

M. Tech. in Environmental Engineering

Program Learning Objectives:	Program Learning Outcomes:
Program Goal 1: Equip the students with strong foundation in civil and environmental engineering for both research and industrial scenarios.	Program Learning Outcome 1a: Student develops ability to design and conduct experiments. Program Learning Outcome 1b: Student is able to organize and analyze the experiment data to draw conclusions.
Program Goal 2: Provide scientific and technical knowledge in planning, design, construction, operation and maintenance of civil engineering infrastructure.	Program Learning Outcome 2: Students are able to (i) develop material and process specifications, (ii) analyze and design projects, (iii) perform estimate and costing and (iv) manage technical activities.
Program Goal 3: Prepares the students to apply knowledge in policy and decision making related to civil engineering infrastructure.	Program Learning Outcome 3a: Student develops understanding of professional and ethical responsibility. Program Learning Outcome 3b: Student is able to consider economic, environmental, and societal contexts while developing engineering solutions.
Program Goal 4: Prepare students to attain leadership careers to meet the challenges and demands in civil engineering practice.	Program Learning Outcome 4a: Students is prepared for leading roles/profiles in government sector, construction industry, consultancy services, NGOs, corporate houses and international organizations. Program Learning Outcome 4b: Student develops ability to identify, formulate, and solve engineering problems.
Program Goal 5: Nurture interdisciplinary education for finding innovative solutions.	Program Learning Outcome 5: Student is able to solve complex engineering problems by applying principles of engineering and science.

Sl. No.	Subject Code	SEMESTER I	L	T	P	C
1.	HS5111	Technical Writing and Soft Skill	1	2	2	4
2.	CE5101	Chemistry for Environmental Engineers	3	0	2	4
3.	CE5102	Physico-Chemical Principles and Processes	3	0	0	3
4.	CE5103	Solid and Hazardous Waste Management	3	0	0	3
5.	CE51XX/ CE61XX	DE-I (Environmental Elective)	3	0	0	3
6.	CE51XX/ CE61XX	DE-II (Environmental / Department Elective)	3	0	0	3
7.	XX61PQ	IDE	3	0	0	3
	TOTAL		19	2	4	23

IDE (Inter Disciplinary electives) in the curriculum aims to create multitasking professionals/ scientists with learning opportunities for students across disciplines/apptitude

of their choice by opting level (5 or 6) electives, as appropriate, listed in the approved curriculum.

Sl. No.	Subject Code	SEMESTER II	L	T	P	C
1.	CE5201	Biological Principles and Processes	3	0	0	3
2.	CE5202	Air Pollution and Control	3	0	2	4
3.	CE5203	Environmental Impact Assessment	3	0	0	3
4.	CE52XX/ CE62XX	DE-III (Environmental Elective)	3	0	0	3
5.	CE52XX/ CE62XX	DE-IV (Environmental Elective/ Department Elective)	3	0	0	3
6.	RM6201	Research Methodology	3	1	0	4
7.	IK6201	IKS	3	0	0	3
	TOTAL		21	1	2	23

Sl. No.	Subject Code	SEMESTER III	L	T	P	C
1.	CE6198	Summer Internship/Mini Project*	0	0	12	3
2.	CE6199	Project I **	0	0	30	15
	TOTAL		0	0	42	18

***Note: Summer Internship (Credit based)**

(i) Summer internship (*) period of at least 60 days' (8 weeks) duration begins in the intervening summer vacation between Semester II and III. It may be pursued in industry / R&D / Academic Institutions including IIT Patna. The evaluation would comprise **combined grading based on host supervisor evaluation, project internship report after plagiarism check and seminar presentation at the Department (DAPC to coordinate)** with equal weightage of each of the three components stated herein.

(ii) Further, on return from 60 days internship, students will be evaluated for internship work through combined grading based on host supervisor evaluation, project internship report after plagiarism check, and presentation evaluation by the parent department with equal weightage of each component.

**** Note: M. Tech. Project outside the Institute:** A project-based internship may be permitted in industries/academia (outside IITP) in 3rd or 4th semester in accordance with academic regulations. In the IIIrd Semester, students can opt for a semester long M. Tech. project subject to confirmation from an Institution of repute for research project, on the assigned topic at any external Institution (Industry / R&D lab / Academic Institutions) based on recommendation of the DAPC provided:

(i.) The project topic is well defined in objective, methodology and expected outcome through an abstract and statement of the student pertaining to expertise with the proposed supervisor of the host institution and consent of the faculty member from the concerned department at IIT Patna as joint supervisor.

(ii.) The consent of both the supervisors (external and institutional) on project topic is obtained a priori and forwarded to the academic section through DAPC for approval by the competent authority for office record in the personal file of the candidate.

(iii.) Confidentiality and Non Disclosure Agreement (NDA) between the two organizations with clarity on intellectual property rights (IPR) must be executed prior to initiating the semester long project assignment and committing the same to external organization and vice versa.

(iv.) The evaluation in each semester at Institute would be mandatory and the report from Industry Supervisor will be given due weightage as defined in the Academic Regulation. Further, the final assessment of the project work on completion will be done with equal weightage for assessment of the host and Institute supervisors, project report after **plagiarism check**. The award of grade would comprise **combined assessment based on host supervisor evaluation, project report quality and seminar presentation at the Department (DAPC to coordinate)** with equal weightage of each of the components stated herein.

(v.) In case of poor progress of work and / or no contribution from external supervisor, the student need to revert back to the Institute essentially to fulfill the completion of M. Tech. project as envisaged at the time of project allotment. However, the recommendation of DAPC based on progress report and presentation would be mandatory for a final decision by the competent authority.

Sl. No.	Subject Code	SEMESTER IV	L	T	P	C
1.	CE6299	Project II	0	0	42	21
	TOTAL		0	0	42	21

Total Credit from Semester I to IV: 85

ELECTIVE GROUPS

Department Elective -I: Environmental Elective Course						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	CE6101	Atmospheric Physics and Chemistry	3	0	0	3
2.	CE6102	Sampling, Analytical Methods, and Statistics for Environmental Engineering	3	0	0	3
3.	CE6103	Environmental Toxicology and Risk Assessment	3	0	0	3
4.	CE6104	Environmental Hydraulics	3	0	0	3
5.	CE6105	Atmospheric Science and Climate Change	3	0	0	3

Department Elective -II: Department Elective Course						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	CE5117	Water Resources Management	3	0	0	3
2.	CE6109	Geoenvironmental Engineering	3	0	0	3
3.	CE6114	Probabilistic Methods in Geotechnical Engineering	3	0	0	3
4.	CE6130	Analytical Methods in Civil Engineering	3	0	0	3
5.	CE6131	Sustainability of Water Resources System	3	0	0	3

Department Elective -III: Environmental Elective Course						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	CE6201	E-waste Management for Circular Economy	3	0	0	3
2.	CE6202	Industrial Pollution Control and Prevention	3	0	0	3
3.	CE6203	Water Supply and Sewerage Network Design	3	0	0	3

4.	CE6204	Design of Water and Wastewater Treatment Facilities	3	0	0	3
5.	CE6205	Advanced Water and Wastewater Engineering	3	0	0	3

Department Elective - IV: Department Elective Course						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	CE5217	Geoinformatics for Engineers	3	0	0	3
2.	CE5218	Groundwater Hydrology	3	0	0	3
3.	CE5219	Open Channel Hydraulics	3	0	0	3
4.	CE6208	Mine Wastes Generation and Management	3	0	0	3
5.	CE6211	Utilization of industrial Byproducts for Geotechnical Application	3	0	0	3
6.	CE6218	Finite Element Method	3	0	0	3
7.	CE6223	Uncertainty, Risk and Reliability Analyses in Civil Engineering	3	0	0	3
8.	CE6228	Analytical Techniques for Infrastructure Systems Analysis	3	0	0	3

Interdisciplinary Elective (IDE) Course for M. Tech. (Available to students other than CEE)

Sl. No.	Subject Code	Subject Name	L	T	P	C
1.	CE6132	Data Science for Engineers	3	0	0	3

Sl. No.	Subject Code	SEMESTER I	L	T	P	C
1.	HS5111	Technical Writing and Soft Skill	1	2	2	4
2.	CE5101	Chemistry for Environmental Engineers	3	0	2	4
3.	CE5102	Physico-Chemical Principles and Processes	3	0	0	3
4.	CE5103	Solid and Hazardous Waste Management	3	0	0	3
5.	CE51XX/ CE61XX	DE-I (Environmental Elective)	3	0	0	3
6.	CE51XX/ CE61XX	DE-II (Environmental / Department Elective)	3	0	0	3
7.	XX61PQ	IDE	3	0	0	3
	TOTAL		19	2	4	23

Course Number	CE5101: Chemistry for Environmental Engineers
Course Credit (L-T-P-C)	3-0-2-4
Course Title	Chemistry for Environmental Engineers
Learning Mode	Lectures and Practical
Learning Objectives	Complies with PLOs 1, 3,4 and 5: 1. Equip the students with a strong foundation and strengthen their knowledge in environmental chemistry. 2. The student will be able to apply advanced theory and analysis for problem-solving in environmental sciences. 3. The student will prepare for further research and graduate study by critical thinking and improving research skills.
Course Description	This coursework will provide insights in the field of environment sciences. The objective of this course is to provide students' knowledge about chemical processes involved in various environmental systems. The students will understand about chemical kinetics, redox chemistry and other chemical transformations occurring in water or air. The practical course will impart knowledge of determining different water and wastewater quality parameters and understanding their effect on water and wastewater treatment.
Course Outline	Basic Principles - Chemical equations and thermodynamic equilibrium; Chemical Kinetics; Acid Base Equilibria - Alkalinity and acidity, Buffering; Solubility equilibria, Stabilization reactions, Oxidation reduction equilibria, Application of redox chemistry; Fundamentals of process kinetics: Reaction rates and order, Reactor design; Fundamentals of surface and colloidal chemistry; Chemistry of trace constituents; Photo-dissociation, Catalytic Cycles, Aqueous chemistry; Transport of Chemicals; Multi-phase chemical processes, Coagulation and Flocculation; Adsorption – physical versus chemical adsorption, factors influencing adsorption, Adsorption isotherms. Laboratory: Laboratory tests related to environmental quality parameters; Advance instrumentations for environmental analysis.
Learning Outcome	The course structure will impart: Theory: High-quality knowledge to students on chemical processes. Understanding of interplay of chemical transport and fate in the environment will be examined. Practical: Assess the parameters related to environmental quality.
Assessment Method	Theory: Assignments, Quizzes, Presentations, Mid-semester and End-semester Examination Practical: Lab Reports, Lab written Examination and Practical Examination with Viva-voce

Textbooks:

1. Sawyer, C.N., McCarty, P.L., Parkin, G.F., Chemistry for Environmental Engineering, Tata McGraw-Hill, 2000.
2. Manhan, S.E., Environmental Chemistry, Lewis Publishers, 2000, Seventh Edition.

Reference books:

1. Benefield, L. D., Judkins, J. F. and Weand, B. L., Process Chemistry for Water and Wastewater Treatment, Prentice Hall, 1982.
2. Atmospheric Chemistry and Physics: From Air Pollution to Climate Change by John H. Seinfeld and Spyros N. Pandis, 3rd Edition, John Wiley & Sons, Inc., 2016.
3. Introduction to Atmospheric Chemistry, Daniel J. Jacob, Princeton University Press, 1999.
4. Faust, S.D. and Aly, O.M., Chemistry for Water Treatment, Ann Arbor Science Book, 1983.
5. Clesceri, L. S., Greenberg, A. E. and Eaton, A. D. (Eds) Standard Methods for the Examination of Water and Wastewater, Washington, D.C., 1998, 20th Ed.

Course	CE5102: Physico-Chemical Principles and Processes
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Physico-Chemical Principles and Processes
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 1, 3 and 4 1. To provide a basic understanding of different physicochemical processes relevant to water and wastewater Treatment. 2. To elucidate the constraints, merits, and trade-offs associated with each unit operation and process. 3. To investigate the underlying principles and engineering design of physical and chemical treatment systems used to remove undesirable constituents and contaminants from water and wastewater.
Course Description	This course offers a comprehensive overview of various unit operations and processes designed to remove organic and inorganic contaminants, emerging pollutants, and nutrients from water and wastewater. Through this course, students will understand the technologies and strategies used to ensure water quality and environmental safety.
Course Outline	Water and wastewater quality assessment; design and application of physicochemical treatment processes: screening, grit removal, equalization, sedimentation, flotation, coagulation, flocculation, and filtration; disinfection methods; water softening techniques; adsorption and ion exchange processes; gas transfer and aeration systems; membrane technologies including reverse osmosis, electrodialysis, desalination, and ultrafiltration; advanced oxidation processes for contaminant removal.
Learning Outcome	At the end of the course, students would be able to: 1. Understand the various pollutant sources in surface and groundwaters, as well as wastewater, and utilization of physicochemical processes for the treatment. 2. Understand the traditional and advanced treatment methods and modifications to increase their effectiveness. 3. Utilization of various unit operations and physico-chemical processes for treatment of contaminants found in the environment
Assessment Method	Assignments, Quizzes, Mid-semester examination, and End-semester examination.

