Indian Institute of Technology Kanpur

COURSES OF STUDY

2026





Indian Institute of Technology Kanpur
KANPUR-208016

CIVIL ENGINEERING

Template for BT Program in Civil Engineering

Semester 1	Semester 2	Semester 3	Semester 4	Semester 5	Semester 6	Semester 7	Semester 8
SCHEME-1 (9) ELC111/ELC112/ELC113	ETH111 (3)	SCHEME-2 EME (CE212-9)*	SCHEME-3 HSS-I (9-11)	ESO208A [11] (E/SO)	SCHEME HSS-II (9)	SCHEME HSS-II (9)	SCHEME HSS-II (9)
MTH 111 (6)	MTH 113 (6)	ESO202 [11] (E/SO)	ESC201 (14)	CE351 [10] (DC)	CE441M [5] (DC)	DE-5 [9]	DE-8 [9]
MTH 112 (6)	MTH 114 (6)	MSO203M [6] (E/SO)	TA212 [3] § (E/SO)	CE361 [6] (DC)	DE-2 [9]	DE-6 [9]	OE-4 [9]
PHY 112 (11)	PHY 115 (11)	HSO201 [11] (E/SO)	CE272 [9] (DC)	CE331 [8] (DC)	DE-3 [9]	DE-7 [5]	OE-5 [9]
PHY 111 (3)	CHM 111 (3)	CE261 (10) (DC)	CE252 [11] (DC)	CE311 [4] (DC)	DE-4 [9]	OE-2 [9]	OE-6 [6]
TA 111 (9)	ESC 111 (7)	CE243 (8) (DC)	CE214 [9] (DC)	CE381 [9] (DC)	OE-1 [9]	OE-3 [9]	
CHM 112 (4)	ESC 112 (7)	CE341 [2] (DC)		DE-1 [9]			
CHM 113 (4)	LIF111 (6)	TA211 [3] (E/SO)			UGP-1 (CE332) Extra Credits (DE) [4]		UGP-4 (CE493) Extra Credits (DE) [9]
PE111 (3)	PE112 (3)						
55	52	60	55-57	57	50	50	42

1. *All CE student must opt for environment part from the EME basket in semester 3.
2. Students need to ensure that the courses chosen as DE must include
   i) at least one course from CE371 and CE372, and
   ii) at least one course from CE412, CE432, CE462, CE481.
   iii) Total DE credits should be minimum of 68.
3. The DE basket may also contain departmental PG courses. However, some of the 300 level DE courses are pre-requisite to those PG courses.
4. UGP-1 and UGP-4 do not count towards DE/OE credits or minimum graduation requirements. Courses that are mandatorily offered in DE:

   Odd semester – CE371, CE481.
   Even semester – CE372, CE334, CE362, CE382, CE412, CE462, CE432,
   Other courses – CE491, CE492, CE605A, CE606A.

– Credit Table for BT program in Civil Engineering

Course type	Allowable Credit range	Credit in the department
Institute Core (IC)	112	112
E/SO	18-45	45
Department requirements	144-179	159 (91 DC + 68 DE)
Open electives (OE)	51-57	51
SCHEME	54-58	54-58
Total for 4-year BT/BS	391-420	421-425*

*Exceeds the credit range recommended by UGARC

Template for BTH Program in Civil Engineering

Template for 3rd to 8th semester for BTH program in Civil Engineering					
Semester 3	Semester 4	Semester 5	Semester 6	Semester 7	Semester 8
SCHEME-2 EME (CE212- 9)*	SCHEME-3 HSS-I (9-11)	ESO208A [11] (E/SO)	SCHEME HSS-II (9)	SCHEME HSS-II (9)	SCHEME HSS-II (9)
ESO202 [11] (E/SO)	ESC201 (14)	CE351 [10] (DC)	CE441M [5] (DC)	DE-5 [9]	DE-9 [9]
MSO203M [6] (E/SO)	TA212 [3] (E/SO)	CE361 [6] (DC)	DE-2 [9]	DE-6 [9]	OE-4 [9]
HSO201 [11] (E/SO)	CE272 [9] (DC)	CE331 [8] (DC)	DE-3 [9]	DE-7 [5]	OE-5 [9]
CE261 (10) (DC)	CE252 [11] (DC)	CE311 [4] (DC)	DE-4 [9]	OE-2 [9]	OE-6 [6]
CE243 (8) (DC)	CE214 [9] (DC)	CE381 [9] (DC)	OE-1 [9]	OE-3 [9]	DE-10 (9)
CE341 [2] (DC)		DE-1 [9]		DE-8 (9)	DE-11 (9)
TA211 [3] (E/SO)			UGP-1 (CE332A) Extra Credits (DE) [4]		UGP-4 CE493A) Extra Credits (DE) [9]
60	55-57	57	50	59	60

1. *All CE student must opt for environment part from the EME in semester 3.
2. Students need to ensure that the courses chosen as DE must include
   i. at least one course from CE371 and CE372, and
   ii. at least one course from CE412, CE432, CE462, CE481;
   iii. two UGPs (CE491 and CE492); and
   iv. minimum 27 credits of DE (6/7 level) courses.
   v. Total DE credits should be minimum of 95.
3. The DE basket may also contain departmental PG courses. However, some of the 300 level DE courses are pre-requisite to those PG courses.
4. UGP-1 and UGP-4 do not count towards DE/OE credits or minimum graduation. requirements.

– CPI criteria for BTH: 8.5

Courses that are mandatorily offered in DE:

– Odd semester – CE371, CE481, Even semester – CE372, CE334, CE362, CE382, CE412, CE462, CE432, Other courses – CE491, CE492, CE605A, CE606A.

Template for BTM Program in Civil Engineering

Template for 3rd to 8th semester for BTM program in Civil Engineering					
Semester 3	Semester 4	Semester 5	Semester 6	Semester 7	Semester 8
SCHEME-2 EME (CE212-9)*	SCHEME-3 HSS-I (9-11)	ESO208A [11] (E/SO)	SCHEME HSS-II (9)	SCHEME HSS-II (9)	SCHEME HSS-II (9)
ESO202 [11] (E/SO)	ESC201 (14)	CE351 [10] (DC)	CE441M [5] (DC)	MTB-1 [9]	MTB-4 [9]
MSO203M [6] (E/SO)	TA212 [3] (E/SO)	CE361 [6] (DC)	DE-2 [9]	MTB-2 [9]	MTB-5 [9]
HSO201 [11] (E/SO)	CE272 [9] (DC)	CE331 [8] (DC)	DE-3 [9]	DE-5 [5]	MTB-6 [9]
CE261 (10) (DC)	CE252 [11] (DC)	CE311 [4] (DC)	DE-4 [9]	OE-2 [9]	OE-3 [6]
CE243 (8) (DC)	CE214 [9] (DC)	CE381 [9] (DC)	OE-1 [9]	MTB-3 [9]	
CE341 [2] (DC)		DE-1 [9]			
TA211 [3] (E/SO)			UGP-1 (CE332) Extra Credits (DE) [4]		UGP-4 (CE493) Extra Credits (DE) [9]
60	55-57	57	50	50	42

1. *All CE student must opt for environment part from the EME basket in semester 3.
2. Students need to ensure that the courses chosen as DE must include
   iv) at least one course from CE371 and CE372, and
   v) at least one course from CE412, CE432, CE462, CE481.
   vi) Total DE credits should be minimum of 41.
3. The DE basket may also contain departmental PG courses. However, some of the 300 level DE courses are pre-requisite to those PG courses.
4. UGP-1 and UGP-4 do not count towards DE/OE credits or minimum graduation requirements. Courses that are mandatorily offered in DE:

- Odd semester – CE371, CE481.
- Even semester – CE372, CE334, CE362, CE382, CE412, CE462, CE432
- Other courses – CE491, CE492, CE605A, CE606A.

Template for five-year dual degree in Civil Engineering

Template for 3rd to 10th semester for BT-MT dual degree program in Civil Engineering (Category A)							
Semester 3	Semester 4	Semester 5	Semester 6	Semester 7	Semester 8	Semester 9	Semester 10
SCHEME-2 EME (CE212-9)*	SCHEME-3 HSS-I (9-11)	ESO208A [11] (E/SO)	SCHEME HSS-II (9)	SCHEME HSS-II (9)	SCHEME HSS-II (9)	CE699A (36) M. Tech Thesis	CE699A (36) M. Tech Thesis
ESO202 [11] (E/SO)	ESC201 (14)	CE351 [10] (DC)	CE441M [5] (DC)	DE-5 [9]	PGOE-4 [9]		
MSO203M [6] (E/SO)	TA212 [3] (E/SO)	CE361 [6] (DC)	DE-2 [9]	DE-6 [9]	PGOE-5 [9]		CE698A (0) M. Tech Seminar
HSO201 [11]	CE272 [9]	CE331 [8] (DC)	DE-3 [9]	PGOE-1 [9]	PGOE-7 [9]		

Template for 3rd to 10th semester for BT-MT dual degree program in Civil Engineering (Category A)							
Semester 3	Semester 4	Semester 5	Semester 6	Semester 7	Semester 8	Semester 9	Semester 10
(E/SO)	(DC)						
CE261 (10) (DC)	CE252 [11] (DC)	CE311 [4] (DC)	DE-4 [9]	PGOE-2 [9]	PGOE-8 [9]	Additional PG-OE courses in consultation and with consent of thesis supervisor	
CE243 (8) (DC)	CE214 [9] (DC)	CE381 [9] (DC)	OE-1 [9]	PGOE-3 [9]			
CE341 [2] (DC)		DE-1 [9]				Any remaining courses from the BT template	
TA211 [3] (E/SO)			UGP-1 (CE332) Extra Credits (DE) [4]		UGP-4 (CE493) Extra Credits (DE) [9]		
60	55-57	57	50	54	45	Max. 45	Max. 45

1. *All CE student must opt for environment part from the EME basket in semester 3.
2. Up to 42 OE and 14 DE credits may be waived from the minimum BT template requirement.
3. Students need to ensure that the courses chosen as DE must include
   i) at least one course from CE371 and CE372, and
   ii) at least one course from CE412, CE432, CE462, CE481.
   iii) Total DE credits should be minimum of 54.
4. Minimum 63 credits of PG courses and 72 credits of M. Thesis is required.
5. Students, opting for the dual degree programme within CE, please check the list of mandatory PG courses for the respective specialization.
6. The DE basket may also contain departmental PG courses. However, some of the 300 level DE courses are pre-requisite to those PG courses.
7. UGP-1 and UGP-4 do not count towards DE/OE credits or minimum graduation requirements.
8. Students opting for the dual degree programme within CE are allowed to take CE491 or CE492 as DEs or as OE.

<table>
<tr><td colspan="5">Template for 7th to 10th semester for dual degree program in Civil Engineering- Environmental Engineering (Category B)</td></tr>
<tr><td>Semester 3 – Semester 6</td><td>Semester 7</td><td>Semester 8</td><td>Semester 9</td><td>Semester 10</td></tr>
<tr><td rowspan="6">BT / BS Template of Parent Department (BSBE, CHE, CHM, ECO, ME, MME, MTH, PHY)</td><td>CE664A [9]</td><td>CE667A [5]</td><td>CE699A [36]
(M. Tech. Thesis)</td><td>CE699A [36]
(M. Tech. Thesis)</td></tr>
<tr><td>CE665A [9]</td><td>CE668A [10]</td><td></td><td>CE698A [0]
(M. Tech. Seminar)</td></tr>
<tr><td>CE666A [9]</td><td></td><td></td><td></td></tr>
<tr><td></td><td colspan="3">At least additional 21 PG-OE credits in consultation and with consent of thesis supervisor</td></tr>
<tr><td colspan="4">Other Courses from BT template of parent Department</td></tr>
<tr><td>Max 65</td><td>Max 65</td><td>Max 65</td><td>Max 65</td></tr>
</table>

1. 36 OE credits waived from the BT/BS program of the parent department.
2. Minimum 63 credits of PG course and 72 credits of M. Tech thesis required.
3. These 63 PG course credits may include 1 UG course taken for PG credits on advice of the thesis supervisor.
4. Another UG/PG course (over and above the first 63 PG credits) may also be taken for PG credits on advice of the thesis supervisor.

<table>
<tr><td colspan="5">Template for 7th to 10th semester for dual degree program in Civil Engineering- Hydraulics and Water Resources (Category B)</td></tr>
<tr><td>Semester 3 – Semester 6</td><td>Semester 7</td><td>Semester 8</td><td>Semester 9</td><td>Semester 10</td></tr>
<tr><td rowspan="5">BT / BS Template of Parent Department (AE, CHE, ME)</td><td>CE610A [9]</td><td>CE612A [9]</td><td>CE699A [36]
(M. Tech. Thesis)</td><td>CE699A [36]
(M. Tech. Thesis)</td></tr>
<tr><td>CE611A [9]</td><td>CE613A [9]</td><td></td><td>CE698A [0]
(M. Tech. Seminar)</td></tr>
<tr><td colspan="4">At least additional 27 PG-OE credits in consultation and with consent of thesis supervisor</td></tr>
<tr><td colspan="4">Other Courses from BT template of parent Department</td></tr>
<tr><td>Max 65</td><td>Max 65</td><td>Max 65</td><td>Max 65</td></tr>
</table>

1. 36 OE credits waived from the BT/BS program of the parent department.
2. Minimum 63 credits of PG course and 72 credits of M. Tech thesis required.
3. These 63 PG course credits may include 1 UG course taken for PG credits on advice of the thesis supervisor.
4. Another UG/PG course (over and above the first 63 PG credits) may also be taken for PG credits on advice of the thesis supervisor.

