3**

Course Objective: Students should have an overview about assessment of damage and deterioration of structures by visual, non-destructive tests, load tests and other techniques. They should understand the various methodology of retrofitting of masonry structures, reinforced concrete structures and steel structures considering durability aspects of repairing materials. They should also learn about System Identification approach of damage detection of structures from measured responses.

Course Outcome: At the end of the course, the students will be able to:

- Understand the reasons for distress of different structures.
- Understand non-destructive tests, load tests & other methods for condition assessment of structures.
- Know the methodology of repairing and retrofitting of masonry structures,
- Know the techniques of strengthening and retrofitting of RCC structures,
- Know the techniques of retrofitting of steel structures,

- Know about System Identification approach of damage detection of structure from measured responses.

Syllabus (Brief outline): Condition assessment of deterioration of structures by visual, non-destructive tests, load tests and other techniques. Reasons for distress of structures. Repair and retrofitting of masonry structures, reinforced concrete structures and steel structures including case histories. Durability of repairing materials. Introduction to System Identification approach of damage detection of structures from measured responses

Module No.	Course Module and Lesson Plan	Contact hours
1	Appraisal of damage and deterioration of structures by visual, non-destructive tests, load tests and other techniques.	8
2	Reasons for distress – wear and tear. Support settlement, foundation sinking, over-loading and aggressive environment effects. Defects in construction material.	4
3	Repair and strengthening of superstructure – structural components, load bearing wall, panel walls; Strengthening of foundation; Grouting; Grout material, guniting, shotcreting, under pinning;	12
4	Repair of steel structures – bridge, building, towers etc., monuments and historical structures. Prevention of water leakage in structures; Under-water repair; Durability of repairing material; Case histories	8
5	Introduction to System Identification approach of damage detection of structures from measured responses	7
	Total =	**39**

Suggested Readings:

1. Retrofitting of simple buildings damaged by earthquakes - Teddy Boen & Associates
2. Vibration Monitoring, Testing, and Instrumentation Edited by Clarence W. de Silva, CRC Press Taylor & Francis Group
3. Forensic Engineering, Edited by Kenneth L. Carper, CRC Press Taylor & Francis Group
4. Non Destructive Testing by Malhotra & Carino (CRC Press)
5. Sidney, M. Johnson “Deterioration, Maintenance and Repair of Structures”.
6. Fundamentals of Bridge Maintenance and Inspection - New York State Department of Transportation.

CE 5228 Structural Vibration Control

Weekly Contact: 3-0-0 (L-T-S)

Full Marks: 100 **Credits: 3**

Course Objective: To have a thorough understanding of the various concepts of vibration control, learn their working technologies, with focus on vibration energy dissipation and vibration isolation.

Course Outcome: At the end of the course, the students will be able to:

- Differentiate between the different types of vibration control methods and devices.
- Appreciate the specific benefits of various vibration control technologies.
- Have a knowledge of the design of cost-effective passive energy dissipation devices for structural applications.
- Have the knowledge of semi-active and active vibration control strategies.
- Have a knowledge of smart vibration control technologies.

Syllabus (Brief outline): Fundamentals of vibration control, passive energy dissipation systems, vibration isolation, semi-active and active control, smart materials.

Module No.	Course Module and Lesson Plan	Contact hours
1	Introduction, overview of structural vibration control methodologies, damping models	3
2	Dynamic Vibration Absorbers – basic principles, tuned mass damper, tuned liquid damper - characteristics, types, modelling, design considerations, structure-damper analysis	8
3	Friction dampers, Viscoelastic dampers, Fluid viscous dampers – basic principles, modelling, design considerations, structure-damper analysis	8
4	Vibration isolation – theory of isolation, types of isolators, characteristics and modelling of isolators, seismic isolation of buildings and bridges	8
5	Semi-active and Active vibration control – basic concepts, overview of different types of control strategies and control devices	6
6	Smart materials in structural vibration control – shape memory alloys, piezoelectric materials, electrorheological and	6

	magnetorheological fluids	
	TOTAL	**39**

Suggested Readings:

1. A. K. Mallik and S. Chatterjee, Principles of Passive and Active Vibration Control, East-West-Press.
2. T.T. Soong and G.F. Dargush, Passive Energy Dissipation Systems in Structural Engineering, John Wiley & Sons.
3. F. Naeim and J.M. Kelly, Design of Seismic Isolated Structures – From Theory to Practice, John Wiley & Sons.
4. L. Meirovitch, Dynamics and Control of Structures, John Wiley & Sons.
5. A. Preumont and K. Seto, Active Control of Structures, John Wiley & Sons.
6. D. J. Inman, Vibration with Control, John Wiley & Sons.

Specialization: Water Resources Engineering

Course Structure

1st Semester

Sl. No	Course Name	Course code	Class Load/Week			Credit	Class load/ Week	Marks
			L	T	P			
1.	Course-I: Advanced Hydrology and Stochastic Analysis	CE 5113	3	0	0	3	3	100
2.	Course-II: Applied Hydrodynamics and Numerical Modeling	CE 5114	3	0	0	3	3	100
3.	Course-III: Water Resources Management with Remote Sensing, GIS and spatialstatistics	CE 5115	3	0	0	3	3	100
4.	Course-IV: (Dep. Elective)		3	0	0	3	3	100
5.	Course-V: (Open Elective)		3	0	0	3	3	100
	Theory Sub-total		15	0	0	15	15	500
6.	Hydrology and HydraulicsLaboratory	CE5183	0	0	3	2	3	100
7.	Computer Applications in Hydrodynamics and Hydrology	CE5184	0	0	3	2	3	100
8.	Remote Sensing and GIS Laboratory	CE5185	0	0	3	2	3	100
	Practical Sub-total		NIL	NIL	9	6	9	300
	1st Semester Total					21	24	800

2nd Semester

Sl. No	Course Name	Course code	Class Load/Week			Credit	Class load/ Week	Marks
			L	T	P			
1.	Course-VI: Water Resources Planning and Management	CE5213	3	0	0	3	3	100
2.	Course-VII: Ground Water Hydrology and Water Resources Development	CE5214	3	0	0	3	3	100
3.	Course-VIII: Hydrology of Extreme Events and Mitigation Measures	CE5215	3	0	0	3	3	100
4.	Course-IX (Dep. Elective)		3	0	0	3	3	100
5.	Course-X (Open Elective)		3	0	0	3	3	100
	Theory Subtotal		15	0	0	15	15	500
6.	M. Tech Project Part - I (Term Paper)	CE5291	0	0	0	4	0	200
7.	Term Paper Seminar & Viva-voce	CE5292	0	0	0	2	0	100
	Practical Subtotal		0	8	0	6	8	300
	2nd Semester Total					21	23	800

3rd Semester

Sl. No	Course Name	Course code	Class Load/Week			Credit	Class load/ Week	Marks
			L	T	P			
1.	M. Tech Project Part - II (Progress Report)	CE6191	0	0	0	12	0	300
2.	Progress Report Seminar & Viva-voce	CE6192	0	0	0	6	0	100
	Total Credit		0	0	0	18	0	
	3rd Semester Total					18	0	400

4th Semester

Sl. No	Course Name	Course code	Class Load/Week			Credit	Class load/ Week	Marks
			L	T	P			
1.	M. Tech Project Part - III (Thesis)	CE6291	0	0	0	22	0	400
2.	Thesis seminar and viva voce	CE6292	0	0	0	8	0	200
	Total Credit		0	0	0	30	0	
	4th Semester Total					30	0	600

Course-IV [Departmental elective]	Course- IX [Departmental elective]
CE5153 Climate Modeling in Water Resources CE5154 Advanced Hydraulic Structures CE 5155 Irrigation and Drainage Engineering CE5156 Soft Computing in Water Resources CE5157 Watershed Management and Sustainable Development CE5158 Hydropower Development CE5160 Isotope Hydrology	CE5253 Loose Boundary Hydraulics and Sediment Transport CE5254 Storm Water Management CE5255 Coastal Hydraulics and Port Management CE5257 River Mechanics and Control Structures CE5258 Environmental Hydrology CE5259 Reservoir Planning and Operation

CE 5113 Advanced Hydrology and Stochastic Analysis

Weekly Contact: 3-0-0 (L-T-S) **Credits: 3**
Full Marks: 100

Course Objective:A majority of the hydrological events are stochastic in nature and in this context, applying stochastic models are inevitable in the field of Water Resources Engineering. The course is designed in such a way that the students will gather a knowledge of wide range of statistical methodswhich are essential to deal with the real-life problems in the field of hydrology.

Course Outcome: At the end of the course, the students will be able to:

- Understand the basic concepts of probability and statistics
- Apply different probability distributions for problems related to hydrology
- Determine the design magnitude of the structures within its expected life to withstand different hydrologic events by applying risk analysis
- Draw some inferences about some parameter on population on the basis of available data by applying hypothesis testing and parametric test
- Analyze the time-series data with different models

Syllabus (Brief outline): Concepts of probability and statistics, Basic statistical properties of data, Parameter Estimation, Probability Distributions and their applications, Frequency analysis, Synthetic unit hydrograph, Instantaneous unit hydrograph, Hydrologic Design, Design storm, Hypothesis testing and non-parametric test, Regression analysis, Multivariate analysis, Time-series analysis

