

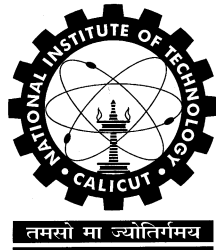
M.Tech.

IN

ENVIRONMENTAL ENGINEERING

CURRICULUM AND SYLLABI

(Applicable from 2024 admission onwards)



Department of Civil Engineering
NATIONAL INSTITUTE OF TECHNOLOGY CALICUT
Kozhikode - 673601, KERALA, INDIA

The Program Educational Objectives (PEOs) of M.Tech. in Environmental Engineering

PEO1	Demonstrate advanced knowledge in Environmental Engineering, enabling them to excel in their profession and pursue higher academic goals
PEO2	Exhibit strong communication, technical writing and interpersonal skills
PEO3	Be strongly committed to ethical practices, adherence to quality and performance standards, sustainability, and self-directed life-long learning

Programme Outcomes (POs) & Programme Specific Outcomes (PSOs) of M.Tech. in Environmental Engineering

PO1	Ability to independently carry out research / investigation and development work to solve practical problems.
PO2	Ability to write and present a substantial technical report/ document.
PO3	Demonstrate a degree of mastery over the area as per the specialisation of the programme.
PSO1	Identify, formulate & solve complex Environmental Engineering problems and develop the confidence for self-education.
PSO2	Demonstrate ability for life-long learning of new and innovative technologies in the field of Environmental Engineering and their application adhering to ethical practices.

CURRICULUM

Total credits for completing M. Tech. in Environmental Engineering is 75

COURSE CATEGORIES AND CREDIT REQUIREMENTS: The structure of M. Tech. programme shall have the following Course Categories:

Sl. No.	Course Category	Minimum Credits
1.	Program Core (PC)	23
2.	Program Electives (PE)	15
3.	Institute Elective (IE)	2
4.	Projects	35

The effort to be put in by the student is indicated in the tables below as follows:

L: Lecture (One unit is of 50 minutes duration)

T: Tutorial (One unit is of 50 minutes duration)

P: Practical (One unit is of one-hour duration)

O: Outside the class effort / self-study (One unit is of one-hour duration)

PROGRAMME STRUCTURE

Semester I

Course Code	Course Title	L	T	P	O	Credits	Category
CE6601E	Environmental Chemistry and Microbiology	3	0	0	6	3	PC
CE6602E	Physico-chemical Processes for Water and Wastewater Treatment	3	0	0	6	3	PC
CE6603E	Municipal Solid Waste Management	3	0	0	6	3	PC
CE6604E	Statistics for Environmental Engineers	3	0	0	6	3	PC
CE6691E	Advanced Environmental Engineering Laboratory	0	0	2	1	1	PC
*****E	Programme Elective I	3	0	0	6	3	PE
*****E	Programme Elective II	3	0	0	6	3	PE
*****E	Institute Elective	2	-	-	4	2	IE
Total						21	

Semester II

Course code	Course Title	L	T	P	O	Credits	Category
CE6611E	Biological Process Design for Wastewater Treatment	3	0	0	6	3	PC
CE6612E	Air Pollution Modelling, Monitoring and Control	3	0	2	7	4	PC
CE6613E	Environmental Impact Assessment	3	0	0	6	3	PC
CE6696E	Project phase I	0	0	0	6	2	PC
*****E	Programme Elective III	3	0	0	6	3	PE
*****E	Programme Elective IV	3	0	0	6	3	PE
*****E	Programme Elective V	3	0	0	6	3	PE
Total						21	

Semester III

Course Code	Course Title	L	T	P	O	Credits	Category
CE7697E	Project Phase II*	0	0	0	9	3	PC
CE7698E	Project Phase III	0	0	0	45	15	PC
Total						18	--

*Summer Internship/Project to be carried out during the summer break.

Semester IV

Course Code	Course Title	L	T	P	O	Credits	Category
CE7699E	Project Phase IV	0	0	0	45	15	PC
Total						15	--

List of Programme Electives

Sl. No.	Course Code	Course Title	L	T	P	O	Credits
1.	CE6621E	Design and Analysis of Water and Wastewater Transport Systems	3	0	0	6	3
2.	CE6622E	Industrial Wastewater Management	3	0	0	6	3
3.	CE6623E	Advanced treatment of Water and Wastewater	3	0	0	6	3
4.	CE6624E	Environmental Legislations	3	0	0	6	3

5.	CE6625E	Life Cycle Assessment and Circular Economy	3	0	0	6	3
6.	CE6626E	Applied Environmental Microbiology	3	0	0	6	3
7.	CE6627E	Fundamentals of Aerosol Science	3	0	0	6	3
8.	CE6628E	Environmental Forensics	3	0	0	6	3
9.	CE6629E	Assessment and Management of Environmental Risk	3	0	0	6	3
10.	CE6630E	Ecological and Ecosystems Engineering	3	0	0	6	3
11.	CE6631E	Hazardous and Special Waste Management	3	0	0	6	3
12.	CE6632E	Carbon Capture and Storage	3	0	0	6	3
13.	CE6633E	Atmospheric Processes and Climate Change	3	0	0	6	3
14.	CE6634E	Thermal Techniques for Waste Treatment	3	0	0	6	3
15.	CE6635E	Environmental Modeling and Simulations	3	0	0	6	3
16.	CE6636E	Design of Engineered Landfills	3	0	0	6	3
17.	CE6425E	Bioremediation Technologies for Contaminated Soils	3	0	0	6	3
18.	CE6447E	Geoenvironmental Engineering	3	0	0	6	3
19.	CE6503E	Remote Sensing and GIS Applications in Water Resources Engineering	3	0	2	7	4
20.	CE6512E	Flow and Transport in Porous Media	3	0	0	6	3
21.	CE6525E	Hydrogeology and Groundwater Development	3	0	0	6	3
22.	CE6527E	Water Quality Modeling	3	0	0	6	3
23.	CE6529E	Watershed Management	3	0	0	6	3
24.	CE6530E	Environmental Hydraulics	3	0	0	6	3
25.	CE6536E	Disaster Management	3	0	0	6	3
26.	CE6537E	Environmental Flows	3	0	0	6	3
27.	EC6130E	Machine Learning for Intelligent Systems	3	0	0	6	3
28.	MT6101E	Experimental Techniques for Materials	3	0	2	8	4
29.	MT6103E	Nanosized Structures	3	0	0	6	3
30.	MT6111E	Spectroscopy for Nanomaterials	3	0	0	6	3
31.	MT6121E	Nano Materials for Energy and Environment	3	0	0	6	3

List of Institute Electives

Sl. No.	Course Code	Course Title	L	T	P	O	Credits
1.	IE6001E	Entrepreneurship Development	2	0	0	4	2
2.	MS6174E	Technical Communication and Writing	2	0	0	4	2
3.	ZZ6002E	Research Methodology	2	0	0	4	2

CE6601E ENVIRONMENTAL CHEMISTRY AND MICROBIOLOGY

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions:39

Course outcomes

- CO1: Demonstrate knowledge on the fundamentals of chemistry and microbiology in environmental systems
CO2: Characterise and analyse the different water and wastewater quality parameters.
CO3: Demonstrate knowledge on the basic chemistry involved in the treatment of water and wastewater.
CO4: Demonstrate knowledge on the microbial growth kinetics and the factors affecting.

Chemical Equations - Conservation of Mass and Charge, Solutions. Thermodynamics, Principles of Solvent Extraction, Electrochemistry, Chemical Kinetics, Catalysis, Adsorption, Colloids - redox potentials- Chemical Equilibrium - Acid and Bases- pC-pH diagram, partition coefficient- Langelier index, solubility diagram, oxidation-reduction equilibria.

Chemistry of degradation process- degradation of organic compounds- Photocatalysis– Fenton, Electro-oxidation. Detergents- Soaps, Pesticides and hydrocarbons. Fats, Oil and Waxes, Pharmaceutically Active Compounds, Endocrine Disrupting Chemicals, etc.. Chemical Analysis - Gravimetric Method, Volumetric Method, Beer Lambert's law - limitations – spectroscopy. Instrumental Analysis – Principles and Methods. Overview of the standard methods of analysis of water and wastewater.

Microbiological concepts - classification of microorganisms - prokaryotic, eukaryotic, structure, characteristics, nucleic acids - DNA, RNA, replication.

Culturing of microorganisms - environmental factors influencing microbial growth - growth kinetics - Batch and continuous culture. Distribution of microorganisms - water, air and soil - Indicator organisms - coliforms, faecal coliforms, streptococcus, clostridium, Enumeration techniques - MPN and MFT - algae in water supplies - problems and control - bioaccumulation - biomagnification - bioassay - biomonitoring. Disinfection.

References:

1. Sawyer, C. N, McCarty, P. L, and Parkin, G. F, Chemistry for Environmental Engineers, 4th Edition, McGraw Hill, 2017.
2. Benefield, Judkins and Weand, Process Chemistry for Water and Wastewater Treatment, Prentice Hall, 1982.
3. Maier, R. M, Pepper, I. L and Gerba, C. P, Environmental Microbiology, 2nd Edition, Elsevier - AP, 2009.
4. Pelczar, M. J, Jr, Chan, E. C. S, Krieg, N. R, and Pelczar, M. F, Microbiology, 5th Edition, McGraw-Hill, 2001.
5. Rittman, B. E and McCarty, P. L, Environmental Biotechnology: Principles and Applications, 2nd Edition, McGraw-Hill, 2000.

CE6602E PHYSICO-CHEMICAL PROCESSES FOR WATER AND WASTEWATER TREATMENT

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course outcomes:

- CO1: Evaluate various physical and chemical treatment options for water and wastewater
- CO2: Demonstrate the mechanism behind the treatment processes and their advantages and limitations
- CO3: Design various physico-chemical treatment units for water and wastewater
- CO4: Suggest appropriate methods for the treatment of various types of wastewater

Water quality and Standards - Process dynamics, Reactions- Mechanics of Mass Transport, Reactor Engineering and Process Design, Particle Separation Processes - Sedimentation and Floatation, Gravity Thickeners - Coagulation and Flocculation- Processes-Particle Surface Charge- Surface Potential and Stability of Colloidal Dispersions.

Filtration- Mechanisms and Types- Multimedia Filter- Design and Modeling Approaches for Rapid Sand Filters. Solute Separation Processes - Gas Transfer Processes, Diffused and Surface Aeration, Air Stripping of Volatile Contaminants in Packed Tower.

Adsorption and Ion Exchange Processes, Sorption Isotherm Models and Rates Considerations, Sorption in Completely Mixed and Packed Bed Reactors - Precipitation Processes – Membrane processes - Species Transformation Processes – Chemical Oxidation / Reduction Processes, Disinfection using Chlorine, UV and Ozone, Advanced Oxidation Process.

References:

1. Weber, Jr. and Walter J. Physicochemical processes for water quality control. John Wiley and sons, New York, 2003.
2. Weber, Jr., Walter, J., Jr, and DiGiano, F.A. Process Dynamics in Environmental Systems. John Wiley and Sons Inc., New York, 1996.
3. Peavy, H. S, Rowe, D. R, and Tchobanoglous, G. Environmental Engineering. McGraw Hills, New York, 2013.
4. Metcalf, L., and Eddy, P. Wastewater Engineering; Treatment and Reuse. 5th Edition, Tata McGraw-Hill, New Delhi, 2013.
5. Benefield, L. R, Judkins, J. F and Weand, B. L. Process Chemistry for Water and Wastewater Treatment. 1982.

CE6603E MUNICIPAL SOLID WASTE MANAGEMENT

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

- CO1: Demonstrate knowledge on the sources, types, quantity, and characteristics of municipal solid waste (MSW).
- CO2: Evaluate environmental and socio-economic impacts of open disposal of MSW.
- CO3: Demonstrate knowledge on Integrated Solid Waste Management (ISWM)
- CO4: Provide expert guidance on collection, separation, transport, and treatment of MSW.

Municipal Solid Waste: Introduction- definition- sources- generation- composition- physical and chemical characteristics of MSW. Open disposal of MSW and its impacts- environmental pollution, health risk analysis, leachate pollution, socio-economic impacts. Role of informal sector in MSW management- roles of ragpickers, public awareness, role of NGOs.

Integrated solid waste management (ISWM), waste management hierarchy, stages in MSW management, MSW handling and treatment: Storage- collection- transportation- transfer station, tools and equipment, reuse and recycling possibilities, processing and transformation technique, Material recovery facility (MRF). MSW treatment - biological processing- composting - anaerobic digestion- co-digestion of MSW with other waste- thermal processing of combustible wastes- incineration- pyrolysis- combustion. Case studies on ISWM.

Disposal of MSW and regulation: Sanitary landfills– site selection– design and operation of sanitary landfills– landfill liners and covers– landfill closure and environmental monitoring– management of leachate and landfill gas– landfill bioreactor– dumpsite rehabilitation and reclamation. MSW management and handling rules. Household hazardous waste – types – overview of its handling and management.

References:

1. Tchobanoglous, G., and Frank Kreith. Handbook of solid waste management, New York, USA: McGraw-Hill Education, 2002.
2. Swachh Bharat Mission, Municipal Solid Waste Management Manual, Part II: The manual, Central Public Health and Environmental Engineering Organization (CPHEEO), Ministry of Urban Development, 2016.
3. Manser, A. G. R., and Alan Keeling. Practical handbook of processing and recycling municipal waste. CRC Press, 1996.
4. Tchobanoglous, G., Hilary Theisen and Samuel Vigil. Integrated solid waste management: engineering principles and management issues, McGraw Hill, 2014.
5. The Solid Waste Management Rules, Ministry of Environment, Forest and Climate Change (MoEFCC), 2016.
6. Vesilind, P. Aarne, William A. Worrell, and Debra R. Reinhart. Solid waste engineering. 2nd Edition, Thompson Press. 2012.
7. Townsend, Timothy G., Jon Powell, Pradeep Jain, Qiyong Xu, Thabet Tolaymat, and Debra Reinhart. Sustainable practices for landfill design and operation. Springer, 2015.