Template for 7th to 10th semester for dual degree program in Civil Engineering- Geoinformatics (Category B)				
Semester 3 – Semester 6	Semester 7	Semester 8	Semester 9	Semester 10
BT / BS Template of Parent Department (CSE, MTH, PHY)	CE331 [8] (UG Pre-Requisite)	CE334 [8] (as PG)	CE699A [36] (M. Tech. Thesis)	CE699A [36] (M. Tech. Thesis)
	CE671A [11]			CE698A [0] (M. Tech. Seminar)
	CE677A [9]			
		At least additional 35 PG-OE credits in consultation and with consent of thesis supervisor		
	Other Courses from BT template of parent Department			
	Max 65	Max 65	Max 65	Max 65

1. 36 OE credits waived from the BT/BS program of the parent department.
2. Minimum 63 credits of PG course and 72 credits of M. Tech thesis required.
3. These 63 PG course credits include 1 UG course (CE334 [8]) taken for PG credits.
4. Another UG/PG course (over and above the first 63 PG credits) may also be taken for PG credits on advice of the thesis supervisor.

Template for 7^{th} to 10^{th} semester for dual degree program in Civil Engineering- Transportation Engineering (Category B)				
Semester 3 – Semester 6	Semester 7	Semester 8	Semester 9	Semester 10
BT / BS Template of Parent Department (AE, ECO, ME, MTH, PHY)	CE682A [9]	CE684b [5]	CE699A [36] (M. Tech. Thesis)	CE699A [36] (M. Tech. Thesis)
	CE683A [9]	CE685a [5]		CE698A [0] (M. Tech. Seminar)
		CE780A [9]		
	At least additional 26 PG-OE credits in consultation and with consent of thesis supervisor			
	Other Courses from BT template of parent Department			
	Max. 65	Max. 65	Max. 65	Max. 65

1. 36 OE credits waived from the BT/BS program of the parent department.
2. Minimum 63 credits of PG course and 72 credits of M. Tech thesis required.
3. These 63 PG course credits may include 1 UG course taken for PG credits on advice of the thesis supervisor.
4. Another UG/PG course (over and above the first 63 PG credits) may also be taken for PG credits on advice of the thesis supervisor.

Template for Double Major: Second Major in Civil Engineering

<table>
<tr><td colspan="5">Template for 7th to 10th semester for double major with second major in Civil Engineering</td></tr>
<tr><td>Semester 3 – Semester 6</td><td>Semester 7</td><td>Semester 8</td><td>Semester 9</td><td>Semester 10</td></tr>
<tr><td rowspan="8">BT/BS Template of Parent Department

Pre-Requisites
1) ESO204 or equivalent else CE261 in 7th Sem
2) ESO202
3) CE212 as part of SCHEME else in 7th Sem</td><td>CE341 [2] (DC)</td><td>CE272 [9] (DC)</td><td>CE351 [10] (DC)</td><td>CE411 [5] (DC)</td></tr>
<tr><td>CE243 [8] (DC)</td><td>CE252 [11] (DC)</td><td>CE361 [6] (DC)</td><td>DE [9]</td></tr>
<tr><td>CE331 [8] (DC)</td><td>CE214 [9] (DC)</td><td>CE381 [9] (DC)</td><td>DE [9]</td></tr>
<tr><td></td><td></td><td>CE311 [4] (DC)</td><td>DE [9]</td></tr>
<tr><td></td><td></td><td>DE [9]</td><td>DE [9]</td></tr>
<tr><td colspan="4">Other Courses from BT template of parent Department</td></tr>
<tr><td>Max 65</td><td>Max 65</td><td>Max 65</td><td>Max 65</td></tr>
</table>

Students need to ensure that the courses chosen as DE must include –

i. at least one course from CE371 and CE372, and
ii. at least one course from CE412, CE432, CE462, CE481.
iii. Total DE credits should be minimum of 45.

2. The DE basket may also contain departmental PG courses. However, some of the 300 level DE courses are pre-requisite to those PG courses.
3. UGP-1 and UGP-4 do not count towards DE/OE credits or minimum graduation requirements.
4. 36 OE credits waived from the BT/BS program of the parent

department. Courses that are mandatorily offered in DE:

- Odd semester – CE371, CE481.
- Even semester – CE372, CE334, CE362, CE382, CE412, CE462, CE432.

Other courses – CE491, CE492, CE605A, CE606A.

DEPARTMENT OF CE			
Courses ID	**Course Title**	**Credits L-T-P-D-C**	**Content**
CE212	ENVIRONMENT AND SUSTAINABILITY	3-0-0-0-9	Biosphere; essential components for life: energy, carbon, water and nutrients and their role in sustaining life; biomes and ecosystems; Lithosphere; plate tectonics, types of rocks, rock and soil formation processes, types of rocks, rock cycle; Hydrosphere; water cycle, surface and groundwater origin and its quality, oceans, ocean currents, ocean water quality; Atmosphere; components of atmosphere; earths energy budget; air quality, winds, cloud formation, storms; biogeochemical cycles (water, carbon, nutrient, nitrogen etc.); Human evolution and history of how humans have degraded the environment over past 100,000 years; Current state of environment in India and world; Underlying reasons (root causes) of modern environmental degradation (social, psychological, cultural); Global environmental problems (climate change, biodiversity extinction, land degradation, resource scarcity, ecosystem service loss); Local and regional scale environmental problems (air pollution, surface water and marine pollution, groundwater pollution, solid waste); Impact of different economic sectors on the environment; Negative impacts of environmental degradation on economies and human health (e.g., rise in pandemics); Environmental impact assessment (EIA); Sustainable Development Goals (SDGs); Life cycle assessment (LCA) tool; Ecological economics and payment for ecosystem services concepts; Renewable energy and green transport; Sustainable agricultural and diets; Sustainable construction and smart cities; International policies and environmental missions by Indian government, industries and NGOs to deal with impacts.
CE214	ENVIRONMENTAL QUALITY AND PROCESSES THEORY	3-0-0-0-9	This is an introductory course for undergraduate students. This course provides an overview of the different facets of Environmental Engineering, particularly the underlying concepts and the intended applications to prepare a graduating engineer with the skills needed to effectively intervene in the safeguarding of the environment, in whatever role they ultimately play in the society. Pollutant mobility, toxicity, and amenability to treatment in the environment depend on the physical and chemical reactions the pollutant undergoes in the environmental systems. This course introduces fundamental principles and processes that govern the fate and transport of these chemicals in pristine and polluted soil, air, surface, and groundwater environments. The course examines the equilibrium and kinetics of chemical reactions relevant to environmental systems. For each reaction, the fundamental molecular

			interactions affecting the process are first examined. The quantitative application of the reaction to environmental behaviour is then presented. Topics covered include acids and bases, mineral solubility, carbonate chemistry, chemical speciation, reduction-oxidation (redox) reactions, adsorption and ion exchange, and the speciation, mobility, and toxicity of metals and organic compounds. Furthermore, the theory and application of the physical and chemical processes of coagulation, flocculation, sedimentation, softening, filtration, and disinfection in water and wastewater treatment is presented. Principles that can be used in the analysis and modeling of environmental engineering processes, including material and energy balances, mass transfer, and reaction engineering are elucidated
CE243	CIVIL ENGINEERING MATERIALS	2-0-2-0-8	Properties of material and their evaluation (creep, elastic modulus, fatigue, impact, etc.); test methods and specifications; Cement: Chemical composition, properties – setting, strength, fineness, hydration; Aggregates: Sources, properties, chemical reactivity; Concrete: Constituents, proportioning, properties of fresh and hardened concrete, characteristic strength, quality control (sampling, acceptance, etc.), transportation and placing, testing (including NDT), porosity; Admixtures in concrete: Chemical and mineral; Steel: Properties and types; Bricks: Manufacture, properties and classification; masonry bonds; Bitumen: Source, composition, characterization, various forms, tests on bitumen; Bituminous mix design.
CE252	SOIL MECHANICS	3-0-2-0-11	Soil classification and composition; Stresses within a soil, effective stress principle, stress point, and stress path; soil-water systems, capillarity, Darcy's law, permeability, hydraulic heads, piping, quicksand condition, seepage, flownets; compressibility and consolidation characteristics; shear strength, direct shear and triaxial shear test, Mohr-coulomb strength criterion, drained and undrained conditions, consolidated drained and undrained tests, unconfined compressive strength test, strength of loose and dense sand, NC and OC soils, dilation, pore pressures, Skempton's coefficient; Compaction characteristics, water content-dry unit weight relationships, OMC, maximum dry unit weight, field compaction control; Slope stability analysis. **Laboratory sessions:** Visual identification of soils; Specific gravity and Atterberg limits; Sieve and Hydrometer analysis; California Bearing Ratio test; Proctor compaction test; Permeability Constant head; Permeability falling head; In situ filed density of soil (sand cone/core cutter); Unconfined compression test; Direct shear test; Triaxial (UU); Consolidation tests (loading and unloading).
CE261	FLUID MECHANICS	3-0-1-0-11	Introduction to fluid mechanics, fluid statics, Reynolds

	FOR CIVIL ENGINEERS		Transport Theorem, Navier Stokes Equation, Energy Equation, Laminar Flow, Boundary Layer Theory, Drag and Lift, Pipe Flow, Open Channel Flow.
CE272	STRUCTURAL ANALYSIS	3-0-0-0-9	Stability and Determinacy of Structures. Review of shear force and bending moment diagrams in beams and frames. Plane trusses: method of joints and method of sections. Deflection of trusses: method of virtual work. Deflection of beams and frames: momentarea method, conjugate beam method, method of virtual work. Influence line diagrams and moving loads. Force and stiffness methods of analysis. Plane trusses by using method of consistent deformations. Beams and frames: method of consistent deformations, slopedeflection equation, moment distribution method. Plane trusses and beams by using direct stiffness method.
CE311	ENVIRONMENTAL QUALITY AND PROCESSES PRACTICAL	0-0-4-0-4	This is a follow-up course for CE undergraduate students who have previously taken Environmental Quality and Processes Theory course. This course provides students practical training on pollution monitoring techniques so as to prepare a graduating engineer with the skills needed to effectively intervene in the safeguarding of the environment, in whatever role they ultimately play in the society. The course equips the students with skills to perform water and wastewater quality analysis and also introduces them to air pollution monitoring equipment like ambient air quality samplers and stack monitoring kit. The course also includes demonstration of advanced analytical instruments like gas and liquid chromatography, organic carbon analyzers, measurement of metals and other advances instruments in the Environmental Engineering laboratory.
CE331	PRINCIPLES OF GEOINFORMATICS	2-0-2-0-8	Basic concepts of surveying: Objectives; Basic measurements, control networks, locating topographic details; Units of measurement; Error in measurement and their types, indices of precision, weight, outliers; Error sources, types; accuracy and precision, propagation of variance/covariance Linear measurements: Taping; Optical distance measurement; Electronic distance measurement, classification and calibration; Errors in distance measurement and precautions Vertical control: Level surface; Levelling principles, determination of height, leveling instruments; Sources of error and minimization, curvature and refraction effects; closure tolerances; Types of leveling; Characteristics of contours; methods of contouring Angle measurements: Concept of direction, azimuth, meridian; Theodolite, fundamental characteristic of theodolite and adjustment, measuring angles, sources of error, Total Station surveys Adjustments: Adjustment of errors using observation equation and condition equation approach (matrix-based solution) Control surveys: Traversing, Triangulation, Trilateration,

			and Triangulateration: types, field procedure, error minimization Coordinate systems and datum transformation: Important surfaces in geodesy: earth surface, geoid, MSL, reference ellipsoid; Reference systems: 2D and 3D coordinate systems and transformations; map projection, UTM projection
CE332	SURVEY CAMP (UGP I)	0-0-0-4-4	Survey Camp: Reconnaissance, control establishment, topographic mapping using electronic surveying techniques, report writing
CE334	MODERN METHODS IN GEOINFORMATICS	2-0-2-0-8	Review of principles: Measurements, errors, networks, coordinate systems and reference surfaces GNSS: Principles, errors, DGPS, DOP, GPS survey Methods and plans Gravimetry: Role of gravity in surveying, principles of gravimetry, terrestrial, airborne and spaceborne gravimetry, gravity networks and their adjustment Hydrography: Ocean processes and tides, Coastal and maritime zones, Hydrographic reference surfaces, Maritime Positioning, Bathymetry, Nautical Charts LiDAR & Photogrammetry, GIS Applications: Infrastructure construction, Infrastructure monitoring, Earth Observation
CE341	CIVIL ENGINEERING COMMUNICATION SKILLS	0-0-2-0-2	Introduction to Professional Communication: written, verbal and non-verbal (tone, posture, body language); Issues of Plagiarism; Technical writing: Planning, composition and organization of papers, technical reports and proposals; Technical presentation: development of content based on target audience, organization, presentation, use of multi-media.
CE351	FOUNDATION DESIGN	3-0-1-0-10	Site investigations, methods of drillings, Sampling, in-situ test, SPT, CPT, plate load and dynamic tests, groundwater levels; Earth pressure theories, Coulomb and Rankine approaches, c-ϕ soils, smooth and rough walls, inclined backfill; Bearing capacity, general, local and punching shear failures, corrections for size, shape, depth, water table, compressibility, ultimate and allowable stress, methods based on in-situ tests; Settlement of foundations, Design of foundation, types of foundation-shallow/deep, isolated, combined, mat, etc, contact pressure distributions; Stresses due to applied loads, Stress distribution (Boussinesq, Westergaard, Newmark's influence chart) under various load conditions; Deep foundations, pile; and Retaining wall design. **Laboratory Session:** Pit Sampling and Auge boring; Standard penetration test; Static Cone penetration test Dynamic Cone penetration test; Field Permeability; Plate load test
CE361	ENGINEERING HYDROLOGY	2-0-0-0-6	Hydrologic cycle, water budget, world water quantities; Precipitation and Abstractions: Forms of precipitation, data analysis, rain-gauge networks; Infiltration - process, infiltration indices and Horton's equation; Evaporation