Module No.	Course Moduleand Lesson Plan	Contact Hours
1.	**Concepts of probability and statistics** – Random variable, probability, Conditional Probability Theorem, Total Probability Theorem and Bayes' Rule, Univariate and BivariateProbability Distribution, Marginal and Conditional Probability Distribution **Basic statistical properties of data** - Descriptive Statistics: Measures of Central Tendency,Measures of Dispersion, Measures of Symmetry, Moments and Expectations, Momentgenerating functions **Parameter Estimation** - Method of moment, Method of maximum likelihood	7
2.	**Probability Distributions and their applications** – Discrete probability distributions–Binomial Distribution, Poisson Distribution, Continuous probability distributions – Extreme value distribution, Normal distribution, Log-normal distribution, Gamma Distribution, Pearson Distribution, Log-Pearson Type-IIIDistributionImportant distributions of sample statistic – Chi-square Distribution, T Distribution, FDistribution **Frequency analysis** - Concept of Return Period, Probability Plotting and Plotting PositionsFormulae, Frequency Analysis of Hydrologic Extremes using Different Distribution	9
3.	**Unit Hydrograph** – Synthetic unit hydrograph, Instantaneous unit hydrograph	4
4.	**Hydrologic Design:** Estimated Limiting Value, Hydrologic Design scale, Hydro economicanalysis, Risk and reliability in hydrologic design, Reliability, resilience and vulnerability ofhydrologic time-series **Design storm** – Design Precipitation Depth, Intensity-Duration-Frequency	6

	relationship,Design hyetograph – Triangular hyetograph, Alternating Block Method, InstantaneousIntensity Method	
5.	**Hypothesis testing and non-parametric test** – Populations, Samples, Sampling distribution, Statistical Inference – Point Estimation, Interval Estimation, Hypothesis testing, Goodness of fit test, Non-parametric test **Regression analysis** – Simple linear regression, Multiple linear regression, Correlation andregression, confidence interval **Multivariate analysis** – Principal component analysis, Data generation – univariate andmultivariate, Analysis of variance	7
6.	**Time-series analysis** – Data representation, stationary and non-stationary time-series, trend analysis, analysis of periodicity, Time-series modelling– measures of linear association in time-series, statistical operators on time-series, properties of time-series models, Autoregressive models, Moving-average models, Autoregressive Integrated Moving Average (ARIMA) Model, Diagnostic Check	6
	Total	**39**

Suggested Readings:

1. C.T. Haan, 'Statistical Methods in Hydrology', Iowa State University Press.
2. RajibMaity,'Statistical Methods in Hydrology and Hydro climatology', Springer Transaction in Civil and Environmental Engineering.
3. Ven, T Chow, David R. Maidment and Larry, W. Mays, 'Applied Hydrology', Mc-Graw Hill International Editions.

Semester: 1

CE 5114 Applied Hydrodynamics and Numerical Modeling

Weekly Contact: 3-0-0 (L-T-S) **Credits: 3**
Full Marks: 100

Course Objective: The objectives of this course are to provide knowledge to the students regarding flow of water and flow mechanism. The students will gain knowledge and be able to apply fundamental concepts and techniques of hydraulics in the analysis, design and operation of water resources system.

Course Outcome: At the end of the course, the students will be able to:

- Apply the knowledge of fluid mechanics to address the flow in open channels
- Solve the equations of the hydraulic systems by different numerical and algebraic techniques
- Solve the problems of gradually and rapidly varied flows in open channels under steady state conditions.
- to solve open channel flow problems through the selection of appropriate equations and apply the physical mechanism of hydraulic jump
- Design hydraulically most efficient channel sections

Syllabus (Brief outline): Introduction, Equation of Continuity, Energy Equation, Momentum Equation, Solution of Non-linear Algebraic Equation, Numerical Solution of Ordinary Differential Equations ,Gradually Varied Flow, Unsteady Flows, Spatially Varied Flows

Module No.	Course Module and Lesson Plan	Contact Hours
1.	**Introduction:** Classification of flows, Velocity Distribution, Pressure Distribution, Equation of Continuity, Energy Equation, Momentum Equation, Energy-Depth Relationship, Uniform Flow: Chezy Equation, Manning's Formula, Uniform Flow Computations, Hydraulic Jump,Flow over Sharp Crested Weir	6
2.	**Methods of Solving Algebraic Equations and Their Systems:** Solution of Non-linearAlgebraic Equations, Solution of Systems of the linear Algebraic Equations. Solutions ofSystems of Nonlinear Algebraic Equations, Numerical Solution of Ordinary DifferentialEquations	7
3.	**Gradually Varied Flow:** Differential Equation of GVF. Analysis of Flow Profile. Differential Equation, Numerical Solution of the Initial Value Problem for Steady GVFEquation in a Single Channel, Numerical Solution of the Boundary Value Problem forSteady GVF Equation in a Single Channel, Numerical Solution of the Steady GVFEquations in Channel Networks	10
4.	**Unsteady Flows:** Simplified Equations of the Unsteady Flow in Open Channel, Numerical Method of Solution of the Saint Venant Equations, Kinematic and Diffusive Wave Equations. Numerical Solution of the Muskingum Equation. The Muskingum-Cunge Model. Convolution Integral in Open Channel Hydraulics	10
5.	**Spatially Varied Flows:** Basic Differential Equations of SVF. Numerical Solution of SVFEquations with Increasing Flow and Decreasing Flow conditions. Side Weirs and Bottomracks	6
	Total	**39**

Suggested Readings:

1.Romauld Szymkiewicz, “Numerical Modeling in Open Channel Hydraulics”, Springer.
2.Subramanya, K. “Flow in Open Channel”, Tata McGraw-Hill Education.
3. Balagurusamy, E., “Numerical Methods”, Tata McGraw-Hill Education.
4. Chow, V. T., “Open Channel Hydraulics”, Tata McGraw-Hill Education.
5. Grewal, B.S., ‘Higher Engineering Mathematics’, Khanna Publishers, New Delhi

CE 5115 Water Resources Management with Remote Sensing, GIS and spatial statistics

Weekly Contact: 3-0-0 (L-T-S) **Credits: 3**
Full Marks: 100

Course Objective: The objective of the course is to impart the students a basic knowledge of GIS and Remote Sensing in context toWater Resources Management. This will help them to solve the practical problems with the help of geospatial technique using satellite data and other ancillary data.

Course outcome: At the end of the course, the students will be able to:

- Understand the basic concepts of Remote Sensing and gather knowledge on platforms and sensors
- Process the digital remote sensing data to extract information required for analysis
- Understand the basic concepts of GIS
- Prepare the digital map with attribute database and learn basic concepts of database management
- Learn about the spatial statistics and modelling in GIS
- Apply Remote Sensing and GIS in various fields of Water Resources

Syllabus (Brief outline): Introduction, Electromagnetic Radiation, Digital Imagery, Image Enhancement, Image Preprocessing, Image Classification, Raster and Vector data, Attribute database and overlay, Spatial Statistics and GIS modelling, Applications of Remote Sensing and GIS in Water Resources

Module No.	Course Module and Lesson Plan	Contact Hours
1.	**Introduction:** History and Scope of Remote Sensing, Definitions, Milestones in History of Remote Sensing, Overview of Remote Sensing Process **Electromagnetic Radiation:** The Electromagnetic spectrum, Major divisions of the Electromagnetic spectrum, Radiation laws, Interaction with the Atmosphere, Interactionswith the surface. **Digital Imagery:** Introduction, Digital Data, Data formats, Band combinations, Multispectral Imagery, Resolutions of Digital image	9
2.	**Image Enhancement:** Linear Contrast Enhancement, Non- Linear Contrast Enhancement, Spatial Enhancement, Convolution Filtering, Image Transformation. **Image Preprocessing:** Geometric Corrections, Ground Control Points and Co-Registration, Atmospheric Corrections. **Image Classification:** Supervised Classification, Unsupervised Classification, Fuzzy Classification, Principal Component Analysis, Field Data collection, Accuracy Assessment	15

3.	**Introduction:** Information System, Geographic Information System, GIS database, GIS data type, Measurement scale in GIS **Raster and Vector data:** Introduction about raster and vector data, Raster Encoding methods, Shape of the earth, Transformation, Vectorization **Attribute database and overlay:** Attribute data, Relations, GIS functionality, Spatial Query, Vector data query, Overlay, Buffer	6
4.	**Spatial Statistics and GIS modelling** - Conceptual models, measuring compactness, Example of spatial autocorrelation, Geary's index, Moran's index, Identifying relationships, Quadrat Counts and Nearest Neighbor analysis, Trend Surface Analysis, Gravity Models, Network Analysis	6
5.	**Applications of Remote Sensing and GIS in Water Resources**	3
	Total	**39**

Suggested Readings:

1. James B. Campbell and Randolph Wynne, "Introduction to Remote Sensing", Guilford Publications, New York
2. T. M. Lillesand, & R. W. Kiefer. "Remote Sensing and Image Interpretation", Wiley
3. C.P. Lo and Albert K.W. Yeung, "Concepts and Techniques of Geographic Information Systems", Prentice-Hall, India.
4. David L. Verbyla, "Practical GIS Analysis", Taylor and Francis

Departmental Electives (Course IV)

CE 5153 Climate Modeling in Water Resources

Weekly Contact: 3-0-0 (L-T-S) **Credits: 3**
Full Marks: 100

Course Objective: The objectives of this course are to familiarize the students with the science of climate change and how to conduct a climate change impact study related to hydrology like urban flooding and draughts.

Course Outcome: At the end of the course, the students will be able to:

- Orient the students towards the issue of global climate change
- Understand the climate change related issues on water resources related processes
- Understand how the climate system is modelled
- Plan an Impact study using GCM date and downscaling techniques
- Take decision under uncertainty

Syllabus (Brief outline): General overview of climate change problem and impacts on societies and ecosystems, Climate Change Science, Observed Climate Change, Statistical Downscaling, Impact Analysis

Module No.	Course Module and Lesson Plan	Contact Hours
1.	**Introduction:** General overview of climate change problem and impacts on societies andecosystems, Overview of different aspects involved in climate change impact investigation	3
2.	**Climate Change Science:** Climate System, Hydrologic Cycle, Weather,	10

	Climate, GlobalWarming, Green House Gas, Climate Variability and Noise, Climate Change, Natural Climate Variations, Carbon Cycle, Prediction or Projection? Energy Balance Model, Radiative Transfer, Climate feedback, Atmospheric Circulation, Trade Winds and the Hadley Cell, El Nino, La Nina, Climate Change Adaptation and Mitigation Measures	
3.	**Observed Climate Change:** Paleoclimatology, Impacts of Climate Change of Hydrologic Cycle, IPCC, Historical trend testing, separation of trends from natural variability	4
4.	**Statistical Downscaling:** On the needs for statistical downscaling and bias correction: introduction on methods, Methods for statistical downscaling and bias correction: Deltachange method, Weather typing/ Resampling, Rainfall generator method, Application ofdelta change and weather generator method for hydrological impact analysis of climatechange	15
5.	**Impact Analysis:** Climate scenario development, Methods for impact analysis of climatechange, Climate adaptation needs & Decision making under uncertainty	7
	Total	**39**

Suggested Readings:

1. John Houghton, "Global Warming: The Complete Briefing", Cambridge Univ. Press.
2. Jan C. Van Dam, "Impacts of Climate Change and Climate Variability on Hydrological Regimes", Cambridge University Press.
3. IPCC AR4 and AR5 Reports
4. McGuffie, K. and Henderson-Sellers, "A Climate Modeling Primer", Wiley

CE 5154 Advanced Hydraulic Structures

Weekly Contact: 3-0-0 (L-T-S) **Credits: 3**
Full Marks: 100

Course Objective: This course is designed to impart the fundamental concept of planning, design and maintenance of hydraulic structures.