CE6604E STATISTICS FOR ENVIRONMENTAL ENGINEERS

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1. Analyze environmental data for quality and represent data graphically

CO2. Carry out various tests for comparison of environmental datasets

CO3. Carry out design of experiments for environmental applications

CO4. Analyze for correlation between environmental datasets

Environmental problems and Statistics; A brief review of Statistics; Plotting data; Smoothing data; Shape of a distribution; External reference distributions; Using transformations; Estimating percentiles; Accuracy, bias, and precision of measurements; Precision of calculated values; Laboratory quality assurance; Fundamentals of process control charts; Specialized control charts; Limit of detection; Analysing censored data.

Comparing a mean with a standard; Paired t-test for assessing the average of differences; Independent t-test for assessing the difference of two averages; Assessing the difference of proportions; Multiple paired comparisons of k averages; Tolerance intervals and prediction intervals; Experimental design; Sizing the experiment; Analysis of variance (ANOVA) to compare k averages; Components of variance; Multiple factor analysis of variance; Factorial experimental designs; Fractional factorial experimental designs; Screening of important variables.

Correlation; Serial correlation; Method of least squares; Precision of parameter estimates in linear models; Precision of parameter estimates in nonlinear models; Calibration; Weighted least squares; Empirical model building by linear regression; Coefficient of determination (R^2); Regression analysis with categorical variables; Effect of autocorrelation on regression.

The iterative approach to experimentation; Seeking optimum conditions by Response Surface Methodology; Designing experiments for nonlinear parameter estimation; Fitting models to multiresponse Data.

References:

1. Brown, Paul Mac Berthouex Linfield C., and Douglas F. Hambley, Statistics for environmental engineers (II Edition), CRC Press LLC, Boca Raton, Florida, 2002.
2. Kottegoda, Nathabandu T., and Renzo Rosso, Applied statistics for civil and environmental engineers. Blackwell Publishing, 2008.
3. Montgomery, Douglas C., and George C. Runger, Applied statistics and probability for engineers. John Wiley & Sons, 2010.
4. Benjamin, Jack R., and C. Allin Cornell. Probability, statistics, and decision for civil engineers. Courier Corporation, 2014.

CE6691E ADVANCED ENVIRONMENTAL ENGINEERING LABORATORY

L	T	P	O	C
0	0	2	1	1

Course Outcomes

- CO1: Carry out analysis of water and wastewater quality parameters.
CO2: Carry out adsorption experiments and prepare isotherms.
CO3: Carry out analysis of biological parameters in water and wastewater.
CO4: Carry out sampling and analysis of air quality parameters

List of Experiments

1. Water/Soil analysis - Anions and cations, heavy metals, etc.
2. Wastewater analysis - BOD, COD, MLSS, MLVSS, SVI, etc.
3. MPN, MFT, and culturing of microorganisms
4. Treatment based experiments – Coagulation, Adsorption, disinfection and sedimentation.
5. Demonstration of advanced instruments – HPLC, GC, TOC analyzer, Stereo microscope

References:

1. Standard Methods for the Examination of Water and Wastewater, 21st Edition, American Public Health Association, Washington. D.C, 2005.
2. Bureau of Indian Standards for analysis of water and wastewater (IS3025).
3. Sawyer C. N., McCarty P. L., and Parkin, G. F. Chemistry for Environmental Engineering and Science, 5th Edition, McGraw Hill, 2013.
4. Anil K. De. Environmental Chemistry, New Age International Ltd., New Delhi, 2003.

CE6611E BIOLOGICAL PROCESS DESIGN FOR WASTEWATER TREATMENT

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions:39

Course outcomes:

- CO1: Describe the range of conventional and advanced biological treatment processes for bulk organics, nutrients and micro pollutants
CO2: Design the biological reactors based on bio-kinetics
CO3: Assess the performance of bioreactors under various conditions
CO4: Select appropriate processes for specific applications based on practical design considerations

Constituents of Wastewater - Sources - Significant Parameters - Fundamentals of Process Kinetics, Enzyme Reactions - Bioreactors - Design Principles - Wastewater Treatment Systems - overview of Primary, Secondary and Tertiary Treatments – Fundamentals of Biological Treatment, Microbial Metabolism, Evaluation of Bio-kinetic Parameters- Modeling Suspended Growth Treatment Process

Activated Sludge Process - Modifications, Biological Nitrification and Denitrification - Attached Growth Biological Treatment Systems -Trickling Filters - Rotating Biological Contactors – membrane bio-reactor- Sequencing Batch Reactor-Moving bed biofilm reactor (MBBR) - Waste Stabilization Ponds and Lagoons - Aerobic Pond, Facultative Pond, Anaerobic Ponds-Polishing Ponds, Aerated Lagoons

Anaerobic Processes – Process Fundamentals - Standard High Rate and Hybrid Reactors, Anaerobic Filters- Expanded /Fluidized Bed Reactors - Upflow Anaerobic Sludge Blanket Reactors - Expanded Granular Bed Reactors - Two Stage/Phase Anaerobic Reactors – On-site wastewater treatment systems - Sludge Digestion, Sludge Disposal.

References:

1. Metcalf, L., and Eddy, P. Wastewater Engineering; Treatment and Reuse. 5th Edition, Tata McGraw-Hill, New Delhi, 2013.
2. Arceivala, S. J. and Asolekar, S. R. Wastewater Treatment for Pollution Control. 3rd Edition, McGraw-Hill Education (India) Pvt. Ltd., New Delhi, 2006.
3. Benefield, L.D. and Randall C.W. Biological Processes Design for wastewaters. Prentice-Hall, Inc. Eaglewood Cliffs, 1989.
4. Grady, Jr., Leslie, C.P., Glen, T. D., Nancy G. Love, and Carlos, D. M. Biological wastewater treatment. CRC Press, 2011.
5. Gray N. F. Biology of Wastewater Treatment. Oxford University Press, London, 1989.

CE6612E AIR POLLUTION MODELLING, MONITORING AND CONTROL

L	T	P	O	C
3	0	2	7	4

Total Sessions: 65 (Lecture-39, Practical-26)

Course Outcomes:

- CO1. To identify the impact of air quality on human health and environment
- CO2: To suggest suitable methods for monitoring various air quality parameters.
- CO3. To model the dispersion of air pollutants under various atmospheric conditions
- CO4. To design air pollution control system as per regulatory requirements

Air Pollution – historical perspective, Air pollutants –definition and classification, properties of gaseous and particulate pollutants, effects of Air pollution on plants, animals, materials, human health. Sources of Air pollution, Emission inventory, Sampling and Analysis: Ambient air sampling and Stack sampling, sampling frequency, sampling network design, Air quality standards and Air Quality Index, Rules and Regulations, Air pollution meteorology: Atmospheric energy balance, environmental lapse rates and atmospheric stability, winds, wind profiles, plume behaviour, convective current, turbulence.

Dispersion of Air pollutants, Introduction to various air quality models – steady state, dynamic, continuous, discrete and empirical, Box model, Gaussian dispersion model, Prediction of effective stack height - physics of plume rise, Holland's equation, Briggs equation, modifications of Gaussian dispersion models, Receptor models-CMB, PMF. Air quality monitoring instruments, Indoor Air Pollution – Cause and Effects.

Air pollution control devices, theory and design. Control of Particulate matter, settling chambers, cyclones, spray towers, bag-filters, electrostatic precipitators, etc. Control of gaseous pollutants, Control devices for vehicular emissions. Noise Pollution – effects of noise, measurement methods, Noise abatement and Control.

Practical Sessions:

1. Sampling and analysis of suspended particulate matter, SO₂, and NO₂, in air.
2. Dispersion modelling using AERMOD and CALINE 4.
3. Demonstration of Plume rise models.
4. Receptor modelling using CMB and PMF.
5. Modelling Indoor Air Quality using fundamental mass balance models.
6. Noise measurements.

References:

1. Vallero, Daniel A. Fundamentals of air pollution. Academic press, 2014.
2. Seinfeld, John H., and Spyros N. Pandis. Atmospheric chemistry and physics: from air pollution to climate change. John Wiley & Sons, 2016.
3. Wark, Kenneth, and Cecil Francis Warner. Air pollution: its origin and control, 1981.
4. De Nevers, Noel. Air pollution control engineering. Waveland press, 2010., McGraw Hill, 1st Edition, 2017.
5. Brauer, Heinz, and Yalamanchili BG Varma. Air pollution control equipment. Springer Science & Business Media, 2012.

CE6613E ENVIRONMENTAL IMPACT ASSESSMENT

L	T	P	O	C
3	0	0	6	3

Total hours: 39

Course Outcomes:

CO1: Demonstrate knowledge on the concept and procedure of environmental impact assessment

CO2: Quantify the impact of projects on physical environments using mathematical tools

CO3: Propose measures to mitigate environmental impacts

CO4: Prepare an EIA report with suitable environmental management plan

Evolution of EIA, Concepts, EIA vs Strategic Environmental Assessment (SEA), EIA Procedure overview- Screening, Scoping, Base Line Studies, Impact identification, impact prediction, mitigation, public participation, Initial Environmental Examination, Matrices, Check Lists, Networks, role of GIS in EIA, Rapid and Comprehensive EIA

Legislative and Environmental Clearance Procedures in India, Prediction Tools for EIA, Assessment of Impacts - Air - Water - Soil - Noise - Biological - Socio Cultural Environment, quantitative evaluation

Public Participation- levels, Resettlement and Rehabilitation, Documentation of EIA, Environmental Management Plan, Post Project Monitoring, Case Studies in EIA.

Environmental Audit, Life Cycle Assessment, Material flow analysis, life cycle costing, Environmental Management System.

References:

1. Canter, R. L., Environmental Impact Assessment, Mc Graw Hill International Edition, 1997.
2. Rau, John G. and David C. Wooten (Ed), Environmental Impact Analysis Handbook, McGraw Hill Book Company, 1980.
3. Hundloe, Tor, Environmental Impact Assessment: Incorporating Sustainability Principles, Springer Nature, 2022.
4. Hanna, Kevin, Routledge handbook of environmental impact assessment, Routledge, 2022.

CE6696E PROJECT PHASE-I

L	T	P	O	C
0	0	0	6	2

Course Outcomes:

CO1: Identify a relevant research problem, carry out literature review and identify the research gaps

CO2: Propose a methodology for solving the problem

CO3: Document and present the work done

The primary objective of the course 'Project Phase I' is to introduce the students to the various areas of research in Environmental Engineering. The students will identify a problem, carry out a systematic and exhaustive literature review and identify the research gaps. The students will propose a methodology for solving the identified problem. At the end of the semester, the students will document their work and make a presentation before the designated evaluation committee.

CE7697E PROJECT PHASE-II

L	T	P	O	C
0	0	0	9	3

Course Outcomes:

CO1: Identify a relevant problem, carry out literature review and identify the research gaps

CO2: Propose a methodology for solving the problem

CO3: Document and present the work done

The student will identify a relevant problem in the broad area of Environmental Engineering and work on it. The study could be experimental, analytical, or computational. At the end of summer vacation, the students will document their work and make a presentation before the designated evaluation committee. This also applies to those who take this up as an internship in an industry/ company/ other institutes.

For students opting for internship, course outcomes will depend on the actual work performed during the internship.

CE7698E PROJECT PHASE-III

L	T	P	O	C
0	0	0	45	15

Course Outcomes:

CO1: Demonstrate theoretical and practical research skills to become independent researcher with high ethical values

CO2: Demonstrate a degree of originality in research emphasizing real life applications

CO3: Develop professional documentation and presentation skills

The student will identify a relevant problem in the broad area of Environmental Engineering and work on it. The study could be experimental, analytical, or computational. At the end of the semester, the students will document their work and make a presentation before the designated evaluation committee. This also applies to those who take this up as an internship in an industry/ company/ other institutes.

For students opting for internship, course outcomes will depend on the actual work performed during the internship .

CE7699E PROJECT PHASE-IV

L	T	P	O	C
0	0	0	45	15

Course Outcomes:

CO1: Demonstrate theoretical and practical research skills to become independent researcher with high ethical values

CO2: Demonstrate a degree of originality in research emphasizing real life applications

CO3: Develop professional documentation and presentation skills

The student will identify a relevant problem in the broad area of Environmental Engineering and work on it. The study could be experimental, analytical, or computational. At the end of the semester, the students will document their work and make a presentation before the designated evaluation committee. This also applies to those who take this up as an internship in an industry/ company/ other institutes.

For students opting for internship, course outcomes will depend on the actual work performed during the internship .

CE6621E DESIGN AND ANALYSIS OF WATER AND WASTEWATER TRANSPORT SYSTEMS

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions:39

Course Outcomes:

- CO1: Analyze the flow of water in conduits and estimate the losses
- CO2: Design and analyze water supply distribution network for various field conditions
- CO3: Design and analyze sewer network for various field conditions
- CO4: Use appropriate computer software packages for the design of water and sewage network

Fluid properties - fluid flow - continuity principle, energy principle and momentum principle - frictional head loss in free and pressure flow, minor heads losses, Carrying Capacity - Flow measurement - Estimation of storage capacity - impounding reservoirs - intakes - gravity and pressure conduits - hydraulics of fluid flow- pumps and accessories - capacity of pumps - selection of pumps - maintenance - economic design of pumps and pumping mains, Jointing, laying and maintenance, water hammer analysis- water meter- instrumentation and SCADA.

Water distribution networks, Distribution system Design, analysis and optimization, distribution and balancing reservoirs, optimal design, pipe materials, appurtenances, design for external loads, basics of transients - corrosion prevention - minimization of water losses - leak detection - storage reservoirs- Storm water Drainage – Necessity of combined and separate system - Estimation of storm water runoff - Formulation of rainfall intensity duration and frequency relationships - Rational methods – Planning factors – Design of sanitary sewer - partial flow in sewers, economics of sewer design - Wastewater pumps and pumping stations- sewer appurtenances - material, construction, inspection and maintenance of sewers

Design of sewer outfalls - mixing conditions; transition flow critical depth in sewers - draw down curves and hydraulic jump - Use of computer software in water transmission, water distribution, sewer and storm water design – EPANET 2.0, SEWER, BRANCH and Canal ++.