			and Evapotranspiration – Pan evaporation, empirical equations for estimating evaporation and evapotranspiration; Transpiration; Crop water requirements; Runoff and Hydrographs: Rainfall runoff relations, time area concept, flow duration curve, mass curve, flow hydrograph, Unit Hydrograph (UH), its analysis, S-curve hydrograph; Floods and Routing: Concepts of return period, flood frequency analysis, Gumbel's distribution, Rational method, risk, reliability, and safety factor; Hydrologic storage routing; Groundwater Hydrology: Types of aquifers and properties, Darcy's law, Well hydraulics, Irrigation methods
CE362	ENGINEERING HYDRAULICS	2-1-0-0-8	Introduction; Dimensional Analysis; Flow through closed conduits: Laminar flow, Turbulent flow, Pipes in Series and Parallel, Pipe Networks, Unsteady flow, Design of water distribution network; Flow through open channels: Uniform flow, Critical flow, Gradually Varied flow, Rapidly Varied flow, Channel Transitions, Spatially Varied flow, Unsteady flow, Analysis and design of rigid boundary and mobile boundary channels; Flow Measurement: Pressure, Velocity and Discharge measurements.
CE371	DESIGN OF REINFORCED CONCRETE STRUCTURES	3-0-0-0-9	Reinforced concrete (RC) structures, Loadings, analytical models for analysis and design of RC structures, Design Methodologies: Working Stress Method and Limit State Method; Behavior of RC members under flexure; Working stress design for common flexural members; Limit state design of beams and one-way slabs for flexure; Singly and doubly reinforced sections; Rectangular and flanged sections; Shear and torsion; Bond and anchorage; Short columns under axial compression, Short columns under axial compression with uni-axial bending, Short columns under axial compression with bi-axial bending; Slender columns; Deflection computation for RC beams, Creep strain; Limit state design of two-way slabs, Yield line theory; Types of footings; design of isolated / combined footing.
CE372	DESIGN OF STEEL STRUCTURES	3-0-0-0-9	Introduction to steel structural systems and components; Properties of structural steel, Hot rolled sections; Analysis and design methods; Design philosophies: Working stress design, Ultimate load (plastic) design, and Limit states design; Partial safety factors and load combinations; Design of tension members based on net section including shear lag effects, staggered holes and block shear; Design of Bolts and Welds, Strength under combined stresses, Prying action, Common simple connections; Design of compression members for flexural and flexural-torsional buckling, Column formula, Buckling class, End restraints and effective length factor; Role of plate buckling; Strength of compression members as affected by local buckling; Classification of sections: plastic, compact, semi-compact, slender; Plastic hinge; Design strength of laterally supported beams; Shear buckling strength, post-critical method;

			Shear-moment interaction; Design strength of laterally unsupported beams; Lateral torsional buckling; Effect of restraints and effective length; Design of plate girders, Tension field method; Effect of axial load on flexure behaviour; Cross-section yielding and member instability, P-M interaction and moment amplification; Bi-axial bending; Plastic analysis and design of continuous beams and rigid frames; Eccentric bolted and welded joints and frame connections; Column bases.
CE381	INTRODUCTION TO TRANSPORTATION ENGINEERING	3-0-0-0-9	Introduction, Transportation engineering elements, Geometric design, Traffic flow fundamentals, Uninterrupted traffic flow, Interrupted traffic flow, Material modeling as an input to pavement analysis, Analysis of bituminous pavement (load and thermal analysis), Analysis of concrete pavement (load and thermal analysis)
CE382	TRANSPORTATION SYSTEMS ANALYSIS	3-0-0-0-9	Introduction, Basics of Optimization, Static assignment problems and corresponding solution techniques, Combinatorial network optimization problems and solution approaches, Sequential decisionmaking in infrastructure management, Additional applications
CE412	WATER SUPPLY AND WASTEWATER DISPOSAL SYSTEMS	3-0-2-0-11	Introduction; need for water and wastewater treatment, associated environmental laws, drinking water and wastewater discharge standards, water reuse and recycling concepts; Water Treatment Water sources, Water quantity, process description of conventional water treatment; design of individual unit processes, water treatment plant layout and related issues; Water Distribution Treated water storage structures; Design of water distribution systems; Wastewater Collection Description and design of wastewater collection system; Wastewater Treatment Quantity and quality of wastewater, process description for conventional wastewater treatment; design of individual unit processes, wastewater treatment plant layout and related issues; Rural water supply and sanitation; Water sources, treatment and distribution systems; Rural sanitation, surface drains, septic tank, onsite sanitation systems etc.
CE432	GEOGRAPHICAL INFORMATION SYSTEM (GIS)	3-0-2-0-11	Introduction: What is GIS? Applications of GIS, Examples of use cases, Components of GIS, Brief History of GIS, Elements of GIS: Geospatial data, Data acquisition, data management, data display, data exploration and data analysis; Future of GIS. Geospatial data; data types: Spatial and non-Spatial, Vector and Raster data types; Elements of raster and vector data types; vector and raster data models and encoding; advantages and disadvantages of raster data model; advantages and disadvantages of vector data model; Integration of raster and vector data models in GIS; Geo-referencing; Transformation models using GCPs; accuracy analysis; Resampling: Nearest Neighbour, Bilinear, Bicubic; Advantages and Disadvantages of each

			resampling approach; Map to Image registration, Image to Image registration. Geospatial data acquisition: raster data and vector data acquisition; Metadata; Importing data in GIS; Raster to vector data conversion (digitization): Manual approach, Semi-automatic approach, Automatic approach, Errors in digitization: Topological errors; rasterization of data; Management of attribute data. Coordinate reference systems, Projection Systems and Coordinate Transformations. Database models: Flat, Hierarchical, Network, Relational, Georelational (Shape file and coverage); Primary and Foreign Key; Database Normalization and rules; Relationships in database: One to one, one to many, many to one, many to many; Joins and Relates; Hybrid Data model (Geodatabase); SQL: Language structure, queries by attribute, queries by geography. Spatial interpolation: multi-linear regression, density map, Delaunay Triangulation and Theissen polygons, Kriging. Vector data operations: Buffering and Overlay, Raster data operations: Display, Local operations, Reclassification, Overlay, Neighbourhood operations, Zonal operations, Global operations. Least cost path analysis, Network analysis, Viewshed and Watershed analysis, Geocoding.
CE441M	CONSTRUCTION MANAGEMENT	3-0-0-0-5	Stakeholders in construction projects – client, consultant, contractor, financial institutions, regulators, Private Public Partnership, Environmental Impact Assessment; Planning and scheduling (CPM & PERT), resource levelling, crashing; Construction process and life cycle of a project – concept, technical feasibility, planning, qualification of bidders, award of contract, procurement (of equipment, etc.), execution, maintenance, monitoring of progress; Contract management – types of contracts, contract process, dispute management and arbitration, labour laws, Federation Internationale des Ingenieurs Counseils (International Federation of Consulting Engineers, FIDIC); provisions for safety and quality in contracts; Construction economics and finance, cost estimation (clients and contractor versions), depreciation
CE451	APPLICATION OF GEOTECHNICAL ENGINEERING	3-0-0-2-11	Earth and Earth retaining structures: flexible and rigid retaining wall, gravity, cantilever, counter fort, reinforced earth etc., design and check for stability. Introduction to ground improvement techniques: methods for difficult or problematic ground conditions for soft clays, loose sands, expansive or collapsible soils etc., preloading, vertical drains, stone columns, heavy tamping, grouting etc., Machine foundation and design. Special topic: (Well foundation/Soil nailing/Sheet pile)
CE462	HYDRAULIC AND HYDROLOGIC DESIGN	2-1.5-0-0-9	Synthetic design storms & Estimation of peak discharge, Urban storm drainage design, Culvert design, Detention storage design, Watershed modeling, Flood frequency analysis and hydrologic design under uncertainty; Design of canal headworks, distribution works, and cross-drainage works, Design of gravity dams, spillways, and

			energy dissipators.
CE481	TRANSPORTATION FACILITIES DESIGN	3-0-0-2-11	Any two of the three modules listed below will be taught in any semester: Module 1: Traffic Design: Introduction, freeway and toll booths, intersections/interchanges, signs and lighting, arterials/ weaving section, congestion mitigation. Module 2: Pavement Design: Introduction, design parameters, bituminous pavement, concrete pavement, composite pavement. Module 3: Geometric Design: Introduction, design controls and criteria, freeway design, arterial/collector design, atgrade intersections, terminals.
CE491	UNDER GRADUATE RESEARCH -II	0-0-0-0-9	UNDER GRADUATE RESEARCH II
CE492	UNDER GRADUATE RESEARCH -III	0-0-0-0-9	UNDER GRADUATE RESEARCH III
CE493	UNDER GRADUATE RESEARCH -IV	0-0-0-0-9	UNDER GRADUATE RESEARCH III
CE603	MATHEMATICS FOR CIVIL ENGINEERS	1.5-0-0-0-5	Linear Differential Equations: Homogeneous Linear Equations of Second Order; Second Order Homogeneous Equations with Constant Coefficients; Case of Complex Roots, Complex Exponential Function; Nonhomogeneous Equations; Solution by Undetermined Coefficients; Solution by Variation of Parameters Fourier Integrals and Transforms: Fourier Integrals; Fourier Cosine and Sine Transforms; Fourier Transform andProperties; Dirac Delta Function; Convolution Theorem; Parseval's Theorem; Fourier integral to Laplace transform Partial Deerential Equations: Basic Concepts; Modeling: Vibrating String, Wave Equation; Separation of Variables,Use of Fourier Series; Modeling: Membrane, Two Dimensional Wave Equation; Rectangular Membrane, Use ofDouble Fourier SeriesLinear Algebra: Rank of a Matrix, Linear Independence, Vector Space; Solutions of Linear Systems: Existence,Uniqueness, General Form; Vector Spaces, Inner Product Spaces, Linear Transformations; Eigenvalues,Eigenvectors; Similarity of Matrices, Basis of Eigenvectors, Diagonalization
CE604	NUMERICAL METHODS FOR CIVIL ENGINEERS	1.5-0-0-0-5	Introduction; Floating Point operations, Round-off and truncation errors, Error Propagation; Solution of Linear System of equations: Gauss Elimination, Matrix Inversion by Gauss Jordon, Thomas Algorithm, Gauss-Siedel iteration, pivoting, equilibration, Ill-Conditioning; Solution of non-linear equation: Newton-Raphson, Bairstow method for polynomials, non-linear system of equations; Eigenvalues: maximum and minimum eigenvalue by Power and Inverse Power Method; All eigenvalues by Fadeev-Leverrier method; Introduction to diagonalization and QRFactorization; Approximation Theory: Interpolation by Newton's and Lagrange polynomials; Method of Least Squares; Numerical Differentiation: Finite difference formulae; Richadson's extrapolation;