Course Outcome: At the end of the course, the students will be able to:

- Understand about the design principles of various types hydraulic structures
- Analyse and design different types of dams
- Know the methods to perform stability analysis of earth and rock-fill dams and to know about measures for their slope's protection
- Plan and Design Weir, Barrage, Canal Fall and Aqueduct and other cross-drainage structures
- Prepare various reports of a hydraulic structure project

Syllabus (Brief outline): Investigation survey, Selection of dam site, Earth and Rockfill Dams, Gravity Dams, Structures on Permeable Foundations, Cross Drainage Structures

Module No.	Course Module and Lesson Plan	Contact Hours
1.	**Dams:** Investigation survey, Selection of dam site, Selection of type of dam, Classification, Geological Investigation, Field Exploration, Spillways and energy dissipation.	4

2.	**Earth and Rockfill Dams:** Causes of failures and remedial measures, Selection of earthdams, Criteria for safe design of an earth dam, Section of an earth dam, Phreatic lines,Seepage loss through earth dams, Stability analysis, Control of seepage through earthdams, Slope Protection, Design considerations in Earthquake Regions, Rockfill dams.	8
3.	**Gravity Dams:** Forces acting on gravity dams, Modes of failures, Load combination fordesign, Elementary profile, Stability analysis, Control of cracking, Galleries	13
4.	**Structures on Permeable Foundations:** Modes of failures, Bligh's Creep theory, Lanesweighted creep theory, Potential flow theory, Khosla's method of independent variables,Design of barrages	8
5.	**Cross Drainage Structures:** Types and layout of cross-drainage structures, Canal fall structures	6
	Total	**39**

Suggested Readings:

1. P.N. Modi, "Irrigation Water Resources and Water Power Engineering", Standard Book House, New Delhi.
2. V.C. Agarwal, "Irrigation Engineering and Hydraulic Structures

CE 5155 Irrigation and Drainage Engineering

Weekly Contact: 3-0-0 (L-T-S) **Credits: 3**
Full Marks: 100

Course Objective: The objective of this course is to introduce the students to the design and optimised operation of the irrigation and drainage systems.

Course Outcome: At the end of the course, the students will be able to:

- Provide solutions to drainage problem on agricultural soils.
- Appreciate the importance of good irrigation practices as a solution to food scarcity
- Understand the different types of irrigation systems
- Acquire skill to design and install irrigation and drainage systems
- Acquire knowledge of how to determine soil moisture content, field capacity, bulk density, permanent wilting point, infiltration and hydraulic conductivity.

Syllabus (Brief outline): Necessity of Irrigation, Components of an Irrigation System, Water Availability, Irrigation Systems Design, Irrigation Systems Optimization and Operation, Drainage Engineering

Module No.	Course Module and Lesson Plan	Contact Hours
1.	**Introduction:** Necessity of Irrigation, Components of an Irrigation System, Irrigation Project Report Preparation, Irrigation Frequency and Amount, Water Distribution and Application Methods	4
2.	**Water Availability:** Various Sources of Irrigation Water, Design of a complete SurfaceWater Source based Irrigation System. Design and	7

	Consideration of Utilization of Ground Water as Source of Irrigation Water, Water Demand Calculation for a Watershed by FAO Method. Stochastic Analysis of River Flow to Ascertain River Water Availability	
3.	**Irrigation Systems Design:** Design of Drip Irrigation System, Mapping Irrigation WaterDistribution Network, Sprinkler Irrigation System Design, Canal Automation, Reduction of Canal Loss, Piped Irrigation Network Design	15
4.	**Irrigation Systems Optimization and Operation:** Modern Canal Operation Techniques, Optimal Reservoir Operation and Water Release, Evaluation of Performance of Canal and Pipe Irrigation Systems, Methods for Improving Canal Irrigation Management, Maintenance of Canal and Pipe Irrigation Systems, Operation and Maintenance of Pipe Irrigation Systems	7
5.	**Drainage Engineering**: Needs of Drainage, Alkali and its Effects, Effects of Drainage on Soil, Drainage Investigation, Drainage Pipes and Accessories Steady State and Transient Designs of Surface and Sub-Surface Drainage Systems, Drainage by Wells, Installation and Maintenance of Drainage Materials	6
	Total	**39**

Suggested Readings:

1.Newell, F.H. and Murphy, D. W., "Principles of Irrigation Engineering", McGraw-Hill Book Company.
2. Asawa G L, "Irrigation and Water Resources Engineering", New Age International Publishers
3. Michael A M, "Irrigation theory and practices", Vikas Publishing House.
4. Reddy, R.N., "Irrigation Engineering", Gene-Tech Books.

CE 5156 Soft Computing in Water Resources

Weekly Contact: 3-0-0 (L-T-S) **Credits: 3**
Full Marks: 100

Course Objective: The objective of the course is to impart knowledge about applications of soft computing in water resources

Course Outcome: At the end of the course, the students will be able to:

- Learn the basic concepts of soft computing
- Gather knowledge about different methods and applications of models in hydrology and water resources

Syllabus (Brief outline): Concept of computing systems, "Soft" computing versus "Hard" computing, Artificial Neural Networks (ANNs), Fuzzy Logic, Genetic Algorithms (GAs)

Module No.	Course Module and Lesson Plan	Contact Hours
1.	**Introduction:** Concept of computing systems, "Soft" computing versus "Hard" computing, Characteristics of Soft computing, some applications of Soft computing techniques.	3

2.	**Artificial Neural Networks (ANNs):** Background and History of ANNs, Definition and basic concepts of ANNs, Biological and Artificial Neural Networks, feed-forward and feed-back networks, Supervised and Unsupervised learning methods- Standard Back-Propagation (BP), Conjugate Gradients BP, development of ANN models for specific problems and selected case studies.	12
3.	**Fuzzy Logic:** Information and uncertainty, chance versus ambiguity, classical sets and fuzzy sets, Membership Functions, Fuzzy set operations and fuzzy relations, Fuzzy Systems, fuzzy interface systems, Decision making with fuzzy information, Defuzzification techniques, Fuzzy classification and pattern recognition, Neuro-Fuzzy Systems, Applications fuzzy logic in Hydrology	12
4.	**Genetic Algorithms (GAs):** Fundamentals and preliminary concepts of GA, preliminaries of optimization, components of genetic algorithm, genetic operators-selection, crossover and mutation binary and real-coded Gas, constraint handling in Gas, Selected case studies involving GA applications in Hydrology and Water Resources.	12
	Total	**39**

Suggested Readings:

1. S.V. Kartalopoulos, "Understanding Neural Network and Fuzzy Logic – Basic Concepts and Applications", IEEE Press.
2. Martin T. Hagan, "Neural Network Design", Cengage Learning.
3. T.J. Ross, "Fuzzy Logic with Engineering Applications", Wiley India.
4. Kalyanmoy Deb, "Multi-objective Optimization using Evolutionary Algorithms", Wiley

CE 5157 Watershed Management and Sustainable Development

Weekly Contact: 3-0-0 (L-T-S) **Credits: 3**
Full Marks: 100

Course Objective: The objective of this course is to provide a framework for students to learn about our water future and ways we might define and achieve sustainability in water management.

Course Outcome: At the end of the course, the students will be able to:

- Articulate a personal philosophy on sustainability and discuss the challenges and opportunities associated with pursing it
- Explain how current (or future) water use and management practices threaten ecological integrity, human health, and security
- Discuss how pursuing different sustainable development ideals can affect our future with regard to water resources, human equity and other social factors
- Enhance their understanding of the vulnerability of aquatic systems to anthropogenic stress and our vulnerability to water resource limitations and ecosystem degradation

Syllabus (Brief outline): Watershed Management Concepts, Principles of Watershed Management, Watershed Modelling, Sustainable Development, Water Sustainability

Module No.	Course Module and Lesson Plan	Contact Hours
1.	**Watershed Management Concept:**Introduction, Concept of Watershed	6

	Management- History of Watershed Management and its Relevance to India, Watershed Characteristics, Climatic Characteristics- Physiographic Characteristics- Causes of Watershed Deterioration- Effect of Watershed on the Community- Water Resources Region of India	
2.	**Principles of Watershed Management:** Integrated Watershed Management Approach (IWMA), Objectives of IWMA, strategies. Identification of Problems, Watershed Development Plan Entry Point Activities, Concept of Priority Watersheds, Agroforestry Grassland Management, Wasteland Management. Watershed Approach in Government Programmes, People's Participation, Evaluation of Watershed Management	6
3.	**Watershed Modeling:** Introduction, Data of Watershed for Modeling Application of Watershed Models- Model Calibration and Validation. A Brief Description and Significance of Watershed Models: SWAT, TMDL, AGNPS, BASINS, CREAMS –Case Studies	8
4.	**Sustainable Development:** Definition, Introduction and History, Basic Concepts, Quality of life, economic growth, and the environment, Efficiency and Innovation, Sufficiency, Income and Labor, Consumption Patterns and Lifestyles, Different perspectives of Sustainable development	7
5.	**Water Sustainability:**Recent Environmental degradation, Environmental Crisis, Importance of water in sustainability, Local Water Issues. Reaching the Limits of Water Resources, Problems related to water and its causes, Ethics in water sustainability, Steps for Sustainable Water Development. Water Footprints and Water Inequities. Water Conflicts, Watery Consequences of Food. Water Controversies. Role of Culture in Sustaining Water Sustainability	12
	Total	**39**

Suggested Readings:

1. Watershed management by Madan mohan das-Mimi das Saikia-PHI learning pvt. Ltd.
2. Watershed Management by Murty- J.V.S.-- New Age Intl.- New Delhi
3. Watershed Management- American Soc. of Civil Engineers- New York-
4. Fundamentals of Sustainable Development by Niko Roorda- by Routledge publication

CE 5158Hydropower Development

Weekly Contact: 3-0-0 (L-T-S) Credits: 3
Full Marks: 100

Course Objective: The objective of this course is to expose the students to the design aspects of hydropower plants, various components of hydropower plants and their layout in harmony with hydraulic structures.