References

1. Manual on Storm Water Drainage Systems. CPHEEO, Ministry of Urban Development, GoI, New Delhi, 2019
2. Manual on water supply and Treatment. CPHEEO, Ministry of Urban Development, GoI, New Delhi, 2013.
3. Manual on Operation and Maintenance of Water Supply System. CPHEEO, Ministry of Urban Development, GoI, New Delhi, 2005
4. Manual on Water Supply and Treatment. CPHEEO, Ministry of Urban Development, GoI, New Delhi, 1999
5. Bajwa, G.S. Practical Handbook on Public Health Engineering, Deep Publishers, Shimla, 2003
6. Hammer, Mark J. Water and Wastewater Technology, Prentice Hall, New Jersey, 2001

CE6622E INDUSTRIAL WASTEWATER MANAGEMENT

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions:39

Course Outcomes:

- CO1: Assess various environmental problems due to improper management of industrial wastewater
CO2: Evaluate various technologies for removal of pollutants from industrial wastewater
CO3: Prepare waste treatment flow sheets for industries
CO4: Recommend the pollution control methods for specific industries

Industrial Wastewater - Sources - Characteristics - Environmental Impacts – Regulatory Requirements -Toxicity and Bioassay Tests - Prevention vs Control of Industrial Pollution - Source Reduction Techniques – Waste Audit – Water and energy balance - Evaluation of Pollution Prevention Options - Waste Minimization- Zero Effluent Discharge Systems - Wastewater Reuse.

Equalization - Neutralization - Floatation - Precipitation - Adsorption - Aerobic and Anaerobic Biological Treatment - Sequencing Batch Reactors - High-Rate Reactors - Chemical Oxidation - Ozonation - Photocatalysis - Wet Air Oxidation - Evaporation - Ion Exchange - Membrane Technologies – Advanced Oxidation Processes.

Effluent Disposal on Land/Surface water/ Marine Environment - Residual Management - Industrial Manufacturing Process - Description, Wastewater Characteristics, Source Reduction Options and Waste Treatment Flow Sheet for Textiles - Tanneries -Pulp and Paper - Metal Finishing - Petroleum Refining - Pharmaceuticals - Sugar and Distilleries - Food Processing - Fertilizers - Thermal Power Plants - Electroplating - Industrial Estates.

References:

1. Eckenfelder, W. W. Industrial Water Pollution Control. 3rd Edition, McGraw-Hill, 1999.
2. Arceivala, S. J. and Asolekar, S. R. Wastewater Treatment for Pollution Control. 3rd Edition, McGraw-Hill Education (India) Pvt. Ltd., New Delhi, 2006.
3. Frank Woodard. Industrial waste treatment Handbook. 2nd Edition, New Delhi, 2006.
4. Patwardhan, A. D. Industrial wastewater treatment. PHI Learning Pvt. Ltd., 2017.
5. Metcalf, L., and Eddy, P. Wastewater Engineering; Treatment and Reuse. 5th Edition, Tata McGraw-Hill, New Delhi, 2013.

CE6623E ADVANCED TREATMENT OF WATER AND WASTEWATER

L	T	P	O	C
3	0	0	6	3

Total lecture sessions: 39

Course Outcomes:

- CO1: Demonstrate knowledge on various membrane processes, principles, separation mechanisms and its applications
CO2: Suggest suitable membrane processes for a given condition and carry out its design.
CO3: Analyse and design the treatment process for the removal of dissolved pollutants
CO4: Analyse and design the treatment process for the degradation of organic pollutants

Microstaining, coagulation, electrocoagulation, electro-floatation, precipitation, Filtration- Theory - Microfiltration, Nanofiltration - Ultrafiltration. Principles of Membrane Processes - Types and Classification - Theory of Membrane Separation - Liquid Membranes - Characterization of Membranes - Recent Development in Membranes - Modules and Washing Process - Electrodialysis - Principles, Electrodialysis Stack and its various components

Ion Exchange Capacity - Electrical Resistance of Ion Exchange Membrane - Donnon Dialysis - Reverse Osmosis - Theory and Principle – Membrane Materials - Design Considerations. Design of Membrane Systems - Membrane Bioreactors. Design Principles - Submerged Anaerobic Membrane Bioreactors – Fouling - Rejects in Membranes and its disposal- Synthetic Membranes

Air stripping, Advanced oxidation process – photocatalysis – Sono-catalysis – hydrodynamic cavitation – Fenton process. Electrooxidation, peroxi-coagulation, Electro-Fenton – homogeneous and heterogeneous catalysis. Plasma pyrolysis, gamma ray - based treatment, scale-up of emerging technologies. Hybrid treatment train approach: Case studies.

References

1. Noble R. D., and Stern S. A. Membrane Separations Technology: Principles and Applications, Elsevier, 1995.
2. Vladimir S. K. Liquid Membranes: Principles and Applications in Chemical Separations and Wastewater Treatment, Elsevier, 2009
3. Paul G. J. An Introduction to Advanced Wastewater Treatment (Wastewater treatment engineering), Independently Published, 2018.
4. Nidheesh P. V., Milad M., Mika S., and Zacharias F. Advanced Oxidation Processes for Contaminants of Emerging Concern, 2023
5. Metcalf and Eddy, Inc. Wastewater Engineering, Treatment and Reuse, 5th Edition, Tata McGraw-Hill, New Delhi, 2013.

CE 6624E ENVIRONMENTAL LEGISLATION

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes

- CO1: Demonstrate knowledge about functions of various environmental regulatory authorities.
CO2: Demonstrate knowledge on the importance of Environmental Legislation (Acts and rules) and standards.
CO3: Guide industries to get different Environmental clearances, consents and authorization.

Key Institutions responsible for the formulation and enforcement of Environmental Acts and rules in India. Role of Ministry of Environment, Forests & Climate Change, Central Pollution Control Board, State Pollution Control Boards, Municipal Corporations. Background of Environmental Legislation, Constitutional provisions, Water Act 1974, Air Act 1981 and Environment (Protection) Act 1986: Genesis of the Act, delegation of powers, Role of Central Government, EIA Notification, Siting of Industries, Coastal Zone Regulation, Polluter pays principle, Precautionary principle, Strict and absolute liability principles, public trust doctrine; National Green Tribunal Act, 2010; National Environment Policy

Responsibilities of local bodies in Municipal Solid Waste Management, Responsibilities of stakeholders under Hazardous Waste rules, Biomedical waste rules, responsibilities of generators and role of Pollution Control Boards, Public Liability Insurance for Industries. Environmental Clearance, NOC, Water Consent, Air Consent, Hazardous Waste Authorization, Ground Water Abstraction Approvals, Forest Clearance

Principles of International Environmental Law and treaties. International Environmental Legislation: US EPA, European Environmental laws, United Nations Conference on Human Environment-1972, Kyoto and Montreal Protocols, Doha convention and other important conventions for Environmental protection, General and Industry specific Indian environmental standards for stack emission, industrial wastewater discharge, ambient air quality, noise levels, work zone air quality and sewage water. Comparison of environmental standards of India, US-EPA & European Union. EMS and ISO14000 series.

References

1. CPCB, Pollution Control acts, Rules and Notifications issued there under Pollution Control Series – PCL/2/1992, Central Pollution Control Board, Delhi, 1997.
2. Shyam Divan and Armin Roseneranz, Environmental law and policy in India, Oxford University Press, New Delhi, 2001.
3. Goel, P. K. and K. P. Sharma, Environmental guidelines and standards in India, Technoscience Publications, Jaipur, 1996.
4. Gurdip Singh, Environmental law in India, Macmillan India, New Delhi. 2005.
5. Kailash Thakur, Environmental protection law and policy in India, Deep and Deep publishers. 1997.
6. Mehta, M. C. Lal's Commentaries on Water & Air Pollution and Environment (Protection) Laws, Delhi Law House, 2000.

CE6625E LIFE CYCLE ASSESSMENT AND CIRCULAR ECONOMY

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course objectives

CO1: Evaluate the environmental footprint of various systems, technologies and products.

CO2: Demonstrate knowledge on concepts of sustainability, circular economy and UN Sustainable Development Goals.

CO3: Perform a robust and moderately complex LCA assessment using modern tools.

CO4: Apply the necessary theoretical, practical and research knowledge, skill and aptitude in circularity

Concepts of sustainable development – indicators of sustainability – sustainability strategies – barriers to sustainability – resource degradation – industrialization and sustainable development – industrial ecology – socio-economic policies for sustainable development, UN Sustainable development goals (SDGs); Cleaner production (CP) for achieving sustainability – definition – historical evolution – importance – principles and concepts of CP – benefits – promotion – roles of industry, Green buildings.

Life Cycle Thinking, LCA History and ISO Framework, Goal and Scope Definition, Life Cycle Inventory Analysis, Developing Process Tree/Table, understanding a Unit Process, Customizing/Creating a Unit Process, Economic Input-Output LCA, Material Flow Analysis, Process-Based LCA Demo with OPENLCA, EASETECH, SimaPro, Consequential LCA, LCA Interpretation, Uncertainty in LCA, LCA Case Studies - Applications and Critics, Design for the Environment - UPLCI, Process Planning, and Optimization, Recent Development in LCA.

Linear Economy and its emergence, Economic and Ecological disadvantages of linear economy, Replacing Linear economy by Circular Economy, Development of Concept of Circular Economy, A differential - Linear Vs Circular Economy, Material recovery, Waste Reduction, reducing negative externalities, Explaining Butterfly diagram, Concept of Loops, Role of governments and networks, Sharing best practices, Universal circular economy policy goals, India and CE strategy, ESG.

References:

1. Scott M. H., Chris T. H., and Deanna M. Life Cycle Assessment: Quantitative Approaches for Decisions that Matter, Open access textbook, 2014. (retrieved from <https://www.lcatextbook.com/>)
2. Michael H., Ralph R., and Stig I. O. Life cycle assessment: Theory and Practice, Springer International Publishing AG; 1st ed. 2018.
3. Chris T. H., Lester B. L., and Scott H. M. Environmental Life Cycle Assessment of Goods and Services: An Input-Output Approach, Routledge, 1st edition, 2006
4. Rita S. and Phillip W. Environmental Life Cycle Assessment: Measuring the Environmental Performance of Products, American Center for Life Cycle Assessment, 2014
5. Hejungs R. and Sangwon S. The Computational Structure of Life Cycle Assessment, Springer Science & Business Media, 2002
6. María-Laura F. G., Jorge C. C. A., and Hans B. Towards Zero Waste: Circular Economy Boost, Waste to Resources, Springer International Publishing, 2019
7. Marcello T., and Nicolo C. Strategic Management and the Circular Economy, Routledge, 2018.
8. Sadhan K. G. Circular Economy: Global Perspective, Springer, 2020.
9. Lerwen L., and Seeram R. An Introduction to Circular Economy, Springer Singapore, 2021.

CE6626E APPLIED ENVIRONMENTAL MICROBIOLOGY

Pre-requisite: Basic knowledge in microbiology

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Demonstrate knowledge on the behaviour of microorganisms under various environmental conditions.

CO2: Apply the knowledge of microbiology in water and wastewater treatment.

CO3: Apply the knowledge of microbiology in air pollution control.

CO4: Apply the knowledge of industrial pollution control and microbial forensics.

Tools and Techniques in Microbiology: Microscopy – Light, phase contrast, electron, scanning and transmission electron microscopy, staining techniques for light microscopy, sample preparation for electron microscopy. Calorimetry and spectrophotometry, Electrophoretic techniques – proteins and nucleic acids, PCR, biotyping, serotyping, molecular techniques. Water and Wastewater Microbiology: Microbial aspects of drinking water treatment, Treatment of wastewater by aerobic and anaerobic process - microbiology of Septic tank and Activated Sludge including process, loading parameters, Trickling filters including types of media, microbiology, Biodiscs, Oxidation ponds, Different types of lagoons, Microbial fuel cells, Bio monitors and Bioindicators.

Soil Microbiology - Introduction to soil microbiology, Soil as a microbial habitat, Microbial populations and activities in soil, Soil microbial community - microfauna - fungi and bacteria, Microbial transformation of carbon, phosphorus and sulphur, iron and manganese; Nitrogen cycle - nitrification, denitrification, ammonification, immobilization, Microbial interactions in soil, Bioleaching, Bioremediation. Industrial Microbiology - Exploitation of microorganisms and their products, screening, strain development strategies, immobilization methods, , Fermentation - Types of fermenters and fermentations- single, batch, continuous, multiple, surface, submerged and solid state. Biofuels: ethanol, methane, and biogas.

Air Microbiology - Significance of Microorganisms in air, Bio-aerosols - Dust phase and Droplet phase, Factor affecting growth of microorganisms in air, Aeromicrobiological (AMB) pathway - Launching, Transport and Deposition, Techniques of trapping airborne microbes - Gravity sedimentation methods, Impaction methods, Impingement techniques and other methods, bio-filters. Microbial Forensics - Types and identification of Bacteria and Viruses in Forensic Science, Microbial profiles as identification tools, use of microorganisms in bioterrorism, Anthrax, transmission of HIV as a criminal act, role of microbes in food poisoning. Extremophiles, Metagenomics, Space Microbiology.

References:

1. Bitton, G. Wastewater Microbiology. 3rd Edition, John Wiley & Sons, Inc., Hoboken 2005.
2. Pelczar, Jr, M.J., Chan, E.C.S., Krieg, R.N., and Pelczar M. F, Microbiology, 5th Edition, Tata McGraw-Hill Publishing Company Limited, New Delhi, 2001.
3. Ronald M. Atlas and Richard Bartha Microbial ecology: Fundamentals and Applications. Pearson Education India, 1997.
4. Ananthanarayan and Paniker's, Textbook of Microbiology, Eleventh Edition, University Press, 2020
5. Rajendran, P. and Gunasekaran, P. Microbial bioremediation in Microbiology: Applications and Current trends, Pointer Publishers, 2007
6. N S Subba Rao. Soil Microbiology. Oxford and IBH, 2020.
7. Whitaker and Stanbury. Principles of Fermentation Technology. Butterworth-Heinemann, 2016.