			Numerical Integration: Newton-Coates formulae; Romberg integration; introduction to quadrature schemes; Ordinary Differential Equations (ODEs): Euler Methods; Trapezoidal methods; Runge-Kutta methods; application to system of ODEs and higher order ODEs; concepts of consistency; stability and convergence; Solution of boundary value problems by shooting method and finite difference method; Partial Differential Equations (PDEs): finite difference methods for Laplace equation; partial and direct discretization schemes; CrankNicholson method for parabolic equation; upwind scheme for first order wave equation; direct discretization and time lumping schemes for second order wave equation.
CE605	PROBABILITY AND STATISTICS FOR CIVIL ENGINEERS	1.5-0-0-0-5	Review of Basic Concepts of Probability and Distributions; Review of Estimation and Hypothesis Testing; Properties of good estimates, Interval estimation, Maximum likelihood estimates, Sample size determination, Basic format of hypothesis testing, Type I and Type II errors, One and two tailed tests, Tests on mean and variance from samples under different assumptions and knowledge of the underlying distribution; Regression Analysis and Hypothesis Testing; OLS estimates; Assumptions and proof of BLUE; Detection, effect, and remedy of multi-colinearity; Detection, effect, and remedy of heteroskedasticity; Detection, effect, and remedy of autocorrelation; Mis-specification errors and regression model building; Hypothesis testing on OLS estimates; GLS; Comparison of regression model; Use of dummy independent variables; Robust regression and effect of outliers Miscellaneous Topics; Fitting theoretical distributions to observed frequency distributions and Tests of goodness-of-fit (chi-square test, Kolmogorov-Smirnov test); Identification of outliers; Simultaneous equation models; Regression with discrete dependent variables; Practical applications with (civil) engineering data.
CE606M	OPTIMIZATION METHODS FOR CIVIL ENGINEERS	3-0-0-0-5	Introduction to the course and its importance. Optimization methods: problem formulation, solution techniques for linear and integer problems (both unconstrained and constrained), sensitivity analysis. Brief introduction to nonlinear problems. Introduction to nontraditional optimization methods. Case studies from Civil Engineering.
CE610	ADVANCED HYDROLOGY	3-0-0-0-9	Hydrologic cycle, systems concept, hydrologic model classification; Reynold's Transport Theorem, continuity, momentum, and energy equations; Atmospheric hydrology:atmospheric circulation, water vapor, formation and forms of precipitation, precipitable water, monsoon characteristics in India, Thunderstorm Cell model, IDF relationships; factors affecting evaporation, estimation and measurement of evaporation, energy balance method,aerodynamic method, Priestley Taylor method, and pan evaporation; Surface Water:Catchment storage

			concept, Hortonian and saturation overland flow, streamflow hydrographs,baseflow separation, index, ERH & DRH, algorithm for abstraction using Green Ampt equation, SCS method, overland and channel flow modeling, time area concepts, and stream networks; Unit Hydrograph: General hydrologic system model, response functions of a linearhydrologic systems and their interrelationships, convolution equation; definition and limitations of a UH; UH derivation from single and complex storms; UH optimization using regression, matrix, and LP methods; Synthetic unit hydrograph, SCurve, IUH; Subsurface Water: Soil moisture, porosity, saturated and unsaturated flow; Richards; equation,infiltration, Horton's, Philip's, and Green Ampt methods, parameter estimation, ponding timeconcepts; Groundwater Hydrology: Occurrence of groundwater, aquifers & their properties,Darcy's law, permeability, transmissibility, stratification, confined groundwater flow,unconfined groundwater flow under Dupit's assumptions; Well hydraulics, steady flow intoconfined and unconfined wells; Unsteady flow in a confined aquifer.
CE611	ADVANCED HYDRAULICS	3-0-0-0-9	Basics: dimensional analysis, equations of continuity, motion, and energy, irrotational flow, drag and lift of immersed bodies; Pipe flow: laminar flow, turbulent flow, boundary layer theory, wall turbulent shear flow, free turbulent shear flow; Open Channel flow: energy depth relationships, uniform flow, gradually varied flow, hydraulic jump, rapidly varied flow, spatially varied flow unsteady flow.
CE612	FLUID MECHANICS LABORATORY	2-0-3-0-9	Verification of momentum equation; Friction loss in pipes; Rainfall runoff relationship; Flow over sharp crested weir; Flow in pipe networks; Bernoulli theorem; Fall velocity of objects; Point velocity measurement by ADV; Reynolds apparatus; Venturimeter and orifice meter; Energy loss in bends; Ground waterflow/ well abstraction; Hydrogen bubble flow visualization; Hydraulic jump; Flowpast a cylinder
CE613	COMPUTATIONAL METHODS IN HYDRAULICS AND HYDROLOGY	2-0-3-0-9	Basic: Introduction to computer programming and computation with Matlab. (02 lectures) Open channel flow: Estimation of normal and critical depth; uniform flow computations; computation ofwater surface profile (WSP) gradually varied flow estimation using standard step and direct stepmethods, WSP in presence of hydraulic structures; unsteady flow SaintVenant equation, kinematic wave routing, diffusion routing, overland flow; steady and unsteady modelling using HECRAS. (07 lectures) Closed conduit flow: Steady and unsteady state modelling; pipe network analysis; introduction toEPANET/WaterCAD. (05 lectures) Surface water hydrology: Estimation of Unit hydrographs; lumped and distributed flow routing; hydrologic statistics parameter estimation, time series analysis, frequency analysis, geostatistics; hydrologic modelling using HECHMS. (05

			lectures) Groundwater hydrology: Solving groundwater flow equation saturated and unsaturated flow, Richard's equation, GreenAmpt infiltration model; introduction to MODFLOW. (05 lectures) Application of soft computing methods and GIS in Hydraulic and Hydrologic modelling. (03 lectures) Laboratory: Programming exercises for the related topics. (I 0 lab classes)
CE614	STOCHASTIC HYDROLOGY	3-0-0-0-9	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.
CE615	INTRODUCTION AI TECHNIQUES	3-0-0-0-9	Expert Systems (ES): history of ES, basic concepts of ES, definition and components of ES, inference engines and reasoning mechanisms e.g. forward reasoning, backward reasoning, and mixed reasoning, knowledge representation methods and development of the rule based knowledge base, dealing with uncertainty, and selected case studies of ES applications to engineering and sciences; Artificial Neural Networks (ANNs): background and history of ANNs, definitions and basic concepts of ANNs, biological and artificial neural networks, feedforward and feedback networks, supervised and unsupervised learning methodsstandard backpropagation (BP), conjugate gradients BP, self organizing networks, etc., development of ANN models for specific problems and selected case studies; Genetic Algorithms (GAs): fundamentals and preliminary concepts of evolution and GA, preliminaries of optimization, genetic operatorsselection, crossover, and mutation, binary and realcoded GAs, constraint handling in GAs, and selected case studies involving GA applications to engineering.
CE616	SEDIMENT TRANSPORTATION	3-0-0-0-9	Properties of sediment, incipient motion, bed load, suspended load, totalload, sediment measurements, regime concept, bed form mechanics, plan formand stream bed variations of rivers, reservoir sedimentation, erosion and deposition, sediment control, sediment transport in pipes.
CE617	ADVANCED MODELING OF SUBSURFACE FLOW AND TRANSPORT	3-0-0-0-9	Review of Governing Equations: Definition of Variables, Phase Equations, Component Equations, Initial and Boundary Conditions, constitutive relationships. Review of Numerical Methods: Finite Difference Methods, Finite Element Methods, Other Relevant Methods. Simulation of Groundwater Flow: Finite Difference and Finite Element Formulations. Simulation of Contaminant Transport: Finite Difference and Finite Element methods,

			Improved Eulerian Methods, Fourier analysis, Characteristic Methods. Simulation of Multiphase Flow and transport with emphasis on unsaturated flow and Transport; Introduction to existing packages for simulation of subsurface flow and transport The course will involve two major modeling and simulation projects, one for flow and other for combination of flow and transport. The students will have to make presentations of their results.
CE618	VADOSE ZONE HYDROLOGY	3-0-0-0-9	The Soil System: Physical properties of soil; soil water potentials, soil water characteristic curves and pedo-transfer functions; spatial variability of soils and scaling issues; Water Flow in Soils: Bernoulli's, Poiseuille's and Darcy's Laws; unsaturated hydraulic conductivity models; Richards equation and its alternate forms; Solutions of Richards equation: Analytical, approximate and numerical solutions of Richards equation, stability of numerical schemes, numerical dispersion, multi-dimensional water flow: spherical and cylindrical sources; introduction to Hydrus software for solving multidimensional flow problems; Solute Transport in Soils: Solute concentrations; transport mechanisms; transfer functions and stream-tube models; mobile-immobile systems; Heat Transport in Soils: Soil thermal properties; Fourier's law; steady and unsteady state transport equations and boundary conditions
CE619	ECOHYDROLOGY	3-0-0-0-9	Introduction: Origin and scope of ecohydrology. (03 Lectures) Ecohydrological processes: Interactions between physical, chemical and biological processesat basin scale soil water dynamics, land surface energy budgets; scales of interactions; ecohydrological optimality theory; ecohydrological controls on nutrient cycle; Landscapeconnectivity morphological, ecological and hydrological connections. (12 Lectures) Techniques in ecohydrological measurements: Measuring energy and water fluxes in atmosphere, soil and vegetation; atmosphere latent, sensible and C02 fluxes, distribution ofwind, temperature and humidity; soil soil moisture, soil respiration and soil heat flux; vegetation leaf area index, stomatal conductance and transpiration. (08 Lectures) Ecohydrological modelling: Governing equations; mathematical models stochastic and deterministic models; process based and empirical models; calibration and validation ofmodels; scale issues in ecohydrological modelling. (10 Lectures) Applications of ecohydrology: Use of ecohydrogical principles in paleohydrology and climatechange studies; ecohydrological approach for sustainable management of floods anddroughts; case studies from tropical river basins and dry land ecosystems. (08 Lectures)
CE620	STRUCTURAL DYNAMICS	3-0-0-0-9	Loading: nature of dynamic loading, harmonic, random, types of dynamic loading; Continuous systems: rods (axial vibrations), beams (shear, axial and axial shear flexural vibrations); Discrete mass systems: SDOF (free

			and forced vibrations), MDOF (generalized coordinates, eigenvalue analysis, matrix and modal time history analysis); Introduction of random vibration: stochastic processes, stochastic analysis of linear dynamical systems to Gaussian inputs, SDOF, MDOF.
CE621	ENGINEERING MECHANICS	3-0-0-0-9	Stress analysis: forces and moments, theory of stress, principal stresses andstress invariants, compatibility equations, equilibrium equations; Strain:deformation and velocity gradients, Lagrangian and Eulerian description andfinite strain, small deformation theory, principal strains and strain invariants,compatibility conditions; Fundamental physical principles: conservation of mass,linear momentum, angular momentum, and energy, second law of thermodynamics;Constitutive theory: St. Venants principal, linear elasticity and generalized Hooks law, Stokesian and Newtonian fluids, NavierStokes equations, Bernoulli equation, linear viscoelasticity, yield criteria; Applications: Airy stress function,two dimensional elastostatics problems, torsion.
CE622	STABILITY OF STRUCTURES	3-0-0-0-9	Criteria for design of structures: stability, strength, and stiffness; Classical concept of stability; Stability of discrete systems: linear and nonlinear behaviour;Stability of continuous systems: stability of columns: axialflexural buckling,lateral bracing of columns, combined axial flexural torsion buckling; Stabilityof frames: member buckling versus global buckling, slenderness ratio of frame members; Stability of beams: lateraltorsion buckling; Stability of plates: axial flexural buckling, shear flexural buckling, buckling under combined loads;Introduction to inelastic buckling and dynamic stability.
CE623	EXPERIMENTAL METHODS IN STRUCTURL ENGINEERING	2-0-3-0-9	Similitude and Structural Models: Dimensional analysis, Buckingham's Pi theorem, Scale factors and dynamic similitude; Uses and Applications of Models: Types of model investigation, Indirect and direct models, Elastic and Inelastic Models (steel, concrete and masonry), size effects Analysis of Experimental Data: Error and uncertainty in experiment, Measurement systems, Accuracy in models and reliability of results.Test Planning, Design and Implementation: Testing sequence and experimental plan, Loading systems, devices, actuators and their control, etc.Instrumentation: Mechanical, electrical, electronic system and their calibration, various types of sensors for displacement, velocity, acceleration, pressure, loads, strains, etc, fullfield measurements, Data Acquisition System and Data Processing: Analog systems, digital systems using personal computers, dynamic measurement, numerical and graphical data processing and archiving Lab Exercises: Experiments to illustrate buckling of structural members; load deformation behaviour of beams, columns, joints, and fiames under various loads; mode shapes, natural frequency, damping factors fiom free and forced vibrations, shake table tests, etc.

CE624	NONLINEAR STRUCTURAL ANALYSIS	3-0-0-0-9	Introduction to nonlinear structural analysis; Overview, Sources of nonlinearities, types of structural analysis (1st order elastic, 1st order inelastic, 2nd order elastic, and 2nd order inelastic), overview of solution strategies for nonlinear structures; Principles of computational plasticity; overview, yield criterion, flow rule, hardening rule, loading/unloading criterion. Some commonly used uniaxial material models; elastic material, elastic-perfectly plastic material, bilinear steel material with kinematic and isotropic hardening, Ramberg-Osgood steel material model, Giuffre-Menegotto-Pinto model with isotropic strain hardening, Kent-Scott-Park concrete material model, Visco-elastic material model, Bouc-Wen model; Member section analysis; fiber section discretization; moment-curvature response; force-deformation response; Material nonlinear beam-column element formulation; lumpedplasticity models (beam with hinges formulation), distributed nonlinearity models; displacement-based nonlinear beam-column element; force-based nonlinear beam-column element. Geometrically nonlinear analysis; simplified 2nd order P-Δ analysis, co-rotational formulations of truss and beam elements. Solution strategies for nonlinear system of equations; incremental single-step methods; Euler method, second-order Runge-Kutta methods, incremental-iterative methods, load control, displacement control, work control, arc-length control; Nonlinear structural dynamic analysis; semi-discrete equations, of motion, explicit time integration, implicit time integration, dissipative integration algorithms, stability and accuracy. Application to hybrid simulation; overview, sub-structuring in hybrid simulation; application to modeling analytical substructures, solution of time discretized equations of motion.
CE625	MASONARY STRUCTURES	3-0-0-0-9	Properties of constituents: units burnt clay, concrete blocks, mortar, grout,reinforcement; Masonry bonds and properties: patterns, shrinkage, differential movement, masonry properties compression strength ; Stresses in masonrywalls: vertical loads, vertical loads and moments eccentricity & kern distance,lateral loads inplane, outofplane; Behaviour of masonry walls and piers:axial and flexure, axial shear and flexure, Behaviour of Masonry Buildings:unreinforced masonry buildings importance of bands and corner & verticalreinforcement, reinforced masonry buildings cyclic loading & ductility of masonry walls; Behaviour of masonry infills in RC frames: strut action; Structural design of masonry in buildings: methods of design WSD, USD, seismic design seismic loads, code provisions, infills, connectors, ties; Seismic evaluation and strengthening of masonry buildings: methods insitu, non-destructive testing; Construction practices and new materials.
CE626	BRIDGE ENGINEERING AND	3-0-0-0-9	Introduction to Bridge Engineering: Components on bridge structures, Planning of bridges (traffic, hydro-