Course Outcome: At the end of the course, the students will be able to:

- Understand the importance of hydropower as a sustainable energy source
- Know how to plan and implement a hydropower project
- Know about the different types of power plants and their layout and components
- Understand how to design different components of the power plants

Syllabus (Brief outline): Introduction to Hydro Power Energy, Planning and Management of hydropower projects, Power Plants, Design of Components, Embankment Engineering, Concrete Dam Engineering

Module No.	Course Module and Lesson Plan	Contact Hours
1.	**Introduction to Hydropower Energy**: Introduction to non-conventional energy, Types of energy – solar energy, wind energy, biomass energy, ocean and geothermal energy etc. Need for hydropower energy and its power estimation. Law of conservation of energy. Climate change and hydropower	3
2.	**Planning and Management**: Government Hydropower policies, environmental issues, SWOT-(Strength weakness opportunity threatening) of hydropower projects, type of clearance required for Hydropower project, Survey & investigation, PFR(Pre-feasibility report), DPR (Detailed Project Report), Process of development of site (announcement, allotment, clearance, agreement, commissioning).Types of survey- Topographical, metrological, hydrological, ecological and geological	5
3.	**Power Plants**: Sources and forms of energy, types of power plants, and elements of hydropower scheme, hydropower development in India. Power house structures-substructure and superstructure layout and dimensions, deign considerations. Hydropower plants classification: Surface and underground power stations, Low medium-high head plants-layout and components, pumped storage plants, tidal power plants, micro-tidal units. Load and power studies: load curve, load factor, load duration curve, firm capacity, reservoir capacity, capacity factor	7
4.	**Design of Components**: Classification of penstocks, Design of Penstocks, economic diameter, bends, anchor blocks, surges in canals design criteria of power canals. Intake structures, Location function and types of intakes, energy losses at intake trash rock, design of intakes	12
5.	**Embankment Dam Engineering**: Introduction. Nature and classification of engineering soils. Principles of design. Materials and construction. Internal seepage. Stability and stress. Settlement and deformation. Rockfill embankments	6
6.	**Concrete Dam Engineering**: Loading: Concepts and criteria. Gravity dam analysis. Buttress dam analysis. Arch dam analysis. Design features and construction. Properties of concreteused for dams. Dam safety and instrumentation. Foundation measurements. Analysis of strain data	6
	Total	**39**

Suggested Readings:

1. Varshiray, R.S., “Hydropower structures”, Nem Chand and Bros. Roorkee
2. Dandekar, M.M., and Sharma, K.N., “Water Power Engineering”, Vani Educational Books.
3. Sharma, H.D. Concrete Dams Metropolitan New Delhi
4. Desmukh, M.M., “Water Power Engineering”, Dhanpat Rai and Sons

CE 5160 Isotope Hydrology

Weekly Contact: 3-0-0 (L-T-S) **Credits: 3**
Full Marks: 100

Course Objective: The objective of this course is to introduce the students to the emerging area of evaluation of the water environment using the natural abundance of stable and radio isotopes

Course Outcome: At the end of the course, the students will be able to:

- Apply isotope fingerprints for better understanding of hydrological processes and mechanism for water resources development and management
- Calculate catchment water balances using environmental tracer data
- Develop application of Isotope Hydrology Principals including Evaluation of Surface Water with Isotopes and Evaluation of Groundwater with Isotopes

Syllabus (Brief outline): Basic Principles, Measurement Techniques, Application in Catchment Studies, Ground Water and Surface Water Hydrology.

Lecture Plan:

Module No.	Course Module and Lesson Plan	Contact Hours
1.	**Basic Principles**: Isotopes, their classifications and characteristics, law of radioactivity and radio isotopes and basic principles of absorption and scattering of alpha and beta particles, gamma rays and neutrons, Principles of detection of radioactive and stable isotopes and related Instruments, Environmental isotopes and their variations in nature	5
2.	**Measurement Techniques**: Sampling-sample preparation for isotope analysis-Mass spectrometric techniques – Instrumentation - Continuous Flow and Dual injection systems	6
3.	**Application in Catchment studies:** Isotopes as tracers, snow melt equivalent and suspended sediment concentration studies. Use of isotopes for study of interrelation of hydrologic elements and interconnection of water bodies, Case Studies	9
4.	**Application in Surface Water Hydrology**: Water balance - Lake dynamics-sub-surface inflow and outflow estimates sedimentation in lakes and reservoirs – seepage from dams, reservoirs, canals -stream flow measurements, Isotope application in estuarine environment	7
5.	**Application in Ground Water Hydrology**: isotopes as sealed sources for soil moisture variation - Groundwater velocity in saturated zone - Identification of source of recharge and recharge mechanism - Seawater intrusion - Contaminant hydrogeology	12
	Total	**39**

Suggested Readings:

1. Clark, I. And Fritz. P, “Environmental Isotopes in Hydrogeology”, Lewis Publishers.
2. Rao, S.M., “Practical Isotope Hydrology”, New India Publishing Agency, New Delhi.
3. Kendal C. and McDonnell J.J., “Isotopes in Catchment Hydrology”, Elsevier
4. Use of Artificial Tracers in Hydrology, Proc. Adv. Group Meeting, Vienna, IAEA

CE 5183 Hydrology and Hydraulics Laboratory

Weekly Contact: 0-0-03(L-T-S) **Credits: 2**
Full Marks: 100

Course Objective: To equip the students with hydraulics experiments to understand fluvial flow and hydrologic field experiments to gain insight of the hydrologic processes.

Course Outcome: At the end of the course, the students will be able to:

- Determine velocities in natural and constructed water conveyance system
- Measure discharge in open channels.
- Know about Rainfall – Runoff correlations and its role in flood prediction
- Measure the different processes of the hydrologic cycle
- Gain knowledge about the erosion and scouring processes.
- Determine the water quality parameters

Syllabus (Brief outline): Study of Hydraulics of flowing water. Study of hydrologic cycle and processes

Module No.	Course Module and Lesson Plan	Contact Hours
1	Study of Hydrologic Cycle: (at least four experiments) Catchment Area delineation, Hydrologic data collection from Automatic Weather Station, Determination of infiltration rate by Double Ring type Infiltrometer, Determination of rate of evaporation through Pan Evaporimeter, Determination of Evapotranspiration by Lysimeter, Determination of transpiration by phytometer. Depth measurement by Echo-Sounder, Velocity and Discharge measurement, Groundwater level survey with Water Level Indicator	12
2	Studies on Soil Moisture for Irrigation: Measurement of permeability, Measurement of field capacity, permanent wilting point and optimum moisture content. Irrigation Scheduling	6
3	Water Quality Analysis tests: Dissolved Oxygen (DO),Electrical Conductivity, pH Value, TSS (Total Suspended Solid). TDS (Total Dissolved Solid), Sodium adsorption ratio (SAR)	3
4	Fluvial Processes: Sediment Transport studies in Tilting Flume and sediment transport apparatus	6
5	Studies on Hydraulics: (Any of the three experiments) Measurement of velocity profile in straight and meandering open channel, Experiments on velocity distribution and Boundary shear in rough and smooth channels. Determination of the energy losses in pipes. Determination of minor losses due to sudden expansion and contraction in a pipe flow. Study of laminar to turbulent flow and determination of lower critical Reynolds number.	9
6	Viva	3
	TOTAL	39

Suggested Readings:

1. Standard Methods for the Examination of Water and Waste Water : American Public HealthAssociation Inc., New York
2. Maidment, David R. Handbook of Hydrology. New York: McGraw-Hill
3. Experiments in Fluid Mechanics: by Singh Sarbjit , PHI Learning Pvt.Ltd

CE 5184 Computer Applications in Hydrodynamics and Hydrology

Weekly Contact: 0-0-3(L-T-S) Credits: 2
Full Marks: 100

Course Objective: The objective of the course is to help the students to solve the practical problems of hydrodynamics and hydrology with the help of applicable software and programming language by applying the fundamental concepts in the field.

Course Outcome: At the end of the course, the students will be able to:

- Solve the problems in open channel hydraulics and pipe flow problems with the help of 'Open Flow Flowmaster' software
- Solve problems of sewer design with other software
- Learn Hydrological modelling with the help of HEC-HMS
- Apply the concept of programming to solve the problems in stochastic hydrology

Syllabus: (Brief outline): Solving problems related to hydrodynamics, Solving problems in Hydrological modelling, Programming in R

Module No.	Course Module and Lesson Plan	Contact Hours
1	Introduction to Open Flows 'Flow Master' or related software to solve simple problems in open channel flow	3
2	Application of 'Flow Master' or related softwaresfor solving problems of irregular section, pipe flows	6
3	Solving problems with Open Flows 'WaterGEMS/SewerGEMS/SWMM' software	6
4	Introduction to HEC-HMS/Mike/SMS for hydrological modeling	3
5	Application of HEC-HMS/Mike/SMS for rainfall-runoff simulation of a catchment	6
6	Introduction to R/Matlab/Scilab/Python programming	3
7	Application of R/Matlab/Scilab/Python programming to solve problems related to statistical hydrology	9
	Test	3
	TOTAL	**39**

Suggested Readings:

1. RajibMaity,'Statistical Methods in Hydrology and Hydro climatology', Springer Transaction in Civil and Environmental Engineering
2. Subramanya, K. "Flow in Open Channel", Tata McGraw-Hill Education
3. Bentley Software Documentation, www.bentley.com
4. US Army Corps of Engineers Hydrologic Modelling System HEC-HMS User's Manual

CE5185 Remote Sensing and GIS Laboratory

Weekly Contact: 0-0-3(L-T-S) **Credits: 2**
Full Marks: 100

Course Objective: To provide the students with basic understanding of the remote sensing and GIS techniques and impart a practical knowledge of digital image processing and applications of GIS in Water Resources.