Text Books:

1. Peavy, H.S., Rowe, D.R., and Tchobanoglous, G., Environmental Engineering, McGraw-Hill International Ed., 1985.
2. J. Weber, W.J. Physicochemical Processes for Water Quality Control, John Wiley and Sons, 1972.
3. Nazaroff, W.W. and Alvarez-Cohen, L., Environmental Engineering Science, Wiley, 2000.
4. Metcalf and Eddy Inc., Wastewater Engineering – Treatment and Reuse, Tata McGraw Hill India, 2003, 4th Edition.
5. Montgomery, J. M., Water Treatment: Principles and Design, John Wiley & Sons, 1985.

Reference Book:

1. Vigneswaran, S. and Visvanathan, C., Water Treatment Processes: Simple Options, CRC Press, 1995.
2. Droste, R. L., Theory and Practice of Water and Wastewater Treatment, John Wiley & Sons, 1996.

3. Benefield, L. D., Judkins, J. F. and Weand, B. L., Process Chemistry for Water and Wastewater Treatment, Prentice Hall, 1982.
4. Schroeder E D. Water and Wastewater Treatment, McGraw-Hill, 1997.

Course Number	CE5103: Solid and Hazardous Waste Management
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Solid and Hazardous Waste Management
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 2, 3 and 4 1. To familiarize the students about the problem of solid waste generation and hazardous composition, and impact on the environment and human health on the backdrop of national legislations 2. To train students to understand, plan, design, and implement various steps and processes involved for solid and hazardous waste management 3. To inculcate scientific and technical knowledge, to prepare students to address present issues and challenges along with the emerging techniques for solid and hazardous waste management for a circular economy
Course Description	The course intends to provide basic as well as advanced concepts and engineering practices involved in solid and hazardous waste management. The course will provide a broader understanding of municipal solid waste generation and influencing factors, composition, hazardous waste characteristics, segregation and collection, processing and disposal techniques for solid and hazardous waste management with theoretical and practical aspects. Further, the course intends to provide and discuss real-life case studies on solid and hazardous waste recycling for urban mining and circular economy.
Course Content	Municipal Solid Waste Management – Fundamentals: Sources; composition; generation rates; collection of waste; separation, transfer and transport of waste; treatment and disposal options; Hazardous Waste Management Fundamentals: Characterization of waste; compatibility and flammability of chemicals; fate and transport of chemicals; health effects; Specific waste streams: construction and demolition (C&D) waste, electronic waste (e-waste), etc.; National Legislations: Municipal solid waste (management and handling) rules; hazardous waste (management and handling) rules; biomedical waste handling rules; e-waste management rules; batteries (management and handling) rules; Physicochemical Treatment of Solid and Hazardous Waste: Physico-chemical treatment processes for MSW (combustion, stabilization and solidification of hazardous wastes); physicochemical processes for hazardous wastes (soil vapour extraction, air stripping, chemical oxidation); Biological Treatment of Solid and Hazardous Waste: Composting; bioreactors; anaerobic decomposition of solid waste; principles of biodegradation of toxic waste; inhibition; co-metabolism; oxidative and reductive processes; slurry phase bioreactor; in-situ remediation; Landfill Design: Disposal of solid waste including sanitary landfill; Landfill design for solid and hazardous wastes; leachate collection and removal; landfill covers; incineration; Emerging Concepts and Practices: Urban mining and circular economy with real-life case studies; Planning, site and design aspects of solid waste engineering.

Learning Outcome	At the end of the course, students would be able to: 1. Understand about the problem of municipal solid waste generation and composition with the influencing factors, hazardous waste characteristics, national legislations, and adverse effects on the environment and human health. 2. Comprehend, understand, devise and adopt various steps and processes involved in the solid and hazardous waste management in integrated manner. 3. Plan and implement various processing and disposal techniques for solid and hazardous waste management for a circular economy 4. Learn and understand about present issues and challenges along with the emerging techniques for solid and hazardous waste management
Assessment Method	Assignments, Quizzes, Mid Semester Examination and End Semester Examination

Text Books:

1. CPHEEO, Manual on Municipal Solid Waste Management, Central Public Health & Environmental Engineering Organisation (CPHEEO), Ministry of Housing and Urban Affairs, Govt. of India, 2016.
2. LaGrega, M.D., Buckingham, P.L. and Evans, J.C., Hazardous Waste Management, 2nd edition, Medtech, 2015.
3. Tchobanoglous, G., Theisen, H. and Vigil, S.A., Integrated Solid Waste Management: Engineering Principles and Management Issues, Indian edition, McGraw Hill, 2014.
4. Vesilind, P.A., Worrel, W.A. and Ludwig, C., Solid Waste Engineering: A Global Perspective, SI edition, CL Engineering, 2016.

Reference Books:

1. Bagchi, A., Design of Landfills and Integrated Solid Waste Management, 3rd edition, Wiley, 2004.
2. Wentz, C.A., Hazardous Waste Management, 2nd edition, McGraw-Hill, 1995.

Department Elective -I: Environmental Elective Course						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	CE6101	Atmospheric Physics and Chemistry	3	0	0	3
2.	CE6102	Sampling, Analytical Methods, and Statistics for Environmental Engineering	3	0	0	3
3.	CE6103	Environmental Toxicology and Risk Assessment	3	0	0	3
4.	CE6104	Environmental Hydraulics	3	0	0	3
5.	CE6105	Atmospheric Science and Climate Change	3	0	0	3

Course Number	CE6101- Atmospheric Physics and Chemistry
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Atmospheric Physics and Chemistry
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 3,4 and 5: 1. Equip the students with a strong foundation and strengthen their knowledge in atmospheric physics and chemistry. 2. The student will be able to apply advanced theory and analysis for problem-solving in atmospheric sciences. 3. The student will prepare for further research and graduate study by critical thinking and improving research skills.
Course Description	This coursework will provide insights in the field of atmospheric sciences. The objective of this course is to provide students' knowledge about radiative and climatic effects of gases and particles; formation and chemistry of clouds; meteorology of air pollution; atmospheric chemistry and atmospheric chemical/transport models.
Prerequisite course	Air pollution and control, Environmental Studies, or any other equivalent course.
Course Outline	Atmospheric Physics: Atmosphere as a Physical system, Composition of Atmosphere, Atmospheric Dynamics, Stability and Transport, General Circulation, Moisture in the Atmosphere, Cloud Formation; Solar and terrestrial radiation; Effect of pollutants on Earth's radiation budget; Radiation scattering by aerosols and clouds; Greenhouse Effect, Global Warming, Introduction to Atmospheric Models: Simple Radiative model, Models for global warming and cooling. Atmospheric Chemistry: Thermodynamics of Chemical Reactions, Chemical Kinetics, Bimolecular Reactions Photo-dissociation, Stratospheric Ozone, Chapman Chemistry, Catalytic Cycles, Transport of Chemicals; the Antarctic Ozone Hole; Multi-phase Processes, Tropospheric Chemistry, Aerosol formation; Aerosol Dynamics: Discrete and continuous aerosol size distributions; Thermodynamics of atmospheric aerosols; Homogeneous and heterogeneous nucleation; Sedimentation and dry deposition; Chemical equilibria; Aerosol-cloud interactions; Aerosol and Global Climate: Trends in anthropogenic emissions and troposphere composition.
Learning Outcome	The course structure will impart: 1. High-quality knowledge to students on chemical and physical processes involved in the emissions, transport, transformation and fate of atmospheric pollutants. 2. Insights into sources and sinks of gases and particles of importance for environment and climate. 3. Importance of electromagnetic radiation laws will be examined in relation to earth's radiative balance and photo-chemistry. 4. Understanding of interplay of atmospheric gases and particles, transformation of gases and particles, their transport and fate in the atmosphere will be examined.
Assessment Method	Quizzes, Presentations, Mid-semester and End-semester Examination

Textbooks:

1. Atmospheric Chemistry and Physics: From Air Pollution to Climate Change by John H. Seinfeld and Spyros N. Pandis, 3rd Edition, John Wiley & Sons, Inc., 2016.
2. Introduction to Atmospheric Chemistry, Daniel J. Jacob, Princeton University Press, 1999.

Reference books:

1. Environmental Chemistry, Stanley E. Manahan, 9th Edition, CRC Press, 2009.
2. Atmospheric Science: An Introductory Survey by Wallace, J.M., and P. V. Hobbs, 2nd edition, Elsevier, 2006.
3. Modeling of Atmospheric Chemistry by G. P. Brasseur and Daniel J. Jacob, Cambridge University Press, 2017.
4. Atmospheric Thermodynamics: Elementary Physics and Chemistry by G. R. North and T.L. Erukhimova, Cambridge University Press, 2009.
5. Atmospheric Chemistry by Julian Heicklen, Academic Press, 1976.
6. Atmospheric Chemistry by Ann M. Holloway and Richard P Wayne, RSC Publication, 2010.
7. Meteorology Today by Ahrens, C. Donald, 9th edition, Wadsworth Publishing Co. Inc., 2008.
8. Atmospheric Reaction Chemistry by Hajime Akimoto, Springer, 2016.
9. Chemistry of the Upper and Lower Atmosphere B.J. Finlayson -Pitts and J.N. Pitts, Jr., Academic Press, 2000.
10. IPCC, 2007 Fourth Assessment Report, Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Course	CE6102: Sampling, Analytical Methods and Statistics for Environmental Engineering
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Sampling, Analytical Methods and Statistics for Environmental Engineering
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 1, 2 and 4 The objective of this course is 1. Develop an understanding of various sampling techniques used in environmental engineering. 2. Learn the principles and applications of common analytical methods for environmental samples. 3. Gain proficiency in statistical analysis and interpretation of environmental data.
Course Description	This course provides an in-depth exploration of sampling techniques, analytical methods, and statistical analyses used in environmental engineering. Students will learn how to design sampling strategies, select appropriate analytical methods, and apply statistical tools to interpret environmental data.
Course Outline	Sampling: Principles of sample collection, Importance of sampling for environmental analysis, Types of samples (grab samples, composite samples, etc.), Factors to consider in sampling design (location, frequency, timing) Analytical methods: Gravimetric methods, titrimetric methods, electrochemical methods, Spectrometric method of analysis, Chromatographic method of analysis, Advanced analytical techniques (FTIR, XRD, SEM, TEM, TGA, etc.) Quality Assurance and Quality Control (QA/QC): Standard Operating Procedures (SOPs), Documentation and record keeping, Calibration and standardization, Control Samples-blanks, duplicates, spiked samples: accuracy, precision, Limit of Detection (LOD), Limit of Quantification (LOQ) Statistical Analysis: Basics of statistical analysis (mean, median, standard deviation, etc.), Advanced statistical tools: regression, hypothesis testing, ANOVA, Error analysis, Reproducibility/repeatability.
Learning Outcome	At the end of the course, students would be able to: 1. Learn the basics of sample collection, including types, locations, and sampling frequency. 2. Develop expertise in using various analytical techniques, such as gravimetric, titrimetric, electrochemical, spectrometric, and chromatographic methods. 3. Establish and maintain quality assurance and quality control (QA/QC) processes to ensure accuracy, reliability, and consistency in sampling and analysis. 4. Acquire the ability to apply statistical methods to analyze, interpret, and validate environmental data, ensuring accuracy and reliability.
Assessment Method	Assignments, Quizzes, Mid-semester examination, and End-semester examination.

Text Books and Reference:

1. Zhang, C., 2007. Fundamentals of environmental sampling and analysis. John Wiley & Sons.
2. Csuros, M., 2018. Environmental sampling and analysis: lab manual. Routledge.
3. Berthouex, P.M. and Brown, L.C., Statistics for Environmental Engineers, Lewis Publishers, CRC Press, Boca Raton, 1994.
4. Ott, W.R. Environmental Statistics and Data Analysis, Lewis Publishers, New Jersey, 1995.
5. Csuros, M. and Csuros, C., 2016. Environmental sampling and analysis for metals. CRC Press.
6. Popek, E.P., 2017. Sampling and analysis of environmental chemical pollutants: a complete guide. Elsevier.
7. Rice, E.W., Bridgewater, L. and American Public Health Association eds., 2012. Standard methods for the examination of water and wastewater (Vol. 10). Washington, DC: American public health association.
8. Rong, Y. ed., 2011. Practical environmental statistics and data analysis. ILM publications.

