

B. Tech. (Civil Engineering) – M. Tech. (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.

Semester – VII

Sl. No.	Course Code	Course	L	T	P	C
1.	CE41PQ	B. Tech. Elective - I	3	0	0	3
2.	CE41PQ	B. Tech. Elective – II	3	0	0	3
3.	XX41PQ	IDE - III	3	0	0	3
4.	HS41XX	HSS Elective - II	3	0	0	3
5.	XX4198	Summer Internship*	0	0	12	3
6.	XX4199	Project – I	0	0	12	6
7.	CE5102	Physico-Chemical Principles and Processes	3	0	0	3
TOTAL			15	0	24	24

Note :

*** For specific cases of internship after VIth Semester, the performance evaluation would be made on joining the VIIth Semester and graded accordingly in the VIIth Semester:**

Note :

a) (i) Summer internship (*) period of at least 60 days' (8 weeks) duration begins in the intervening vacation between Semester VI and VII that may be done 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.

a) (ii) Further, on return from 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.

b) (i) In the VIIth semester, students can opt for a semester long internship on recommendation of the DAPC and approval of the Competent Authority.

b) (ii) On approval of semester long internship, at the maximum two courses (properly mapped/aligned syllabus) at par with institute electives may be opted from NPTEL and / or SWAYAM and the other two more should be done at the institute through course overloading in any other semester (either before or after the internship) and/or during following summer semester.

b) (iii) The candidates opting two courses from NPTEL and / or SWAYAM would be required to appear in the examination at the Institute as scheduled in the Academic Calendar.

Semester – VIII

Sl. No.	Course Code	Course	L	T	P	C
1.	RM6201	Research Methodology	3	1	0	4
2.	CE5201	Biological Principles and Processes	3	0	0	3
3.	CE5202	Air Pollution and Control	3	0	2	4
4.	CE52PQ/ CE62PQ	M. Tech. Elective - I	3	0	0	3
5.	CE4299	Project - II	0	0	12	6
TOTAL			12	1	14	20

Semester – IX

Sl. No.	Course Code	Course	L	T	P	C
1.	CE51PQ/ CE61PQ	M. Tech. Elective - II	3	0	0	3
2.	CE51PQ/ CE61PQ	M. Tech. Elective - III	3	0	0	3
3.	CE51PQ/ CE61PQ	M. Tech. Elective - IV	3	0	0	3
4.	CE5199	Project - III	0	0	16	8
TOTAL			9	0	16	17

Semester – X

Sl. No.	Course Code	Course	L	T	P	C
1.	CE5299	Project – IV**	0	0	36	18
TOTAL			0	0	36	18

****Note: M. Tech. Project outside the Institute**

In the IXth 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.

Total Credit - 208 (including B. Tech. Sem I to Sem VI credits)

ELECTIVE GROUPS

SEMESTER-VII: DEPARTMENT ELECTIVE COURSE

Department Elective - I						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	CE4101	Introduction to Bridge Engineering	3	0	0	3
2.	CE4102	Prestressed and Precast Concrete Structures	3	0	0	3
3.	CE4103	Fundamentals of Solid Mechanics	3	0	0	3
4.	CE4104	Matrix Methods for Structural Analysis	3	0	0	3

Department Elective - II						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	CE4105	Stochastic Hydrology	3	0	0	3
2.	CE4106	Irrigation Engineering and Hydraulic Structures	3	0	0	3
3.	CE4107	Elementary Soil Behaviour	3	0	0	3
4.	CE4108	Fundamentals of Geoenvironmental Engineering	3	0	0	3
5.	CE4109	Biogeotechnical Engineering	3	0	0	3
6.	CE4110	Pavement Geotechnology	3	0	0	3

SEMESTER-VIII: ELECTIVE COURSE

M. Tech. Elective - I						
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

SEMESTER-IX: ELECTIVE COURSE

M. Tech. Elective - II						
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

M. Tech. Elective - III						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	CE6104	Environmental Hydraulics	3	0	0	3
2.	CE6105	Atmospheric Science and Climate Change	3	0	0	3