CE6627E FUNDAMENTALS OF AEROSOL SCIENCE

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions:39

Course Outcomes:

- CO1. To evaluate the formation and dynamic behaviour of aerosols in atmosphere
- CO2: To demonstrate knowledge on the basic concepts of aerosols and their physico chemical characteristics.
- CO2. To apply mathematical models for the prediction of aerosol deposition
- CO3. To assess the role of aerosols in climate change and human health

Aerosol Definition; Particle size, shape and density; Gas and Particle Motion, Straight line acceleration and Curvilinear particle motion, Newton's and Stokes Law, Slip correction Factor, Aerodynamic diameter, Behavior of non-spherical particles, Particle size distribution and concentration, Log normal distribution, Adhesion of particles, Brownian motion and diffusion, Aerosol thermodynamics and Kinetics, Coagulation and coagulation kernels. Condensation and evaporation, Kelvin Effect, Homogeneous and heterogeneous nucleation, New particle Formation, saturation vapor pressure corrections.

Electrical Properties – units, electric fields, charging mechanism, corona discharge; Optical Properties of aerosols – Definition, Extinction, scattering, visibility, optical measurements, aerosol optical depth (AOD); Aerosol Deposition – Inhaled aerosols and health implications, Deposition Models, Analysis techniques, Methods of measurement and instrumentation. Bioaerosols – Characteristics and Sampling.

Aerosol and Global Climate: Trends in anthropogenic emissions and troposphere composition, Solar and terrestrial radiation; Effect of pollutants on Earth's radiation budget, Radiation scattering by aerosols and clouds, Aerosol-cloud interactions, Regional and global climate change, Models for global warming and cooling.

References:

1. Hinds, William C., and Yifang Zhu. Aerosol technology: properties, behavior, and measurement of airborne particles. John Wiley & Sons, 2022.
2. Friedlander, Sheldon K. Smoke, dust, and haze. Vol. 198. New York: Oxford university press, 2000.
3. Kulkarni, Pramod, Paul A. Baron, and Klaus Willeke, eds. Aerosol measurement: principles, techniques, and applications. John Wiley & Sons, 2011.
4. Seinfeld, John H., and Spyros N. Pandis. Atmospheric chemistry and physics: from air pollution to climate change. John Wiley & Sons, 2016.

CE6628E ENVIRONMENTAL FORENSICS

L	T	P	O	C
3	0	0	6	3

Total hours: 39

Course Outcomes:

- CO1: Demonstrate knowledge in the different Environmental Acts and statutes pertaining to Environmental forensics in India.
CO2: Advice on the scientific tools/techniques suitable for a particular Environmental forensic investigation.
CO3: Adopt proper sampling and testing method for Environmental forensics investigation.
CO4: Carry out an Environmental forensic investigation.

Principles of international environment law -liability principles-polluter pays principle, principle of preventive action-precautionary principle-principle of public trust.

Environmental redress mechanism in India-Constitutional provisions, IPC provisions, tort law provisions, Water (Prevention and Control of Pollution) Act, 1974 -Air (Prevention and Control of Pollution) Act, 1981, Environmental (Protection) Act, 1986- and corresponding rules -The National Green Tribunal Act, 2010 -Other environment related rules at the national and state level- Case law.

Types of environmental forensic problem- Forensic techniques used in environmental litigation-Aerial photography, Remote sensing, Underground tank corrosion models, Inventory reconciliation, Chemical fingerprinting, Use of stable and radioactive isotopes, dendroecology, Microbial techniques-traditional microbial forensics, DNA Fingerprinting techniques, Use of Geographic Information System (GIS), Use of contaminant transport models, source apportionment methods-Chemical mass balance (CMB) modelling, Principal component analysis (PCA), Positive matrix factorization (PMF).

History, chemistry and transport of chlorinated solvents, petroleum hydrocarbons, crude oil and refined products, Transport in groundwater.

Environmental sampling and analysis for forensic applications -soil collection for chemical analysis, groundwater sampling, air sampling, analysis methods.

Indian Standards for sampling and testing –Air, Water and Soil. Standard protocol for environmental forensic investigation- INTERPOL procedure for typical cases. Guidelines on liability allocation following forensic investigations.

References:

1. Sands, Philippe, Principles of International Environment Law, 2nd ed., Cambridge, UK: Cambridge University Press, 2003.
2. Morrison, Robert D, Environmental Forensics: Principles and Applications, CRC Press, 2000.
3. Hester, R. E and R. M. Harrison (Ed.), Environmental Forensics, RSC Publishing, 2008.
4. Murphy, Brian L. and Robert Morrison (Ed.), Introduction to Environmental Forensics, Elsevier Academic Press, Burlington, USA, 2007.
5. INTERPOL, Pollution crime forensic investigation manual (Vol 1&2), Lyon: INTERPOL General Secretariat, 2014
6. Website of the Ministry of Environment, Forest and Climate Change, Government of India.

CE6629E ASSESSMENT AND MANAGEMENT OF ENVIRONMENTAL RISK

L	T	P	O	C
3	0	0	6	3

Total hours: 39

Course Outcomes:

- CO1: Demonstrate knowledge in risk assessment and risk communication
- CO2: Carry out human health risk assessment for a given exposure scenario
- CO3: Carry out quantitative microbial risk assessment for a given exposure scenario
- CO4: Demonstrate knowledge in ecological risk assessment

Concepts of hazard and risk, environmental risk- NAS framework for human health risk assessment: hazard identification- Environmental toxicology, dose-response assessment, exposure assessment, risk characterization- carcinogenic and non- carcinogenic risk assessment- exposures via ingestion, inhalation, dermal uptake- bio-concentration-radiation risks- deterministic vs. probabilistic risk assessment-managing health risk from chemicals.

Quantitative Microbial risk assessment (QMRA) - microbial risk vs. chemical risk, dose-response models in QMRA- risk of infection, illness, fatality- managing health risk from microorganisms.

Global Burden of Diseases-Concept of DALY- calculation of DALY

Risk Communication- the US EPA SALT framework of risk communication

Ecological Risk Assessment (EcoRA), US EPA's EcoRA framework- stressors- assessment endpoints- conceptual models- planning- problem formulation- analysis- risk characterization. Ecological risk indices.

References:

1. Suter, Glenn W. II, Ecological Risk Assessment (II Edition), Florida: CRC Press, 2006
2. National Research Council, Risk Assessment in the Federal Government: Managing the Process, Washington, DC: The National Academies Press, 1983
3. Robson, Mark, William Toscano (Ed.), Risk Assessment for Environmental Health, John Wiley and Sons Inc, 2007.
4. Simon, Ted, Environmental risk assessment: A toxicological approach, CRC Press, 2019.
5. WHO, Quantitative microbial risk assessment -Application for water safety management, Geneva: World Health Organization, 2016.

CE6630E ECOLOGICAL AND ECOSYSTEMS ENGINEERING

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

- CO1: Demonstrate knowledge on the evolution of ecosystems and flow of energy.
- CO2: Estimate the productivity and material recycling of ecosystem
- CO3: Demonstrate knowledge on ecological modelling.
- CO4: Evaluate the sustainable loading for self-organizing processes.

Development and evolution of ecosystems – Principles and concepts – Energy flow and material cycling – productivity – Classification of ecotechnology – ecological engineering. Classification of systems – Structural and functional interactions of environmental systems –Mechanisms of steady-state maintenance in open and closed systems.

Principles and components of Systems and Modeling, Modeling and ecotechnology – Classification of ecological models – Applications- Ecological economics- Self-organizing design and processes – Multi seeded microcosms. Interface coupling in ecological systems - Concept of energy - Adapting ecological engineering systems to potentially catastrophic events - Agro ecosystems - Determination of sustainable loading of ecosystems.

Eco sanitation – Eco-sanitation vs. conventional sanitation, Composting toilets: principles, practices and types, Social factors impacting use of composting toilets, Soil infiltration systems–Wetlands and ponds–Source separation systems– Aqua cultural systems – Agro ecosystems – Detritus based treatment for solid wastes – marine systems- Case studies.

References:

1. Patrick C. Kangas, Ecological Engineering: Principles and Practice, CRC Publishers, 2003.
2. Marty D. Matlock and Robert A. Morgan, Ecological Engineering Design: Restoring and Conserving Ecosystem Services, John Wiley & Sons, Inc. 2011.
3. Rana, S.V.S. Essentials of Ecology and Environmental Science, PHI Learning, 2007.
4. Namita Joshi and P.C. Joshi, A Textbook of Ecology and Environment, Himalaya Publications, 2000.

CE6631E HAZARDOUS AND SPECIAL WASTE MANAGEMENT

L	T	P	O	C
3	0	0	6	3

Total lecture sessions: 39

Course outcomes:

- CO1: Demonstrate knowledge on the importance of hazardous and special waste management
- CO2: Advice on the environmental laws and regulations governing the management of hazardous and special wastes
- CO3: Quantify and evaluate the impacts of hazardous and special waste disposal on human health and ecosystem
- CO4: Advice on suitable remedial measures to reduce the impacts of waste disposal

Introduction to Hazardous wastes: Definition – generation – classification – Characterization – Landmark episodes – TCLP Tests – Waste Sampling – flammability of chemicals – fate and transport of chemicals – The magnitude of the problem – Health effects – Labelling, Handling and transport of Hazardous Wastes – Basel Convention and other international statutes – Environmental legislation – Hazardous Waste (Management and Handling) Rules (2016), Guidelines for Hazardous waste management (HWM) from MoEFCC – Overseas regulatory frameworks (USA and EU) on HWM.

Characterization and site assessment, Waste minimization and resource recovery – Treatment and disposal methods: Physicochemical processes; Biological processes; Stabilization and solidification; Thermal methods; Land disposal, Groundwater contamination, Current Management Practices: Environmental audit, Pollution Prevention, Facility Development and operation, Site Remediation: Quantitative risk assessment, site and subsurface characterization, Containment, remedial alternatives.

Management of Special wastes: Nuclear waste: Introduction, Radioactive Decay and Emissions, Parent/Daughter Decay and Use of the Chart of the Nuclides, Radiation Effects on Humans, Natural Radioactivity, Fission Power, Weapons and Other Sources of Radioactivity, Site Cleanup and Transportation of Waste, Waste Types and Disposal, Remediation Case Studies, Nuclear Accidents. Biomedical waste: Regulatory framework, categorization; generation, collection, transport, treatment and disposal. Electronic waste (E-waste): Issues and Status in India and Globally, E-Waste Management Rules 2016 and Management Challenges. C&D waste: overview, Regulation, Beneficial Reuse of C&D Waste Materials.

References:

1. Guidelines for Hazardous and Other waste Rules MoEFCC (2016), Govt. of India.
2. Freeman, Harry M. Standard handbook of hazardous waste treatment and disposal.(1989).
3. LaGrega, Michael D., Phillip L. Buckingham, and Jeffrey C. Evans. Hazardous waste management. Waveland Press, 2010.
4. Freeman, Harry M. Standard handbook of hazardous waste treatment and disposal.(1989).
5. Martin, Edward J., and James H. Johnson. Hazardous waste management engineering. (1986).
6. Wentz, Charles A., Hazardous Waste Management. 2nd Edition, McGraw Hill, New York, 1995
7. National Research Council, Risk Assessment in the Federal Government: Managing the Process, Washington, DC: The National Academies Press(US), 1983
8. Shah, Kanti L. Basics of Solid and Hazardous Waste Management Technology. Prentice Hall..2000.

CE6632E CARBON CAPTURE AND STORAGE

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions:39

Course Outcomes:

- CO1: Analyze and estimate the carbon emission from different sector
- CO2: Advice on different carbon sequestration techniques for selected industries
- CO3: Suggest clean energy mechanisms for the mitigation of pollution
- CO4: Demonstrate knowledge on various international conventions on greenhouse gases (GHGs)

Climate Change Mitigation: Global warming and climate change – GHGs – GHG Reduction – Issues in Energy Intensive Industries – Carbon emission –CO₂ Properties –Measurement – Stabilising Atmospheric Carbon Dioxide – Global Carbon Cycle – Carbon Capture and Sequestration (CCS): Modalities and Procedures, Case studies – Cement manufacturing, Petrochemical Industries. Fossil Power Generation with CCS: Policy Development for Technology and Deployment, Carbon Neutrality.

Capturing carbon: Combustion – Post-Combustion Capture – Capture by Oxyfuel Combustion – Pre-Combustion Capture – Carbon Dioxide Utilisation.. Geological Storage of Carbon Dioxide through Enhanced Hydrocarbon Recovery – Enhanced Oil Recovery (EOR) – Enhanced Coal Bed Methane Recovery – Shale Gas – storage options. Kyoto Protocol and its implication- Kyoto mechanisms - Emission Trading (ET), Clean Development Mechanism (CDM), Joint Implementation (JI), Prototype carbon funds (PCF) – carbon finance. Important global conventions on GHG reduction, UNFCCC, Role and Function of IPCC.

Forestry Perspective: Source or Sink of Carbon – Climate Change Mitigation potential of Forest and its evaluation – Land use, Land use Change and Forestry (LULUCF) – Evolution of LULUCF. Evaluation of Carbon Credit of solar energy systems, Carbon footprints. Carbon Negative Technologies.

References:

1. Hester, Ronald E., and Roy M. Harrison, eds. Carbon capture: sequestration and storage. Vol. 29. Royal Society of Chemistry, 2010.
2. Wilson, Elizabeth, and David Gerard. Carbon capture and sequestration: integrating technology, monitoring, regulation, 2007.
3. Faure, Michael, Joyeeta Gupta, and Andries Nentjes. Climate change and the Kyoto Protocol. Edward Elgar Publishing, 2003.

CE6633E ATMOSPHERIC PROCESSES AND CLIMATE CHANGE

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions:39

Course Outcomes:

- CO1. Demonstrate expert knowledge of weather and climate of earth
- CO2: Apply thermodynamic concepts to the analysis of atmospheric phenomena.
- CO3. Apply the knowledge of satellite observations to study atmospheric processes.
- CO4. Evaluate effects of global warming and its role in climate change

Elements of Atmosphere and Physical Meteorology: Vertical temperature and pressure profile of atmosphere, atmospheric composition, scale height, solar and terrestrial radiation, transport of matter, energy and momentum in nature, wind, type of clouds and rain formation process. Meteorology of tropics, Conventional observational techniques, conventional measurement of pressure, temperature, humidity, wind, precipitation, visibility, Modern Observational Techniques: LIDARS, SODARS, RADARS, CTD, ARGO, Introduction of remote sensing from space.