Course	CE6103: Environmental Toxicology and Risk Assessment
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Environmental Toxicology and Risk Assessment
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 4 and 5 1. To foster awareness of toxicological aspect of surroundings and environment. 2. To prepare students for estimating the risk associated with various chemicals present in environment. 3. It will prepare students for further research study by critical thinking and improving research skills.
Course Description	The primary goal of this course is to comprehend the toxicity of various chemicals, understand dose-response relationship and prepare to develop models for risk assessments.
Course Outline	Importance of environmental toxicology, dose-response relationship, hazard and risk; Routes of exposure, toxico-kinetics, oral route, dermal route, inhalation route, distribution, elimination, absorption and bioavailability; Mechanism of action, endocrine disruption, cytotoxic, enzyme inhibition, reproductive toxicology, teratology, biotransformation and secondary effect; Data sources for exposure risk characterization; Toxicology/epidemiology–Biomarkers; Ecology Trophic levels, BCF (bio concentration factor), BCF modeling, indicator species; Integrated exposure assessment – (case studies); Physiological-based Pharmacokinetic (PBPK) Models EU; Application of statistical and Monte Carlo simulations and other techniques for probabilistic exposure assessment; Risk Characterization, communication and decision making
Learning Outcome	At the end of the course, students would be able to: 1. Able to recognize the toxic compounds and understand their impact on health. 2. Apply fundamental theories and techniques from the chemical and ecological sciences to find out the health risk. 3. Analyse the exposure to different environment. 4. Understanding about risk estimation, characterization, and modelling.
Assessment Method	Assignments, Quizzes, Mid-semester examination, and End-semester examination.

Text Books:

1. Wright, D.A. and Welbourn, P. Environmental toxicology, Cambridge University Press, 2002.
2. Lee, E. S., Hernandez, M. and Forthofe, R. N. Biostatistics: a guide to design, analysis and Discovery, 2nd edition, Academic Press Inc., 2007.
3. Landis, W., Sofield, R., Yu, M. Introduction to Environmental Toxicology, Molecular Substructures to Ecological Landscapes, Fifth Edition, 2018.

Reference book:

1. Cross, C.L. and Daniel, W.W. Biostatistics: a foundation for analysis in the health sciences, 11th edition, Wiley, 2018.
2. Shaw, I. and Chadwick, J. Principles of Environmental Toxicology, CRC Press, 1998.

Course	CE6104: Environmental Hydraulics
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Environmental Hydraulics
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 1, 2 and 4 The objective of this course is 1. Analyze fluid flow in pipes and open channels. 2. Design both separate and combined drainage systems. 3. Understand the ground water hydraulics and the movement of pollutants in groundwater. 4. Understand the hydraulics of water and wastewater treatment plants.
Course Description	This course covers fluid dynamics in pipes and open channels, including turbulent and viscous flow, pipe network analysis, and groundwater hydraulics. Students will learn to design drainage systems, estimate aquifer parameters, and understand the hydraulics of water and wastewater treatment plants.
Course Outline	Fundamentals of Friction and Flow in Pipes, Turbulent and Viscous Flow, Analysis Methods for Pipe Networks including Hardy-Cross, Basic Open Channel Hydraulics, Energy and Momentum Equations, Critical Flow, Channel Control and Transitions, Uniform and Gradually Varied Flow, Computation of Flow Profiles, Unsteady Flow and Hydraulic Jumps, Design of Drainage Systems, Groundwater Hydraulics, Aquifer Parameter Estimation, Confined and Unconfined Aquifers, Steady and Unsteady Flow into Wells, Dupuit Approximations, Well Systems, Well Losses, Recharge, Well Development, Pollutant Transport in Groundwater, Hydraulics of Water and Wastewater Treatment Plants.
Learning Outcome	At the end of the course, students would be able to: 1. Understand the mechanics of flowing water 2. Design and evaluate drainage systems 3. Apply principles of open channel hydraulics to understand critical flow, uniform and gradually varied flow, and hydraulic jumps. 4. Understand the hydraulics of water and wastewater treatment plants
Assessment Method	Assignments, Quizzes, Mid-semester examination, and End-semester examination.

Text Books and Reference:

1. V.P. Singh, Willi H. Hager, Environmental Hydraulics, Springer, 1996.
2. L. Hamill, Understanding Hydraulics, Palgrave Macmillan; 2nd Rev. Ed., 2001
3. K Subramanya, Flow in Open Channels (5th Edition), McGraw-Hill, 2019.
4. F. M. White and Henry Xue, Fluid Mechanics, McGraw Hill, 2022.
5. Som, Biswas and Chakrabarty, Introduction to Fluid Mechanics and Fluid Machines, Tata McGraw-Hill Education, 2017.
6. V.T. Chow, Open-channel hydraulics, McGraw Hill Publications (1973).
7. Bhagu R Chahar, Groundwater Hydrology, McGraw-Hill Education, 2015
8. Todd D.K., Ground Water Hydrology, John Wiley and Sons, 2000
9. Garg, S.K., Environmental Engineering (Vol. I) Water Supply Engineering, Khanna Publishers, 37th edition, 2024
10. Garg, S.K., Environmental Engineering (Vol. II) Sewage Waste Disposal and Air Pollution Engineering, Khanna Publishers, 40th edition, 2024
11. Manual on Water Supply and Treatment Systems (Drink from Tap): Revised and Updated, Ministry of Housing and Urban Affairs, Govt. of India, 2024.

Course Number	CE6105- Atmospheric Science and Climate Change
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Atmospheric Science and Climate Change
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 3,4 and 5: 1. Equip the students to strengthen their knowledge in climate change. 2. The student will be able to apply advanced theory for climate change mitigation and adaptation. 3. The student will prepare for further research and graduate study by critical thinking and improving research skills.
Course Description	This coursework will provide insights in the field of climate studies and sciences. The objective of this course is to provide students' knowledge about radiative and climatic effects of pollutants; climate modelling; mitigation, governance, and adaptation; carbon capture, utilization and storage.
Course Outline	Introduction to Earth's climate and atmospheric sciences, Global Climate: Trends in anthropogenic emissions and troposphere composition. Climate monitoring and variability; advanced computing in climate change; impacts of climate change on human health and environment, United Nations Sustainable Development Goals on climate change; Introduction to climate models: Simple Radiative model, Models for global warming and cooling. Climate governance; Climate change mitigation and adaptation; Design innovations; Carbon capture, utilization and storage.
Learning Outcome	The course structure will impart: 1. High-quality knowledge to students on climate studies. 2. Insights into climate adaptation modelling and its application in various fields. 3. Understanding of interplay of climate change and mitigation actions will be examined.
Assessment Method	Quizzes, Presentations, Mid-semester and End-semester Examination

Textbooks:

1. Handbook of Climate Change Mitigation and Adaptation, M. Lackner, B. Sajjadi, W. Chen, Springer, 2022.
2. Climate System Modeling, K. E. Trenberth, Cambridge University Press, 2010.
3. Atmospheric Chemistry and Physics: From Air Pollution to Climate Change by John H. Seinfeld and Spyros N. Pandis, 3rd Edition, John Wiley & Sons, Inc., 2016.

Reference books:

1. Global Warming and Climate Crisis, B. E. Johansen, Springer, 2023.
2. Introduction to Three-Dimensional Climate Modeling, W. M. Washington and C. Parkinson, University Science Books, 2005.
3. Atmospheric Science: An Introductory Survey by Wallace, J.M., and P. V. Hobbs, 2nd edition, Elsevier, 2006.
4. Modeling of Atmospheric Chemistry by G. P. Brasseur and Daniel J. Jacob, Cambridge University Press, 2017.
5. Meteorology Today by Ahrens, C. Donald, 9th edition, Wadsworth Publishing Co. Inc., 2008.
6. IPCC, 2007 Fourth Assessment Report, Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B.

Averyt, M.Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Department Elective -II: Department Elective Course						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	CE5117	Water Resources Management	3	0	0	3
2.	CE6109	Geoenvironmental Engineering	3	0	0	3
3.	CE6114	Probabilistic Methods in Geotechnical Engineering	3	0	0	3
4.	CE6130	Analytical Methods in Civil Engineering	3	0	0	3
5.	CE6131	Sustainability of Water Resources System	3	0	0	3

Course	CE5117: Water Resources Management
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Water Resources Management
Learning Mode	Lectures
Learning Objectives	Complies with PLO 2, 3, 4 and 5 Students will be introduced to the role of disciplines of ecology and socio-economics, and legal and regulatory settings in the context of integrated water resources management.
Course Description	The course examines the development, use, management, and conservation of water resources in India and worldwide about the multiple, multi-scale interconnections between Integrated water resource management, and environmental and socioeconomic issues. In particular, it considers multidisciplinary approaches to water management problems and its sustainability.
Course Outline	Economics of water resources systems: principles of engineering economics; Microeconomics and efficient resource allocation, conditions of project optimality; Planning for multipurpose water resource projects; Introduction to mathematical optimization techniques; Multi-objective optimization; Application of optimization techniques; Water resources planning under uncertainty; Stochastic planning models; Application of simulation models. Regulation policies and governance of water; Water quality monitoring and measurement; Water and climate.
Learning Outcome	After attending this course, the following outcomes are expected: 1. Students will understand the theory and practice of water management at international, national and local scales 2. Understand hydrological, socioeconomic and environmental aspects of water management and apply critical thinking to water management 3. They will gain a broad understanding of the complexities of dealing with water resources problems
Assessment Method	Assignments, Projects and case studies, Quizzes, Mid-semester examination, and End-semester examination

Text Books/ Reference Book:

1. Q. Grafton and K. Hussey, Water Resources Planning and Management, Cambridge University
2. J.A.A. Jones, Global Hydrology: Processes, Resources, and Environmental Management, Prentice Hall, New York, 399 pp., 1998 (ISBN: 9780582098619).
3. S.A. Thompson, Water Use, Management, and Planning in the United States, Academic Press, San Diego, 371 pp., 1999 (ISBN: 9780126893403)

Course	CE6109: Geoenvironmental Engineering
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Geoenvironmental Engineering
Learning Mode	Lectures
Learning Objectives	Complies with PLO- number 1, 2, 3, and 4 1. Understanding methods of waste management and disposal 2. Learning methods of contaminated site characterization 3. Learning methods of remedial measures of a contaminated site 4. Understanding application of unsaturated soil in Geoenvironmental Engineering
Course Description	The course covers the source of various types of waste and its proper disposal, remediation of contamination sites. Municipal solid waste and industrial waste disposal techniques. Role of compacted unsaturated clay as liner material in landfill.
Course Outline	Production and classification of wastes, contaminated site characterization, Selection of waste disposal sites, selection criteria. Design of various landfill components such as liners, covers, leachate collection and removal, gas generation and management, ground water monitoring, stability analysis. Ash disposal facilities, dry disposal, wet disposal, design of ash containment system, stability of ash dykes, mine tailings. Planning, source control, soil washing, bioremediation, stabilization of contaminated soils and risk assessment approaches. Basics of unsaturated soil, soil suction, suction measurement techniques, SWCC, application of unsaturated soil in Geoenvironmental engineering.
Learning Outcome	At the end of the course, student would be able to: 1. Able to manage and dispose particular type of waste 2. Should be able to characterise contaminated site 3. Should be able to take appropriate remedial measures for a contaminated site 4. Should be able to use unsaturated clay as liner material in Geoenvironmental application.
Assessment Method	Assignments, Quizzes, Mid-semester examination and End-semester examination.

Textbooks:

1. H D Sharma and K R Reddy, "Geoenvironmental Engineering: Site Remediation, waste containment, and emerging waste management technologies", John Willey and Sons, 2004.
2. R N. Yong, "Geoenvironmental Engineering: Contaminated Ground: Fate of Pollutions and Remediation", Thomson Telford, 2000.
3. D. G. Fredlund and H. Rahardjo, "Soil Mechanics for Unsaturated soils", Wiley Publication, 1993.

Reference books:

1. R Kerry Rowe, R M Quigley, Richard W I Brachman and John R Booker, "Barrier Systems for Waste Disposal Facilities", 2nd edn, CRC press, 2019.