	DESIGN		technical, geotechnical, environmental and constructability/economic feasibility studies), Bridge types and selection criteria, Geometric design considerations, Aesthetics, Bearings, Piers, Abutment, and Introduction to IRC/IRS bridge design codes; Bridge Loads and Design Methods: Highway bridge loads as per IRC codes, Load combinations, Design philosophies (ASD/LSD) for various bridge types; Bridge Deck Analysis: Simplified deck analysis and load distribution methods (Pigeaud, Courbon, Morrice-Little methods), Influence functions and girder line analysis, and refined analysis using grillage and FEM; Culverts: General considerations, hydraulic and structural design; Concrete Bridge Design: Behavior and design of RC and pre-stressed concrete (PSC) flexural members, Solid slab and T-beam, box section and girder bridges; Steel & Composite Bridge Design: Behavior and design of steel flexural members, steel plate girder and composite bridges; Substructure Design Subsurface investigation and design considerations for bridge foundation types, design of bridge piers, pile cap, and abutments
CE627	ADVANCED DESIGN OF STEEL STRUCTURES	3-0-0-0-9	Properties of steel: mechanical properties, hysteresis, ductility; HotRolled Sections: compactness and noncompactness, slenderness, residual stresses; Design of steel structures: inelastic bending curvature, plastic moments, design criteria stability, strength, drift; Stability criteria: stability of beams local buckling of compression flange & web, lateral torsional buckling, stability of columns slenderness ratio of columns, local buckling of flanges and web, bracing of column about weak axis, method of design allowable stress design, plastic design, load and resistance factor design; Strength Criteria: beams flexure, shear, torsion, columns moment magnification factor, effective length,PM interaction, biaxial bending, joint panel zones; Drift criteria: P effect, deformation based design; Connections: types welded, bolted, location beamcolumn,column foundation, splices.
CE628	DURABILITY OF CONCRETE STRUCTURES	3-0-0-0-9	Concrete and the environment: interaction; Overview of concrete deterioration: alkali-aggregate reaction, corrosion, carbonation; Permeability of concrete and its measurement: penetration of carbon dioxide and chlorides into concrete, corrosion of steel in concrete electrochemistry of corrosion, micro and macrocell corrosion, corrosion cells and currents, role of concrete, prevention of corrosion; Corrosion induced longitudinal cracks: nature and properties of corrosion products; Alkali aggregate reaction: reactive minerals, mechanism of deterioration, identification and tests; Codal provisions for durability; Nondestructive testing; repair/rehabilitation of structures.
CE629	EARTHQUAKE ANALYSIS AND DESIGN OF STRUCTURES	3-0-0-0-9	Characteristics of earthquakes; Earthquake response of structures; Concept of earthquake resistant design; Code provisions of design of buildings; Design of liquid storage tanks; Liquefaction; Nonengineered construction; Special

			topics: bridges, dams, strengthening of existing buildings.
CE630	ROCK MECHANICS	3-0-0-0-9	Physical properties and classification of intact rock and rock masses, rock exploration, engineering properties of rock, stresses in rock near underground openings; Rock tunneling, rock slope stability, bolting, blasting, grouting and rock foundation design.
CE631	ADVANCED GEOTECHNICAL ENGINEERING	3-0-0-0-9	Soil composition and soil structure, Steady State flow, 2D and 3D seepage, Transient flow; Compressibility and Rate of consolidation, One, two, and three-dimensional consolidation theories; Shear strength and stress strain relationships of soils; Stability of slopes, Arching-effects, Buried Structures.
CE632	FOUNDATION ANALYSIS AND DESIGN	3-0-0-0-9	Settlement and bearing capacity; shallow spread footings, mats, and deep foundations. Foundation models, contact pressure distribution for footings, Rafts, Piles, Retaining Structures; Soil structure interaction studies; Case studies.
CE633	REINFORCED EARTH STRUCTURES	3-0-0-0-9	Reinforcing materials, Advantage of RE, behaviour of Reinforced earth walls, Soil reinforcement interaction internal and external stability condition, field application of RE. Randomly reinforced earth and analysis of reinforced soils, testing of soil reinforcements Development, fabrication, design, and applications of geotextiles, geogrids, geonets, and geomembranes.
CE634	GROUND IMPROVEMENT TECHNIQUES	3-0-0-0-9	Engineering properties of soft, weak and compressible deposits, principles of treatment loading (static and Dynamic), Accelerated flow, Reinforcement, Drainage and fillers, Injections, Thermal, electrical and Chemical Methods Preloading, Dynamic Consolidation, Vertical drains, Granular piles, soil nailing, Anchors, Design Methods and Case histories.
CE635	FOUNDATION DYNAMICS	3-0-0-0-9	Dynamics of elastic systems; Single and multi-degrees of freedom systems; Empirical and semiempirical approaches to the theory of soil dynamics; Elastic theories of soil dynamics; Wave propagation; Dynamic soil properties; Design of machine foundations; Vibration isolation; Pile dynamics.
CE636	GEOTECHNICAL EARTHQUAKE ENGINEERING	3-0-0-0-9	Introduction; Seismic Hazards: Mitigation of Seismic Hazards, seismology and earthquakes, strong ground motion, seismic hazard analysis; Wave propagation in unbounded media: in semi-infinite bodies, in layered soils and attenuation of stress waves; Dynamic soil properties; Ground response analysis; Effect of local site conditions on the ground motion; Liquefaction: evaluation of liquefaction hazards, effects of liquefaction; Case studies.
CE637	CONSTITUTIVE MODELING OF FRICTIONAL MATERIALS	3-0-0-0-9	Role of constitutive modeling; Importance of laboratory testing with relation to constitutive modeling; Elasticity: linear, quasi linear, anisotropic; Plasticity basics: yield criteria, flow rule, plastic potential, hardening/softening; Rate Independent Plasticity: Mohr Coulomb, nonlinear failure criteria, Drucker Prager, and cap models; Critical

			state soil mechanics: critical state concept, cam clay models, simulation of single element test using cam clay, consolidation drained and undrained triaxial test; Stress dilatancy theory; Work hardening plasticity theory: formulation and implementation; Applications of elastoplastic models; Special Topics: hypoelasticity plasticity, disturbed state concept
CE638	GEOTECHNICAL MEASUREMENTS AND EXPLORATIONS	2-0-3-0-9	Subsurface exploration planning; drilling and sampling techniques, field and laboratory tests, instrumentation and monitoring of field data, report preparation
CE639	ANALYTICAL AND NUMERICAL METHODS IN GEOMECHANICS	3-0-0-0-9	Finite difference, finite element and other analytical methods of solution to (i) Elasticity and stability problems in Geomechanics, (ii) Analysis of response of soil media to applied loads, (iii) Limiting equilibrium, Failure theories, Method of characteristics, (iv) Limit analysis, etc.
CE640	INFRASTRUCTURE ASSET MANAGEMENT	2-0-0-0-6	Basic discussion of concepts of infrastructure assets and their management, performance of infrastructure assets, stakeholders involved, along with factors affecting the demand and supply of public works services; relating infrastructure and economic development; Strategies for financing public works; performance indicators and measures; Framework for Infrastructure Management: Design for reliability, maintainability, supportability, and service life; Inventory and database management; Condition assessment; Performance modelling and failure analysis; Maintenance strategies, Life-cycle cost and benefits analysis; Introduction to the basic policies and initiatives of the Government in the area of infrastructure asset creation and management (JNNURM, Smart cities, etc.); Case studies including Bridge Management Systems, Pavement Management System, Pipeline management, Hydro-system Asset Management
CE641M	PROJECT MANAGEMENT	3-0-0-0-5	Fundamentals: Overview of project management, project, stakeholders, role of project manager, stages in planning a project, developing an objective or goal for the project, project risk plan, work breakdown or organizational structure, scheduling project work, workable schedule, project control and evaluation, managing the project team Project Management: Scope Management, Integration Management, Time Management, Cost Management, Quality Management, Human resource Management, Communication Management, Risk and safety Management, Procurement Management, Stakeholders Management
CE642	LABORATORY COURSE IN INFRASTRUCTURE ENGINEERING AND MANAGEMENT	3-0-0-0-9	Effect of chemical admixtures on properties of mortars, (i) Water reducers; (ii) Air-entraining agents, (iii) Accelerators or retarders; Properties of freshly mixed concrete, (i) Slump; (ii) Bleeding potential; (iii) Initial & final setting time; (iv) Air content; (v) Temperature and density; Properties of hardened concrete, (i)

			Compressive strength; (ii) Toughness; (iii) Rapid chloride ion permeability; Non-destructive testing, (i) Rebound hammer; (ii) Ultra-sonic pulse velocity; (iii) Ground penetrating radar; (iv) Electrical Resistivity; (v) Others; Bitumen characterization tests like softening point, flash point, float test, ductility and bituminous mix design; Calibration of profilograph and its use in the determination of roughness index of road Sub-grade improvement techniques for pavements; Control establishment and detailed mapping using Global Navigation Satellite System (GNSS) receivers and Total station (TS) [For the use of GNSS, TS and corresponding data processing SW for the preparation of digital maps]; Development of geospatial database in Geographic Information System (GIS) environment [For the use of GIS SW for creation and analysis of geospatial database]
CE645	BASIC QUALITY AND SAFETY MANAGEMENT IN CONSTRUCTION	1.5-0-0-0-5	Overview: Diverse nature of construction projects, definitions, stakeholders, specifications, compliance, acceptance, relating quality of materials, components and system, factors influencing quality and safety, contracts, inspection, cost of quality and safety, processes and products, archiving records; Concepts of quality control: Objectives, definitions, systems, ISO 9000 family of standards, third-party certification, QC in construction and large projects (aircraft, ship building); Basic construction safety: Hazards, human factors in construction safety, introduction to occupational health and safety, problem areas in construction safety, elements of an effective safety program, job-site safety assessment, safety planning, safety audit; Legal issues in quality and safety: Regulatory framework, labour laws, compensation; Safety engineering: Training, audit, management practices, safety planning, PPE, construction accidents: nature, causes, investigation and reporting accidents; Case studies and examples: Quality and safety issues in steel construction, concrete construction (including pre-cast, pre-stressed), tunnelling, bridges.
CE653M	ADVANCEMENTS OF CONCRETES	3-0-0-0-5	*Mineral Admixtures:* Mineral Admixtures (Fly ash, silica fume and slag) – Production – Physical and chemical properties, Classification, Lab tests, Specifications and Acceptance Criteria. *Additives*: Gypsum, Air-Entrainer, Lime and others. Performance and prescriptive specifications; Situations demanding special performance; Important features in the Development of Special Concretes. *Special Concretes*: Modified Portland and Blended Cement Concretes (Using natural, artificial and/or processed materials as pozzolans), High Strength, Self-Compacting, Fiber Reinforced Concretes, Mass and Roller Compacted Concrete, Ultra-High-Performance Concretes, Geo-Polymer Concretes, etc. Special Cements: Concrete containing special cements

			such as Calcium Aluminate Cements, Expansive Cements, Fast-Setting Cements, etc. *Special Concreting Methods*: Shotcreting, Underwater concreting, Preplaced Aggregate Concrete, Anti-Wash Out Concretes, Precast Concrete, others.
CE648	REPAIR AND REHABILITATION OF CONCRETE STRUCTURES	1.5-0-0-0-5	Deterioration in Concrete Structures: Causes of deterioration, construction defects (formwork-related, placement-related, consolidation-related, etc.); materials defects (improper mix design, poor materials, etc.); design defects; over-loading; foundation problems; loading-related failures; fire-damaged concrete; Types of cracks and properties, crack depth, crack width, crack diagnosis. Non-destructive testing (NDT): Load testing on structures, buildings, bridges, and towers, rebound hammer, acoustic emission, ultrasonic testing principles and application, holography, advanced NDT methods, ultrasonic pulse echo, impact echo, impulse radar techniques, GECOR, ground penetrating radar (GPR). Methods for Repair and Rehabilitation: General principles - design for rehabilitation, relieving loads, strengthening superstructures, plating, post-stressing, jacketing, bonded overlays, reinforcement addition, strengthening sub-structures, under-pinning, increasing the load capacity of footing, seismic retrofitting, strengthening of beams, columns, slab, masonry walls, protection methods of structures, mud-jacking and grouting for foundation, micro-piling, sub-grade water proofing, soil stabilization techniques, epoxy injection, repairing of concrete floors and pavements, case studies.
CE654M	CONCRETE SCIENCE AND ENGINEERING PROPERTIES	3-0-0-0-5	*Introduction to Concrete*: Historical background, Concrete – A Three-Phase System, Importance, Sustainability. *Aggregates*: Production, Physical and Chemical Properties, Classification, Lab Tests, Specifications and Acceptance Criteria. *Cement:* Production, Physical and Chemical properties, Classification, Lab Tastings and Specifications. *Cement Hydration*: Hydrated compounds – Importance and characteristic features, Growth and Models; Crystal pressures, Pores and voids – Importance, types and size ranges; Degree of hydration – Volume Relationships, Porosity and permeability – Relationship and Inter-relationship with strength, test methods for porosity. *Concrete Mix Design*: Mixture proportioning – IS & ACI method; Mix design strategies, Problems, Concrete Production Operations: Concrete production operations – Importance of Curing; Curing Methods. *Properties of Freshly Mixed Concrete*: Chemical Admixtures, Workability and Rheology, Setting Time, Air Content, Density, Temperature, etc., Test methods and factors affecting properties. *Properties of Hardened Concrete*: Compressive Strength, Modulus of Elasticity, Creep,