General Meteorology: Thermodynamics of dry and moist air: atmospheric stability and dry adiabatic lapse rate, saturated adiabatic lapse rate, pseudo adiabatic processes and equivalent potential temperature Clausius-Clapeyron (C-C) equation. Micrometeorology: Atmospheric fluid mechanics, turbulence, surface roughness and convective boundary layer.

Satellite Meteorology: Introduction to satellite meteorology, weather satellite and orbits, satellite images, satellite winds, Data acquisition, data processing and applications, monitoring the global environment, Climate Change: Global Climate – Past, Present and Future, Elements of weather and climate modeling, Climate variability and climate change, Global warming, Basic equation and dynamics of atmosphere, Elementary idea of Global climate models (GCMs), Comparison of various IPCC assessment reports (ARs), Impacts of climate change – Global and India.

References:

1. Seinfeld, John H., and Spyros N. Pandis. Atmospheric chemistry and physics: from air pollution to climate change. John Wiley & Sons, 2016.
2. Wallace, John M., and Peter V. Hobbs. Atmospheric science: an introductory survey. Vol. 92. Elsevier, 2006.
3. Brock, Fred V., and Scott J. Richardson. Meteorological measurement systems. Oxford University Press, USA, 2001.
4. Ruddiman, William F. Earth's Climate: past and future. Macmillan, 2001.
5. Andrews, David G. An introduction to atmospheric physics. Cambridge University Press, 2010.
6. Mukherji, Aditi. "Climate Change 2023 Synthesis Report." (2023).

CE6634E THERMAL TECHNIQUES FOR WASTE TREATMENT

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

- CO1: Demonstrate knowledge about energy recovery potential of waste materials
- CO2: Provide guidance on appropriate technologies for waste-to-energy conversion
- CO3: Apply design criteria for biomass-based thermo-chemical treatment units
- CO4: Demonstrate knowledge on bioenergy production systems

Thermal Techniques: Introduction, Classification of Waste as Fuel – Physico-Chemical Characteristics and Calorific Value of Components- Incinerability, Conversion Devices – Incinerators, Gasifiers and Digesters. Incineration, Different Types of Incineration, and Design of Incineration Plants. Pyrolysis: Types – Manufacturing of Biochar, Charcoal, Pyrolytic Oils and Gases– Yields and Application, Liquefaction. Pollution Control Techniques for Thermal Facilities.

Biomass Gasification: Gasifiers – Fixed Bed System – Updraft and Downdraft Gasifiers – Fluidized Bed Gasifiers – Design and Operation – Gasifier Burner Arrangement for Thermal Heating – Gasifier Engine Arrangement and Electrical Power – Equilibrium and Kinetic Consideration in Gasifier Operation. Biomass Combustion: Biomass Stoves – Improved Chullahs, Types, Fixed Bed Combustors, Types, Inclined Grate Combustors, Fluidized Bed Combustors, Design and Operation, Cogeneration or Combined Heat and Power (CHP) from Waste.

Bioenergy: Production System, Design and Constructional Features – Biomass Resources and their Classification – Biomass Conversion Processes – Alcohols and Other Biofuels Production from Biomass.

Biogas, Anaerobic Digestion, Properties of Biogas – Biogas Plant Technology and Status – Types of Biogas Plants – Applications – Bioenergy Programme in India.

References

1. Rogoff, Marc J., and Francois Screve. Waste-to-Energy: technologies and project implementation. Academic Press, 2019.
2. Young, Gary C. Municipal solid waste to energy conversion processes: economic, technical, and renewable comparisons. John Wiley & Sons, 2010.
3. Tchobanoglous, G., Hilary Theisen and Samuel Vigil. Integrated solid waste management: engineering principles and management issues, McGraw Hill, 2014.
4. Metcalf & Eddy, Mohammad Abu-Orf, Gregory Bowden, Franklin Louis Burton, William Pfrang, H. David Stensel, George Tchobanoglous, Ryujiro Tsuchihashi, and AECOM (Firm). Wastewater engineering: treatment and resource recovery. McGraw Hill Education, 2014.

CE6635E ENVIRONMENTAL MODELING AND SIMULATIONS

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcome

CO1: Analyze the system performance using simulation models

CO2: Optimize environmental systems using optimization models

CO3: Employ model-based environmental analysis

CO4: Choose a suitable environmental systems analysis method and tool for a given decision situation

Systems modeling as applied to environmental Systems- Models for environmental systems, Definition, Classification; Nature of Environmental Systems- modeling specific environmental systems - Role of Optimization Models.

Deterministic Models/Linear Programming - Dynamic Programming - Separable and Nonlinear Programming Models – Lumped and distributed parameter model - Formulation of Objective Functions and Constraints for Environmental Engineering Planning and Design-Probabilistic Models - Fuzzy Models – Simulation Models; Continuous, discrete, Monte-Carlo – Introductory exercises on MATLAB, spreadsheet and other modelling software.

Introduction to air quality models; Meteorology; Atmospheric stability and turbulence; Gaussian plume model and modifications; Numerical models, Urban diffusion models - Global radiation balance and climatic changes - Transport and fate of pollutant in aquatic systems; Introduction to river, estuarine and lake hydrodynamics; Stratification and eutrophication of lakes; Dissolved oxygen model for streams.

References:

1. Deaton, M., and Winebrake, J. Dynamic Modeling of Environmental Systems. Springer Science and Business Media, 1999.
2. Ramaswami, A., Milford, J. B., Small, M. J. Integrated Environmental Modeling: Pollutant Transport, Fate, and Risk in the Environment. John Wiley, 2005.
3. Walter J., and Weber Jr. Environmental Systems and Processes – Principles, Modeling and Design. Wiley Interscience, 2001.
4. Jorgensen, Sven E. Handbook of environmental and ecological modeling. CRC Press, 2017.
5. Maurya, Satya Prakash, Akhilesh Kumar Yadav, and Ramesh Singh, eds. Modeling and Simulation of Environmental Systems: A Computation Approach. CRC Press, 2022.

CE6636E DESIGN OF ENGINEERED LANDFILLS

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

- CO1: Demonstrate knowledge about various techniques of engineered landfills
- CO2: Design liners, covers, and other components of engineered landfills
- CO3: Apply knowledge of leachate's chemical constituents for pollution abatement
- CO4: Demonstrate knowledge on landfill reclamation and mining

Landfills: Geoenvironmental Applications – Introduction – Basic Considerations of Ground Improvement Systems – Soil Structure – Soil-Waste Interaction – Subsurface Contamination – Sources – Waste Disposal on Land – Impact of Contamination – Principles, and Planning of Landfills – Site Selection – Site Investigation and Characterization – Basic Design Components – Leachate Quantity and Quality, Compatibility of Liner Materials to Chemicals in Leachate.

Landfill Liners: Liner System – Different Types – Clay Liners, Properties of Liners – Design Aspects and Considerations – Landfill Barriers – Geosynthetics for Waste Disposal – Overview – Geo-Synthetic Liners, Composite Liners, Geosynthetic Clay Liners (GCLs), Geomembranes - Leakage and Transport, Landfill Containment Walls, Design of Leachate Collection and Recirculation Systems.

Landfill Covers: Landfill Gas – Generation Profile – Principal Gas Components and Their Properties – Landfill Gas Collection and Monitoring Systems – Vent Pipes – Data Assessment and Remedial Solutions, Soil Covers, Site Preparation, Establishing Grass Cover– Local Vegetation– Trees and Shrubs– Maintenance of Covers– Bio-Cover System, Fundamentals of Slope Stability, Geogrids. Closure of Landfills – Post-Closure Monitoring. Aged Landfill Reclamation – Landfill Mining – Utilization of Soil-Like Materials. Ash Disposal – Slurry Ponds.

References:

1. Peavy, Howard S., Rowe Donald. R. and George Tchobanoglous. Environmental Engineering, McGraw Hills, New York, 2020.
2. Christensen, Thomas H., Raffaello Cossu, and Rainer Stegmann. Landfilling of waste: Biogas. CRC Press, 2020.
3. Swachh Bharat Mission, Municipal Solid Waste Management Manual, Part II: The manual, Central Public Health and Environmental Engineering Organization (CPHEEO), Ministry of Urban Development, 2016.
4. Tchobanoglous, G., Hilary Theisen and Samuel Vigil. Integrated solid waste management: engineering principles and management issues, McGraw Hill, 2014.
5. Bagchi, Amalendu. Design of landfills and integrated solid waste management, John Wiley & Sons, 2004.
6. Fang, Hsai-Yang, and Ronald C. Chaney. Introduction to environmental geotechnology. CRC press, 2016.
7. Townsend, Timothy G., Jon Powell, Pradeep Jain, Qiyong Xu, Thabet Tolaymat, and Debra Reinhart. Sustainable practices for landfill design and operation. Springer, 2015.

CE6425E BIOREMEDIATION TECHNOLOGIES FOR CONTAMINATED SOILS

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: To examine the sources, causes and effects of soil contamination.

CO2: To distinguish the suitable bioremediation mechanism based on contaminant types.

CO3: To implement appropriate bioremediation technique considering the soil site conditions.

Soil Contamination

Introduction - Basic concepts - Sources of soil contaminants – Natural and man-made – Inorganic and Organic pollutants - Effects of soil contamination - Types of contaminants - Role of physical and chemical properties of soil in contamination; Factors effecting retention and transport of contaminants in soil - Sampling of contaminated soil - Site investigation and monitoring parameters.

Bioremediation mechanism

Bioremediation - Microbial systems of bioremediation - Factors influencing bioremediation (environmental, physical and chemical factors) - Genetic responses of microorganisms to the presence of pollutants - Application of microorganisms for soil treatment - Microbial transformation reactions (aerobic and anaerobic bio-transformations) - Microbial detoxification of specialty chemicals (insecticides, heavy metals, etc.).

Bioremediation methods

Methods of bioremediation – In-situ (Intrinsic and Enhanced) – Bio-venting, bioslurping, Biosparging, bioaugmentation, biostimulation, phytoremediation – Ex-situ – slurry phase, solid phase, land farming, soil biopiles, composting – Bioreactors – Slurry reactor, aqueous reactor – Applicability to contaminants - Advantages – Disadvantages – Case histories – Economic and regulatory considerations.

References:

1. Baker, K.H., and Herson, D.S., Bioremediation, McGraw-Hill Publishing Company, New York, 1994.
2. Cairns, John E. Biological monitoring in water pollution. Elsevier, 2017.
3. Eweis, J.B., Ergas, S.J., Chang D.P.Y., and Schroeder E.D., Bioremediation Principles, McGraw-Hill Publishing Company, Singapore, 1998
4. Fingerman, Milton, ed. Bioremediation of aquatic and terrestrial ecosystems, CRC Press, 2016.
5. Prashanthi, Marimuthu., eds. Bioremediation and Sustainable Technologies for Cleaner Environment. Springer, 2017.
6. Reddy, K.R., and Cameselle, C. Editors, Electrochemical Remediation Technologies for Polluted Soils, Sediments and Groundwater, John Wiley & Sons, Inc., Hoboken, New Jersey, 2009, 760p. (ISBN: 0-470-38343-7).
7. Reddy, K.R., and Adams, J.A., Sustainable Remediation of Contaminated Sites, Momentum Press, New York, December 2014.
8. Sharma, H.D., and Reddy, K.R., Geoenvironmental Engineering: Site Remediation, Waste Containment, and Emerging Waste Management Technologies, John Wiley & Sons, Inc., Hoboken, New Jersey, 2004.
9. Walker, Colin Harold, R. M. Sibly, and David B. Peakall. Principles of ecotoxicology. CRC press, 2014.

CE6447E GEOENVIRONMENTAL ENGINEERING

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

- CO1: Explain the methods to carry out geoenvironmental site investigation
- CO2: Explain the processes that lead to the contamination of a site and its consequences
- CO3: Recommend and guide the implementation of suitable techniques to remediate a site contaminated with a particular type of pollutants
- CO4: Recommend and design a suitable containment system based on the site conditions

Scope of Geo-environmental Engineering- Various Sources of Contaminations- Need for contaminated site characterization- Characterization methods- Preliminary site assessment- exploratory and detailed site investigation- Geostatistical Applications

Solid and Hazardous Waste Management: Classification of waste, Characterization wastes, Environmental Concerns with waste.

Contaminant Release Mechanisms: Vaporization, Dusting, Leaching

Groundwater Contaminant Transport: Transport process- Mass-transfer process

Remediation of contaminated sites - Introduction to Exposure Assessment - Risk-Based Estimation of Required Clean-Up Levels

Remediation Techniques: Treatment Approaches - In-Situ Versus Ex-Situ Treatment - Basis for Treatment Technology Selection - Pump-and-Treat Principles - In-Situ Soil Flushing - Volatilization and Air Pressurization Principles - In-Situ Vitrification Principles -In-Situ Chemical Treatment in Reactive Walls - Solidification/Stabilization- Ex-Situ Chemical Treatment Principles - In-Situ Natural Attenuation Principles - In-Situ Phytoremediation Principles - In-Situ Bioremediation Principles - Other Techniques

Waste Containment- Containment System Implementation - Essentials of Waste Containment - Hydraulic and Physical Containment - Containment Site Selection - Containment Site Improvement -Configurations of Containment Systems: Landfills - Slurry Walls - Drainage Trenches and Wells - Surface Impoundments - Grout Curtains - Composite Systems

Elements of Containment System Design - Leachate Generation - Water Balance in Waste Containment Systems - Leachate Collection and Removal Systems (LCRS) - Flow and Transport Through Barriers - Stability of Waste Containment Systems - Barrier Composition and Performance - Containment System Performance Elements - System Performance Pattern - Types of Barrier Materials -Material Deterioration Mechanisms - System Performance Monitoring Techniques

References:

1. Reddi, Lakshmi, and Hilary I. Inyang. *Geoenvironmental engineering: principles and applications*. CRC Press, 2000.
2. Sharma, Hari D., and Krishna R. Reddy. *Geoenvironmental engineering: site remediation, waste containment, and emerging waste management technologies*. John Wiley & Sons, 2004.
3. Sarsby, Robert W. *Environmental Geotechnics*. Thomas Telford, 2000.
4. Bagchi, Amalendu. *Design of landfills and integrated solid waste management*. John Wiley & Sons, 2004.