2. L N Reddy and H.I. Inyang, "Geoenvironmental Engineering: Principles and Applications", Marcel Dekker, 2000
3. James K Mitechell, K Soga, "Fundamentals of soil behaviour", Wiley Publication, 2005.
4. Charles W.W.Ng, B Menzies, "Advanced unsaturated soil mechanics and engineering", CRC Press, 2014

Course	CE6114: Probabilistic Methods in Geotechnical Engineering
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Probabilistic Methods in Geotechnical Engineering
Learning Mode	Lectures
Learning Objectives	Complies with PLO- number 1, 2, 3, and 4 1. To provide the knowledge of the advanced concept of probabilistic methods in geotechnical engineering. 2. Equip the students with a strong foundation in civil engineering for both research and industrial scenarios.
Course Description	This course intends to bridge the basic concepts with the advanced topics related to the application of probabilistic methods in geotechnical engineering. Topics ranging from risk, uncertainty, Monte Carlo simulation, and FORM are covered. The course started with the basic knowledge gained by the attendee up to undergraduate level regarding the probabilistic methods. Thereafter, the basics and advanced concept related to risk and reliability analysis will be studied by the students.
Course Outline	Introduction: Concept of risk; and uncertainty in geotechnical engineering analysis and design; Fundamental of probability models. Analytical models of random phenomena: Bayesian Analysis; Analysis of variance (ANOVA); Application of central limit theorem; confidence interval; expected value; and return period. Application of Monte Carlo simulation (MCS): Determination of function of random variables using MCS methods; Application of MCS in various geotechnical engineering problems. Determination of Probability Distribution Model: Probability paper; testing of goodness-of-fit of distribution models. Methods of risk Analysis: Composite risk analysis; Direct integration method; Method using safety margin; reliability index and safety factor; FORM; SORM; Applications of risk and reliability analysis in engineering systems.
Learning Outcome	At the end of the course, student would be able to: 1. Analyzed structure using various probabilistic methods available along with the method suggested in the Euro code. 2. Perform reliability analysis for various geotechnical problems. 3. Assess composite risk using various techniques to estimate failure of geotechnical structures.
Assessment Method	Assignments, Quizzes, Mid-semester examination and End-semester examination.

Textbooks:

1. Ang, A. H-S., and Tang, W. H., Probability Concepts in Engineering, Vol. 1, John Wiley and Sons, 2006.
2. Scheaffer, R. L., Mulekar, M. S. and McClave, J. T., Probability and statistics for Engineers, 5th Edition, Brooks / Cole, Cengage Learning, 2011.

Reference books:

1. Halder, A and Mahadevan, S., Probability, Reliability and Statistical Methods in Engineering Design, John Wiley and Sons, 2000.
2. All relevant IS and International Codes.

Course	CE6130 Analytical Methods in Civil Engineering
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Analytical Methods in Civil Engineering
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 2, 4, and 5 and the objective for learning this course are Lecture: 1. To brush up the undergraduate level understanding in light with some advanced approaches. 2. To develop p proficiency in numerical techniques and algorithms pertaining to various civil engineering problems. 3. To form a stepping stone towards advance understanding of risk and reliability analyses.
Course Description	First part of this course deals with the numerical method for non-linear equation solution, numerical integration, solution of liner system of equations, curve fittings, solution of differential equations. Second part of the course basic concept of probability theory and statistics, estimation of distribution property, stochastic data generation, risk and reliability methods for civil engineering.
Course Outline	<i>Module – I: Linear Algebra and Differential Equation</i> Linear algebra: Rank of a matrix, solutions of linear systems, linear independence and linear transformations, eigenvalues, eigenvectors, matrices similarity, basis of eigenvectors, diagonalization; Differential equations: homogeneous linear equations of second order, second order homogeneous equations with constant coefficients, case of complex roots, complex exponential function, non-homogeneous equations, solution by undetermined coefficients and variation of parameters. <i>Module – II: Numerical Methods</i> Introduction to Numerical Methods: Objectives of numerical methods, Sources of error in numerical solutions: truncation error, round off error, order of accuracy - Taylor series expansion; Roots of equations: Graphical method, Bisection method, Simple fixed-point iteration, Newton-Raphson method, Secant method, Modified secant method; Direct Solution of Linear systems: Naive Gauss elimination, LU decomposition, Gauss-Seidel, Gauss-Jordon, Jacobi iteration, Cholesky decomposition; Curve fitting: linear regression, polynomial regression, interpolation, spline fitting; Numerical Calculus: trapezoidal and Simpson's rule for integration; Solving differential equation: Euler's method, Runge-Kutta method, boundary value and eigenvalue problem and their application, solving partial differential equation. <i>Module – III: Probability and Statistics</i> Introduction: concept of risk, uncertainty in engineering analysis and design, fundamental of probability models; Analytical models of random phenomena: Bayesian analysis, analysis of variance (ANOVA), tests of hypothesis, confidence interval, properties of good estimates, interval estimation, maximum likelihood estimates, Sample size determination, central limit theorem, expected value, and return period; Miscellaneous Topics: Fitting theoretical and tests of goodness-of-fit (chi-square test, Kolmogorov-Smirnovtest), identification of outliers, regression with discrete dependent variables; Application of Monte

	Carlo simulation (MCS): determination of function of random variables using MCS methods, application of MCS in various problems.
Learning Outcome	At the end of the course, student would be able to Lecture: 1. Understand the different numerical methods for solving non-linear equations and numerical integration method. 2. Should be able to solve differential equations numerically. 3. Understand basic concept probability theory and statistics. 4. Should be able to fit statistical distribution and parameter estimation. 5. Should be able to perform MC simulation and perform risk and reliability analysis.
Assessment Method	Assignments, Quizzes, Project work, Mid-semester examination and End-semester examination.

Textbooks/ Reference books:

1. E. Kreyszig, Advanced Engineering Mathematics, Wiley, 10th edition, 2011.
2. M. D. Greenberg, Advanced Engineering Mathematics, Pearson, 2nd edition, 1998.
3. S. Chapra and R. Canale, Numerical Methods for Engineers, McGraw Hill, 6th edition, 2010.
4. S. Guha and R. Srivastava, Numerical Methods: For Engineering and Science, Oxford University Press, 1st edition, 2010.
5. R. L. Scheaffer, M. S. Mulekar, and J. T. McClave, Probability and statistics for Engineers, Brooks / Cole, Cengage Learning, 5th Edition, 2011.
6. A. Haldar and S. Mahadevan, Probability, Reliability, and Statistical Methods in Engineering Design, Wiley, 2000.
7. H. S. Ang and W. H. Tang, Probability Concepts in Engineering Planning and Design, John Wiley, 1975.
8. J. Benjamin and A. Cornell, Probability, Statistics, and Decision for Civil Engineers, McGraw Hill, 1963.

Course	CE6131: Sustainability of Water Resources System
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Sustainability of Water Resources System
Learning Mode	Lectures
Learning Objectives	Complies with PLO 2, 3, 4 and 5 Students will be introduced to the role of disciplines of ecology and socio-economics, and legal and regulatory settings in the context of integrated water resources management.
Course Description	The course examines the development, use, management, and conservation of water resources and the sustainability of water resources systems.
Course Outline	Advanced topics related to the sustainable management of groundwater systems will be discussed, emphasizing research applications.
Learning Outcome	After attending this course, the following outcomes are expected: 1. Students will understand the theory and practice of sustainable water resources management at international, national and local scales 2. Understand hydrological, socioeconomic and environmental aspects of water management and apply critical thinking to water management 3. They will gain a broad understanding of the complexities of dealing with water resource problems and develop research-based solution techniques.
Assessment Method	Assignments, Projects and case studies, Quizzes, Mid-semester examination, and End-semester examination

Text Books/ Reference Book:

1. Q. Grafton and K. Hussey, Water Resources Planning and Management, Cambridge University
2. J.A.A. Jones, Global Hydrology: Processes, Resources, and Environmental Management, Prentice Hall, New York, 399 pp., 1998 (ISBN: 9780582098619).
3. S.A. Thompson, Water Use, Management, and Planning in the United States, Academic Press, San Diego, 371 pp., 1999 (ISBN: 9780126893403)

Sl. No.	Subject Code	SEMESTER II	L	T	P	C
1.	CE5201	Biological Principles and Processes	3	0	0	3
2.	CE5202	Air Pollution and Control	3	0	2	4
3.	CE5203	Environmental Impact Assessment	3	0	0	3
4.	CE52XX/ CE62XX	DE-III (Environmental Elective)	3	0	0	3
5.	CE52XX/ CE62XX	DE-IV (Environmental Elective/ Department Elective)	3	0	0	3
6.	RM6201	Research Methodology	3	1	0	4
7.	IK6201	IKS	3	0	0	3
	TOTAL		21	1	2	23

Course Number	CE5201: Biological Principles and Processes
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Biological Principles and Processes
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 1, 2 and 5 1. To provide fundamental knowledge of biological principles and processes applicable for water and wastewater treatment. 2. To provide advanced scientific and technical knowledge of applicability of environmental microbiology and biochemistry for water and wastewater treatment. 3. To acquaint students with the advanced knowledge and application of bioreactors design and operation with reactor kinetics for water and wastewater treatment.
Course Description	The course intends to provide an overview of various biological principles and processes along with different unit operations and unit processes for removing organic and inorganic contaminants, emerging pollutants, and nutrients present in water and wastewater with the application of environmental microbiology and biochemistry.
Course Content	Water and wastewater characteristics, Natural and engineered environmental systems, Schematic and flow diagram of water and wastewater treatment plants, Preliminary and primary treatment, secondary treatment, tertiary treatment, Environmental microbiology and biochemistry, Stoichiometry and energetics of bacterial reactions, Kinetics of bacterial growth, Reactor kinetics, Aerobic and anaerobic processes, suspended growth, attached growth and hybrid processes, Biological reactors design and operation, Activated sludge process and its modifications, Trickling filter, trickling filter, Upflow anaerobic sludge blanket (UASB) reactor, Lagoon and oxidation pond, Biofilm reactors applications, moving bed biofilm reactor, membrane bioreactor, sequencing batch reactor, Biological nutrients removal, Nitrification, Denitrification, Phosphorous removal, Bioprocesses for heavy metals removal.
Learning Outcome	At the end of the course, students would be able to: 1. Understand fundamental knowledge of biological principles and processes applicable for water and wastewater treatment. 2. Comprehend, understand and apply the concept of environmental microbiology and biochemistry for water and wastewater treatment with an interdisciplinary flavor. 3. Analyze and apply suitable biological processes and unit operations for the removal of contaminants including emerging contaminants with bioreactor configurations and process kinetics.
Assessment Method	Assignments, Quizzes, Mid Semester Examination and End Semester Examination

Text Books:

1. Peavy, H.S., Rowe, D.R., and Tchobanoglous, G., Environmental Engineering, McGraw-Hill International Ed., 1985.
2. S. J. Arceivala and S. R. Asolekar, Wastewater Treatment for Pollution Control and Reuse, 3rd Edition, McGraw-Hill Education (India) Pvt. Ltd., New Delhi, 2006.
3. R. Mitchell, Environmental Microbiology, John Wiley, 1992.
4. B.E. Rittmann, Environmental Biotechnology: principles and applications, McGraw-Hill, 2001.

5. Metcalf & Eddy, Wastewater Engineering - Treatment and Reuse (Revised by Tchobanoglous, G., Burton, F.L. and Stensel, H.D.), Tata McGrawHill, 2004.

Reference Books:

1. L.D. Benefield, and C.W. Randall, Biological Process Design for Wastewater Treatment, Prentice-Hall, Englewood Cliffs, New Jersey, 1980.
2. N. F. Gray, Biology of Wastewater Treatment, Oxford University Press, London, 1989.