Course Outcome: At the end of the course, the students will be able to:

- Develop a knowledge about the remote sensing system
- Extract information from the satellite images
- Estimate the rainfall over a catchment
- Develop a basic knowledge on solving problems with the GIS using spatial modeling

Syllabus (Brief outline): Basics of digital images, Image processing, Image Classification, Delineation of catchment and average rainfall estimation, Spatial data modelling

Module No.	Course Module and Lesson Plan	Contact Hours
1	Basics of Remote Sensing Images	3
2	Georeferencing of toposheets, mosaicking and extracting area of interest	3
3	Image Classification	6
4	Introduction to GIS	6
5	Digital Elevation Model Data Downloading and Processing	3
6	Catchment Delineation	6
7	Average Rainfall Estimation of a catchment using GIS	3
8	Spatial Modeling in GIS and map preparation	6
	Viva-voce	3
	TOTAL	**39**

Suggested Readings:

1. James B. Campbell and Randolph Wynne, "Introduction to Remote Sensing", Guilford Publications, New York
2. C.P. Lo and Albert K.W. Yeung, "Concepts and Techniques of Geographic Information Systems", Prentice-Hall, India.
3. David L. Verbyla, "Practical GIS Analysis", Taylor and Francis

Semester: 2

CE 5213 Water Resources Planning and Management

Weekly Contact: 3-0-0 (L-T-S) Credits: 3
Full Marks: 100

Course Objective: The overall aim of the course is to develop the skills of the students to know how to plan, develop and manage water resources using the concepts of system approach to mathematical modelling.

Course Outcome: At the end of the course, the students will be able to:

- Learn how to develop suitable plans for water resource development and management.
- Learn the principles of integrated water resources management.
- Learn the optimization techniques in water resources planning and management.
- Apply the stochastic principles for hydrologic data generation
- The students should be able to use LP, DP and TSM for water resources management and planning

Syllabus (Brief outline): Concept of Systems, types of system, Optimization Techniques, linear programming, Dynamic Programming, probability concepts and methods, analyzing systems with uncertainty, Synthetic Streamflow Generation, Stochastic Optimization

Module No.	Course Module and Lesson Plan	Contact Hours
1.	**Introduction:** Water Resources Planning, necessity, importance, methods; Concept of Systems, types of system, examples, irrigation planning and operation, single reservoir planning and operation, multi-reservoir design and operation, models and solution procedures, objective functions and constraint equations, simulation and optimization	4
2.	**Water Resources Management:** Management of hydrological data, Water policies and institutional aspects of management of water resources, Hierarchical modeling of water resources development, Management of watersheds and water quality, Urban water supply planning/management, Planning of watersheds, Watershed behavior and conservation practices, Trans-boundary water resources, National waterpolicy, Water Laws	8
3.	**Optimization:** Mathematical Programming Techniques, linear programming, Simplex method, Primal and Dual formulations, applications, non-linear programming, Lagrange multipliers, Kuhn-Tucker conditions, applications,	13

	use of spreadsheets for linear and non-linear programming, Dynamic Programming (DP), Principles, recursive equations, discrete DP, applications, complexities with applications to multidimensional problems, curse of dimensionality, Discrete Differential DP, applications, programming for DP, Economic Analysis of water resources projects	
4.	**Uncertainty:** Stochastic systems, probability concepts and methods, distribution of random events,stochastic processes and times series, properties of times series, planning with uncertainty, analyzing systems with uncertainty. Stochastic Reservoir Operation, Stochastic DP, Transition Probabilities, applications, Stochastic Linear programming	6
5.	**Synthetic Streamflow Generation:** Concepts, simple autoregressive models, reproducing marginal distributions, single site models multi-site models, non-seasonal and seasonal models, parameter estimation and generation.	8
	Total	**39**

Suggested Readings:

1. Loucks D.P, Stedinger J.R and Haith D.A, 'Water Resources Systems Planning and Analysis', Prentice Hall, USA
2. Vedula S. and Mujumdar P.P., 'Water Resources Systems: Modelling Techniques and Analysis', Tata-McGraw Hill
3. Jain S.K. and Singh V.P., 'Water Resources Systems Planning and Management', Elsevier, TheNetherlands
4. Loucks D.P. and van Beek E., 'Water Resources Systems Planning and Management', UNESCO Publishing, The Netherlands

CE 5214 Ground Water Hydrology and Water Resources Development

Weekly Contact: 3-0-0 (L-T-S)Credits: 3
Full Marks: 100

Course Objective: The objective of this course is to make students understand the basic principles and movement of ground water and properties of ground water flow.

Course Outcome: At the end of the course, the students will be able to:

- Understand the basic fundamentals of groundwater flow.
- Define the key components of a functioning groundwater, can determine the main aquifer properties – permeability, transmissivity and storage
- Understand the seawater intrusion process in the coastal regions.
- Learn the hydraulics of different kinds of wells
- Learn about Conjunctive use of ground water along with other fresh water sources using various recharging techniques

Syllabus (Brief outline): Ground water resources of India, Aquifers Properties and Ground Water Flow, Well hydraulics, Seawater intrusion, Groundwater Recharge

Module No.	Course Module and Lesson Plan	Contact Hours
1.	**Introduction:** Ground water resources of India, geological formations. **Aquifers Properties and Ground Water Flow:** Aquifer Properties, Specific yield, Ground water movement, Darcy's law, permeability and its measurement, fundamental equations for steady and unsteady ground water flow, steady and unsteady flow in confined and unconfined aquifers, flow nets.	12
2.	**Well hydraulics:** Radial flow into well, Superposition; Image wells, Multiple well system, Well Loses, Different methods of well construction; construction of well casings and screens, natural and artificial gravel packed wells. Safe yields, estimation, pumping and recuperation tests; Infiltration galleries, ground-water recharge, different methods.	12
3.	**Seawater intrusion:** concept; interface and its location; control of intrusion. Pollutant transport; plume transport, source identification, tracer methods.	9
4.	**Groundwater Recharge:** Recharge of ground water, Methods of Artificial Recharge Ground Water Basin Management and Conjunctive Use: Ground water basin management, Conjunctive use, Mathematical modelling of a dual aquifer system, Mathematical model for a basin.	6
	Total	**39**

Suggested Readings:

1. H.M Raghunath , 'Ground Water', New Age International Publishers.
2. V.C. Agarwal, 'Ground Water Hydrology', PHI Learning.

CE 5215 Hydrology of Extreme Events and Mitigation Measures

Weekly Contact: 3-0-0 (L-T-S) **Credits: 3**
Full Marks: 100

Course Objective: Extreme hydrological events like flood, drought etc. forms a major portion of the natural hazards and in this context, it is essential to have an idea of modelling these events. The objective of the course is to impart knowledge of hydrological extreme events like flood, drought etc. and mitigation measures to handle them.

Course Outcome: At the end of the course, the students will be able to:

- Learn about the methods of estimating design flood
- Determine the flood hydrograph at a section of a river by utilising the flood data at upstream section
- Assess the flood damage and mitigation measures
- Learn the basic concepts of drought and modelling approaches for drought assessment

Syllabus (Brief outline): Design Flood, Methods of Estimating Design Flood, Flood Routing, Inundation modeling using HEC-RAS, Flood Damage Assessment, Flood Damage Mitigation, Modeling approaches for drought monitoring and assessment

Module No.	Course Module and Lesson Plan	Contact Hours

1.	**Flood:** Definition, Historical Perspectives, Causes, and Consequences. **Flood Hydrology:** Design Flood, Methods of Estimating Design Flood, Considerations in Selection of a Method, Steps in Estimating Design Flood, Analysis of Design Storms, Probable Maximum Precipitation, Standard Project Storm, Use of HEC-HMS for Estimating Design Flood	12
2.	**Flood Routing:** Concepts, Types, Governing Equations, Reservoir Routing Flood Plains: Definition, Necessity of Flood Plain Mapping, Methods of Flood Plain Delineation, Inundation modeling using HEC-RAS	9
3.	**Flood Damage Assessment:** Factors Affecting Damages, Type and Importance of Various Damages, Definition of Various Terms Associated, Methods of Assessment, Economics of Damage Assessment. **Flood Damage Mitigation:** Structural Measures– Flood Mitigation Reservoirs, Levees and Flood Walls, Floodways, Channel Improvements, Non-structural Measures– Flood Plain Management, Evacuation and Flood Proofing, Land Management, Flood Warning	9
4.	**Drought** – Definition, Different types of droughts, Meteorological drought indices, Agricultural drought indices based on Satellite data, Modeling approaches for drought monitoring and assessment	9
	Total	**39**

Suggested Readings:

1. K. Subramanya, 'Engineering Hydrology', Mc Graw Hill Education.
2. V.P. Singh, 'Elementary Hydrology', Prentice-Hall of India.
3. 'Hydro-Meteorological Hazards, Risks and Disasters', edited by P. Paron and G.D. Baldassarre

Departmental Electives (Course IX)

CE 5253 Loose Boundary Hydraulics and Sediment Transport

Weekly Contact: 3-0-0 (L-T-S) **Credits: 3**
Full Marks: 100

Course Objective: The main objective of the course is to impart detail knowledge about generation, transport and aggregation of the sediments and design stable channel free from erosion or degradation.