			Shrinkage (types) and Porosity and Permeability – Test methods and factors affecting properties. Case Studies.
CE656	ENVIRONMENTAL FLUID MECHANICS	3-0-0-0-9	Introduction: Continuity and momentum equations in cartesian and cylindrical coordinates, Rotating frame of reference, Coriolis effects, Basics of buoyancy driven flows, Mixing and transport processes in environmental fluid systems. Vertical flows: MTT model, turbulent plumes, filling box, double-diffusive convection. Horizontal flows: Shallow water approximation, single-layer hydraulics, gravity currents, particle-laden flows, flows on inclined plane, high viscous flow. Flow in porous media: Darcy's law, Dispersion, Thermal and Haline convections, Geothermal Plumes, Gravity currents, Capillary effects, Flow through cracks and faults Waves in fluids: Interfacial waves and internal gravity waves. Hydrodynamic instability: Kelvin-Helmholtz Instability. Rayleigh-Taylor instability, Saffman-Taylor instability. Geophysical flows: Stratification, The Richardson number, Advective and diffusive mixing, Coastal region intrusion, Rotation, Vorticity dynamics.
CE657	CONSTRUCTION ECONOMICS & INFRASTRUCTURE FINANCING	3-0-0-0-9	The 'construction economics' part of the course deals with practical applications, problems, and case studies pertaining to economic decision-making in Civil engineering. Specific topics include - Introduction to Engineering economics and its applications: Time value of money; interest and interest rates; cash flow diagrams, evaluation criteria for investment decisions; Break-even analysis, mutually exclusive, replacement and independent projects; practical issues in evaluation of projects; concept of depreciation and amortization; Taxation; evaluation of profits before and after Tax; Principles of accounting; Financial statements; Balance sheets; Working capital and accounting ratios. 'Infrastructure financing' component addresses the need for Infrastructure, Types of Infrastructure sectors and demand; role of government and private sectors; Investments in Infrastructure, Greenfield vs. Brownfield investments; sources of revenue and financing; Infrastructure charging, pricing principles and cost recovery; Competition and regulation; Assessment of infrastructure projects; Cost benefit analysis; decision making framework. Financing of capital projects: Sources of finance; financial securities; financial markets; equity and debt financing; Public private partnerships (PPP), PPP models and types of PPP; structure of agreements; Financial and economic implications of PPP models, risk profiles, allocation, and management.
CE663	HUMANS, ENVIRONMENT, AND SUSTAINABLE DEVELOPMENT	3-0-0-0-9	The course starts with introducing the history of human-environment relation over the past 500,000 years. Next the root causes of modern environmental degradation that need to be tackled, different economic sectors

			(agriculture, forestry, urban, rural, industrial, energy, transportation, manufacturing, service sector) and their impacts, and the major global and regional environmental problems of 21st century are taught. Further, the course explains the concept of sustainable development and what is being done in the fields of technology, policy making and human behaviour to achieve it at the international and national (India) level. Here the emerging topics such as Ecological economics, Payment for ecosystem services, Agricultural and dietary sustainability, Sustainable construction and smart cities, International policies and national missions on sustainable development goals (SDGs) will be taught. The students will also learn upcoming quantitative tools such as life cycle assessment (LCA) that can be used to calculate or compare the impact of different product, process and activities on different domains of the environment such as air, water, land, resources, climate, biodiversity etc. Overall, the course will explore how daily human activities impact the environment and how environmental degradation affects human health, society and economic growth in return.
CE664	PHYSICO-CHEMICAL PRINCIPLES AND PROCESS	3-0-0-0-9	Structure and basic properties of water; their significance in environmental engineering; sources of water impurities; Aquatic chemistry; chemical equilibrium and chemical thermodynamics; acid-base equilibria; complexation; solubility equilibria; oxidation-reduction equilibria; reaction kinetics, reaction rates and catalysis; surface and colloidal chemistry; Solid-liquid-gas interactions; mass transfer in solid-liquid and liquid-gas systems; transport mechanisms of impurities in water and air; advection, diffusion, dispersion; Principles of physicochemical processes; Settling of particles in water; coagulation and flocculation; filtration; ion exchange and adsorption; membrane processes;
CE665	ECOLOGICAL AND BIOLOGICAL PRINCIPLES AND PROCESS	3-0-0-0-9	Ecosystems; biotic and abiotic components; production and consumption; trophic levels; productivity and energy flow; food webs; cycling of elements; Ecology of population; ecological niche; mortality and survivorship; community interactions; Changes in ecosystems; succession; long range changes, long range stability; The organization and dynamics of ecological communities. Description and study of typical natural and artificial ecosystems; Biochemistry; photosynthesis and respiration, important biological compounds, enzymes; Microbiological concepts; cells, classification and characteristics of living organisms, characterization techniques, reproduction, metabolism, microbial growth kinetics; Applications to environmental engineering; assimilation of wastes, engineered systems, concepts and principles of carbon oxidation, nitrification, denitrification, methanogenesis, etc.
CE666	AIR POLLUTION AND ITS CONTROL	3-0-0-0-9	Air pollutants, their sources and harmful effects and on the environment; Meteorology as applied to air pollution

			and dispersion of air pollutants; Air quality and emission standards; Air pollution legislation; Methods for monitoring and control; Selection of control equipments; Engineering control concepts; process change, fuel change; pollutant removal and disposal of pollutants; Control devices and systems, removal of dry particulate matter, liquid droplets and mist removal, gaseous pollutants and odor removal; Control of stationary and mobile sources; Economics and trends in air pollution control.
CE667	PRINCIPLES OF ENVIROMENTAL MANAGEMENT	3-0-0-0-9	Concept of Sustainable Development and Clean Development Mechanisms (CDMs); Overview of Environmental Laws and International Treaties; Environmental Impact Assessment (EIA) and Environmental Management Plan (EMP) for Industries and other Developmental Projects; Life Cycle Assessment of Products, Processes and Services; Concepts of Environmental Justice and Environmental Ethics; Environmental Movements; Environmental Activism;
CE668	ENVIRONMENTAL QUALITY & POLLUTION MONITORING TECHNIQUES	2-0-4-0-10	General principles of sample collection and data analysis; Gravimetric methods for solids analysis in water and wastewater; Determination of color, odor, taste; turbidity by nephelometric methods; Titrimetric methods for determination of environmental parameters; acid-base titrations, precipitation titrations, complexometric titrations, oxidation-reduction titrations. Spectrophotometric methods for determination of environmental parameters; Atomic Absorption spectroscopy for determination of metals; Determination of nitrogen, phosphorus and chemical oxygen demand (COD) in sewage; Biochemical oxygen demand (BOD) in sewage; MPN test for microbial pollution; plate counts; confirmatory tests; Sampling techniques for air pollution measurements; analysis of particulates and common chemical air pollutants like oxides of nitrogen, oxides of sulphur, carbon monoxide, hydrocarbon; Introduction to advanced instruments for environmental analysis
CE669	ATMOSPHERIC PHYSICS AND CHEMISTRY	3-0-0-0-9	Atmosphere as a Physical system, Introduction to Atmospheric Models: Simple Radiative model, Greenhouse Effect, Global Warming; Atmospheric Observations: The mean Temperature and Wind Fields, Gravity Waves, Rossby Waves, Ozone. Potential Temperature, Parcel Concepts, The Available Potential Energy, Moisture in the Atmosphere, The Saturated Adiabatic Lapse Rate, The Tephigram; Cloud Formation; Thermodynamics of Chemical Reactions, Chemical Kinetics, Bimolecular Reactions Photo-dissociation, Stratospheric Ozone, Chapman Chemistry, Catalytic Cycles, Transport of Chemicals; the Antarctic Ozone Hole; Aerosol Dynamics: Discrete and continuous aerosol size distributions; Thermodynamics of atmospheric aerosols; Homogeneous and heterogeneous nucleation; Coagulation and coagulation

			kernels; Condensation/evaporation, saturation vapor pressure corrections; Fluxes to a particle population; Sedimentation and dry deposition; Chemical equilibria; Heterogeneous reactions in aerosol aqueous phase; Aerosol-cloud interactions; Aerosol and Global Climate: Trends in anthropogenic emissions and troposphere composition Solar and terrestrial radiation; Effect of pollutants on Earth's radiation budget; Radiation scattering by aerosols and clouds; Models for global warming and cooling.
CE670	ENVIRONMENTAL GEODESY	3-0-2-0-11	The Earth system: Systems approach to studying Earth, Climate and weather systems, Mass distribution, transport and exchange in the Earth system, Impact of physical processes on the geometry and gravity of the Earth, Loading theory and the sea level equation. Observation techniques in Geodesy: Geometric techniques – Total stations, Strain meters, Tide gauges, Global Navigation Satellite Systems, Satellite Laser Ranging, Very Long Baseline Interferometry, Satellite altimetry (radar and laser), Interferometric SAR; Gravimetric techniques – Absolute gravimetry, relative gravimetry, satellite gravimetry. Tides: Gravitational interaction of the Sun, Moon and the Earth, Ocean tides Atmospheric tides, Solid earth tides, Doodson numbers. Hydrological Observables: Water storage change, Soil moisture, River runoff and lake levels, Groundwater variability. Oceanographic observables: Sea surface topography and the mean sea level, Ocean currents, Ocean mass redistribution, Ocean bathymetry. Cryosphere observables: Sea ice thickness observations, Ice mass balance, Glacier thickness and drift. Atmospheric observables: Total precipitable water, Ionospheric total electron content, Atmospheric circulation and mass redistribution. Solid earth observables: Elastic, viscoelastic and episodic deformation and gravity responses to geodynamic processes like plate tectonics, earthquakes and volcanic activity.
CE671	INTRODUCTION TO REMOTE SENSING	3-0-2-0-11	Introduction to remote sensing, remote sensing system and components; Physics of remote sensing including wave equation and EMR propagation through medium, EMR source characteristics, Role of atmosphere, Physics of EMR interaction with objects, BRDF, EMR (optical and microwave) interaction with soil, vegetation, water, rocks etc. Concept of digital image and CCD; Sensor characteristics: various resolutions, FOV, IFOV, point spread function, push broom, whisk broom, side looking sensors, PAN, MS, SLAR; image recording formats; Various operational satellites and their data products. Image processing; interpretation elements, manual versus digital interpretation, image histogram and histogram manipulation, image convolution, high and low pass filters, directional and non-directional image derivatives; Image classification, unsupervised and

			supervised-various methods, training data selection, classification accuracy measures-error matrix, khat index. Geometric distortion in remotely sensed data, parametric and non-parametric methods of distortion removal, Geo-referencing and GCPs, accuracy indices, resampling methods; Atmospheric errors in data, models for removal of atmospheric errors. Satellite orbits; terminology, characteristics of ideal and actual orbit, equations governing satellite orbits, geostationary orbit, sun-synchronous orbit, exactly repeating orbits, orbital sub-cycles, examples of operational satellite orbits. Application of optical and microwave remote sensing techniques in problem solving: Civil Engineering related examples/projects.
CE672	MACHINE PROCESSING OF REMOTELY SENSED DATA	3-0-0-0-9	DIP system: components and functions, basic imaging process, multi-concept in RS data analysis, Elements of human and computer assisted interpretation. Formats of digital imagery, colour look up tables and transformations. Geometric and radiometric distortions and their corrections. Image histogram, point operations and look-up tables, contrast enhancements, Spatial and frequency filtering, Edge detection and enhancement, filters for radar images. Image transformations. Image Fusion. Pattern recognition: feature selection and extraction, unsupervised and supervised classifications, accuracy estimation, Fuzzy classification. Spatial classification: Texture, Contextual. Object-based classification, Other classifiers: ANN, SVM classification, Binary and hybrid classification, Hyperspectral classification.
CE673	INSTRUMENTATION, LABORATORY AND FIELD PRACTICES IN GEOINFORMATICS	0-0-0-9-9	Use of automatic and digital levels, electronic theodolites, total stations; Control surveys using GPS, Total Station (adjustment and computations of coordinates); topographic mapping and report writing.
CE674M	GLOBAL NAVIGATION SATELLITE SYSTEMS (GNSS)	3-0-2-0-6	Background / Revision to Satellite Geodesy, Keplerian Laws, Inertial Coordinate Systems etc. Overview of GNSS and Introduction to GPS, GLONASS, GALILEO, BIDOU, IRNSS Satellite Systems etc. GPS: basic concepts, signal structure and code modulation, Pseudo range measurements and navigation solution. Accuracy of navigation position: UERE and DOP. Intentional degradation of GPS signals: Selective availability (SA) and Anti-spoofing (AS), Differential GPS: Space based augmentation systems (e.g., GAGAN, WAAS, EGNOS) and Ground based augmentation systems. GPS Carrier Phase measurements: Single Differencing, Double Differencing and Triple Differencing in GPS measurements. Ambiguity resolution, multi path and other observational errors, Doppler effect on GPS signals, Cycle slip detection and repair. GNSS observation, Data downloading, Processing and Discussion of processed Data.
CE675M	GLOBAL NAVIGATION	3-0-2-0-6	GNSS Basic Observables: Pseudo Ranges and Carrier