M. Tech. Elective - IV						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	CE6109	Geoenvironmental Engineering	3	0	0	3
2.	CE6114	Probabilistic Methods in Geotechnical Engineering	3	0	0	3
3.	CE5117	Water Resources Management	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

Semester – VII

Sl. No.	Course Code	Course	L	T	P	C
1.	CE41PQ	B. Tech. Elective - I	3	0	0	3
2.	CE41PQ	B. Tech. Elective – II	3	0	0	3
3.	XX41PQ	IDE - III	3	0	0	3
4.	HS41XX	HSS Elective - II	3	0	0	3
5.	XX4198	Summer Internship*	0	0	12	3
6.	XX4199	Project – I	0	0	12	6
7.	CE5102	Physico-Chemical Principles and Processes	3	0	0	3
TOTAL			15	0	24	24

Department Elective-I						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	CE4101	Introduction to Bridge Engineering	3	0	0	3
2.	CE4102	Prestressed and Precast Concrete Structures	3	0	0	3
3.	CE4103	Fundamentals of Solid Mechanics	3	0	0	3
4.	CE4104	Matrix Method for Structural Analysis	3	0	0	3

Course	CE4101 Introduction to Bridge Engineering
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Introduction to Bridge Engineering
Learning Mode	Lectures
Learning Objectives	Lectures: Complies with PLO-1, 2, 3 and 4 1. Apply the fundamental principles of bridge engineering, including load distribution, dead and live load analyses etc. to evaluate the performance of different types of bridges. 2. Design of various bridge components following various Indian as well as international standards and safety regulations. 3. To become proficient in using advanced computational tools and software for the modelling, simulation considering dynamic loading like wind and earthquake.
Course Description	This course offers a comprehensive exploration of bridge engineering and design, covering fundamental principles, methodologies, and practical applications. This course covers key aspects including structural analysis, material selection, construction techniques, and environmental considerations.
Course Outline	Introduction: Classification of Bridges, General Features of Design, IRC Loading (viz. 70R, Class AA tracked and wheeled vehicle), Design Codes, Working Stress Method, Limit State Method of Design as per IS456 and IRC 112; Analysis & Design: Consideration of various loading (dead load, vehicular load etc.), Slab bridge, Box Culvert, T-beam bridge, Box Girder bridge.
Learning Outcome	At the end of the course, student would be able to Lectures: 1. Understand behaviour of structural steel members. 2. Estimation of various design loads including wind loads. 3. Identify and interpret the appropriate relevant design codes. 4. Familiar with design and fabrication of steel members.
Assessment Method	Assignments, Quizzes, Project work, Mid-semester examination and End-semester examination.

Textbooks/ Reference books:

1. Swami Saran, Analysis and Design of Substructures: Limit State Design, 28 February 2018.
2. K. K. Rakshit, Design and Construction and Highway Bridges.
3. Raju N. K, Design of Bridges, 5Ed (Pb 2019) – 1 January 2019.
4. Daniel J. Inman, Charles R. Farrar, Vicente Lopes Junior, Valder Steffen Junior, Damage Prognosis: For Aerospace, Civil and Mechanical Systems, John Wiley & Sons, 2005.
5. Latest version of relevant IRC (viz. IRC6, IRC112 etc.) and IS (viz. IS456, IS800 etc.) codes.

Course	CE4102 Prestressed and Precast Concrete Structures
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Prestressed and Precast Concrete Structures
Learning Mode	Lectures
Learning Objectives	Lectures: Complies with PLO-1, 2, 3 and 4 1. Familiarize with the concept of pre-stressed concrete and design of pre-stressed concrete structures. 2. Analyse prestressed concrete structural members and estimate the losses of prestress.
Course Description	The course deals with the design of pre-stressed concrete structures for various types of loading and will provides an understanding of behaviour of pre-stressed concrete members under various action of forces.
Course Outline	Analysis and design of beams - Rectangular, Flanged and I section, for limit state of flexure. Analysis and design of end blocks in post tensional members -primary and secondary distribution zones, Bursting and spalling tensions. Shear strength of prestressed concrete beams and design of shear reinforcement. Bond in prestressed concrete. Analysis and design of prestressed concrete structures such as concrete pipes and sleepers. Precast Structural Building components such as slab panels, beams, columns. Prefabricated building using precast load bearing and non-load bearing wall panels. Prefab systems, structural schemes, and their classification including design considerations. Joints - requirements of structural joints and their design considerations.
Learning Outcome	At the end of the course, student would be able to Lectures: 1. Become familiar with basic of pre-stressed concrete structure. 2. Understand the behaviour of pre-stressed concrete structural members structures under flexure, shear, axial forces, combined flexure and axial forces, and in-plane shear forces. 3. Learn the methods of pre-stressed concrete construction and detailing practices.
Assessment Method	Assignments, Quizzes, Project work, Mid-semester examination and End-semester examination.