Course Outcome: At the end of the course, the students will be able to:

- Get knowledge of fluvial geomorphology and sediment water interaction.
- Identify different mechanisms of sediment transport
- Estimate sediment load in streams and rivers
- Identify management practices for sediment control
- Analyse hydraulic geometry and to design stable alluvial channels

Syllabus (Brief outline): Real-fluid Flow, Viscous Incompressible Flow, Steady, Unsteady, GVF and Hydraulic Jump, Navier-Stokes Equations, Sediment Transport, Sediment sampling, Design of Loose Boundary Channels, River Training

Module No.	Course Module and Lesson Plan	Contact Hours
1.	**Introduction:** Real-fluid Flow, Viscous Incompressible Flow, Steady,	6

	Unsteady, GVF and Hydraulic Jump, Navier-Stokes Equations, Laminar and Turbulent Boundary Layer,Turbulence and Coherent Structure of Flow, Reynolds Stresses, Skin Friction, Vorticity	
2.	**Sediment Transport:** Sediment properties, Universal soil loss equation, Initiation of motion – Shields' diagram, Regime concept, Modes of sediment transport, Bed load, Bedform mechanics, Effective bed roughness, Armouring, suspended load, Total load,Transport of sediment due to unsteady flow, Meandering of rivers, Braided river, Localscour at different structures, Sediment sampling	14
3.	**Design of Loose Boundary Channels:** Design of Stable Channels, Regime Channels, Mathematical Models of Sediment Transport, Hydraulic Geometry of Alluvial Streams, Bed Level Variation of Alluvial Streams, Aggradations and Degradation Models, Reservoir Sedimentation, Local Scours	14
4.	**River Training:** Guide lines for planning and design of river embankments (levees), Planning, design, construction and maintenance of guide banks and groynes for alluvialrivers, Application of Geo-synthetics and other materials in river training works	5
	Total	**39**

Suggested Readings:

1. Arved. J. Raudkivi, "Loose Boundary Hydraulics" Netherland: Balkema, 1998. ISBN : 90-5410-448-1.
2. Walter Hans Graf, "Hydraulics of Sediment Transport", McGraw-Hill Book Company.
3. Hsieh Wen Shen , "River Mechanics", Vol. I & II, H.W.Shen, Colorado,USA
4. Garde R J , River Morphology, New Age International Publishers, New Delhi
5. Subramanya, K., "Öpen Channel Flow", McGraw-Hill Book Company.

CE 5254 Storm Water Management

Weekly Contact: 3-0-0 (L-T-S)Credits: 3
Full Marks: 100

Course Objective: To develop an understanding of urban hydrologic cycle and learn about design, maintenance and operation of urban drainage systems.

Course Outcome: At the end of the course, the students will be able to:

- Develop an understanding of the urban hydrological cycle.
- Design different elements of drainage system
- Learn the operation and management of urban drainage system
- Develop storm water management models

Syllabus (Brief outline): Hydrologic Cycle, Rainfall to Runoff Conversion Process, Methods of Estimation of Time of Concentration., StormwaterMangement Practices, Urban Stormwater Management Models, General Stromwater Management Models, Practical Problem Practice

Module No.	Course Module and Lesson Plan	Contact Hours
1.	**Introduction:** Hydrologic Cycle, From Rainfall to Runoff Conversion Process, Introduction to Urbanisation and its Effect on Water Cycle, Time of Concentration, Importance of High Frequency Rainfall and Runoff Data, Methods of Estimation of Time of Concentration.	6
2.	**StormwaterMangement Practices:**Stormwater Collection Systems, Design of following: Detention Basins, Water Quality, Vegetated Swales, Bioretention, Green Roofs, Sediment Traps and Basins, Infiltration trenches, Rain Water Harvesting	10
3.	**Urban Stormwater Management Models:** Process of Designing Urban Stormwater Drainage Systems, Review of Urban Stormwater Models, use of any of the models SWMM, MIKE-URBAN, HSPF, StormCAD to Model the Urban Drainage System and Management of Urban Stromwater	8
4.	**General Stromwater Management Models**: Catchment based Stormwater ManagementProcedures. Soil Erosion Reduction Methods. Design of Rain Water Harvesting Projects,Use of HEC-HMS, HEC-RAS and TR-55 for Stormwater Management	9
5.	**Mini Project on Practical Problem**	6
	Total	**39**

Suggested Readings:

1.Butler D., J. W. Davis, "Urban Drainage", Spon Press.
2. Martin, P. Wanelista and Yousef, A. Yousef., Storm Water Management, John Wiley and sons
3. Overtens D.E. and Meadows M.E., Storm Water Modelling, Academic Press.
4. Hall M J., "Urban Hydrology", Elsevier Applied Science Publisher.
5. John E. Gribbin, "Introduction to hydraulics and hydrology with applications for Storm water Management", DELMAR,Thomson Learning

CE 5255 Coastal Hydraulics and Port Management

Weekly Contact: 3-0-0 (L-T-S) **Credits: 3**
Full Marks: 100

Course Objective: To provide an overview of the analysis and design procedures used in the field of coastal and harbour engineering.

Course Outcome: At the end of the course, the students will be able to:

- Understand the various hydraulic and morphologic coastal processes.
- Evaluate and implement coastal engineering solutions in a multidisciplinary and interdisciplinary environment.
- Design the dredging requirement to keep a channel navigable
- Apply the hydrodynamic wave and sediment transport theories in a coastal environment.
- Apply state-of-the-art coastal engineering design techniques to advance the needs of society

Syllabus (Brief outline): Introduction to coastal environments, wave propagation, Wave Theories, Hydrodynamics, Wave dynamics in estuaries, Sediment Transport, Basics of sediment transport and morpho-dynamics in estuaries, Dredging

Module No.	Course Module and Lesson Plan	Contact Hours
1.	**Introduction:** Introduction to coastal environments, estuaries, inlets, deltas, backwater,characteristics of different types of estuaries, examples, coastal structures, jetties, portand harbors	4
2.	**Waves:** Causes, processes involved, wind, cyclones, tsunamis, wave propagation, wavetransformations, wave decay, tides, generating systems, characteristics.	4
3.	**Wave Theories:** Linear wave theory, bottom boundary conditions, kinematic free surface boundary conditions, dynamic free surface boundary conditions, Solutions to linear water-wave problems	4
4.	**Hydrodynamics:** Introduction to long waves, Nearshore wave transformation: shoaling,reflection, refraction, diffraction, breaking; wave run-up, wave overtopping. Wavedynamics in estuaries, energy dissipation by bottom friction and bed porosity. Near-shoremean motion: Wave setup, wave-induced currents (longshore and undertow)	6
5.	**Sediment Transport:** Basics of sediment transport and morpho-dynamics in estuaries, 1-D, 2-D and 3-D models: governing equations, solution methods, assessment of morphological changes, Application of software	12
6.	**Dredging:** Types of dredging, Hydrographic survey information required for formulation of dredging project, Monitoring of dredging process and its progress, Siltation in dredgedchannel, Estimation of siltation during dredging, assessment of re-silting Factor,calculation of dredged quantity, assessment of dredge volumes, formulation of dredgingscheme, disposal of dredged material (Open River and shore), Application of remotesensing and GIS for monitoring dredging	9
	Total	**39**

Suggested Readings:

1. Greenwood, B.; Davis, Richard A. 'Hydrodynamics and Sedimentation in Wave-Dominated Coastal Environments', Elsevier
2. Kreeke, Aubrey and Weishar, 'Hydrodynamics and sediment dynamics of Tidal Inlets', Springer, New York
3. Mani S, ‘Coastal Hydrodynamics’, Prentice Hall, India

CE 5257 River Mechanics and Control Structures

Weekly Contact: 3-0-0 (L-T-S)Credits: 3
Full Marks: 100

Course Objective: The objective is to understand theoretical concepts of water and sediment movements in rivers and to gain knowledge about how to become safe from the vagaries of the river.

Course Outcome: At the end of the course, the students will be able to:

- Get knowledge of fluvial geomorphology
- Understand concept of analysis of river flow hydraulics
- Be able to analyse hydraulic geometry and to design stable alluvial channels
- Be able to do fluvial design for river bank protection

Syllabus (Brief outline): Functions and Rivers in India, Fluvial Geomorphology, River Hydraulics, Regime Rivers and Responses, Modelling of river channel changes, River Management

Module No.	Course Module and Lesson Plan	Contact Hours
1.	**Introduction**: Primary function of a river – River uses and measures – Water and Sediment loads of river – Rivers in India, Himalaya and Peninsular	4
2.	**Fluvial Geomorphology**: Fluvial system, variables for alluvial rivers, regime concept, river classifications, thresholds of river morphology, hydraulic geometry, meander platform, geomorphic analysis of river channel responses	4
3.	**River Hydraulics:** Hydraulics of flow in river channel, physical properties of sediments, scour criteria and scour-related problems, alluvial bed forms and flow resistance, sediment movements in Rivers, flow in curved channels, Fundamental relationships for flow and transport, Diffusion and Dispersion, Transport process in Rivers, Lakes and Reservoirs, Estuaries.	4
4.	**Regime Rivers and Responses**: River Equilibrium, Stability of Channel – regime relations – river bend equilibrium – hydraulic geometry of downstream- design of stable alluvial channel, analytical river morphology, plan geometry and processes of river meanders, Bars and meandering - River dynamics – degradation and aggradation of river bed – Confluences and branches – River Database	6
5.	**Modelling of river channel changes**: Mathematical model for erodible channels, gradual breach morphology tidal responses of river and delta system, Dam-break problem	12
6.	**River Management**: River training works and river regulation works – Flood plain management – waves and tides in Estuaries - Interlinking of rivers – River Stabilization, fluvial design of river bank protection	9
	Total	**39**

Suggested Readings:

1. River Engineering : Margaret S. Petersen, Prentice Hall of India
2. Fluvial Processes in River Engineering : H. H. Chnag, John Wiley and Sons
3. River Basin Planning: Theory and Practice: Suranjit K. Saha and Christopher J. Barrow, J. Wiley and Sons
4. Loose Boundary Hydraulics: Arved. J. Raudkivi, Netherland: Balkema
5. River Mechanics : Pierre Y. Julien, Cambridge University Press

CE 5258 Environmental Hydrology

Weekly Contact: 3-0-0 (L-T-S)Credits: 3
Full Marks: 100

Course Objective: The objective is to disseminate knowledge about different environmental issues in water resources development particularly knowing about different methods of environmental impact assessment and water quality impact assessment

Course Outcome: At the end of the course, the students will be able to:

- Know about the methods of Environmental Impact Assessment and Ecological diversity, its importance and conservation
- Develop an understanding of current assessment methods and legislation and suggest appropriate mitigation measures and prepare environmental management plans.
- Know about Environmental issues in water resource development
- Understand the importance of water quality in water resources and sources of pollution and its treatment and recycling

Syllabus (Brief outline):Environmental Issues and Impacts. Environmental Impact Assessment. Risk Analysis. Environmental Management. Water Quality Impact Assessment. Water Pollution abatement strategies