	SATELLITE SYSTEMS (GNSS) FOR SURVEYING AND MAPPING		Phase Measurements. GNSS Surveying Techniques: Point positioning and Differential Positioning, DGPS and SBAS. Relative positioning: Static – Rapid Static and Pseudo Kinematic; Kinematic positioning – Pure Kinematic, Semi Kinematic and Real Time Kinematic (RTK) methods of observations. Real Time Network (VRS) services. Planning and field observations, Networking, Data Post processing: with Vendor Software and Scientific software. CORS, Setting up of Regional Geodetic Networks and Development of Regional Geoid Models. GNSS applications to Global, Regional and Local issues. IUGG, IAG, IGS and IERS services.
CE676	LASER SCANNING AND PHOTOGRAMMETRY	2-0-3-0-9	Introduction to Photogrammetry; Photogrammetric terms; applications; advantages; limitations and a brief history; Types of cameras: metric vs. non-metric; types of photogrammetry. Aerial Photogrammetry; Geometry of vertical/near-vertical aerial photographs: Orthographic vs. perspective projection, Map vs. Photograph, Scale of photograph, estimate the scale, Relief displacement and its determination, Parallax in photographs and measurement; stereoscopy. Transformation between image and object space, collinearity equations; Interior & exterior orientation; Space resection; Space forward intersection and limitations; Aerial triangulation and bundle block adjustment. Ortho-photo and DTM generation; Terrestrial photogrammetry; computer vision approach; DLT; Epipolar geometry; Image matching methods: SURF, RANSAC etc; Structure from Motion (SfM) (Introduction and brief). LiDAR: Introduction, Laser characteristics, laser interaction with objects; Types of LiDAR systems: Terrestrial, airborne, static and dynamic; Altimetric LiDAR: topographic and bathymetric, single and multiple return, full waveform digitization. Components of a LiDAR system, INS/GNSS/LiDAR integration, system calibration, Kalman filter (brief); LiDAR geo-location; accuracy of LiDAR components; error propagation and error analysis; Airborne LiDAR surveys: Flight Planning, survey execution; Examples and applications of integrated LiDAR systems: MMS, Airborne LiDAR systems, UAVs. Integration of LiDAR with spectral data (camera); LiDAR data classification techniques, raw data to bald earth DEM processing, applications of return intensity and full waveform in information extraction; LiDAR applications: building, tree, powerline extraction. Integrated systems (UAV, Car, Aircraft etc).: Applications and some case studies: Mining, Exploration, SLAM.
CE677M	INTRODUCTION TO INERTIAL AND MULTI-SENSOR NAVIGATION	3-0-2-0-6	Introduction to Inertial Sensors: Operating principle of inertial sensors, Observations and types. Brief introduction of coordinate frames used by inertial sensors. Allan variance and performance quantification of inertial sensors. State space model, Measurement model, Smoothing, Filtering, Estimation theory: Least squares, Sequential Least Squares, Kalman filter,

			Extended Kalman Filter, Unscented Kalman Filter. Introduction to Inertial Navigation, Kinematic Navigation Equations, IMU/AHRS/INS, INS errors and propagation. INS/GNSS Integration approaches: Loosely coupled, Tightly coupled, Ultra-Tightly coupled Overview of other sensors and integration approaches for navigation in indoor/outdoor environments: Ultra-Wide-Band, Wi-Fi, LiDAR. Brief overview of Centralized Cooperative Localization.
CE678	PHYSICAL GEODESY	3-0-2-0-11	Introduction: Need to study gravity, Historical review, Research areas, Applications, Open questions. Potential theory: Some vector calculus, Attraction and potential, Potential of a solid body, Laplace equation – exterior potential field, Poisson Equation – Interior potential field, Spherical harmonics, Boundary-value problems. Gravity field of the Earth: Gravitation, Gravity, Attraction of a point mass, Attraction of a rigid body, Gravity and shape of the earth, Level surfaces and plumb lines, Natural coordinates. Normal gravity: Superposition principle, Ellipsoid as an approximation of the Earth, The level ellipsoid, Series expansion of the normal gravity field. Gravimetry: Functionals of the gravity field, Terrestrial gravimetry – absolute and relative, Airborne gravimetry, Spaceborne gravimetry, Gradiometry, Torsion balance, Gravity networks. Gravity field modelling: Linear model of physical geodesy, Disturbing potential and gravity, Anomalous potential and gravity, Gravity reductions. Geoid modelling: The Stokes integral, Koch's formula, Vening-Meinesz formula, Molodensky's approach, Practical aspects. Statistics of the gravity field: The power spectrum, Kaula's rule of thumb, Covariance functions. Height systems: Height measurements, Physical and geometric heights and their relationship, Height systems around the world, Geoid as a vertical reference frame. Temporal variations of the gravity field: Geophysical effects on gravity, Loading theory, Tides, Hydrological loading, Atmospheric loading, Ocean loading, Ice-mass loading, Glacial Isostatic Adjustment.
CE679	SIGNAL PROCESSING ON THE SPHERE	3-0-2-0-11	Harmonic analysis on the line: Fourier series and transforms (discrete and continuous), orthogonality (discrete and continuous), sampling theorem (uniform sampling), aliasing, convolution, window functions, autocovariance/autocorrelation functions, power spectral densities, computational aspects, periodogram estimation, FFT, Least Squares Spectral Analysis. Global harmonic analysis on the sphere: Orthogonal base functions on the sphere, Associated Legendre functions, Spherical harmonics, convolution, sampling theorems (uniform), aliasing, filtering, autocovariance/autocorrelation functions, power spectral density, computational aspects. Localized analysis on the sphere: Space localizing basis functions (Radial basis functions, spherical splines, Band-limited spline functions), computational aspects. Slepian functions:

			Uncertainty principle of signal processing, uncertainty principle on the sphere, Slepian functions, Shannon number, periodogram estimation, computational aspects. Empirical Orthogonal Functions: Spatio-temporal datasets, eigenvalue decomposition, significance testing of modes, signal reconstruction, data compression, computational aspects.
CE683	TRAFFIC ENGINEERING	3-0-0-0-9	Microscopic and macroscopic traffic parameters; Traffic flow models (for both uninterrupted and interrupted flow; includes macroscopic and microscopic models; gap acceptance analysis, queue and delay analysis, etc.) Capacity and level of service analysis; Design of traffic facilities like un-signalized and signalized intersections, interchanges, expressways, traffic signs, parking areas etc.; Simulation of traffic streams.
CE685M	URBAN TRANSPORTATION	3-0-0-0-5	Urban form, urban transportation and their evolution; Urban travel characteristics; Demand analysis (trip generation, distribution, mode and route choice, etc.); Supply analysis (road network: overview of the pre-requisite courses); Supply analysis (public transportation: route and schedule; development, fleet size determinations, etc.); Congestion mitigation (demand modification, private and public transportation solutions).
CE687	STATISTICAL AND ECONOMETRIC METHODS FOR TRANSPORTATION DATA	3-0-2-0-11	Statistical inference; linear regression and its extensions; panel data analysis, ordinal probit, multinomial logit and its extensions, count data modeling (poisson, negative binomial regression), applications in road safety, infrastructure management, travel demand, etc.
CE697	M TECH SEMINAR I	0-0-0-0-0	Each M.Tech student registered for CE697 will give a 30-40 minute seminar based on his/her research work. In addition, they will be expected to attend all CE697A seminars in their specialization scheduled that semester. In addition to registered M. Tech students, other researchers from within and outside the Institute may be invited to give seminars as a part of CE697. Grading for CE697A shall be in the S/X mode and based on the quality of the seminar presented by the student and his/her attendance in other CE697 seminars. CE DPGC Convener will be the nominal instructor for the course. However, grades will be given in consultation with thesis supervisor(s) of the concerned student.
CE698	M.TECH SEMINAR II	0-0-0-0-0	Each M. Tech. student registered for CE698 will give a 45-60 minute seminar based on his/her research work. In addition, they will be expected to attend all CE698 seminars scheduled that semester. In addition to registered M. Tech students, other researchers from within and outside the Institute may be invited to give seminars as a part of CE698. Grading for CE698 shall be in the S/X mode and based on the quality of the seminar presented by the student and his/her attendance in other CE698 seminars. CE DPGC Convener will be the nominal instructor for the course. However, grades will be given in consultation with thesis supervisor(s) of the

			concerned student.
CE699	M. TECH THESIS	0-0-0-9-9	M. Tech. Thesis
CE711M	CONSTRUCTION EQUIPMENT AND METHODS I	3-0-0-0-5	The emphasis of the course is on construction equipment and the construction methods relevant for infrastructure creation. Initially, the course introduces different types of infrastructure viz, transportation, irrigation and water supply, power and buildings. Subsequently the course delves into various components of infrastructure along with their specific requirements will be explained. Common elements across the infrastructure types will be introduced. Building on the knowledge from the general civil engineering courses, the course focuses on recent developments, equipment, practices and issues in Surveying, Earthwork in Excavation, Slope Stabilization, Ground Improvement, Earthwork in Embankment, Concrete – Production, Transportation and Placement, and formwork design. Besides the broad principles involved, specifications and quality requirements, and productivity and cost issues will also be addressed.
CE712M	CONSTRUCTION EQUIPMENT AND METHODS II	3-0-0-0-5	The emphasis of the course is on construction equipment and the construction methods relevant for infrastructure creation. Initially, the course introduces different types of infrastructure viz, transportation, irrigation and water supply, power, and buildings. Subsequently the course delves into various components of infrastructure along with their specific requirements will be explained. Common elements across the infrastructure types will be introduced. Building on the knowledge from the general civil engineering courses, the course focuses on recent developments, equipment, practices, and issues in Tunnelling and Underground Construction, Foundations, Highways, Railways, Irrigation structures like dams and canals, Pipelines, Airports, Harbours, and Ports. Besides the broad principles involved, specifications and quality requirements, and productivity and cost issues will also be addressed.
CE713M	CONSTRUCTION EQUIPMENT AND METHODS FOR BRIDGES	3-0-0-0-5	The emphasis of the course is on the construction equipment and the construction methods relevant for the construction of bridges. Initially, the course introduces different types of infrastructure viz, transportation, irrigation and water supply, power, and buildings. Subsequently the course delves into various components of infrastructure along with their specific requirements will be explained. The course introduces the basics of bridges in terms of types and special design and construction requirements. The course touches upon the specialized equipment and enabling / temporary works that are used in bridge construction. Subsequently the course delves into the construction of foundations, substructure viz., abutments and piers and superstructure. Different methods of superstructure viz., girder launching, cantilever construction, incremental launching and precast concrete segmental construction

			will be dealt with in detail. Besides the broad principles involved, specifications and quality requirements, and productivity and cost issues will also be addressed.
CE721	RANDOM VIBRATIONS	3-0-0-0-9	Random processes; Stochastic response of linear structural systems: normal mode approach; Level crossing; Peak and envelop statistics; Application to wind and earthquake engineering; Non-stationary processes; Non-linear random vibrations.
CE722	GEOTECHNICS OF TAILINGS AND TAILINGS STORAGE FACILITIES	3-0-0-0-9	Introduction: Course overview; Generation and disposal strategies of mine tailings; Challenges in management of mine tailings; Possible reusability of mine tailings; Role of geotechnical engineering in sustainable management of mine tailings; Geotechnical characterisation of tailings: Gradational properties, specific gravity; Plasticity properties and mineralogy; Densification - settlement, consolidation, evaporation, dewatering; Drained and undrained strengths; Triaxial testing and analysis; Simple shear testing and analysis; Cone penetration testing; Introduction to “state parameter”; Application of critical state soil mechanics to interpret test results; Hydraulic conductivity; Water retention and volume change behaviour; Testing methods for understanding unsaturated response of the material; Disposal of tailings in TSFs: Types of components of TSFs; Physical processes involved in a typical; TSF; Failure mechanism of TSFs; Health monitoring of TSFs; Operator manual,Trigger ActionResponse Plans (TARPs) ; Global Industry Standard on Tailings Management (GISTM); Governance structure for management of TSFs, stakeholder engagement; Case studies and interaction with industry professionals Forensics of failure: Merriespruit, South Africa, 1994; Mount Polley, Canda, 2014; Cadia, Australia, 2018; Brumadinho, Brazil, 2019; Few case studies from India; Invited guest lectures by industry professionals and academic colleagues on current practice of tailings management; Possible visit to a TSF site
CE723	FINITE ELEMENT METHODS FOR CIVIL ENGINEERING APPLICATIONS	3-0-0-0-9	Problem formulation, numerical and closed form solutions, weak form, collocation, least square, Galerkin technique, derivation of finite element equations, stiffness matrices, global assembly, coordinate transformation, enforcing boundary conditions, solution of the systems of equations. Convergence, Stability and possible sources of errors; Formulation of one-dimensional truss and beam elements. Application to 2D trusses and frames; Formulation of 2D problems involving plane stress, plane strain, and axis symmetry. Applications to pressure vessels, chimneys, dams, embankments, and pavements; Formulation of plate bending elements. Bending of plate, Von Karman nonlinear plate theory and formulation; Formulation of thin shell elements. Applications to dome, water tank etc; 6. Formulation of three dimensional brick elements. Applications to stress analysis in dam, earthen