Course Number	CE5202- Air Pollution and Control
Course Credit (L-T-P-C)	3-0-2-4
Course Title	Air Pollution and Control
Learning Mode	Lectures and Practical
Learning Objectives	Complies with PLOs 2,3 and 5: 1. To provide insights into causes and effects of air pollution and its control by technological interventions 2. To provide technical knowledge to students to plan, design and implement various technological solutions for air pollution control in the industrial setup 3. To equip students to address current issues and challenges in field of air pollution control
Course Description	The course will provide a deeper understanding of air pollutants and their fate and dispersion, measurements, monitoring and modelling on the backdrop of meteorology and environmental legislations. The course also helps to understand the impacts of air pollution on human health and various technological interventions for the improvement of air quality in real-life scenario.
Course Outline	Theory: Module I: Air Pollution-sources of pollutants, Effects on human health and environment, Classification of pollutants, Fate and transport of pollutants, Criteria pollutants, Photochemical smog, Greenhouse gases, Global warming and climate change, Indoor air pollution. Module II: Meteorology: Elemental properties of atmosphere, Influence of meteorological parameters on air quality, Effect of atmospheric pollutant on meteorological parameters, Dispersion of air pollutants, Atmospheric modelling, Box model, Gaussian plume dispersion model, Atmospheric cleansing processes. Module III: Air quality and emission standards: Air Pollution legislations, Air quality monitoring, Measurement techniques and instrumentation Module IV: Air pollution control techniques: selection of control devices, particulate and gaseous pollutant control devices, Design of air pollution control devices. Module V: Air quality index (AQI) and health risk: Concept of AQI for India and abroad, Ambiguity in existing AQIs, Estimation of AQI from air quality data, Health risk due to particulates and gaseous pollutants, hazard quotient and risk estimation, exposure assessment. Practical: Sampling: Different types of air sampling for particulate matter and gaseous pollutant. Types of samples (grab samples, composite samples, etc.), Factors to consider in sampling design (location, frequency, timing), Operation of the different types particulate matter samplers, gaseous samplers, and sensors. Offline and real-time measurements. Gravimetric analysis of filters, analysis of gaseous samples, chemical speciation of particulate matter using spectrometric and chromatographic method of analysis such as IC, TOC, ICPMS, AAS, UV-Vis Spectrophotometer. Advanced analytical techniques (FTIR, XRD, SEM, TEM, TGA, etc.) on particulate matter.

Learning Outcome	At the end of the course, students would be able to: Theory: 1. Understand the concept of causes and effects of air pollution with the dispersion modelling of the pollutants 2. Comprehend and understand the influence of meteorological factors in air quality modelling and monitoring 3. Analyze and understand the current issues and challenges for air pollution control and impact on human health 4. Comprehend, understand and apply various practices and technologies for betterment of air quality in real-life scenario Practical: 1. Interpret the quality of air by assessing both particulate matter and gaseous pollutants. 2. Hands on experience of operating air samplers. 3. Analyzing the air quality parameters using advanced instruments
Assessment Method	Theory: Assignments, Quizzes, Presentations, Mid-semester and End-semester Examination Practical: Lab Reports, Mid-semester examination and End-semester examination

Text books:

1. Davis, W.T., Fu, J.S. and Godish, T., Air Quality, CRC Press, 2021.
2. de Nevers, N., Air Pollution Control Engineering, Waveland Press, 2016.
3. Wark, K., Warner, C.F. and Davis, W., Air Pollution: Its Origin and Control, Pearson, 1998.

Reference Books:

1. Pandis, S.N. and Seinfeld, J.H., Atmospheric Chemistry and Physics: From Air Pollution to Climate Change, Wiley, 2016.
2. Stull, R.B., Meteorology for Scientist and Engineers, Third Edition, Brooks/Cole, 2015.
3. Cooper, C.D. and Alley, F.C., Air Pollution Control: A Design Approach, Waveland Press, 2010.
4. Introduction to Atmospheric Chemistry, Daniel J. Jacob, Princeton University Press, 1999.

Course	CE5203: Environmental Impact Assessment
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Environmental Impact Assessment
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 3, 4 and 5 Students will be able to advance their knowledge of impact assessment and the procedures that must be followed throughout the integrated environmental assessment process through this course.
Course Description	This course introduces the environmental impact assessment (EIA) technique as a crucial tool for responsible environmental decision-making. It provides an introduction to the concepts, methods, issues and various stages of the EIA process
Course Outline	Introduction to EIA, General Framework for Environmental Impact Assessment, Strategic EIA, Rapid and comprehensive EIA. EIA methodologies: Screening, Initial environmental examination (IEE), Full-scale EIA including scoping, identification, impact prediction, establishing baseline conditions and evaluation, EIA Methods, tools and techniques. Impact analysis on biophysical environment, geomorphological aspect, soil & water, socio-economic aspect, noise, transport etc., Environment Management plans. EIA reporting, Environmental Impact Statement (EIS), Environmental statement procedures, environmental appraisal, Environmental Legislation, Review and screening of EIA, Implementation. Introduction of the terms Environmental Risk Analysis, Cost Benefit Analysis, Life cycle Assessment, Case studies and EIA practices.
Learning Outcome	Upon completion of this course, the students will be able to: 1. Understand the different steps within environmental impact assessment. 2. Be aware of the environmental legislations, and policies of the country and international environmental conventions and protocols. 3. Recognize the role of stakeholders in the EIA process, how to communicate with them, and why they are important. 4. Able to explore various case studies and examples of EIA in practice.
Assessment Method	Assignments, Quizzes, Mid-semester examination, and End-semester examination.

Text Books:

1. Canter, L. W., Environmental Impact Assessment, McGraw-Hill, 2nd Ed., 1996.
2. Kevin Hanna, Environmental Impact Assessment: Practice and Participation, Oxford University Press, 3rd edition, 2015.
3. Percival, R. V., Schroeder, C. H., Miller, A. S., & Leape, J. P. Environmental regulation: Law, science, and policy. Aspen Publishing, 2021.
4. Agarwal, N.P., Environmental Reporting and Auditing, Raj Pub., 2002

Reference Books:

1. Angus Morrison-Saunders, Advanced Introduction to Environmental Impact Assessment, Second Edition, Elgar, 2023.

2. Y. Anjaneyulu. V. Manickam; Environmental Impact Assessment, BS Publication Wiley and Sons, Third Reprint, 2013.
3. John Glasson, Riki Therivel, Andrew Chadwick, Introduction to Environmental Impact Assessment, Routledge, 2012.
4. David P. Lawrence, Environmental Impact Assessment: Practical Solutions to Recurrent Problems, Wiley, 2005.
5. John- Glasson; (edited: Peter Morris, Riki Therivel) Methods in Environmental Impact Assessment. Routledge, 2009

Department Elective -III: Environmental Elective Course						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	CE6201	E-waste Management for Circular Economy	3	0	0	3
2.	CE6202	Industrial Pollution Control and Prevention	3	0	0	3
3.	CE6203	Water Supply and Sewerage Network Design	3	0	0	3
4.	CE6204	Design of Water and Wastewater Treatment Facilities	3	0	0	3
5.	CE6205	Advanced Water and Wastewater Engineering	3	0	0	3

Course Number	CE6201: E-waste Management for Circular Economy
Course Credit (L-T-P-C)	3-0-0-3
Course Title	E-waste Management for Circular Economy
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 2, 4 and 5 1. To familiarize the students about the problem of e-waste generation and hazardous composition, and impact on the environment and human health 2. To acquaint the students with existing international and national legislations, knowledge and practices regarding e-waste management 3. To train the students to plan, implement and operate recycling plants for environmentally-sound e-waste management for resource recovery for a circular economy with case studies
Course Description	The course intends to provide an overview of e-waste generation and associated influencing factors, composition, international and national legislations and various e-waste recycling techniques for resource recovery for a circular economy. Further, the course intends to provide and discuss case studies on e-waste recycling.
Course Content	E-waste and waste electrical and electronic equipment (WEEE), e-waste generation: global and national, factors affecting e-waste generation, classification of e-waste, average obsolescence rate or end of life period, formulas used for estimation of e-waste generation; Components of e-waste, composition of e-waste including printed circuit boards (PCBs), rechargeable batteries, spent magnet, ceramic based equipment, solar PV, etc.; Hazardous materials in e-waste, e-waste toxicity by standard toxicity tests and toxicity standard; International legislation: the Basel convention, WEEE Directive in the European Union, Restrictions of Hazardous Substances (RoHS) Directive, COP; E-waste management rules and amendments in India, Roles and responsibilities of stakeholders - Manufacturers and producers, refurbishes and the recyclers, Guidelines for e-waste management by CPCB; concept and meaning of expected producer responsibility (EPR) and recycling target; E-waste management in developed and developing countries, Informal sectors and rudimentary processes and crude methods, associated pollution, occupational hazards, economics of the informal sectors and loss of valuable materials, way forward for converting informal to formal sector; Sustainability and sustainable development goals (SDGs) in the context of e-waste, Circular economy and urban mining concepts; formal e-waste management framework, sustainable techniques for segregation and dismantling, closed loop recycling, zero discharge concept, energy efficiency; E-waste minimization and hazard reduction: 3Rs, green design with green materials, R to R concept with the Right to Repair Rule and Act, refurbishing concept, modular design; Recycling techniques: Basics of metallurgical techniques and urban mining, pyro-, hydro- and biometallurgical techniques, pulverization, steps and different process for recycling and recovery, beneficiation, Case studies on e-waste recycling.
Learning Outcome	At the end of the course, students would be able to: 1. Understand about the problem of e-waste generation, hazardous composition, national and international legislations, and detrimental effects on the environment and human health 2. Devise and adopt various strategies on e-waste minimization and hazard reduction with green design, right to repair, and refurbishing

	3. Plan and implement environmentally-sound e-waste recycling techniques for resource recovery for a circular economy with case studies 4. Learn about the state-of-the-art and emerging e-waste recycling techniques for sustainability.
Assessment Method	Assignments, Quizzes, Mid Semester Examination and End Semester Examination

Text and Reference Books:

1. Hussain, C.M., Environmental Management of Waste Electrical and Electronic Equipment, Elsevier, 2021.
2. Indian E-waste (Management) Rules, 2022.
3. Fowler, B., Electronic Waste: Toxicology and Public Health Issues, Elsevier, 2017.
4. Prasad, M.N.V., Vithanage, M. and Borthakur, A., Handbook of Electronic Waste Management: International Best Practices and Case Studies, Butterworth-Heinemann, 2019.

Course Number	CE6202: Industrial Pollution Control and Prevention
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Industrial Pollution Control and Prevention
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 2, 4 and 5 1. To learn and implement cleaner production activities and industrial (solid, liquid and gaseous) waste/emission management strategies for pollution control and prevention 2. To discuss the most commonly applied treatment technologies and explain their suitability for industrial (solid, liquid and gaseous) waste/emission treatment applications as well as their advantages and disadvantages based on waste characteristics 3. To able to select the most appropriate treatment technology and devise a treatment train/chain (sequence of treatment processes) to treat an industrial waste/emission stream (solid, liquid and gaseous) for a selected industry 4. To recognize waste treatment technologies applied to industrial waste treatment and analyze industrial waste schemes from case studies presented from a range of industries
Course Description	The course intends to provide an overview of various types of industries including manufacturing industry, process flow schematics with materials/water requirements and waste/emission generation with composition. Further, the course intends to cover and discuss pollution prevention and cleaner production approaches along with waste treatment and emission control techniques with industrial case studies.
Course Content	Introduction to Industrial Waste: Types of industries and industrial pollution, Types of industrial wastes - solid, liquid and gaseous wastes, Hazardous waste - definition and concept, Basics of Water Quality Parameters, Basics of Air Pollution, Characteristics of industrial wastes, Effects of industrial wastes on environment and human health, Toxicity and risk assessment; Environmental standards and legislations; Pollution Prevention and Cleaner Production: Waste minimization, Source reduction, Use of alternate raw materials, Process modifications, Recycle, reuse and byproduct recovery, Zero liquid discharge (ZLD), Opportunities and barriers to cleaner production; Emerging topics – Industry 4.0 and 5.0 concept, and Design for the environment (DfE); Waste Treatment and Emission Control Techniques: Physico-chemical and biological treatment of wastewater, Concept of common effluent treatment plant (CETP), Concept of zero discharge, Industrial sludge management, Industrial air pollution, Control of gaseous emissions; Pollution Control in Major Industries – Case Studies: Manufacturing processes and flow sheets, Sources and characteristics of wastes, Waste treatment and disposal methods – Thermal power plants, Iron and steel, Metal plating, Fertilizer, Refinery, Tannery, Food industry, etc.
Learning Outcome	At the end of the course, students would be able to: 1. Comprehend and understand about the manufacturing processes with materials/water requirements and waste/emission generation with composition in various secondary/manufacturing industries with case studies 2. Devise, integrate and implement cleaner production, water management, effluent treatment processes, sludge handling and

	disposal, and air pollution control towards devising an industrial waste treatment train/chain for a selected industry in a sustainable manner 3. Learn about the state-of-the-art and emerging industrial practices/regimes aiming towards pollution control and prevention.
Assessment Method	Assignments, Quizzes, Mid Semester Examination and End Semester Examination

Text Book:

1. de Nevers, N., Air Pollution Control Engineering, Waveland Press, 2010.
2. Eckenfelder Jr., W.W., Industrial Water Pollution Control, 3rd Edition, McGraw-Hill, 2000.
3. Wark, K. and Warner, C. F., Air Pollution- Its Origin and Control, Harper & Row, 1981.
4. Wise, D.L. and Trantolo, D.J. (eds.), Process Engineering for Pollution Control and Waste Minimization, 1st Edition, Marcel Dekker, 1994.