CE6503E REMOTE SENSING AND GIS APPLICATIONS IN WATER RESOURCES ENGINEERING

L	T	P	O	C
3	0	2	7	4

Total Sessions:65 (Lecture-39, Practical-26)

Course Outcomes:

CO1: Understand the principles of remote sensing and select appropriate remote sensing data for the intended application.

CO2: Perform digital image analysis to extract data from the remote sensing images.

CO3: Carryout spatial analysis by understanding the principles of GIS and basic GIS operations.

CO4: Apply remote sensing and GIS techniques for solving problems in the field of water resources engineering.

Remote Sensing Concepts

Concepts and foundations of remote sensing- Energy sources and radiation principles- Energy interactions in the atmosphere – Energy interaction with earth surface features - Spectral reflectance of vegetation, soil and water - Atmospheric influence on spectral response patterns

Remote Sensing Satellites

Remote sensing platforms – Sun synchronous systems- Geosynchronous systems-Across track and along track scanning systems – Types of sensor resolutions (Spatial, Spectral, Radiometric and Temporal resolution) – Multispectral and thermal scanners – Characteristics of Remote sensing satellites and sensors (IRS, Landsat, SPOT, IKONOS)

Microwave remote sensing – Active and Passive remote sensing systems - Radar development – Side looking Radar System Operation - Synthetic Aperture Radar – Geometric characteristics of side-looking Radar imagery

Satellite Image Interpretation

Visual Image Interpretation – Standard False Colour Composites – Elements of visual image interpretation

Digital Image Analysis

Digital Image Processing – Storage formats (BSQ, BIL, BIP) – Sources for Geometric and Radiometric distortions in images – Image rectification and restoration – Image histogram – Image enhancement – level slicing, contrast stretching, convolution filtering, Band ratioing (NDVI, SAVI, NDWI) – Image classification – Supervised and unsupervised classification algorithms – Accuracy assessment – land use/ land cover mapping - Principal component transformation

Digital Elevation Models – SRTM, LIDAR Techniques

Concepts of GIS

GIS - Definition, Spatial and attribute data, Components of GIS, DBMS – Geospatial data representation (Raster, Vector) -Sources of GIS data – Data input - Raster geospatial data analysis - Output functions of raster geoprocessing – Vector GIS analysis functions - Vector geoprocessing output functions

Applications

Application of Remote Sensing and GIS with specific reference to land use land cover mapping hydrological modelling and watershed management, drainage delineation, soil moisture estimation, DEM Applications

Practical Exercises: (13 Sessions)

1. Preparation of Standard False Colour Composite (SFCC) and visual interpretation
2. Application of various radiometric enhancements – contrast enhancement, histogram equalization
3. Application of geometric enhancements – image domain - convolution filtering
4. Preparation of vegetation indices
5. Image registration/geo-referencing and supervised classification – Land use /Land cover map preparation
6. Unsupervised classification – Land use /Land cover map preparation
7. Digitization and preparation of vector GIS database of well locations, drainage network, water bodies etc
8. Generating DEM and groundwater contours using spatial interpolation techniques
9. Extraction of drainage network from DEM and watershed delineation using GIS
10. Computation of Area-Capacity for a reservoir using GIS

References

1. Thomas. M. Lillesand, Ralph. W. Kiefer and Jonathan W. Chipman, *Remote Sensing and Image Interpretation*, John Wiley and Sons, Inc., Sixth Edition, 2011
2. John R. Jenson, *Remote Sensing of the Environment: An Earth Resource Perspective*, Pearson Education India, Second edition, 2013
3. George Joseph and Jeganathan C, *Fundamentals of Remote Sensing*, Universities Press, Third edition, 2018
4. John A. Richards and Xiuping Jia, *Remote Sensing Digital Image Analysis: An Introduction*, Springer (Sge), Fifth Edition, 2013
5. Lo C. P and K.W. Yeung, *Concepts and Techniques of Geographic Information Systems*, Pearson Education, Second edition, 2016

CE6512E FLOW AND TRANSPORT IN POROUS MEDIA

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

- CO1: Formulate and solve governing equations for steady and transient groundwater flow
- CO2: Perform groundwater resource estimation and plan schemes for recharge
- CO3: Perform numerical modelling of transport problems in the subsurface

Groundwater and the hydrologic cycle. Occurrence and movement of groundwater - origin, age, distribution, types of aquifers. Darcy's law, hydraulic head and fluid potential, hydraulic conductivity and permeability, heterogeneity and anisotropy of hydraulic conductivity, porosity and void ratio, compressibility and effective stress, transmissivity and storativity. Steady State and transient flow - formulation of the governing equations, limitations of the Darcian approach. Groundwater and well hydraulics - steady flow to a well fully penetrating an aquifer (confined and unconfined), unsteady radial flow to a well fully penetrating an aquifer (confined, unconfined and leaky), effect of well bore storage.

Multiple well systems, partially penetrating wells, bounded aquifers, characteristic well losses, specific capacity. Slug tests. Introduction to flow in the unsaturated zone and flow in fractured formations. Saline water intrusion in coastal aquifers: occurrence, shape and structure of the interface, upconing, control of saline water intrusion. Groundwater modelling, Inverse modelling in groundwater. Artificial recharge of aquifers - concepts, hydraulics and methods. Groundwater budget. Groundwater resource estimation.

Introduction to groundwater contamination. Quality of groundwater - measures of quality, groundwater samples, physical, chemical and biological analyses, water quality criteria, and salinity. Transport and transformation of contaminants in groundwater - processes, formulation of the governing equations and initial and boundary conditions, modelling, solutions for simple cases.

References

1. D. K. Todd and L. W. Mays, *Groundwater*, 3rd ed., John Wiley & Sons, Inc., 2011
2. R.A. Freeze and J. A. Cherry, *Groundwater*, Prentice Hall, Inc. 1979
3. C. W. Fetter, *Applied Hydrogeology*, 4th ed., Prentice Hall, Inc. 2007
4. C. W. Fetter, *Contaminant Hydrogeology*, 2nd ed., Waveland Press, 2008
5. F. W. Schwartz and H. Zhang, *Fundamentals of Groundwater*, John Wiley & Sons, Inc., 2003
6. A. K. Rastogi, *Numerical Groundwater Hydrology*, Penram International Publishing (India) Pvt. Ltd., 2007.
7. V. Batu, *Applied Flow and Solute Transport Modeling in Aquifers*, CRC Press, 2006
8. E. S. Bair and T. D. Lahm, *Practical Problems in Groundwater Hydrology*, Prentice Hall, Inc. 2006

CE6525E HYDROGEOLOGY AND GROUNDWATER DEVELOPMENT

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

- CO1: Perform hydrogeologic investigations for groundwater management
- CO2: Select appropriate methods and perform groundwater exploration
- CO3: Identify appropriate water lifting devices and design these devices

Groundwater and the hydrologic cycle, problems and perspectives, groundwater balance, status of groundwater development and utilization – international and national scenarios, influence of physiography and climate on groundwater availability, major hydrogeologic formations in India, groundwater quality/ contamination in India. Basic concepts of groundwater management, investigations and data collection, conjunctive use of surface and groundwaters, legal aspects of groundwater. Basic geologic and hydrogeologic investigations including surface and subsurface investigations of groundwater, water divining/witching. Types of wells, design and construction of open wells, open wells in alluvial and hard rock formations, failure of open wells, contamination and disinfection of open wells.

Types of tube wells, multiple well system, radial wells and infiltration galleries, design of tube wells - casing, bore size and depth, design of well screen and gravel pack, contamination of tube wells, failure of tube wells, rehabilitation of tube wells. Construction of bored and driven tube wells – drilling equipment and methods, hand boring, mechanical percussion boring, direct and reverse circulation hydraulic rotary drilling, air rotary drilling, principles of rock drilling, drilling with foam, core drilling, calyx drilling, jetting. Installation of well screens and check for well alignment. Well development and well completion.

Pumps used for lifting water - indigenous water lifts, positive displacement pumps, centrifugal pumps, vertical turbine pumps, submersible pumps, propeller and mixed flow pumps, jet pumps, air lift pumps, selection of pumps, power requirement, efficiency and economics.

References

1. D. K. Todd and L. W. Mays, *Groundwater*, 3rd ed., John Wiley & Sons, Inc., 2004.
2. F. W. Schwartz and H. Zhang, *Fundamentals of Groundwater*, John Wiley & Sons, Inc., 2003.
3. S. D. Khepar, A. M. Michael and S. K. Sondhi, *Water Wells and Pumps*, McGraw Hill Education (India) Private Ltd., 2008.
4. A. M. Michael, *Irrigation Theory and Practice*, Vikas Publishing House Pvt. Ltd., 2009.
5. Robert A. Bisson, Jay H. Lehr, *Modern Groundwater Exploration*, John Wiley & Sons, Inc., 2004.
6. K. R. Karanth, *Groundwater Assessment: Development and Management*, Tata McGraw Hill, 1987.
7. H. P. Patra, S. K. Adhikari, and Subrata Kumar, *Groundwater Prospecting and Management*, Springer, 2016.
7. Websites of the Ministry of Jal Shakti, Govt. of India, CGWB, and State GWDs.

CE6527E WATER QUALITY MODELLING

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Formulate the governing equations for contaminant transport process

CO2: Analyze different modeling approaches for water quality problems in rivers, lakes, estuaries, wetlands, saturated and unsaturated porous media and pipe networks

CO3: Apply the models to solve water quality problems and suggest remedial measures

Water quality, standards, Types of contaminant, contaminants and their harmful effects, fate of contaminants, transformation of contaminants, transport of contaminants, Advection, diffusion, dispersion, simple transport models, chemical reaction kinetics, law of mass action, rate constants, types of reactions, equilibrium principles, Introduction to modeling, brief review of mass, momentum and energy balance, governing equations for contaminant fate and transport, Models for nitrogen, bacteria, phosphate and toxicants.

Contaminant transport in surface flows, rivers, hydrodynamic processes in rivers, eutrophication, dissolved oxygen in rivers, Streeter-Phelps equation, modification to Streeter-Phelps Equation, models for lakes and reservoirs, biological zones in lakes, eutrophication in lakes, hydrodynamic processes in lakes and reservoirs, stratification, models for estuaries, tidal processes, hydrodynamics of estuaries, stratification of estuaries, eutrophication in estuaries, models for wetlands, characteristics of wetland, hydrodynamics of wetlands, constructed wetlands

Transport through saturated porous media, groundwater transport phenomena, Groundwater bio reaction and bio kinetics, hydrodynamic dispersion, initial and boundary conditions, unsaturated porous media, capillarity and retention curves, motion equations, initial and boundary conditions fractured media, multiphase flow, flow behavior in pipe networks, quality attenuation, physical characteristics, chemical and biological reactions

Modeling and Management, different types of models, different numerical methods, finite difference method, solution of system of linear equations, Pipe network modeling (EPANET), surface water quality modeling (QUAL2K), Groundwater modeling (MODFLOW and MT3D), unsaturated zone modeling (SUTRA/HYDRUS), fractured rock (ModelMuse) water quality management, application of optimization techniques to water quality management, case studies.

References

1. S.C. Chapra, Surface Water Quality Modeling. Long Grove, Ill.: Waveland Press, 2008.
2. J. Martin, S. McCutcheon and R. Schottman, *Hydrodynamics and Transport for Water Quality Modeling*. Boca Raton, FL: CRC Press, 1st edition, 1998
3. C.Zheng, and G.D. Bennett. Applied Contaminant Transport Modeling, 2nd ed. New York: John Wiley & Sons, 2nd edition, 2002.
4. R. Boulding, Practical Handbook of Soil, Vadose Zone, and Groundwater Contamination. Boca Raton: Lewis Publishers, 2nd edition, 2004.
5. Technical Manuals of EPANET, MODFLOW, MT3D, HYDRUS, QUAL2K

CE6529E WATERSHED MANAGEMENT

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions:39

Course Outcomes:

- CO1: Delineate a watershed
- CO2: Assess land use impacts on watersheds
- CO3: Model soil erosion
- CO4: Plan suitable water harvesting method

Watershed - Definition and delineation, Watershed approach, Hydrologic cycle, Watershed components, Water budget, Watershed assessment, Watershed planning, Watershed as a management unit, Total maximum daily load. Characteristics of watershed - Size, Shape, Physiography, Slope, Climate, Drainage, Land use, Vegetation, Geology and Soils, Hydrology and hydrogeology, Socio-economic characteristics, Basic data on watersheds.

Land use and water quality issues - Land use impacts on watersheds, Residential activities, Municipal sources, Construction, Mining operations, Agriculture, Forestry practices, Recreation. Water quality monitoring – Temperature, pH, Dissolved Oxygen and Biological Oxygen demand, Nutrients, Pathogens, Turbidity, Biological monitoring methods, Species indicators, Biological integrity, Habitat index, Land use index, Water resource assessment, Wateryield.

Erosion - Factors affecting erosion, Effects of erosion on land fertility and land capability, Soil Erosion Modelling, Erosivity and erodibility, Processes, USLE and modified/ revised USLE models for erosion processes. Land Management - Survey, Preparation and development, Soil and soil moisture conservation, Conservation measures, Ploughing, Furrowing, Trenching, Bunding, Terracing, Gully control, Rockfill dams, Brushwood dam, Gabion, Rain water management, Reclamation of saline soils.

Water Harvesting: Rainwater harvesting, Catchment harvesting, Harvesting structures, Soil moisture conservation, Check dams, Artificial recharge, Farm ponds, Percolation tanks. Ecosystem management: Role of ecosystem, Crop husbandry, Soil enrichment, Inter, mixed and strip cropping, Cropping pattern, Sustainable agriculture, Bio-mass management, Dry land agriculture, Silvi pasture, Horticulture, Social forestry and afforestation. Model watershed – Government and NGO Projects.