Module No.	Course Module and Lesson Plan	Contact Hours
1.	**Environmental Issues**: Water resources development and environmental issues, Environment in water resources project planning, Environmental regulations	3
2.	**Environmental Impacts Assessment**: Hydrological and water quality impacts – Ecological and biological impacts – Social and cultural impacts – Soil and landscape changes – Agro-economic issues – Human health impacts – Ecosystem changes. Introduction to environmental impact analysis, assessment and statement, evolution of EIA, national environmental policy. EIA process: Screening and scoping criteria; Rapid and comprehensive EIA Impact Assessment Methodologies – Matrices, overlays, network analysis. Specialized areas like environmental health impact assessment, Environmental risk analysis	9
3.	**Environmental Management**: In-stream ecological water requirements, Sustainable water resources development – Ecorestoration. Legislative and environmental clearances procedures in India: Siting criteria; public participations; resettlement and rehabilitation. Environmental management plan; Post project monitoring, EIA report and EIS; Review process. Case Studies of EIA of river valley projects and thermal power projects.	10
4.	**Water Quality Impact Assessment**: Attributes to be Considered, Water Quality Impact Assessment of Water Resources Projects, Data Requirements of Water Quality Impact Assessment for Dams, Impacts of Dams on Environment, Case Studies.	3
5.	**Water Quality and Pollution**: Physical and chemical properties of water – Suspended and dissolved solids – EC and pH – Trace constituents – Principles of water quality. - Water quality investigation – Sampling design - samplers – automatic samplers - data collection platforms–Field kits and investigations – Water quality data storage, analysis and inference – Software packages. Sources of Water Pollution	5
6.	**Water Pollution Abatement Technologies**: Flow diagram and working	9

	principle of Activated sludge process, Trickling filter – Oxidation Pond – Aerated lagoons–Advantages disadvantages and suitability – Packaged treatment units, advantages, disadvantages – Reverse osmosis. Recycling and Reuse of Wastewater	
	Total	**39**

Suggested Readings:

1. Environmental Hydrology: Andy D. Ward and Stanley W. Trimble, Lewis Publishers
2. Newmann, E.I., Applied ecology, Blackwell Science ltd., Oxford
3. Canter, L.W., "Environmental Impact Assessment", McGraw Hill Pub. Co., NewYork
4. George Tchobanoglous, Franklin Louis Burton, Metcalf & Eddy, H. David Stense, Wastewater Engineering: Treatment and Reuse, McGraw-Hill.

CE 5259 Reservoir Planning and Operation

Weekly Contact: 3-0-0 (L-T-S) **Credits: 3**
Full Marks: 100

Course Objective: The Objective is to plan and design the reservoir operating policy using simulation and mathematical modelling techniques.

Course Outcome: At the end of the course, the students will be able to:

- Understand the various stages involved in the planning of reservoir location and size.
- To Control the reservoir sedimentation and enhance the serviceable life of a reservoir
- Develop various mathematical model for efficient operation of the reservoir systems

Syllabus (Brief outline): Types of reservoirs, Determination of reservoir capacity, Planning of Reservoir, Reservoir Sedimentation, Operating policy of reversoir systems under Deterministic and Random inflow, few case studies to illustrate the theories.

Module No.	Course Module and Lesson Plan	Contact Hours
1.	**Introduction**: Types of reservoirs. Zones of storage in a reservoir, Reservoir Yield, Mass curve and Demand Curve, Determination of reservoir capacity, determination of yield of a reservoir	4
2.	**Planning of Reservoir**: Investigation for reservoir planning, Selection of sites for a reservoir, Demand patterns for various types of reservoirs, Apportionment of total cost of a multipurpose reservoir, Concept of Reservoir System-Various methodologies for planning the reservoir, Simulation-Single Objective reservoir planning-Multi objective reservoir planning-Economic Considerations in reservoir Planning	5
3.	**Reservoir Sedimentation:** Erosion and Deposition, Control of Sedimentation, Catchment Area Treatment,Estimation of Sediment Load, Use of Models, Estimation of Life of a reservoir, Reservoir losses, Methods to reduce the reservoir losses	6
4.	**Reservoir systems-Deterministic Inflows**: Reservoir sizing; Reservoir capacity using Linear Programming-Reservoir operations-standard operating policies- Optimal operating policies, multi-reservoir systems policies	7
5.	**Reservoir systems-Random inflows**: Basic Probability Theory, Chance Constrained Linear Programming, Concept of Reliability, Stochastic Dynamic Programming	9

6.	**Model formulation and Case studies**: Applications-Reservoir systems operated for irrigation, Hydropower, Flood Control and Municipal and Industrial Supplies, Water Quality Control in River Systems, Conjunctive use of ground and surface water, Crop yield optimization	8
	Total	**39**

Suggested Readings:

1. Loucks, D.P.andEllco Van Beek,Water Resources Systems Planning and Management: An introduction to Methods, Models and Applications , UNESCO, Netherlands,
2. Vedula, S.andMujumdar,P,P, Water Resources Systems: Modeling Techniques and Analysis; Tata McGraw Hill, New Delhi
3. Vijay P. Singh, Handbook of Applied Hydrology, McGraw-Hill Education
4. K. R. Arora, Irrigation Water Power and Water Resource Engineer, Standard Publishes distributers

Open Electives

Course V: Open Elective

CE 5161 Climate Change Impact Analysis

Weekly Contact: 3-0-0 (L-T-S)

Full Marks: 100 **Credits: 3**

Course Objective: The objectives of the course are to introduce the underlying science of human-induced and naturally-occurring climate change and how to conduct an Impact study using GCM data.

Course Outcome: At the end of the course, the students will be able to:

- Understand the scientific basis of human-induced climate change.
- Understand climate projection models, feedback processes and uncertainties
- Evaluate the implications of climate change impacts
- be in a position to understand the adaptation of climate change;
- demonstrate in producing ideas on mitigation strategies of global climate change.

Syllabus (Brief outline): General Overview of Climate Change Problem and Impacts on Societies and Ecosystems, Climate Change Science, Climate Models and Statistical Downscaling, Impact Analysis, Adaptation and Mitigation

Module No.	Course Module and Lesson Plan	Contact hours
1.	**Introduction:** General Overview of Climate Change Problem and Impacts on Societies and Ecosystems, Overview of Different Aspects involved in Climate Change ImpactInvestigation	3
2.	**Climate Change Science:** Climate System, Weather, Climate, Global Warming, GreenHouse Gas, Climate Variability and Noise, Climate Change, Natural Climate Variations,Carbon Cycle, Prediction or Projection? Energy Balance Model, Radiative Transfer, Climate Feedback, Atmospheric Circulation, Trade Winds and the Hadley Cell, El Nino, La Nina, Paleoclimatology, IPCC, Historical Trend Testing, Separation of Trends from Natural Variability	14
3.	**Climate Models and Statistical Downscaling:** Global Circulation Models, Emission Scenarios, RCP Scenarios, Parameterization, Scale and Resolution of Climate Model, Climate Model Output, On the needs for statistical downscaling and bias correction: introduction on methods, Methods for statistical downscaling and bias correction: Deltachange method, Weather typing/ Resampling, Rainfall generator method, Application ofdelta change and weather generator method for	12

	impact analysis of climate change.	
4.	**Impact Analysis**: Climate Scenario Development, Methods for Impact Analysis of Climate Change	3
5.	**Adaptation and Mitigation:** Climate Adaptation Needs and Decision making under Uncertainty, Adaptation to Climate Change in the fields of Ecosystems and Biodiversity, Agriculture and Food security, Human Health, Water Supply and Sanitation,Infrastructure and Economy (Insurance, Tourism and Transportation) - Vulnerability andSustainable Development, Sector-Specific Mitigation - Carbon dioxide Capture andStorage (CCS) , Bio-energy Crops, Hydropower, Geothermal Energy, Land-use change and Management, Cropland Management, Afforestation and Reforestation	7
	Total =	**39**

Suggested Readings:

1. John Houghton, "Global Warming: The Complete Briefing", Cambridge Univ. Press.
2. Jan C. Van Dam, "Impacts of Climate Change and Climate Variability on Hydrological Regimes", Cambridge University Press.
3. IPCC AR4 and AR5 Reports
4. McGuffie, K. and Henderson-Sellers, "A Climate Modeling Primer", Wily
5. P R Shukla, Subobh K Sarma, NH Ravindranath, AmitGarg and Sumana Bhattacharya, "ClimateChange and India:Vulnerability assessment and adaptation", University Press (India) Pvt Ltd, Hyderabad.

CE 5163 Seismic Hazard of Infrastructure

Weekly contact: 3-0-0 (L-T-S)
Full marks: 100 **Credits: 3**

Course objective: The objective of this course is to familiarize the students with the basics of engineering seismology, ground motion parameters, liquefaction studies, earthquake occurrence and engineering characterization of ground motion. The course involves an overview of global seismicity, theory behind earthquakes, plate tectonics and seismic hazard assessment. Further, the course imparts knowledge about different earthquake scales, intensity and magnitude of earthquakes, seismic instruments, seismic zonation map and concepts of wave propagation. Different predictive equations involved in seismology and source-site attenuation relationships will be discussed a part of the course.