Reference Books:

1. Cooper, C.D. and Alley, F.C., Air Pollution Control: A Design Approach, Waveland Press, 2002.
2. Ghassemi, A. (ed.), Handbook of Pollution Control & Waste Minimization, 2nd Edition, Marcel Dekker, 2002.
3. Metcalf & Eddy, Wastewater Engineering - Treatment and Reuse (Revised by Tchobanoglous, G., Burton, F.L. and Stensel, H.D.), Tata McGrawHill, 2004.

Course Number	CE6203- Water Supply and Sewerage Network Design
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Water Supply and Sewerage Network Design
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 2 and 4: 1. To study and analyze the design criteria of water supply and sewer system 2. To study and analyze the wells and reservoir and service storage for the water supply system 3. To layout and design the water distribution system 4. To layout and design the sewerage system 5. To layout and design the pump station.
Course Description	This course aims to equip students with the skills to design comprehensive water supply systems and sanitary sewer systems, including all necessary pumping station design. Students are expected to demonstrate their knowledge and understanding by applying them to case studies involving a water distribution network and a sewer network
Course Outline	Overview of water supply system components; estimation of water demand; considerations for design period, population growth, and flow rates in water supply systems; factors influencing water consumption and demand variability; design and optimization of water distribution networks, including analysis methods; types of reservoirs, design parameters, and approaches to reservoir design; fundamentals of designing water pumping stations. Principles of wastewater collection system design, including separate, combined, and semi-combined sewers; estimation of dry weather flows; sewer pipe hydraulics, focusing on pipe sizing and design; design of manhole chambers and stormwater overflows; design and operation of pumping stations. Maintenance strategies for water supply and wastewater systems
Learning Outcome	At the end of the course, students would be able to: 1. Understand the components and design principles for water distribution networks, focusing on demand, flow rates, reservoir design and pumping stations. 2. Learn to design wastewater collection systems, including pipe sizing, dry weather flow estimation, and manhole placement. 3. Gain knowledge of operation and maintenance strategies for water supply and wastewater systems.
Assessment Method	Assignments, Quizzes, Mid-semester examination, and End-semester examination

Text Books:

1. Peavy, H. S., Rowe, D. R. and Tchobanoglous, G., Environmental Engineering, McGraw-Hill International Ed., 1985.
2. McGhee, T. J., Water Supply and Sewerage, McGraw Hill International, 1991.
3. Goel, S, Water and Wastewater Engineering, Cambridge University Press, First edition (12 December 2019)

Reference Books:

1. Manual on Sewerage and Sewage Treatment Systems, Central Public Health & Environmental Engineering Organisation, Ministry of Housing and Urban Development, Govt. of India, 2013.
2. Manual on Water Supply and Treatment Systems (Drink from Tap): Revised and Updated, Ministry of Housing and Urban Affairs, Govt. of India, 2024.
3. AWWA/ ASCE, Water Treatment Plant Design, 3rd Edition- McGraw Hill, 1998.
4. Quasim, S. R., Motley E. M. and Zhu, G., Water Works Engineering- Planning, Design and Operation, Prentice Hall, 2000.

Course	CE6204: Design of Water and Wastewater Treatment Facilities
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Design of Water and Wastewater Treatment Facilities
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 1, 2 and 4 1. Understand the principles of water and wastewater treatment for different project scales. 2. Learn the design methodologies for on-site water treatment plants and wastewater treatment plants. 3. Develop skills in selecting appropriate treatment technologies and equipment. 4. Gain hands-on experience through a comprehensive design project that covers all aspects of on-site water and wastewater systems.
Course Description	This course provides an in-depth exploration of the design principles and engineering practices involved in on-site water and wastewater treatment plants for small to large-scale projects. Through a combination of theoretical instruction, case studies, and design projects, students will gain a comprehensive understanding of the entire process of water and wastewater treatment.
Course Outline	Design of water and wastewater treatment facilities: Selection of site, Design of various units; Hydraulics of treatment plant: flow measurement and hydraulic control points, hydraulic analysis of unit operations, hydraulic profile through the treatment plant.
Learning Outcome	At the end of the course, students would be able to: 1. Design water treatment plant including treatment units like sedimentation, filtration, and disinfection, meeting water quality standards. 2. Design wastewater treatment plants, including primary and secondary treatment processes. 3. Analyze hydraulic profiles and flow dynamics in water and wastewater treatment plants.
Assessment Method	Assignments, Quizzes, Mid-semester examination, and End-semester examination.

Text Books:

1. Nazaroff, W.W. and Alvarez-Cohen, L., Environmental Engineering Science, Wiley, 2000.
2. Peavy, H.S., Rowe, D.R., and Tchobanoglous, G., Environmental Engineering, McGraw-Hill International Ed., 1985.
3. Goel, S, Water and Wastewater Engineering, Cambridge University Press, First edition (12 December 2019)
4. J. M. Montgomery, Water Treatment Principles and Design, John Wiley & Sons, 1985
5. T. J. McGhee, Water Supply and Sewerage, McGraw-Hill, Inc, 1991.
6. Qasim, S. R., Wastewater Treatment Plant, Planning Design and Operation, CBS Publishing Japan Ltd, New York, 1985
7. S. J Arceivala and S. R. Asolekar, Wastewater Treatment for Pollution Control and Reuse, Tata McGraw Hill, 2006.
8. Metcalf & Eddy, Wastewater Engineering- Treatment and Reuse (Revised by G. Tchobanoglous, F. L. Burton and H. D. Stensel), Tata McGraw Hill, 4th Edn., 2004.

Reference Books:

1. Manual on Sewerage and Sewage Treatment Systems, Central Public Health & Environmental Engineering Organisation, Ministry of Housing and Urban Development, Govt. of India, 2013.
2. Manual on Water Supply and Treatment Systems (Drink from Tap): Revised and Updated, Ministry of Housing and Urban Affairs, Govt. of India, 2024.

Course Number	CE6205: Advanced Water and Wastewater Engineering
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Advanced Water and Wastewater Engineering
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 2, 3 and 4 1. To acquaint students with advanced knowledge and practices in water and wastewater treatment engineering. 2. Train students to plan, design and operate water treatment plant and wastewater treatment plant in real-life scenario. 3. Provide advanced scientific and technical knowledge to prepare students to address issues and challenges in water and wastewater treatment engineering sector.
Course Description	The course intends to provide a deeper understanding of advanced concepts of principles and processes for water supply and treatment, and wastewater treatment with a major emphasis to advanced treatment techniques for water reuse. The course also intends to cover design aspects of water and wastewater treatment for the improvement of water quality in real-life scenario.
Course Content	Water requirements – Water demand, forecasting and management, Surface water and Ground water sources, Water quality and drinking water standards, Determination of reservoir capacity, Transportation and distribution of water, Distribution system design and analysis, Optimization of pipe network systems, Distribution reservoirs and service storage, Pumping and design considerations for pumps, Water treatment systems, Physico-chemical processes, Sedimentation, Coagulation, Flocculation, Granular media filtration, Disinfection, Water softening, Adsorption and ion exchange processes. Wastewater- Sources, nature and characteristics, Estimation of wastewater flow rate and fluctuations, Estimation of storm water. Combined and separate sewerage systems - Design, Sewer materials, Sewer appurtenances, Construction and maintenance of sewers and pumping of sewage, Analysis of wastewater - determination of solids, COD, BOD, nutrients and their significance, BOD progression and its formulations. Wastewater treatment systems with advance processes- Primary, secondary and tertiary treatments, screens, grit chambers, sedimentation tanks, chemical precipitation, Biological treatment - objectives, methods and design of activated sludge and trickling filter units, moving bed biofilm reactor, membrane bioreactor, sequencing batch reactor, wastewater reuse and emerging contaminants removal techniques; Sewage sludge - its treatment, disposal and reuse, Effluent standards and disposal.
Learning Outcome	At the end of the course, students would be able to: 1. Comprehend advanced knowledge of principles and processes involved in water and wastewater treatment with a major focus to water reuse 2. Comprehend, understand and apply various advanced practices and techniques for water and wastewater treatment with a goal towards water reuse in real-life scenario 3. Comprehend, understand and apply best available technique for a particular contaminant or a set of contaminants including emerging contaminants for improvement in water quality 4. Analyze and understand the current issues and challenges in the water and wastewater treatment sector

Assessment Method	Assignments, Quizzes, Mid Semester Examination and End Semester Examination
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Text Books:

1. H. S. Peavy, D. R. Rowe and George Tchobanoglous, Environmental Engineering, McGraw-Hill International Ed., 1985.
2. M. L. Davis and D. A. Cornwell, Introduction to Environmental Engineering, McGraw-Hill, Inc., 2014.
3. C. N. Sawyer, P. L. McCarty and G. F. Parkin, Chemistry for Environmental Engineers, McGraw- Hill, 1994.
4. Rumana Riffat, Fundamentals of Wastewater Treatment and Engineering, CRC Press, 2012.

Reference Books:

1. Metcalf & Eddy, Wastewater Engineering- Treatment and Reuse (Revised by G. Tchobanoglous, F. L. Burton and H. D. Stensel), Tata McGraw Hill, 4th Edn., 2004.
2. Manual on Sewerage and Sewage Treatment Systems, Central Public Health & Environmental Engineering Organisation, Ministry of Housing and Urban Development, Govt. of India, 2013.
3. Manual on Water Supply and Treatment Systems (Drink from Tap): Revised and Updated, Ministry of Housing and Urban Affairs, Govt. of India, 2024.

Department Elective - IV: Department Elective Course						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	CE5217	Geoinformatics for Engineers	3	0	0	3
2.	CE5218	Groundwater Hydrology	3	0	0	3
3.	CE5219	Open Channel Hydraulics	3	0	0	3
4.	CE6208	Mine Wastes Generation and Management	3	0	0	3
5.	CE6211	Utilization of industrial Byproducts for Geotechnical Application	3	0	0	3
6.	CE6218	Finite Element Method	3	0	0	3
7.	CE6223	Uncertainty, Risk and Reliability Analyses in Civil Engineering	3	0	0	3
8.	CE6228	Analytical Techniques for Infrastructure Systems Analysis	3	0	0	3

Course	CE5217: Geoinformatics for Engineers
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Geoinformatics for Engineers
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 1, 2 & 3- 1. To provide fundamental knowledge in the Basics of GIS. 2. Train students to download, process and prepare the GIS data for Water resources applications. 3. Provide scientific and technical knowledge, to prepare students to prepare maps using GIS for Water resources applications.
Course Description	This course will discuss fundamental concepts in GIS. The course will cover theory and real-world practice in map preparation, flood mapping, rivers and canal mapping and GIS software and databases.
Course Outline	Definition – Basic components of GIS – Map projections and coordinate system – Spatial data structure: raster, vector – Spatial Relationship – Topology – Geodata base models: hierarchical, network, relational, object-oriented models – Integrated GIS database -common sources of error – Data quality: Macro, Micro and Usage level components - Meta data - Spatial data transfer standards. Thematic mapping – Measurement in GIS: length, perimeter, and areas – Query analysis– Reclassification – Buffering - Neighbourhood functions - Map overlay: vector and raster overlay – Interpolation – Network analysis – Digital elevation modelling. Analytical Hierarchy Process, – Object oriented GIS – AM/FM/GIS – Web Based GIS Spatial data sources – GIS approach water resources system – Thematic maps -Rainfall-runoff modelling – Groundwater modelling – Water quality modelling – Flood inundation mapping and Modelling – Drought monitoring – Cropping pattern change analysis – Performance evaluation of irrigation commands. Site selection for artificial recharge - Reservoir sedimentation. Introduction to various remote sensing satellite data (Like Landsat, Sentinel, Radar data, DEM, GRACE etc) and their applications for different water resources engineering applications.
Learning Outcome	At the end of the course, student would be able to: 1. Understand technical aspects and properties of GIS. 2. Download and perform GIS based analysis on different satellite data. 3. Basic flood mapping using Optical and SAR data.
Assessment Method	Assignments (10%), Quizzes (10%), Mid-semester examination (30%) and End-semester examination (50%).