References

1. Randhir, T.O., Watershed Management: Issues and Approaches, IWA Publishing, 2006
2. Murty, J.V.S., Watershed Management, New Age International, 2013
3. Majumdar, D.K., Irrigation Water Management, Prentice Hall, 2014
4. Kenneth N. Brooks, Peter F. Folliott, Joseph A. Magner, Hydrology and the Management of Watersheds, Wiley-Blackwell, Fourth edition, 2012
5. E.M. Tideman, Watershed Management: Guidelines for Indian Conditions, Omega Scientific Publishers, 1996
6. Rajesh Rajora, Integrated Watershed Management: Field Manual for Equitable, Productive and Sustainable Development, Rawat Publications, 2019

CE6530E ENVIRONMENTAL HYDRAULICS

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions:39

Course Outcomes:

- CO1: Model water quality problems in rivers
- CO2: Model water quality problems in lakes and estuaries
- CO3: Perform hydraulic analysis of water and wastewater treatment plants

Fundamental relationships for flow and transport - general principles, instantaneous equation for fluid flow and transport, Reynold's time-averaged mean flow and transport equations, model resolution, solution techniques, data requirements. Measurement and analysis of flow - measurement of velocity and flow, tracer studies, estimating design flows.

Models for rivers and streams - Completely mixed systems - reaction kinetics, mass balance and steady state solution, particular solutions, feed-forward systems of reactors, feed-back systems of reactors, computer methods. Incompletely mixed systems - diffusion, distributed systems – steady and unsteady cases, steady state solutions, simple time variable solutions. BOD and oxygen saturation, Streeter-Phelps equation, point and distributed sources.

Rivers and streams- stream hydro-geometry, low- flow analysis, dispersion and mixings, flow model complexity and data requirements, estimating mixing in streams and rivers, hydraulic methods for steady and unsteady flows and solution techniques, routing and water quality problems. Mixing in lakes and reservoirs, water balance. Transport and mixing in estuaries.

Hydraulic analysis of various units in water treatment and wastewater treatment plants. Turbulent jets and plumes, ocean wastewater discharge systems.

References

1. S. C. Chapra, *Surface Water Quality Modeling*, Waveland Press, 2008.
2. H. Chanson, *Environmental Hydraulics of Open Channel Flows*, Elsevier Butterworth- Heinemann, 2004.
3. James. L. Martin and Steven. C. McCutcheon, *Hydrodynamics and Transport for Water Quality Modeling*, Lewis Pub, 1999.
4. Hugo. B. Fischer, E. John List, Robert. C. Y. Koh, JorgImberger, and Norman. H. Brooks, *Mixing in Inland and Coastal Waters*, Academic Press, 1979.
5. Gerard Kiely, *Environmental Engineering*, Tata McGraw Hill Education, 2007.
6. Frank. R. Spellman, *Handbook of Water and Wastewater Treatment Plant Operations*, 3rd ed., CRC Press, 2003.
7. S. N. Ghosh, *Tidal Hydraulic Engineering*, Oxford and IBH Pub. Co. Pvt. Ltd, 1998.
8. Larry D. Benfield, Joseph. F. Judkins, and A. David Parr, *Treatment Plant Hydraulics for Environmental Engineers*, Prentice Hall, Inc., 1984.
9. Zhen-Gang Ji, *Hydrodynamics and Water Quality*, Wiley, 2017.

CE6536E DISASTER MANAGEMENT

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Assess the hazards and risks involved in various types of disaster

CO2: Apply ICT and geoinformatics in disaster management

CO3: Apply disaster mitigation strategies following the national initiatives and framework

Disaster, Hazard, Vulnerability, Resilience, Risks. Natural disasters - hydro-meteorological disasters such as flood, flash flood, cloud burst, drought, cyclone, forest fires etc; geological disasters like earthquake, tsunami, landslides, volcanic eruption. Man made disasters - chemical industrial hazards, major power break downs, traffic accidents, fire hazards, biological hazards, nuclear accidents. Environmental hazards - forest hazards (deforestation, degradation and forest fire), land and soil degradation, desertification and pollution (water, air and soil). Disasters and national losses. Historical perspective of disasters in India and the Indian sub continent. Recent major disasters. Disaster management cycle and its components. Earthquake, Landslide, Flood, Drought, Fire etc - classification, causes, impacts including social, economic, political, environmental, health, psychosocial, etc. - Differential impacts - in terms of caste, class, gender, age, location, disability - Global trends in disasters: urban disasters, pandemics, complex emergencies, Global warming and climate change. Adaptation. Dos and don'ts during various types of disasters.

Disaster cycle - Phases, Culture of safety, prevention, mitigation and preparedness, community based DRR, structural and nonstructural measures, roles and responsibilities of the community, Panchayati Raj institutions/ Urban Local Bodies, States, Centre, and other stakeholders including NGOs. Institutional processes and framework at State and Central Level – National and State Disaster Management Authorities. Prediction and early warning systems. Role of information, education, communication, and training, geoinformatics and IT in disaster preparedness, risk assessment, response, recovery, and management. Role of engineers on disaster management.

Components of disaster relief - water, food, sanitation, shelter, health, waste management, Institutional arrangements for mitigation, response and preparedness, Legislation in India on Disaster Management. National disaster management policy. Other related policies, plans, programmes and legislation relevant to/ pertaining to disaster management. Disaster damage assessment. Disaster mitigation. Existing organizational structure for managing disasters in India. Case studies.

References

1. S. R. Sharma, *Disaster Management*, A P H Publishers, 2011.
2. Sreeja. S. Nair, *Training Manual on Geoinformatics Applications in Disaster Management*, NIDM, 2012.
3. Harsh. K. Gupta, *Disaster Management*, Universities Press, 2003.
4. J. P. Singhal, *Disaster Management*, Laxmi Publications, 2010.
5. K. Venugopala Rao, *Geoinformatics for Disaster Management*, Manglam Publishers and Distributors, 2010.
6. Matthews, J.A., *Natural Hazards and Environmental Change*, Bill McGuire, Ian Mason, 2002.
7. Sulphrey, M. M., *Disaster Management*, PHI Learning, 2016.
8. Damon P. Coppola, *Introduction to International Disaster Management*, Butterworth-Heinemann, 2016.
9. Parag Diwan, *A Manual on Disaster Management*, Pentagon Press, 2010
10. Websites of the National Disaster Management Authority, National Institute for Disaster Management, and State Disaster Management Authorities

CE6537E ENVIRONMENTAL FLOWS

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions:39

Course Outcomes:

- CO1: Identify the issues related to environmental flow in rivers
- CO2: Model processes affecting the fate and transport of contaminants in the environment
- CO3: Perform realistic assessment of environmental flows and monitoring in the field

Fundamental concept of environmental flow – catchment drainage network and resource regimes – river ecology, the natural flow regime paradigm and hydro ecological principles – reservoir and dam Planning – institutionalising environmental flow through adaptive reservoir operations – defining environmental water status - effects of catchment change and river corridor engineering

River morphology – Meandering of rivers – Control Volume – Mass balance and advective/ dispersive transport – transport in rivers, lakes, wetlands, and estuaries - sediment transport. Paleolimnology

Stream-aquifer interaction - quality of water – factors effecting water quality - control volume – Mass balance and advective / dispersive transport - groundwater aquifers, Darcy's Law and flow nets – Transient well hydraulics, Transport and retardation – Flow in the unsaturated zone, Biodegradation and bioremediation – Gaussian plume modelling

Environmental flow assessment methods – Hydraulic rating and habitat simulation methods – Flow protection methods – flow restoration methods – ecological limits of hydraulic alteration (ELOHA) – environmental flow relationships, models and applications – setting limits to hydrologic alteration – Implementing and monitoring environmental flow – NatCap (Natural Capital Project) – InVest Software tool for mapping, modelling and visualising ecosystemservices - eWater toolkit – IHA (Indicators of Hydrologic Alterations)

References

1. Angela H. Arthington, *Environmental Flows: Saving Rivers in the Third Millennium*, Univ of California Press, 2012.
2. Kirstie. A. Fryirs and Gary. J. Brierley, *Geomorphic Analysis of River Systems*, Wiley-Blackwell, 2013.
3. Nancy D. Gordon, Thomas A. McMahon, and Brian L. Finlayson, *Stream Hydrology: An Introduction for Ecologists*, John Wiley and Sons, 2004.
4. A. J. Schleiss and R. M. Boes (eds.), *Dams and Reservoirs under Changing Challenges*, CRC Press, 2011.
5. Wilbert Lick, *Sediment and Contaminant Transport in Surface Waters*, CRC Press, 2009.
6. John. S. Gulliver, *Introduction to Chemical Transport in the Environment*, Cambridge University Press, 2007.

EC6130E MACHINE LEARNING FOR INTELLIGENT SYSTEMS

L	T	P	O	C
3	0	0	6	3

Total Sessions:39

Course Outcomes:

CO1: Illustrate the knowledge machine learning to comprehend the problems in intelligent systems.

CO2: Design mathematical frameworks to address real-world data engineering problems.

CO3: Apply mathematical skills for analysis and independent research in the area of intelligent systems.

Introduction to Artificial Intelligence, Data Science, Machine Learning and Applications, The Self Driving Car as an Intelligent System. The Machine Learning Process: Supervised, Unsupervised and Reinforcement Learning. Supervised Learning: Classification and Regression, Training, Testing and Validation. Overfitting and Underfitting - The Bias-Variance Tradeoff, Performance Measurement Metrics, Confusion Matrix.

Linear Regression: General Model, Mathematical Representation, Gradient Descent, Univariate and Multivariate regression. Logistic Regression: Binary Classification, Intuitive and Mathematical Formulation of Logistic Regression, Decision Boundaries. Frequently used Terms: Regularization, Standardization, Normalization, Outliers. Support Vector Machines (SVM): Maximum Margin Classifier, Non-linear Separable Data, Implementation of algorithms using Python.

The k-Nearest Neighbor Algorithm, Naïve Bayes Classification Algorithm - Mathematical Formulation and Numerical Calculations. Decision Tree Node Purity, Decision Tree Constructions using Entropy and Gini Index. Ensemble Methods - Adaboost, Bagging and Random Forest algorithms. Unsupervised Learning: k-Means Clustering Algorithm. Implementation of Algorithms using Python.

Artificial Neural Networks: Perceptron, the Sigmoid Function, Linear Separability, Multi-layer Perceptron, The Feed Forward and Backpropagation Algorithms, Objective Functions, Batch, Stochastic and Mini Batch Gradient Descent Techniques. Exploding and Vanishing Gradients, Non-linear Activation Functions, Advanced Optimization Techniques. Popular Deep Learning Networks: Convolutional Neural Networks (CNN) - Image Processing Basics, Convolutional, Pooling and Fully Connected Layers. Standard CNNs, Transfer Learning. Introduction to Recurrent Neural Networks (RNN) and its Applications. Implementation of Deep Learning Networks using Python. Implementation of Machine Learning Algorithms in Embedded Hardware.

References:

1. Lyla B. Das, Sudhish N. George, Anup Aprem *Artificial Intelligence and Machine Learning: Theory and Practice*, IK International Publishing House, 2023.
2. Aggarwal, Charu C., *Neural Networks and Deep Learning*, Springer 10.978, 2020.
3. C.M. Bishop, *Pattern Recognition and Machine Learning*, Springer, 2006.
4. Aggarwal, Charu C., *Machine learning for text: An introduction*. Springer, 2018

MT6101E EXPERIMENTAL TECHNIQUES FOR MATERIALS

L	T	P	O	C
3	0	2	8	4

Total Sessions: 39L + 26P

Course Outcomes:

CO1: Examine various techniques for particle size measurement.

CO2: Distinguish the microscopic measurement techniques for the material characterization.

CO3: Apply different experimental techniques for the surface analysis of the materials

CO4: Analyse the underlying concepts and instruments for thermal analysis and film thickness measurement.

Design of Experiments - Best guess approach, One factor at time approach, Factorial approach. Elementary ideas of blocking, randomization, replication. Errors, Uncertainty analysis. Particle size distribution – Dynamic image analysis (DIA), Static laser light scattering (SLS), Dynamic light scattering (DLS), Attenuation spectroscopy, Zeta potential, Surface streaming potential. Optical microscope - Basic principles and components, Resolution and Magnification, Different modes of operation (Bright field illumination, Oblique illumination, Dark field illumination), Stereomicroscopy,

Scanning Electron Microscopy - instrumentation and application, different imaging modes sample preparation techniques - Transmission electron microscopy- different modes of operation, contrast mechanisms, HRTEM, SAED, EELS, Electron back scattering (EBSD) - X-ray micro analysis (EDS, WDS).

Surface Analysis: Scanning probe microscopy, tapping mode, contact mode, MFM, EFM, I-AFM, DC-AFM, PFM, FMM, LFM, SCM, SThM, SKM, F-d spectroscopy, Nanoindentation, Nano scratching, scanning tunnelling microscopy, Scanning near field microscopy (SNOM), X-ray photoelectron spectroscopy, XRD.

Surface area - Gas Sorption Technique - Brunauer–Emmett–Teller (BET) theory, Mercury Intrusion Porosimetry (MIP). Surface roughness: Direct measurement methods, Non-contact methods.

Temperature measurement: Infrared thermography, Thermo reflectance thermography, Liquid crystal thermography. Interferometry. Thermal Analysis: Differential Scanning Calorimeter (DSC), Differential Thermal Analyzer (DTA), Thermogravimetric Analysis (TGA) - Dynamic mechanical analysis (DMA)-Temperature programme reduction (TPR). Coating thickness measurement: Ultrasonic measurement, Magnetic Induction method, Eddy current method, Ultrasonic thickness gauges.

References:

1. Robert K., Ian H., Mark G., Nanoscale Science and Technology, John Wiley & Sons Ltd., 2007.
2. Weillie Zhou and Zhong Lin Wang, Scanning Microscopy for Nanotechnology, Springer 2007.
3. David B. Williams, C. Barry Carter, Transmission Electron Microscopy, Springer 2009.
4. Nan Yaho and Zhong, Hand book of Microscopy for Nanotechnology, Kluwer Academic press, Boston, 2005.
5. K.S. Birdi, Scanning Probe Microscopy, CRC Press, 2003.
6. Ernest O. Doebelin, Measurement Systems: Application and Design, McGraw Hill (Int. Edition) 1990.
7. Micheal E. Brown, Introduction to Thermal Analysis, Techniques and applications, Kluwer Academic Publishers 2001.
8. Peter Eaton, Paul West, Atomic Force Microscopy, Oxford University Press, 2010.