Textbooks/ Reference books:

1. IS 1343: Code of Practice for Prestressed Concrete by Bureau of Indian Standards.
2. Guyon Y.: Prestressed Concrete, Vol. I & II, John Wiley and Sons, New York.
3. Krishna Raju, N.: Prestressed Concrete, Tata McGraw Hill Publications Company, New Delhi.
4. Lin T. Y.: Prestressed Concrete, Tata McGraw Hill, New Delhi.
5. Dayaratnam P. and Sarah P.: Prestressed Concrete Structures.
6. Elliott K. S.: Precast Concrete Structures, CRC Press; 2nd edition, 2019.

Course	CE4103 Fundamentals of Solid Mechanics
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Fundamentals of Solid Mechanics
Learning Mode	Lectures
Learning Objectives	Lectures: Complies with PLO-1, 2, 3 and 4 1. Understand the concept of deformation, linear and nonlinear measures of strain and stress. 2. Introduce failure theory of different materials. 3. Predict the behaviour elastic solids under different loading.
Course Description	The course deals with analysis of deformable bodies. This course provides the students an exposure for linear and non-linear analysis of solids, analysis of stress and strain, fundamental physical principles, constitutive relation of materials, and two-dimensional electrostatics problems.
Course Outline	Introduction: Suffix notation system, tensor algebra; Strain analysis: deformation and velocity gradients, Lagrangian and Eulerian description of strain, principal strains and strain invariants, compatibility conditions; Stress analysis: forces and moments, theory of stress, energetically conjugate stress and strain measures, plane stress and plane strain, principal stresses and stress invariants, compatibility equations, equilibrium equations; Fundamental physical principles: conservation of mass, linear momentum, angular momentum, and energy; Constitutive theory: St. Venant's principal, linear elasticity and generalized Hook's law, stress, strain and energy based failure theory, yield criteria; Introduction to elasticity: two-dimensional problems, torsion, buckling.
Learning Outcome	At the end of the course, student would be able to Lectures: 1. Understand the concept of deformation mechanisms in solid and different measures of strain and stress. 2. Gain knowledge on material model of liner elastic solid body. 3. Analysis of problem in elastic deformable body.
Assessment Method	Assignments, Quizzes, Project work, Mid-semester examination and End-semester examination.

Textbook/ Reference book:

1. S. Timoshenko and J.N. Goodier, Theory of Elasticity, McGraw Hill Book Company, International Ed, 1970.
2. L. S. Srinath. Advanced Mechanics of Solids, McGraw Hill Education, 2010.
3. Allan F. Bower. Applied Mechanics of Soilds, CRC Press, 2010.
4. Irving H. Shames and Francs A. Cozzarelli. Elastic and Inelastic Stress Analysis, Taylor & Francis Group; Revised edition, 1997.
5. Romesh C. Batra. Element of Continuum Mechanics, AIAA, 2012.