REFERENCES:

1. Lillesand, T.M. and Kiefer, R.W., Remote Sensing, and Image Interpretation III Edition. John Wiley and Sons, New York. 1993.
2. Burrough P.A. and McDonnell R.A., Principles of Geographical Information Systems. Oxford University Press. New York. 1998.
3. Ian Heywood Sarah, Cornelius, and Steve Carver: An Introduction to Geographical Information Systems. Pearson Education. New Delhi, 2002.
4. Jensen, J.R., Introductory digital image processing: a remote sensing perspective, Fourth Edition, Pearson, 2017
5. Joseph, G & Jagannathan, C., Fundamentals of remote sensing (3rd edition), The Orient Blackswan, 2018.

Course	CE5218: Groundwater Hydrology
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Groundwater Hydrology
Learning Mode	Lectures
Learning Objectives	Complies with PLO-1, 2, 3, 4, and 5 1. To provide fundamental knowledge of groundwater hydrology. 2. Train students to plan, design and model groundwater systems. 3. Provide scientific and technical knowledge, to apply the learning in sustainable management of groundwater resources.
Course Description	This course will discuss fundamental concepts of groundwater flow, its occurrence, movement, and flow principles. It will also cover issues related to groundwater management, such as pollution and over-exploitation.
Course Outline	Characteristics of groundwater, Global distribution of water, Role of groundwater in water resources system and their management, groundwater column, aquifers, classification of aquifers. Hydrogeological cycle, water level fluctuations, Groundwater balance. Darcy's Law, Hydraulic conductivity, Aquifer transmissivity and storativity, Dupuit assumptions Storage coefficient - Specific yield Heterogeneity and Anisotropy, Direct and indirect methods for estimation of aquifer parameters. Governing equation for flow and contaminant transport through porous medium - Steady and unsteady state flow - Initial and boundary conditions, solution of flow equations. Tracer techniques using environmental isotopes. Surface water groundwater interaction. Steady and unsteady flow to a well in a confined and unconfined aquifer - Partially penetrating wells - Wells in a leaky confined aquifer - Multiple well systems - Wells near aquifer boundaries - Hydraulics of recharge wells. Dynamic equilibrium in natural aquifers, groundwater budgets, management potential of aquifers, safe yield, seepage from surface water, stream-aquifer interaction, artificial recharge. Hydrodynamic dispersion - occurrence of dispersion phenomena, coefficient of dispersion - Aquifer advection-dispersion equation and parameters - initial and boundary conditions - method of solutions, solution of advection-dispersion equation. Climate change and impact on groundwater. Groundwater monitoring and groundwater sampling techniques. Introduction to sustainable groundwater management.
Learning Outcome	After attending this course, the following outcomes are expected: 1. Student should be able to develop an understanding about the occurrence, movement, and fate of groundwater in aquifer systems. 2. Students comprehend the physical principles of groundwater flow and solute transport processes and can represent those processes through mathematical equations in assessing water quantity and quality in ground-water systems. 3. Students should be able to understand the challenges associated with groundwater resources and apply the scientific method and critical thinking in groundwater quantity and quality management.
Assessment Method	Assignments, Quizzes, Mid-semester examination, and End-semester examination

Text Books/ Reference Book:

1. Bhagu R Chahar, Groundwater Hydrology, McGraw-Hill Education, 2015
2. Todd D.K., Ground Water Hydrology, John Wiley and Sons, 2000
3. Freeze A, Cherry JA, Groundwater, Prentice Hall, 1979.
4. Bear J., Hydraulics of Groundwater, Dover Publications INC, 1979
5. Integrated Groundwater Management, Springer Open
6. Richard W Healey, Estimating Groundwater Recharge, Cambridge University Press

Course	CE5219: Open Channel Hydraulics
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Open Channel Hydraulics
Learning Mode	Lectures
Learning Objectives	Complies with PLO 1, 2, 3, 4 and 5 Students will be enabled to understand the fundamental principles governing open channel hydraulics for the design of engineering systems. The course is intended to assist students in developing the skills needed for systematic decomposition and solution of real-world problems.
Course Description	This course covers principles of flow in open channels, conservation laws, critical flow, uniform flow, gradually varied flow, unsteady flow, flow through hydraulic structures, hydraulic jump, and flow routing, analytical and numerical techniques will also be discussed, programming assignments will be carried out in common software and MATLAB.
Course Outline	Difference between Open Channel Flow and Pipe Flow, Types of Channel, Geometric parameters of a channel, Classification of Open Channel Flow, Continuity and Momentum equation. Resistance flow formula, Velocity distribution, Equivalent roughness coefficient, Velocity coefficients, Uniform flow in rigid boundary channel, Uniform flow in mobile boundary channel. Concept of Specific Energy, Critical Depth, Alternate depth, Specific Force, Sequent depth. Governing equation of GVF, Classification of Gradually Varied Flow, Computation of GVF profile, Rapidly Varied Flow, hydraulic Jump, Flow over a Hump, Flow in Channel Transition. Concept of best hydraulic section, Design of rigid boundary canal, design of channel in alluvial formation- Kennedy's theory, Lacy's theory, Method of Tractive force, Free-board in canal. Wave and their classification, Celerity of wave, Surges, Characteristic equation.
Learning Outcome	At the end of the course, student would be able to: 1. Learn the form of mass, momentum and energy equations under non hydrostatic pressure distribution and non-uniform velocity profiles. 2. Analyse gradually varied flows numerically. 3. Learn how to analyse rapidly varied flow numerically. 4. Design rigid-boundary and erodible channels. 5. Gain information about the flow through spillways and culverts. 6. Basic components of sediment transport in open channels.
Assessment Method	Assignments, Quizzes, Mid-semester examination, and End-semester examination

Text Books/ Reference Book:

1. K Subramaniya, Flow in Open Channels, McGraw Hill, 1997.
2. V.T. Chow, Open-channel hydraulics, McGraw Hill Publications (1973).
3. Sturm, 2001, Open-Channel Hydraulics, McGraw Hill.
4. H. Chaudhury, Open channel flow, Second Edition. Springer (2008).
5. Rajesh Srivastava, Flow through open channels, Oxford University Press (2008).

Course	CE6208: Mine Wastes Generation and Management
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Mine Wastes Generation and Management
Learning Mode	Lectures
Learning Objectives	Complies with PLO- number 1, 2, 3, 4, and 5 1. Understand and explain the mining operations, regulations and acts. 2. Explain the various types of mine generated wastes, characterizations techniques and application. 3. Describe the mine waste disposal techniques and stability analysis of overburden dumps. 4. Comprehend the mine generated contaminated leachate and ground pollution. 5. Analyse technical strategies, approaches and solutions to engineer's role and responsibility for mine waste management risk analysis, potential application, safety factors for sustainable development.
Course Description	The course covers various mine waste generated during the mining operation and their characteristics, mining regulations and acts, waste disposal, potential application and stability analysis of mine overburden waste, leachate formation and ground contamination. This course deals with geomechanics and rehabilitation techniques of mine generated wastes, valorization of mine wastes, risk analysis and mining safety.
Course Outline	Introduction to mining operations and risk; overview of Indian & international mining regulations and acts; different types of mine waste generated during the mining operation; mine waste disposal & rehabilitation; geochemical compositions, physical & chemical nature of mine wastes; disposal of mine wastes; geomechanics of mine waste disposal & rehabilitation; characterizations and application of mining wastes for infrastructure projects; valorization of mining wastes; leachate formation and ground contamination due to mining wastes; stability analysis of mining wastes overburden dumps, reintegration of mine wastes; mining wastes risk assessment & remedial measures; mining safety.
Learning Outcome	At the end of the course, student would be able to: 1. Describe and explain the mining operations, regulations and acts. 2. Explain the various types of mine generated wastes, characterizations techniques and application. 3. Describe the mine waste disposal techniques and stability analysis of overburden dumps. 4. Understand the mine generated contaminated leachate and ground pollution. 5. Analyze technical strategies, approaches and solutions to engineer's role and responsibility for mine waste management risk analysis, potential application, safety factors for sustainable development.
Assessment Method	Assignments, Quizzes, Term-paper project, Mid-semester examination and End-semester examination.

Textbooks:

1. Singh, T N. Surface Mining, Lovely Prakashan, India, 2020.
2. Karra, Ram Chandar, Gayana, B C, Rao, Shubhananda P Mine Waste Utilization, CRC Press, 2022.
3. Hutchison, Ian P.G. and Ellis, Rechard D., Mine Waste Management, CRC Press, India, 1992.
4. Lottermoser, Bernd G., Mine Wastes Characterization, Treatment and Environmental Impacts, Springer, 3rd edition, 2010.

References:

1. Pradhan, S. P., Vishal, V., & Singh, T. N. (Eds.). Landslides: theory, practice and modelling. Springer International Publishing, 2019.
2. Pathak, Pankaj, Rout, Prangya Ranjan, Urban Mining for Waste Management and Resource Recovery, CRC Press, 2021
3. Indian and international acts and regulations for mining operations and waste management
4. Referred journal and publications.

Course	CE6211: Utilization of Industrial Byproducts for Geotechnical Applications
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Utilization of industrial byproducts for geotechnical applications
Learning Mode	Lectures
Learning Objectives	Complies with PLO- number 1, 2, 3, 4, and 5 1. Understand various sources and characteristics of industrial byproducts and their application as geomaterials.

	2. Explain bulk application of industrial by products for soil stabilization and ground improvement with or without admixtures. 3. Analyse and elucidate the behaviour of industrial byproducts subjected to contamination, various remediation and immobilization techniques. 4. Apply the knowledge for economical, environmental and sustainable infrastructure development.
Course Description	The course covers various sources of industrial byproducts in India, status and potential applications. Further, this course deals with utilization of industrial byproducts as geomaterial for soil stabilization and ground improvement with or without using admixtures. This course also emphasizes the advanced characterizations techniques of industrial by products and behaviour subjected to contamination, various remediation and immobilization techniques.
Course Outline	Introduction to industrial byproducts and its types; characteristics and role of industrial byproducts and admixtures; purpose-based classification of soils; principles of soil stabilization and ground improvement; methods of stabilization using industrial byproducts with or without chemical admixtures such as lime, cement, bitumen and special chemicals; mechanisms, uses and limitations; advanced characterizations technique and use of fly ash, rice husk ash, biochar, marble waste, and quarry generated wastes, mine slurry, slag, and other waste materials for both shallow and deep soil stabilization and ground improvement; potential application of industrial wastes as geomaterials and its behaviour subjected to contamination agents; remediation and immobilization techniques of industrial byproducts; methods and applications of grouting; Application to embankments, excavations, foundations and sensitive soils.
Learning Outcome	At the end of the course, student would be able to: 1. Describe various sources and characteristics of industrial byproducts and their application as geomaterials. 2. Explain bulk application of industrial by products for soil stabilization and ground improvement with or without admixtures. 3. Understand the behaviour of industrial byproducts subjected to contamination, various remediation and immobilization techniques. 4. Apply the knowledge for economical, environmental and sustainable infrastructure development.
Assessment Method	Assignments, Quizzes, Term-paper project, Mid-semester examination and End-semester examination.

Textbooks:

1. Ingles, O.G. and Metcalf, J.B., Soil Stabilization, Principles and Practice, Butterworths, 1972.
2. Bowen, R., Grouting in Engineering Practice, Allied Science Publishers Ltd., 1975.
3. Jie Han, Principles and Practice of Ground Improvement, Wiley Publishers, 2015.

References:

1. Yong, R. N. and Warkentin, B. P. Soil properties and behaviour, Elsevier, 2012.
2. Mitchell, J. K. and Soga, K. Fundamentals of soil behaviour, Wiley, New York, 2005.
3. B.M. Das, Principle of Geotechnical Engineering, Cengage Learning, eighth Edition, 2013.
4. All relevant IS and international codes and relevant research papers/reports.

Course	CE6218 Finite Element Method
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Finite Element Method
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 2, 4, and 5 and the objective for learning this course are Lecture: 1. Provide scientific and technical knowledge for the basis for the development of finite element analysis procedure. 2. Equip the students with a strong foundation and understanding for the finite element analysis process of the problems related to various civil and mechanical engineering.
Course Description	The course deals with understanding finite element analysis of various problems. This course provides the students an exposure for topics on analysis of problems related to various civil and mechanical engineering problems which are not covered in undergraduate design courses.
Course Outline	Basic concepts of engineering analysis; Methods of weighted residuals and variational formulations; Finite element discretization; Shape function; Lagrange and serendipity families; Element properties, iso-parametric elements; Criteria for convergence; Numerical evaluation of finite element matrices (Gauss quadrature integration); Assemblage of elements; Analysis of plane stress/strain, axi-symmetric solids; Three dimensional stress analysis; Flow through porous media; Error analyses: estimate of error, error bounds; Solution technique: finite element programming, use of package programs.
Learning Outcome	At the end of the course, student would be able to Lecture: 1. Understand various numerical methods for analysing engineering problems through FEM. 2. Analysis of various civil and mechanical engineering problems. 3. Ability to analyse complex structural system.
Assessment Method	Assignments, Quizzes, Project work, Mid-semester examination and End-semester examination.