MT6103E NANOSIZED STRUCTURES

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions:39

Course Outcomes:

- CO1: Analyse different nanosystems and their properties.
- CO2: Appraise the concepts and principles of various methods for stabilization of the functional nanomaterials.
- CO3: Assess the synthesis and fabrication of emerging nanomaterials and hybrid materials.
- CO4: Apply the nanoparticles in advanced applications of nanomaterials.

Introduction to nanomaterials, quantum confinement, properties and applications, band gap engineering and property tuning, surface science for nanomaterials, surface energy, stabilization mechanisms, electrostatic - Nernst Equation, electric double layer, zeta potential, Interaction between nanoparticles - DLVO Theory, steric stabilization and electrosteric stabilization, nucleation and growth of nuclei, critical radius, homogeneous and heterogeneous nucleation.

Bottom-up approaches for nanostructure fabrication: Metal nanocrystals by reduction, Solvothermal, Photochemical, Template based and Electrochemical synthesis, Nanocrystals of semiconductors and oxides, sol-gel, micelles and microemulsions, top-down approaches for nanostructure fabrication. Quantum clusters of metals, properties, Quantum clusters as catalysts

Anisotropic nanomaterials, properties and applications, One dimensional nanostructures, evaporation condensation growth, Vapor –Liquid-Solid (VLS) growth, electrospinning, Two dimensional nanostructures, thin films, single and multilayered material structure, molecular beam epitaxy, chemical vapour deposition, atomic layer deposition, molecular self-assembly phenomena, Langmuir-Blodgett films and self-assembled monolayers, emerging hybrid materials, nanoporous materials.

Nanomaterials for advanced technology- Photonic crystals, molecular electronics and nanoelectronics, Single electron transistors, Nanoparticle-biomaterial hybrid systems for bioelectronic devices, nanostructures in bionanotechnology, tissue engineering and drug delivery, catalysis, size and shape dependent catalysis, nanotoxicology.

References:

1. G. Cao and Y.Wang, Nanostructures and Nanomaterials, 2nd Ed., Imperial College Press, 2011.
2. R. Kelsall, I.Hamley and M. Geoghegan, Nanoscale Science and Technology, Wiley, 2005.
3. K. J Klabunde, R. M. Richards, Nanoscale Materials in Chemistry, 2nd Ed., Wiley, 2009.
4. T. Pradeep, A text book of Nano Science and Technology, Tata McGraw-Hill Education, 2012.
5. G. Schmidt, Nanoparticles: from Theory to applications, Wiley-VCH, 2011.

MT6111E SPECTROSCOPY FOR NANOMATERIALS

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

- CO1: Apply the concepts and principles of spectroscopic methods for the characterization of Nanomaterials.
CO2: Interpret the analytical information for the comprehensive characterization of nanomaterials.
CO3: Assess the suitable technique for the apt evaluation of nanomaterials.
CO4: Appraise the electrochemical methods to comprehend the nanomaterial.

Surface analytical techniques, Surface sensitivity, Basic elements of practical spectroscopy, Infrared spectroscopy (IR), Functional groups, Attenuated total internal reflection IR, Diffuse reflectance and specular reflectance, AFM-IR, Raman Spectroscopy, resonance Raman, surface enhanced Raman and Tip enhanced Raman spectroscopy, Confocal Raman microscopy, analysis of carbon nanomaterials by Raman spectroscopy, Analysis of nanomaterials using IR, Raman spectroscopy.

UV-Visible absorption spectroscopy, Principle and application in nanomaterials, Metal nanoparticles and semiconductor nanoparticles, Diffuse reflectance, Calculation of band gaps, Fluorescence spectroscopy, Photoluminescence of nanomaterials, Photoelectron spectroscopy, Ultraviolet photoelectron spectroscopy and X-ray photoelectron spectroscopy, detailed analysis of spectra, X-ray Fluorescence, Auger electron spectroscopy, Electron energy loss spectroscopy.

Mass spectrometry techniques -Basics and application in nanomaterials, Tandem Mass, Matrix Assisted Laser Desorption/Ionisation, Secondary ion mass spectrometry, Electron spray ionization, Analysis of quantum clusters using mass spectrometry.

An overview of electrochemistry, Electrochemistry in materials science, Processes at electrodes, Electrochemical instrumentation and techniques, Cyclic voltammetry, Differential pulse voltammetry, Impedance spectroscopy, Electro chemiluminescence, spectroelectrochemistry, scanning electrochemical microscopy, Electrochromic and photoelectrochromic aspects of nanostructured metal oxide films.

References:

1. J. O'Connor, B. Sexton, R. Smart, Surface Analysis Methods in Materials Science, Springer, 2003.
2. Helmut Gunzler and Alex Williams, Handbook of Analytical Techniques, Wiley-VCH, 2002.
3. C. Banwell and E. Mccash, Fundamentals of Molecular Spectroscopy, Mc Graw Hill, 2001.
4. Allen J. Bard, Larry R. Faulkner, Electrochemical Methods: Fundamentals and Applications, Wiley-VCH, 2001.
5. D.P. Woodruff, Modern Techniques of Surface Science, Cambridge University Press, 2016.

MT6121E NANOMATERIALS FOR ENERGY AND ENVIRONMENT

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

- CO1: Apply the concepts and principles of conversion and storage of renewable energy sources.
- CO2: Evaluate the efficiency of nanocatalysts for electrochemical energy generation and storage.
- CO3: Design the suitable nanomaterials for environmental remediation.
- CO4: Analyze the toxicity of nanomaterials.

Energy and Environment, sustainable energy production based on renewable energy sources, Sustainability: Water, Energy, Nanomaterials used in energy and environmental applications and their properties, Solar energy, solar cells, dye sensitized solar cell, QDSSC, organic solar cells, perovskite solar cells, Hydrogen energy, hydrogen production by water splitting, hydrogen storage.

Electrochemical energy conversion and storage systems, Fuel cells, Types of fuel cells, thermodynamics of fuel cells, electrocatalysts for anode reactions, catalysts for oxygen reduction reactions, Batteries, Li-ion battery, Na-ion battery, General properties of electrochemical capacitors, Supercapacitor, Electrical double layer capacitor, pseudocapacitor, Li-ion based hybrid supercapacitors, Applications of electrochemical capacitors.

Green nanotechnology and its principles, Nanomaterials for environmental Remediation, Photocatalysis, Water purification using nanomaterials, desalination of water, Solid waste removal, Porous materials to store clean energy gases, Metal organic framework (MOFs), Storage of carbon dioxide, methane and hydrogen in MOFs.

Potential impacts of nanomaterials on organisms and ecosystems, Nanotoxicology, Introduction to nanomaterial toxicity, environmental and health impacts, Biomagnification, Nanoparticles exposure assessment, toxicity of inhaled nanomaterials, Basics of toxicity studies, Cytotoxicity induced by nanomaterials, ethical, legal, and societal implications of nanotechnology.

References:

1. Jingbio louise Liu, Sajid Bashir, Advanced Nanomaterials and their applications in Renewable energy, Elsevier, 2015.
2. Tetsuo Soga, Nanostructured Materials for Solar Energy Conversion, Elsevier, 2006.
3. G.A. Nazri and G. Pistoia, Lithium Batteries: Science and Technology, Kluwer Academic Publishers, Dordrecht, Netherlands, 2004.
4. J. Larminie and A. Dicks, Fuel Cell System Explained, John Wiley, New York, 2018.
5. Francois B'eguin and El'zbieta Frackowiak, Supercapacitors, Wiley-VCH, 2013.
6. Challa S.S.R. Kumar, Nanomaterials: toxicity, health and environmental issues, Wiley-VCH, 2006.

IE6001E ENTREPRENEURSHIP DEVELOPMENT

L	T	P	O	C
2	0	0	4	2

Total Lecture Sessions: 26

Course Outcomes:

- CO1: Describe the various strategies and techniques used in business planning and scaling ventures.
CO2: Apply critical thinking and analytical skills to assess the feasibility and viability of business ideas.
CO3: Evaluate and select appropriate business models, financial strategies, marketing approaches, and operational plans for startup ventures.
CO4: Assess the performance and effectiveness of entrepreneurial strategies and actions through the use of relevant metrics and indicators.

Entrepreneurial Mindset and Opportunity Identification

Introduction to Entrepreneurship Development - Evolution of entrepreneurship, Entrepreneurial mindset, Economic development, Opportunity Recognition and Evaluation - Market gaps - Market potential, Feasibility analysis - Innovation and Creativity in Entrepreneurship - Innovation and entrepreneurship, Creativity techniques, Intellectual property management.

Business Planning and Execution

Business Model Development and Validation - Effective business models, Value proposition testing, Lean startup methodologies - Financial Management and Funding Strategies - Marketing and Sales Strategies - Market analysis, Marketing strategies, Sales techniques - Operations and Resource Management - Operational planning and management, Supply chain and logistics, Stream wise Case studies.

Growth and Scaling Strategies

Growth Strategies and Expansion - Sustainable growth strategies, Market expansion, Franchising and partnerships - Managing Entrepreneurial Risks and Challenges - Risk identification and mitigation, Crisis management, Ethical considerations - Leadership and Team Development - Stream wise Case studies.

References:

1. Kaplan, J. M., Warren, A. C., & Murthy V. Patterns of entrepreneurship management. John Wiley & Sons. (Indian Adoption) 2022.
2. Kuratko, D. F., Entrepreneurship: Theory, process, and practice. Cengage learning, 2016.
3. Barringer, B. R, Entrepreneurship: Successfully launching new ventures. Pearson Education India, 2015.
4. Rajiv Shah, Zhijie Gao, Harini Mittal, Innovation, Entrepreneurship, and the Economy in the US, China, and India, Academic Press, 2014.
5. Dr. K. Sundar, Entrepreneurship Development, 2nd Ed 2022 Vijaya Nichkol Imprints, Chennai
6. E. Gordon, Dr. K. Natarajan, Entrepreneurship Development, 6th Ed, Himalya Publishers, Delhi, 2017.
7. Debasish Biswas, Chanchal Dey, Entrepreneurship Development in India, T & F group, 2021.

ZZ6002E RESEARCH METHODOLOGY

L	T	P	O	C
2	0	0	4	2

Total Lecture Sessions: 26

Course Outcomes:

- CO1: Explain the basic concepts and types of research.
- CO2: Develop research design and techniques of data analysis
- CO3: Present research to the scientific community
- CO4: Develop an understanding of the ethical dimensions of conducting research.

Exploring Research Inquisitiveness

Philosophy of Scientific Research, Role of Research Guide, Planning the Research Project, Research Process, Research Problem Identification and Formulation, Variables, Framework development, Research Design, Types of Research, Sampling, Measurement, Validity and Reliability, Survey, Designing Experiments, Research Proposal, Research Communication, Research Publication, Structuring a research paper, structuring thesis/ dissertation.

Data Analysis

Literature review :Tools and Techniques, Collection and presentation of data, processing and analysis of data, Descriptive statistics and inferential statistics, Measures of central tendency, dispersion, skewness, asymmetry, Probability distributions, Single population and two population hypothesis testing, Parametric and non-parametric tests, Design and analysis of experiments: Analysis of Variance (ANOVA), completely randomized design, Measures of relationship: Correlation and regression, simple regression analysis, multiple regression, interpretation of results, Heuristics and simulation.

Research writing and Ethics

Reporting and presenting research, Paper title and keywords, writing an abstract, writing the different sections of a paper, revising a paper, responding to peer reviews.

The codes of ethics, copyright, patents, intellectual property rights, plagiarism, citation, acknowledgement, avoiding the problems of biased survey.

References:

1. Krishnaswamy, K.N., Sivakumar, A.I., and Mathirajan, M., Management Research Methodology, Pearson Education, 2006.
2. Leedy, P, D., Practical Research: Planning and Design, Pearson, 2018.
3. Kothari, C.R., Research Methodology – Methods and Techniques, New Age International Publishers, 2004
4. Mike Martin, Roland Schinzinger, Ethics in Engineering, Mc Graw Hill Education, 2004.
5. Vinod V Sople, Managing Intellectual Property-The Strategic Imperative, EDA Prentice of Hall Pvt. Ltd., 2014.

MS6174E TECHNICAL COMMUNICATION AND WRITING

L	T	P	O	C
2	1	0	3	2

Total Lecture Sessions: 26

Course Outcomes:

- CO1: Apply effective communication strategies for different professional and industry needs.
- CO2: Collaborate on various writing projects for academic and technical purposes.
- CO3: Combine attributes of critical thinking for improving technical documentation.
- CO4: Adapt technical writing styles to different platforms.

Technical Communication

Process(es) and Types of Speaking and Writing for Professional Purposes - Technical Writing: Introduction, Definition, Scope and Characteristics - Audience Analysis - Conciseness and Coherences - Critical Thinking - Accuracy and Reliability - Ethical Consideration in Writing - Presentation Skills - Professional Grooming - Poster Presentations

Grammar, Punctuation and Stylistics

Constituent Structure of Sentences - Functional Roles of Elements in a Sentence - Thematic Structures and Interpretations - Clarity - Verb Tense and Mood - Active and Passive Structures - Reporting Verbs and Reported Tense - Formatting of Technical Documents - Incorporating Visuals Elements - Proofreading

Technical Documentation

Types of Technical Documents: Reports, Proposals, Cover Letters - Manuals and Instructions - Online Documentation - Product Documentation - Collaborative Writing: Tools and Software - Version Control Document Management - Self Editing, Peer Review and Feedback Processes

References:

1. Foley, M., & Hall, D., Longman advanced learner's grammar, a self-study reference & practice book with answers Pearson Education Limited, 2018.
2. Gerson, S. J., & Gerson, S. M., Technical writing: Process and product, Pearson, 2009.
3. Kirkwood, H. M. A., & M., M. C. M. I., Hallidays introduction to functional grammar, Hodder Education, 2013.
4. Markel, M., Technical Communication, Palgrave Macmillan, 2012.
5. Tuhovsky, I., Communication skills training: A practical guide to improving your social intelligence, presentation, Persuasion and public speaking skills, Rupa Publications India, 2019.
6. Williams, R., The Non-designer's Design Book, Peachpit Press, 2014.