Course	CE4104 Matrix Methods of Structural Analysis
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Matrix Methods of Structural Analysis
Learning Mode	Lectures
Learning Objectives	Objective for learning this course are Lecture: 1. Understand the analysis and design different type of structural elements under static loading. 2. Predict nonlinear behaviour of different structures and structural components under static loading.
Course Description	The course deals with advanced analysis methods of structures. This course provides the students an exposure for linear and non-linear analysis of structures.
Course Outline	Introduction Structures, loads and response; determinate and indeterminate structures; stiffness and flexibility; Analysis of Indeterminate structures; Force and displacement methods; Mathematical preliminaries; Matrix algebra; stiffness and flexibility matrices; Analysis of Trusses; Analysis of Beams; Analysis of plane frames; Implementation issues; Beyond matrix method: Introduction to nonlinear analysis.
Learning Outcome	At the end of the course, student would be able to Lecture: 1. Analyse structures for designing them. 2. Should be able to understand various types of elements used for structural analysis.
Assessment Method	Assignments, Quizzes, Project work, Lab report, Mid-semester examination and End-semester examination.

Textbooks/ Reference books:

1. R C Hibbeler, Structural Analysis, Ninth Edition, Pearson, 2017.
2. W. McGuire, R. H. Gallagher and R. D. Ziemian, Matrix Structural Analysis, Second Edition, Wiley, 2015.
3. D. Menon, Advanced Structural Analysis. Narosa, 2015.
4. Amin Ghali, Adam M Neville and Tom G Brown, ""Structural Analysis:A Unified Classical and Matrix Approach"", Sixth Edition, 2007, Chapman & Hall.

Department Elective-II						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	CE4105	Stochastic Hydrology	3	0	0	3
2.	CE4106	Irrigation Engineering and Hydraulic Structures	3	0	0	3
3.	CE4107	Elementary Soil Behaviour	3	0	0	3
4.	CE4108	Fundamentals of Geoenvironmental Engg.	3	0	0	3
5.	CE4109	Biogeotechnical Engineering	3	0	0	3
6.	CE4110	Pavement Geotechnology	3	0	0	3

Course	CE4105 Stochastic Hydrology
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Stochastic Hydrology
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 1, 2, 3, 4 and 5 This course is designed to present an understanding of statistical tools applied to hydrologic problems. The objective of this course is to introduce the concepts of probability theory and stochastic processes with applications in hydrologic analysis and design.
Course Description	The course covers the modelling of hydrologic time series with specific techniques for data generation and hydrologic forecasting. Case study applications will be discussed.
Course Outline	Statistical methods in hydrology, probability distribution of hydrologic variables, hypothesis testing and goodness of fit, flood frequency analysis, single and multiple regression analysis, classification of time series, characteristics of hydrologic time series, statistical principles and techniques for hydrologic time series modelling, time series modelling of annual and periodic hydrologic time series (including AR, ARMA, ARIMA, and DARMA models), multivariate modelling of hydrologic time series, practical considerations in time series modelling applications.
Learning Outcome	By taking this course, students will be able to: 1. Analyse hydrological and climatological data using advanced statistical methods and characterize water resources and hydrometeorological data. 2. Analyse hydrologic time series, and perform frequency analysis to estimate the magnitude of an event, frequency of occurrence and associated uncertainty.
Assessment Method	Assignments, Quizzes, Mid-semester examination, and End-semester examination

Text Books/ Reference Book:

1. Haan, C.T., Statistical Methods in Hydrology, First East-West Press Edition, New Delhi, 1995.
2. Bras, R.L. and Rodriguez-Iturbe, Random Functions and Hydrology, Dover Publications, New York, USA, 1993.
3. Clarke, R.T., Statistical Models in Hydrology, John Wiley, Chinchester, 1994.
4. Kite, G.W., Frequency and Risk Analyses in Hydrology, Water Resources Publications, Fort Collins, CO, 1977.
5. Yevjevich V., Probability and statistics in Hydrology, Water Resources Publications, Colorado, 1972.
6. Ang, A.H.S. and Tang, W.H., Probabilistic concepts in Engineering Planning Design, Vol. 1, Wiley, New York, 1975.