Textbooks/ Reference books:

1. T. R. Chandrapatula and A. D. Belegundu, Introduction to finite elements in engineering, Third Edition, Prentice Hall of India, 2001.
2. P. Seshu, Text book of finite element analysis, Prentice Hall of India, 2003.
3. J. N. Reddy, An introduction to the finite element method, McGraw Hill Inc. 1993.
4. R. D. Cook, D. S. Malkus, M. E. Plesha, and R. J. Witt, Concepts and application of finite element analysis, fourth Edition, John Wiley & Sons, 2002.
5. O.C. Zienkiewicz and R. L. Taylor, The Finite element method, Butterworth Heinemann (Vol. I and Vol. II), 2000.
6. C.S. Krishnamoorthy, Finite Element Analysis, Theory and programming, Tata McGraw Hill, 1994.
7. K.J. Bathe, Finite Element Procedures in Engg. Analysis, Prentice Hall of India, 1996.
8. C.S. Desai and T. Kundu, Introduction to finite element method, CRC Press, 2001.

Course	CE6223 Uncertainty, Risk and Reliability Analyses in Civil Engineering
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Uncertainty, Risk and Reliability Analyses in Civil Engineering
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 2, 4, and 5 and the objective for learning this course are Lecture: 1. Make familiar the concept of probability theory and statistics. 2. Gain knowledge on stochastic simulation methods. 3. Develop knowledge on risk and reliability analysis of structure.
Course Description	The course deals with the risk and reliability analysis and design of different civil engineering infrastructural system. Also, this course discusses about the basic probability theory and random field generation.
Course Outline	Introduction and overview: Review of basic probability, Functions of random variables. Joint probability distribution, conditional distributions, Joint Normal distribution, Bayesian Analysis, Analysis of variance (ANOVA), Application of central limit theorem; confidence interval, expected value, and return period, probability paper; testing of goodness-of-fit of distribution models, Random number generation – Monte Carlo simulations, Formulation of structural reliability problems: limit states, composite risk analysis, direct integration method, safety margin method, reliability index and safety factor; FORM and SORM methods, importance sampling and other variance reduction techniques, Reliability – historical development, applications, different measures of reliability; Component reliability - time to failure, Reliability-based maintenance, System reliability - representation of failure, series and parallel systems, redundancy, fault trees, Probability-based acceptance criteria: consequence of failure, concepts of risk, utility, Probability-based design, fragility analysis. Calibration of target reliability: reliability-based design codes.
Learning Outcome	At the end of the course, student would be able to Lecture: 1. Understanding concept of probability theory and application. 2. Risk and reliability analysis of civil engineering infrastructure. 3. Design of civil infrastructure based on risk and reliability.
Assessment Method	Assignments, Quizzes, Project work, Mid-semester examination and End-semester examination.

Textbooks/ Reference books:

1. A. Halder and S. Mahadevan, Probability, Reliability, and Statistical Methods in Engineering Design, Wiley, 2000.
2. H. S. Ang and W. H. Tang, Probability Concepts in Engineering Planning and Design, John Wiley, 1975.
3. R. Ranganathan, Reliability Analysis and Design of Structures, Tata McGraw Hill, New Delhi, 1990.

Course	CE6228 Analytical Techniques for Infrastructure Systems Analysis
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Analytical Techniques for Infrastructure Systems Analysis
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 2, 4, and 5 and the objective for learning this course are Lecture: 1. To provide knowledge of quantitative techniques with application potential for infrastructure systems.
Course Description	This course provides a comprehensive introduction to the analytical methods and tools used in the analysis of infrastructure (transportation) systems. The course focuses on the application of these techniques to real-world transportation systems and includes a mix of theoretical and practical content. Students will learn about various analytical techniques including but not limited to traffic flow theory, network analysis, demand forecasting, and system optimization. The course will cover both traditional methods such as regression analysis and newer techniques such as machine learning and data analytics. The course will also delve into the use of software tools for transportation analysis and modeling. Students will get hands-on experience with these tools through assignments and projects.
Course Outline	Modelling and Simulation: Model Classification, Mathematical; Physical and Analog models, steps involved in simulation, Monte Carlo simulation, validation and verification of simulation models; Multivariate Data Analysis: Vectors and Matrices, Simple estimate of centroid, standard deviation, dispersion, variance and co-variance, correlation matrices, principal component analysis; Curve Fitting: Method of least squares, curvilinear regression, Multiple regression, checking adequacy of model, correlation, multiple linear regression; Queuing Theory: General structure, operating characteristics, deterministic queuing model, probabilistic queuing models, and simulation of queuing system; Forecasting Models: Moving averages, exponential smoothening, trend projections, causal models, time series analysis of vehicle growth & accidents; Neural Networks: Basic concepts; neural network architecture, back propagation networks.
Learning Outcome	At the end of the course, student would be able to Lecture: 1. Understand and Apply Modelling and Simulation Techniques 2. Perform Curve Fitting 3. Understand and Apply Queuing Theory 4. Perform Multivariate Data Analysis 5. Develop and Use Forecasting Models and Neural networks for the transportation related problems
Assessment Method	Assignments, Quizzes, Mid-semester examination and End-semester examination.

Textbooks/ Reference books:

1. Vohra, N.D., "Quantitative Techniques in Management", Tata McGraw Hill, 2001.
2. Johnson, R. A. and Wichern, D.W., "Applied Multivariate Statistical Analysis", Prentice Hall., 2003.
3. Johnson, R., "Probability and Statistics for Engineers", Prentice Hall. 2009.
4. Hair, J. and Anderson, R., "Multivariate Data Analysis", Prentice Hall. 2010.

Course Number	RM6201
Course Credit (L-T-P-C)	3-1-0-4
Course Title	Research Methodology
Learning Mode	Lectures
Learning Objectives	The objective of the course is to train student about the modelling of scalar and multi-objective nonlinear programming problems and various classical and numerical optimization techniques and algorithms to solve these problems
Course Description	Advanced Optimization Techniques, as a subject for postgraduate and PhD students, provides the knowledge of various models of nonlinear optimization problems and different algorithms to solve such problems with its applications in various problems arising in economics, science and engineering.
Course Content	Module I (6 lecture hours) – Research method fundamentals: Definition, characteristics and types, basic research terminology, an overview of research method concepts, research methods vs. method methodology, role of information and communication technology (ICT) in research, Nature and scope of research, information based decision making and source of knowledge. The research process; basic approaches and terminologies used in research. Defining research problem and hypotheses framing to prepare a research plan. Module II (5 lecture hours) - Research problem visualization and conceptualization: Significance of literature survey in identification of a research problem from reliable sources and critical review, identifying technical gaps and contemporary challenges from literature review and research databases, development of working hypothesis, defining and formulating the research problems, problem selection, necessity of defining the problem and conceiving the solution approach and methods. Module III (5 lecture hours) - Research design and data analysis: Research design – basic principles, need of research design and data classification – primary and secondary, features of good design, important concepts relating to research design, observation and facts, validation methods, observation and collection of data, methods of data collection, sampling methods, data processing and analysis, hypothesis testing, generalization, analysis, reliability, interpretation and presentation. Module IV (16 lecture hours) - Qualitative and quantitative analysis: Qualitative Research Plan and designs, Meaning and types of Sampling, Tools of qualitative data Collection; observation depth Interview, focus group discussion, Data editing, processing & categorization, qualitative data analysis, Fundamentals of statistical methods, parametric and nonparametric techniques, test of significance, variables, conjecture, hypothesis, measurement, types of data and scales, sample and sampling techniques, probability and distributions, hypothesis testing, level of significance and confidence interval, t-test, ANOVA, correlation, regression analysis, error analysis, research data analysis and evaluation using software tools (e.g.: MS Excel, SPSS, Statistical, R, etc.). Module V (10 lecture hours) – Principled research: Ethics in research and Ethical dilemma, affiliation and conflict of interest; Publishing and sharing research, Plagiarism and its fallout (case studies), Internet research ethics, data protection and intellectual property rights (IPR) – patent survey, patentability, patent laws and IPR filing process.

Learning Outcome	On successful completion of the course, students should be able to: 1. Understand the terminology and basic concepts of various kinds of nonlinear optimization problems. 2. Develop the understanding about different solution methods to solve nonlinear Programming problems. 3. Apply and differentiate the need and importance of various algorithms to solve scalar and multi-objective optimization problems. 4. Employ programming languages like MATLAB/Python to solve nonlinear programming problems. 5. Model and solve several problems arising in science and engineering as a nonlinear optimization problem.
Assessment Method	Quiz /Assignment/ Project / MSE / ESE

Textbooks & Reference Books:

1. C. R. Kothari, Research methodology: Methods and Techniques, 3rd Edn., New age International 2014.
2. Mark N K. Saunders, Adrian Thornhill, Phkip Lewis, “Research Methods for Studies, 3/c Pearson Education, 2010.
3. K.N. Krishnaswamy, apa iyer, siva kumar, m. Mathirajan, “Management Research Methodology”, Pearson Education, 2010.
4. Ranjit Kumar; “Research Methodology: A Step by Step Guide for Beginners; 2/e; Pearson Education, 2010.
5. Suresh C. Sinha, Anil K. Dhiman, ess ess, 2006 “Research Methodology” Panner Selvam.R. “Research Methodology”, Prentice Hall of India, New Delhi, 2004.
6. C.G. Thomas, Research methodology and scientific writing, Ane books, Delhi, 2015.
7. H. J. Ader and G. J. Mellenbergh, Research Methodology in the Social, Behavioural and Life Sciences Designs, Models and Methods, 3rd Edn., Sage Publications, London, 2000.

Interdisciplinary Elective (IDE) Course for M. Tech.
(Available to students other than CEE)

Sl. No.	Subject Code	Subject Name	L	T	P	C
1.	CE6132	Data Science for Engineers	3	0	0	3

Course	CE6132: Data Science for Engineers
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Data Science for Engineers
Desirable Prerequisites	Knowledge of Remote Sensing and GIS/Advanced Geomatics, digital image processing, machine learning and AI
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 1, 2 & 3- 1. To provide fundamental knowledge in the basics of Data Science. 2. Train students to understand the various applications of Machine Learning and modelling for research applications. 3. Provide scientific and technical knowledge to the students on Errors and Adjustments.
Course Description	This course will discuss fundamental concepts in data science for Civil Engineers. The course will cover theory and real-world practice in data, errors and adjustments to help deal with various research-related problems.
Course Outline	Overview of probability and statistics; statistical learning: definition, principles and different types of statistical learning, assessing model accuracy, bias-variance tradeoff; regression models: simple linear and multiple linear and non-linear; resampling methods: assessing model prediction quality, cross-validation, bootstrap; model selection and regularisation: dimensionality reduction, ridge and lasso; unsupervised learning: clustering approaches, K-means and hierarchical clustering; supervised learning: classification problem, classification using logistic regression, naive Bayes, classification with Support Vector Machines, neural networks. Background of Errors, Expectations and Error Propagation, Random Errors, Model Development and Problem-solving, Observations and Equations, Conditions and Combined Equations, Errors in Surveying.
Learning Outcome	At the end of the course, students would be able to: 1. Understand technical aspects and properties of Data Science. 2. Perform error adjustments in Civil Engineering problems. 3. Skilled to develop more accurate, robust and error-free predictive and classification models.
Assessment Method	Assignments (10%), Quizzes (10%), Mid-semester examination (30%) and End-semester examination (50%).

REFERENCES:

1. Gillani, D. Charles, Adjustment Computations: Spatial Data Analysis, 6th Edition, John Wiley and Sons, 2017.
2. James, G., Witten, D., Hastie, T., & Tibshirani, R., Introduction to Statistical Learning, Springer, 2nd Edition, 2013.
3. Lillesand, T.M. and Kiefer, R.W., Remote Sensing, and Image Interpretation III Edition. John Wiley and Sons, New York. 1993.
4. Mehrotra, A.K., Geo-statistics for Beginners, Zorba, 2020.
5. Ian Heywood Sarah, Cornelius, and Steve Carver: An Introduction to Geographical Information Systems. Pearson Education. New Delhi, 2002.
6. Leick, A., GPS satellite surveying, John Wiley and Sons, 4th Edition, 2015.
7. Ogundare, O.J., Precision Surveying: The Principles and Geomatics Practice, John Wiley and Sons, 2015.