Course outcome: At the end of the course students will able to:

1. Understand earthquake hazards and means to estimate future seismic hazard
2. Quantify earthquake sizes and to interpret seismic data
3. Conduct seismic hazard estimation and to predict liquefaction potential
4. Undertake engineering characterization of ground motion

Sl. No.	Description of Course Modules and Lecture Plan	No. of lectures

1	**Introductionto earthquake engineering-** Fundamental concepts of earthquake engineering, principles of earthquake, depth and size of earthquake, effects of earthquake, seismic zonation map of India, examples of historical earthquakes	**2**
2	**Study of Earthquakes –** Ancient Chinese seismograph,modern seismograph, measurement of earthquakes, prediction of earthquakes involving location, magnitude and duration, preparing for earthquakes	**2**
3	**Overview of Seismology and tectonics-** Plate tectonics and formation of earth's interior, elastic rebound theory, continental drift theory**,** plate boundaries, faults and seismic waves, locating epicenter of an earthquake, measurement of earthquake, magnitude and intensity scales, seismic energy, frequency of earthquake	**4**
4	**Wave propagation-** Basics of vibration theory**,** wave terminology, ground motion recording	**2**
5	**Strong Ground motion parameters**- Ground motion parameters, frequency content of earthquake, amplitude, various intensity measures, spectrum analysis, spatial variability of ground motion, attenuation relationships, three-dimensional wave equation, prediction of wave velocities in homogeneous and layered medium	**6**
6	**Liquefaction -** Introduction to liquefaction phenomena, effects of liquefaction, flow liquefaction and cyclic mobility, factors influencing liquefaction susceptibility, evaluation of liquefaction hazard through field investigation techniques (SPT, CPT and SASW), reduction of liquefaction potential	**6**
7	**Seismic hazard analysis**- Deterministic approach- Identification of earthquake sources, geological and tectonic evidence, historical seismicity, fault activity, Deterministic Seismic hazard analysis (DSHA), Case study on DSHA. Probabilistic Seismic hazard analysis (PSHA), PDF and PMF functions, recurrence laws, uncertainty in computation of seismic hazards. Disaggregation Analysis, Case study on PSHA	**10**
8	**Ground Motion Generation:** Artificial and synthetic method of ground motion generation, brief review of stochastic methods involved in analysis of ground characterization	**7**
	TOTAL	**39**

Suggested Readings:

1. Steven L. Kramer, "Geotechnical Earthquake Engineering", Prentice Hall Inc.
2. Robert W. Day, "Geotechnical Earthquake Engineering Handbook", McGraw Hill, New York.
3. IkuoTowhata, "Geotechnical Earthquake Engineering", Springer-Verlag Heidelberg.
4. ShamsherPrakash, "Soil Dynamics", McGraw-Hill Book Company.
5. MilutinSrbulov, "Geotechnical Earthquake Engineering: Simplified Analyses with Case Studies and Examples", Springer-Verlag.
6. IS 1893, Indian Standard Criteria for earthquake resistant Design of Structures.

CE 5164 Transportation in Logistics Management

Weekly Contact: 3-0-0 (L-T-S)

Full Marks: 100
Credits: 3

Course Objective: To provide the students with a basic understanding of theories and applications of transportation in logistics, inventory management and logistics information systems. The course also intends to impart basic knowledge on designing and planning of transportation networks, for example, multimodal transport system, vehicle routing, shortest path algorithm, quickest time algorithm, uncertainty issues.

Course Outcome: Students will gain a theoretical and applied understanding of transportation and logistics management in this course. The course learning outcomes are:

- Understand the business logistics, supply chain management, procurement, production, distribution
- Understand role of transportation in economic development
- Ascertain problems of road freight transport, measure cost, assess uncertainties
- Develop logistics management information system
- Ability to evaluate network optimisation algorithms and design vehicle routing

Syllabus (Brief outline): Evolution of freight and logistics; transportation in economic development; methodologies to understand freight movement; cost measurement; interrelationships - transportation, warehousing, inventory management systems; transport consolidation in time based logistics control;uncertainty issues; multimodal transport system; logistics information system; vehicle routing; shortest path algorithm

Module No.	Course Module and Lesson Plan	Contact hours
1.	Concepts and evolution of business logistics; concept of integrated business logistics and supply chain management; logistical performance cycle, procurement, production, distribution, logistical functional areas	7
2.	Role of transportation in economic development; business operation; supply-chain management and value addition process	6
3.	Problems of road freight transport industry; the emerging trend; principles of economy of scales and economy of distance in road freight transport operation; freight transport cost factors and elements; fixing the rates of freight structure	7
4.	Interrelationships of transportation, warehousing and inventory management system – integrated management of warehousing & transportation system – warehousing & transportation costs	6
5.	Transport consolidation in time based logistics control; logistics reengineering process; seasonal demand; uncertainty issues	4

6.	Multimodal transport system; designing and planning of transportation networks; city logistics; logistics information system	5
7.	Vehicle routing: one-to-one distribution, one-to-many distribution, shortest path algorithm, quickest time algorithm	4
	Total =	**39**

Suggested Readings:

1. Stroh, M.B., A practical guide to transportation and logistics, Dumant: Logistics network.
2. Augello, W.J., Transportation, logistics and the law.
3. Liu, J., 2011. Supply chain management and transport logistics, Routledge.
4. Sarder, M.D., Logistics transportation systems, Industrial and Systems Engineering

CourseX Open Elective

CE 5261Plastic and Electronic Waste Management

Weekly Contact: 3-0-0 (L-T-S)

Full Marks: 100 **Credits: 3**

Course Objective: To provide the students with basic knowledge on environmental problems created by electronic and plastic waste and its management.

Course Outcome: At the end of the course, the students will be able to:

- Know the sources, production and uses of electronic and plastic waste
- Learn about present global scenario of electronic and plastic waste and future projection
- Knowledge of alternative materials
- Rules and handling

Syllabus (Brief outline): Plastics –Types, Human health impact, Process and handling rules, Pollution pathway, end-of- use extraction and recycling, E-Waste Management Rules of India.

Sl. No.	Course module and lesson plan	Contact hours
1	Plastics –Types, Uses and Global Statistics,Plastic Waste – Sources, Production	4
2	Impact of Plastics on Marine Life, Effect on Wildlife, Human Health and Environment	4

3	Plastic Waste Management Rules 2016 (India) and Global Rules and Regulations	4
4	Possible Alternate Materials to Plastics –Greener Alternatives, Plastics Resource Recovery and Circular Economy	8
5	Categories in E-waste, E-waste generation	4
6	Need to manage/recycle,Exposure pathway of pollutants emitted from Recycling of E-Waste	4
7	Economic assessment of E-waste (Rare earth minerals, precious metals), Extraction of precious and rare earth metals from End-of-Life (EOL) electronic products	5
8	E-Waste Management Rules of India (2011 and 2016 Rules) E-waste Management: Case Studies and Unique Initiatives from around the World, Extended Producer Responsibility (EPR) and other take-back system	6
	Total	**39**

Suggested Readings:

- Electronic Waste Management Rules 2016, Govt. of India, available online at CPCB website.
- MSW Management Rules 2016, Govt. of India, available online at CPCB website.
- Technical Courses to be provided during teaching

CE 5262 Risk Assessment and Remediation of Contaminated Ground

Weekly contact: 3-0-0 (L-T-S)
Full marks: 100 **Credits: 3**

Course Objective: The course intends to familiarize the students with the different sources of waste generation, classification of wastes, along with the relevant environmental laws and regulations related to their disposal, treatment and utilization. Students will develop a knowledge about the methods of calculating the risks associated with waste handling, and to identify the different remedial methods for treating contaminated sites.

Course Outcome: At the end of the course, the students will be able to:

- Understand the sources and production of wastes and means of classification of wastes
- Develop skills to determine the properties of contaminated soils
- Understand the mechanism of contaminant transport
- Predict suitable remedial methods for contaminated soils.
- Develop concepts of waste utilization for sustainable development

Syllabus: Introduction, sources and classification of wastes, environmental laws and regulations, risk assessment approach, contaminant transport, remediation technologies, soil washing, soil vapor extraction, bioremediation, chemical treatment, vitrification, phytoremediation, solidification and stabilization sustainable development and reuse potential of waste materials, case studies.

Lecture Plan:

Module No.	Description of Course Module	No. of lectures
1	Introduction to different sources and classification of wastes	3
2	Environmental laws and regulations	3
3	**Risk assessment approach** –Physical, chemical and biological contamination of geomaterials, determination of properties of contaminated site, site assessment and management, estimation of landfill quantities and landfill site location	6
4	**Contaminant transport processes** – Introduction, mathematical modelling, applications and Case Studies	9
5	**Methodology for remediation of contaminated ground:** Introduction to various remediation techniques, including soil stabilization, bioremediation, chemical treatment, Phytoremediation etc.	15
6	**Sustainable development:** Reuse potential of waste materials, Case Studies	3
	Total=	**39**

Suggested Readings:

1. Sharma, H.D., and Lewis, P.L., "Waste Containment systems, waste stabilization and landfill, John Wiley & Sons, Inc., Hoboken, New Jersey.
2. Oweis, I.S., and Khera, R.P., "Geotechnology of waste management", Butterworths.
3. Yong, R.N., "Contaminated soils, pollutant fate and mitigation", CRC Press.
4. Rowe, R. Kerry, Quigley, Robert M., Brachman, Richard W. I., and Booker, John R., "Barrier Systems for Waste Disposal Facilities", Spon Press, Taylor & Francis Group, London.
5. Tchobanoglous, G., Theisen, H. and Vigil, S.A., "Integrated Solid Waste Management - Engineering Principles and Management Issues," McGraw Hill.
6. Daniel, D. E., "Geotechnical Practice for Waste Disposal", Chapman and Hall, London.

CE5263 Continuum Mechanics and Material Modeling

Weekly Contact: 3-0-0 (L-T-S)

Full Marks: 100 **Credits: 3**

Course Objective: The objective of the course is to introduce continuum mechanics with emphasis on constitutive modeling of classical and advanced materials.

Course Outcome: At the end of the course, the students will be able to:

- Solve related problems in tensor algebra and calculus

- Learn fundamentals of continuum mechanics
- Identify the key parameters and subsequently, learn to model new materials
- Employ suitable programming languages to solve the numerical problems

Syllabus (Brief outline): Tensor algebra and calculus**,** fundamentals of continuum mechanics, continuum thermodynamics, classical constitutive models, shape memory polymers, alloys and piezo-electric materials.

Module No.	Course Module and Lesson Plan	Contact hours
1	Tensor algebra and calculus, field theory, and related mathematical principles	9
2	Kinematics of motion and various deformation measures	6
3	Force and stress; objectivity of stress tensors	3
4	Conservation laws of mechanics and thermodynamics; entropy inequality	6
5	Classical Constitutive equations: linear elastic, viscoelastic, plastic material models	6
6	Coupled constitutive equations for shape memory alloys, shape memory polymers; introduction to piezo-electric, poro-elastic and other emerging materials	9
	TOTAL	**39**

Suggested Readings:

1. Advanced Mechanics of Solids, L S Srinath, TMH publishing company limited
2. Continuum Mechanics Modeling of Material Behavior, Martin H Sadd, Elsevier: Academic Press
3. Applied Mechanics of Solids, A F Bower, http://solidmechanics.org/contents.php
4. An Introduction to Polymer Physics, David I Bower, Cambridge University Press
5. Non-linear Solid Mechanics: A Continuum Approach for Engineering, G A Holzapfel, John Wiley & Sons