Course	CE4106 Irrigation Engineering and Hydraulic Structures
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Irrigation Engineering and Hydraulic Structures
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 1, 2, 3, 4 and 5 1. Students will understand the soil-water-crop management and the role of irrigation system. 2. The students will be exposed to the various irrigation and flood control structure and their design principles.
Course Description	This course offers an introduction to irrigation practices and the development, conservation, regulation and use of water resources through the design of hydraulic structures.
Course Outline	Introduction to irrigation: Necessity and scope, irrigation practices, soil-crop-water requirement. Water resource Development: reservoir planning. Dams: Types of dams, their function and design. Design of Spillways. Diversion work. Distribution System: Flow irrigation canal, theory and design of canals, canal outlet, canal regulation work, cross drainage work, canal head work. Introduction to river engineering.
Learning Outcome	At the end of the course, students would be able to understand: 1. The soil-water-crop relation and the need for irrigation. 2. The principles of design of hydraulic structures.
Assessment Method	Assignments, Quizzes, Mid-semester examination, and End-semester examination

Text Books/ Reference Book:

1. Modi P.N. Irrigation Water Resources And Water Power Engineering, Rajsons Publications, New Delhi 2013
2. Punamia, B. C., & Lal, B..Irrigation and water power engineering. 17th Edition, Laxmi Publications
3. Santosh Kumar Garg, Irrigation Engineering and Hydraulic Structure, Khanna publishers, 2023
4. R. N. Reddy , Irrigation Engineering, Daya Publishing House, 2010
5. P. Novak, A.I.B. Moffat, C. Nalluri, R. Narayanan, Hydraulic Structures, CRC Press, 2017
6. Relevant IS codes

	CE4107 Elementary Soil Behaviour
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Elementary Soil Behaviour
Learning Mode	Lectures
Learning Objectives	Complies with PLO- number 1, 3, 4, and 5. The objectives of this course are to 1. Understand the significance of different clay mineral in behaviour of soils and its determination. 2. Comprehend the arrangement of soil particles and its relevance in behaviour of soils. 3. Analyse the mechanism behind the physio-chemical interactions within soils. 4. Develop an understanding of the factors determining and controlling the engineering properties and behaviour of soils.
Course Description	This course is offered as an elective course in department. This course basically comprises with several topics which should be covered to deal with basics of soil behaviour subjected to variation in climatic changes. Board topics are different clay mineral in behaviour of soils and its determination, arrangement of soil particles and its relevance in behaviour of soils, mechanism behind the physio-chemical interactions within soils, and factors determining and controlling the engineering properties and behaviour of soils under different conditions.
Course Outline	Identification and Classification of Clay Minerals; Origin and description of clay minerals; Determination of soil composition and fabric; Physio-Chemical Behaviour of Soil; Soil-chemical interactions; Microbially Induced Calcite Precipitation (MICP); Effective, Inter-granular and Total stress; Water–Air interactions in soils; Volume Change, Shear Strength and Deformation Behaviour.
Learning Outcome	At the end of the course, student would be able to: 1. Recognize the significance of different clay mineral in behaviour of soils and its determination. 2. Understand the arrangement of soil particles and its relevance in behaviour of soils. 3. Analyse the mechanism behind the physio-chemical interactions within soils. 4. Apply knowledge for determining and controlling the engineering properties and behaviour of soils under different conditions, with an emphasis on Why they are What they are for research/professional perspectives as well as for societal needs.
Assessment Method	Assignments , Quizzes , Term-paper project, Mid-semester examination and End-semester examination.

Textbooks:

1. Mitchell, J. K. and Soga, K. Fundamentals of soil behaviour, Wiley, New York, 2005.
2. Yong, R. N. and Warkentin, B. P. Soil properties and behaviour, Elsevier, 2012.
3. Lambe, T.W. and Whitman, R.V. Soil mechanics, John Wiley and Sons, New York, 1979.

Reference books:

1. Grim, R. E. Applied clay mineralogy, McGraw Hill, New York, 1966.
2. Fredlund, D. G., Rahardjo, H. and Fredlund, M. D. Unsaturated soil mechanics in engineering practice, Wiley, 2012.
3. Malcom, D. Bolton A guide to soil mechanics, University Press (India) Pvt. Ltd., 2003.
4. All relevant codes and research papers.

	CE4108 Fundamentals of Geoenvironmental Engineering
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Fundamentals of 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 characterisation 3. Learning methods of remedial measures of a contaminated site
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
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 characterize contaminated site 3. Should be able to take appropriate remedial measures for a contaminated site
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 Wiley 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.
5. All relevant IS and International Codes.

	CE4109 Biogeotechnical Engineering
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Biogeotechnical Engineering
Learning Mode	Lectures
Learning Objectives	Complies with PLO- number 1, 3, and 5. The objectives of this course are to 1. Understand the significance of geomicrobiology in geotechnical engineering. 2. Comprehend various biological process in ground/soil improvement. 3. Apply the knowledge for upscaling to develop sustainable geomaterials.
Course Description	This course combines the principles of environmental biotechnology and geotechnical engineering. Geotechnical engineers design, build, and maintain structures in the subsurface. This course will be able to provide combine and apply basic theory and concepts from soil mechanics and biology in engineering applications. This course also brings an understanding about various geomicrobiological process for soil improvement.
Course Outline	Introduction to Biogeotechnics, Biological process of the subsurface materials, Stoichiometry and kinetics of bio-chemical reactions, Microbially Induced Calcite Precipitation (MICP), Root-Inspired Foundations, Enzymatically Induced Calcite Precipitation (EICP), Self-healing materials, Termite mounds-, Snake- and Ant-Inspired Excavations, Microbial Ecology, Biofilms, and Zeolite Sorption, Production of bio-cements. Instrumentation and testing for evaluating biological process and geotechnical material behaviour, Upscaled model tests and field trails.
Learning Outcome	At the end of the course, student would be able to: 1. Understand the importance of geomicrobiology in geotechnical engineering. 2. Comprehend various bio-chemical reactions and their application in biological process for ground/soil improvement. 3. Investigate biological process and geotechnical behaviour. 4. Apply the knowledge for upscaling to develop sustainable geomaterials.
Assessment Method	Assignments , Quizzes , Term-paper project, Mid-semester examination and End-semester examination.

Textbooks:

4. Ehrlich, H., Newman, D. Geomicrobiology (5th ed.). Boca Raton: CRC Press (2021).
5. Hemond, Harold F., and Elizabeth J. Fechner. Chemical fate and transport in the environment. academic press, 2022.
6. Rittmann, Bruce E., and Perry L. McCarty. "Environmental biotechnology: principles and applications." (No Title) (2001).

Reference books:

5. Coduto, Donald P., Man-chu Ronald Yeung, and William A. Kitch. "Geotechnical engineering: principles and practices." (No Title) (2011).
6. Zheng, Chunmiao, and Gordon D. Bennett. Applied contaminant transport modeling. Vol. 2. New York: Wiley-Interscience, 2002.
7. All relevant codes and research papers

Course Number	CE4110: Pavement Geotechnology
Course Credit (L-T-P-C)	3-0-0-3
Course Title	Pavement Geotechnology
Learning Mode	Lectures
Learning Objectives	Complies with program learning outcome 1a; 3a 1. Equip the students with a strong foundation and strengthen their knowledge in pavement geotechnics. 2. The student will be able to apply advanced theory and analysis for problem-solving in pavement geotechnics. 3. The student will prepare for further research and graduate study by critical thinking and improving research skills. 4. The student will be able to apply fundamentals in identifying, formulating, and solving complex engineering problems in pavement geotechnics.
Course Description	This coursework will provide practical insights for students in the field of Pavement Geotechnics. The students will be taught the recent developments and design principles to face current and future highway problems in relevance with pavement geotechnics.
Course Content	Geotechnical properties of geomaterials such as soil, rock, soil-rock mixture, and alternative geomaterials. Introduction to stabilized geomaterials. Introduction to various types of pavement, subgrades, materials, subbase, base, and asphalt concrete materials relevant to pavement Geotechnics, Elastic theories and stress distribution in pavements, Geosynthetic stabilized pavements, geotechnical parametric studies for AASHTO, MEPDG, and IRC designs.
Learning Outcome	Students would be able to learn the core principles of pavement designs and advanced sustainable pavement techniques. Exploration of alternative materials, design approaches, and innovation in pavement geotechnics will be disseminated through this course.

Textbooks:

1. Huang, Y. H. (2004). Pavement analysis and design, Second edition, Upper Saddle River, NJ: Pearson Prentice Hall.
2. Yoder, E. J., & Witczak, M. W. (1991). Principles of pavement design. John Wiley & Sons.
3. Mallick, R. B., & El-Korchi, T. (2008). Pavement engineering: principles and practice. CRC Press.
4. Frost, M. W., Jefferson, I., Faragher, E., Roff, T. E. J., & Fleming, P. R. (Eds.). (2003). Transportation Geotechnics: Proceedings of the Symposium Held at The Nottingham Trent University School of Property and Construction on 11 September 2003. Thomas Telford Publishing.
5. Ellis, E., Yu, H. S., McDowell, G., Dawson, A. R., & Thom, N. (Eds.). (2008). Advances in Transportation Geotechnics: Proceedings of the International Conference Held in Nottingham, UK, 25-27 August 2008. CRC Press.
6. Miura, S., Ishikawa, T., Yoshida, N., Hisari, Y., & Abe, N. (Eds.). (2012). Advances in Transportation Geotechnics 2. CRC Press.

Reference books:

1. Ferguson, B. K., & Ferguson, B. K. (2005). Porous pavements. Boca Raton, FL: Taylor & Francis.
2. Rogers, M., & Enright, B. (2016). Highway engineering. John Wiley & Sons.
3. Nikolaides, A. (2014). Highway engineering: Pavements, materials and control of quality. CRC Press.
4. Babu, G. L. S., Kandhal, P. S., Kottayi, N. M., Mallick, R. B., & Veeraragavan, A. (2019). Pavement Drainage: Theory and Practice. CRC Press.
5. Babu, G.L.S., (2006). An Introduction to Soil Reinforcement and Geosynthetics, Universities Press (India) Pvt. Ltd.
6. All relevant codes and standards

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.

Semester – VIII

Sl. No.	Course Code	Course	L	T	P	C
1.	RM6201	Research Methodology	3	1	0	4
2.	CE5201	Biological Principles and Processes	3	0	0	3
3.	CE5202	Air Pollution and Control	3	0	2	4
4.	CE52PQ/ CE62PQ	M. Tech. Elective - I	3	0	0	3
5.	CE4299	Project - II	0	0	12	6
TOTAL			12	1	14	20

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.

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.

M. Tech. Elective - I						
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

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.

Semester – IX

Sl. No.	Course Code	Course	L	T	P	C
1.	CE51PQ/ CE61PQ	M. Tech. Elective - II	3	0	0	3
2.	CE51PQ/ CE61PQ	M. Tech. Elective - III	3	0	0	3
3.	CE51PQ/ CE61PQ	M. Tech. Elective - IV	3	0	0	3
4.	CE5199	Project - III	0	0	16	8
TOTAL			9	0	16	17

M. Tech. Elective - II						
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

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.

M. Tech. Elective - III						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	CE6104	Environmental Hydraulics	3	0	0	3
2.	CE6105	Atmospheric Science and Climate Change	3	0	0	3

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.

M. Tech. Elective - IV						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	CE6109	Geoenvironmental Engineering	3	0	0	3
2.	CE6114	Probabilistic Methods in Geotechnical Engineering	3	0	0	3
3.	CE5117	Water Resources Management	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	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 4. Understanding methods of waste management and disposal 5. Learning methods of contaminated site characterization 6. Learning methods of remedial measures of a contaminated site 7. 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:

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

Reference books:

2. 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.
6. L N Reddy and H.I. Inyang, “Geoenvironmental Engineering: Principles and Applications”, Marcel Dekker, 2000
7. James K Mitechell, K Soga, “Fundamentals of soil behaviour”, Wiley Publication, 2005.
8. 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: 5. Analyzed structure using various probabilistic methods available along with the method suggested in the Euro code. 6. Perform reliability analysis for various geotechnical problems. 7. Assess composite risk using various techniques to estimate failure of geotechnical structures.

Assessment Method	Assignments, Quizzes, Mid-semester examination and End-semester examination.
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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	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	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 preform 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)