			embankments, tunnel, etc; Nonlinear static and dynamic problems; geometric and material nonlinearity, Pdelta effects in tall buildings, elastoplastic analysis as encountered in structures and geotechnical mechanics, seismic soil foundation structure interaction problems;. Formulation for contact elements, infinite elements and crack tip elements; CE applications such as 3D elastic problems, consolidation, seepage, transpott and propagation through heterogeneous media; Finite element formulation of fluid flow and transport problems. Applications to pipe, open channel flow, contaminant and species transport with emphasis to hydraulics and environmental flow modeling.
CE724	RELIABILITY ANALYSIS & RELIABILITY BASED DESIGN OF STRUCTURE	3-0-0-0-9	Random processes; Stochastic response of linear structural systems: normal mode approach; Level crossing; Peak and envelop statistics; Application to wind and earthquake engineering; Non-stationary processes; Non-linear random vibrations.
CE725	VIBRATION BASED STRUCTURAL HEALTH MONITORING FOR CE APPLICATIONS	1.5-0-0-0-5	Introduction to Structural Health Monitoring (SHM): NDE and SHM; Structural health management; Vibration-based techniques for SHM: Basic concepts; Diagnosis Levels; Local and global methods; Damage diagnosis as an inverse problem; Model-based damage assessment; Data-based damage assessment; Experimental and analytical examples; Damage detection using modal parameters: Formulation; Fundamental and higher mode shapes and their derivatives; Numerical illustrations; Damages at multiple locations; Damage characterization; Output-only algorithms for modal parameter extraction: Frequency domain decomposition (FDD); Natural excitation technique (NExT); Eigensystem realization algorithm; Random decrement technique (RDT); Stochastic subspace identification technique (SSID); Performance under varied signal-tonoise ratio (SNR); Time-domain damage detection methods: Kalman filters; Autoregressive model (AR) and AR with exogenous input (ARX); Damage sensitive features (DSFs); Feature selection criteria - Feature versus metric; Damage identification in non-linear systems; Extended Kalman filter; Introduction to Bayesian Model updating: Updating of the initial model, Damage localization and quantification; SHM System Design: Data Handling: Data acquisition and transmission; Processing of recorded data; Evaluate sources of variability; Modeling of environmental conditions; Consideration of soil-structure interaction; Sensor optimization; Sensitivity analysis.
CE730	SOIL-STRUCTURE INTERACTION	3-0-0-0-9	Contact pressure distribution, Foundation models, Limit analysis of rafts and foundation; soil structure interaction studies pertaining to buried structures; Analysis and design of deep foundation; Modern trends in the design of earth retaining structures.
CE731	RISK & RELIABILITY IN GEOTECHNICAL	3-0-0-0-9	Sources and types of uncertainties associated with geotechnical analysis, importance of probabilistic

	ENGINEERING		methods and reliability based analysis in geotechnical engineering Review of probability and statistics: Discrete and continuous random variables, parameter estimation, testing of hypothesis, regression analysis Fundamentals of reliability analysis: First Order Second Moment (FOSM) method, First Order Reliability Method (FORM), Second Order Reliability Method (SORM), Monte Carlo simulation Application towards geotechnical problems: Characterization of uncertainty in field measured and laboratory measured soil properties, uncertainty in interpretation techniques Spatial variability of soil properties, scale of fluctuations, estimation of autocorrelation and autocovariance Probabilistic groundwater modeling, flow through earth dams Probabilistic slope stability analysis Fundamentals of LRFD design methodology, reliability based design of shallow and deep foundations, settlement analysis Reliability based liquefaction analysis, lateral spreading Development of fragility curves for geotechnical problems.
CE732	UNSATURATED SOIL MECHANICS	3-0-0-0-9	Nature and genesis of unsaturated soils: Introduction to phase properties and relations, air-water-solid interface, in-situ stress state component profiles, suction and potential of soil-water system, transient suction and moisture profiles, compaction; Soil suction: Suction component, principle and measurement of total suction, matric suction, osmotic suction, capillarity; State of stress and shear strength: Stress state variables, material variables, effective stress concepts for unsaturated soils, representation of net normal stress, matric suction and suction stress tensor, stress control by axis translation. Shear strength of unsaturated soil, extended Mohr-Coulomb criterion, shear strength and pore pressure parameters, measurements of shear strength parameters; Flow of water in unsaturated soils: Soil-water characteristic curve (SWCC), hysteresis in SWCC, permeability and hydraulic conductivity function, direct and indirect measurements of SWCC and hydraulic conductivity function. One-dimensional consolidation and swelling for unsaturated soils; Applications: Applications of unsaturated material properties in geotechnical and geo-environmental structures.
CE733	GEOTECHNICAL DESIGN ASPECTS OF SOLID WASTE MANAGEMENT	3-0-0-0-9	Identification, characterization and regulatory requirements for disposal of hazardous, non-hazardous and domestic wastes. Waste Management Recycling, composting, incineration and various disposal methods. Site selection and Geoenvironmental investigations. Natural attenuation process and mechanism of attenuation. Design practices of solid wastes. Tailing dams for disposal of flyash, coal, copper, iron and other metal wastes. Single and double lined landfill design, linear material clay, geosynthetics amended soils and other admixtures. Leachate collection and detection system. Landfill construction. Construction quality control

			and performance monitoring. Application of geosynthetics in waste disposal design.
CE734	PLASTIC EQUILIBRIUM IN SOILS	3-0-0-0-9	Review of basic concepts of continuum mechanics: stresses, strains, compatibility conditions, transformation of stresses and strains in rotated co-ordinate system, constitutive relations, stress functions, stress and displacement formulations, plane stress and plane strain problems; Theory of plasticity: yield criterion, plastic potential and plastic flow rule, principle of maximum plastic work, strain hardening and perfect plasticity, isotropic and kinematic hardening, general stressstrain relations; Perfect plasticity constitutive relations: elastic models, plasticity models for cohesive and frictional soils. Method of stress characteristics or slip line method: theorem, formulation for stress characteristics, application to different geotechnical structures such as foundation problem, retaining wall problem, slope stability etc.; Limit analysis: lower and upper bound theorem of plastic collapse, lower and upper bound limit analysis, lower and upper bound analysis using linear programming, application to different geotechnical structures such as foundation problem, retaining wall problem, slope stability etc.; Shakedown analysis: concept and theorems, rolling and sliding line contacts, rolling and sliding point contacts, shakedown analysis using linear programming etc.
CE760M	SURFACE WATER QUALITY MODELING	3-0-0-0-5	Introduction: concepts of scale in natural systems, brief review of the fate processes in the environment, examples of natural systems, principles of model formulation, calibration, validation, error estimation and sensitivity analysis; Derivation of generalized mass balance equation for contaminants in incompressible fluid (water) in the non-inertial frame of reference; River Modeling: one dimensional advection-dispersion-reaction model, river properties and estimation of parameters, different forcing situations (point, non-point, aerial sources and sinks), sediment water interaction; Estuary Modeling: types and properties, flow characterization, advection-dispersion models, salt gradient box models; Lake Modeling: box models, generalized models, special considerations for large lakes, sediment mixing and interaction with water column; Wetlands: box models for flow, equilibrium and kinetic geochemical models for red-ox reactions, transport of heavy metals.
CE761M	SUBSURFACE POLLUTANT FATE AND TRANSPORT	3-0-0-0-5	Groundwater as a resource; general problems of chemical contamination in groundwater; Organic and inorganic contaminants; mass balance and concept of control volume; physical transport of chemicals- the advective-dispersive-reaction equation; Nature of subsurface environment; saturated and unsaturated zones; physics of groundwater movement through these zones; modeling flow through a packed soil column; flow in the unsaturated zone; Understanding fate of contaminants; review of basic environmental chemistry;

			retardation; redox processes in the subsurface; Groundwater flow and quality modeling
CE762M	ATMOSPHERIC MODELING	3-0-0-0-5	Introduction: weather, climate and air pollution, atmospheric processes, scales of motion, differences between weather prediction models and climate models; Atmosphere: pressure, density and composition, equations of state, changes pressure and temperature with altitude, water in atmosphere, first law of thermodynamics ; Continuity and Energy Equation: Derivation of generalized continuity equation for compressible fluid (air) and constituents (gas, particle) suspended in a compressible fluid, examples of wind driven circulation, thermodynamic energy equation; Momentum equation: Coordinate systems and grids: brief descriptions of Cartesian, spherical, UTM, Mercator projection, sterographic projection, Lambert Conformal projection; brief review of Cartesian to spherical Co-ordinate transformation; Generalized derivation of the momentum equation in an inertial frame of reference: local acceleration, coriolis force, gravitational force, pressure gradient force, viscous force, turbulent-flux divergence, Ekman number, Rossby number and Froude number; Applications: Geostrophic wind, Surface-layer winds, Gradient winds and atmospheric waves; Vertical coordinate conversions, introduction to numerical solution of the equations, brief introduction to parameterization of the atmospheric processes.
CE763M	SOLID AND HAZARDOUS WASTE MANAGEMENT	3-0-0-0-5	Municipal Solid Waste (MSW) and Hazardous Wastes (HW) –Introduction and Definitions; Impacts of Unscientific Disposal of MSW and HW; Municipal Solid Wastes (MSW)–Estimation of Quantity and Characteristics; Reduction of Generation at Source, Source Segregation, Collection, Transfer and Transport; MSW Processing – Segregation during Processing, Reduction and Conversion for Reuse/Recycle using Physical, Chemical and Biological methods; Current Status of MSW Management in India; MSW Management Rules; Private Participation in MSW Management; Hazardous Waste (HW) – Characterization of HW; Generation; Handling of Hazardous Wastes - the “Cradle to Grave” Concept; Transport of Hazardous Waste; Incineration for Ultimate Disposal of MSW and HW – Incineration; Fundamentals; Types of Incinerators; Environmental Concerns; MSW Landfills and HW Landfills – Planning, siting and permits; Landfill processes, design, operation, post-closure care and use, and mining; Financing and Contracting of MSW and HW Processing Facilities, Public or Private Ownership and Operation, Public-Private Partnership
CE764M	ENVIRONMENTAL TOXICOLOGY AND RISK ASSESSMENT	3-0-0-0-5	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 Pharmokinetic (PBPK) Models EU; Application of statistical and Monte Carlo simulations and other techniques for probabilistic exposure assessment; Risk Characterization, communication and decision making
CE765M	INDUSTRIAL WASTE MANAGEMENT	3-0-0-0-5	Sources and types of wastes: solid, liquid, and gaseous wastes; General Principles of control and removal of specific pollutants and management; Solid and Hazardous waste: definitions, concepts and management aspects; Combustion processes; Point and fugitive sources, their quantification, fuel quality; Life Cycle Analysis with example; Case studies/process and pollution generation from Dairy, Pulp and paper, Iron and Steel, Metal plating, Thermal power plants, Chlor-Alkali, Aluminum industry etc.; Environmental audit: Definitions and concepts, examples; Environmental regulations; Introduction to ISO and ISO 14000; Preparation and implementation of environmental management plans.
CE766	AGRICULTURAL SUSTAINABILITY AND CLIMATE CHANGE	3-0-0-0-9	Introduction; Concept of Agricultural cycle, Agricultural Productivity, and Food Security; Agricultural activity impact on environment; Introduction to concept of agriculture as a contributor to global warming; Agricultural Productivity, and Food Security; Factors impacting agricultural Growth, Yield. Discussion of main issues affecting food security; mainly global warming, or climate change, and anthropogenic activities; Agriculture and Climate Change; Influence of temperature and carbon dioxide on agricultural productivity. Concept of carbon fertilization; Examination of the relationship between climate change and agriculture under two headings; A. Contribution of agricultural practices to climate change; B. Impact of Climate change on agricultural productivity; Status of Food Security and Need for Sustainable Agriculture; Current agricultural production worldwide; Variation in availability of resources over time and resulting food scarcity; Overview of reports on food security and future predictions by International agencies; Concept of IPM (Integrated Pest Management) & the sustainable intensification of agriculture; Adapting Agriculture to Climate Change; Challenges ahead and mitigation strategies being adopted to ensure food security. Discussion of adaptation options, with detailed discussion of Low-Emissions Climate-Smart Agriculture; Impact of Climate Change on Indian Agriculture: Economic perspective; Case study: India and USA; Govt. Initiatives to ensure food security and enhance food production; Government policies and initiatives, trends

			over time, current focus, future predictions; International treaties and Initiatives worldwide; Modeling Environmental fate and transport of agrochemicals. This will involve examination of the Post application behavior of agrochemicals; Concept of Point and Nonpoint-source pollution (NPSP), Short and Long Range Transport (LRT) to non target destinations, impacts of changes in temperature and carbon dioxide on crops will be investigated
CE767M	SOLID-WATER INTERFACIAL PROCESSES	3-0-0-0-5	Review of basic aquatic chemistry; Review of thermodynamics and equilibrium of acid-base reactions, concept of free energy, ideal and non-ideal systems, ionic strength and activity, equilibrium speciation, complexation reactions, oxidation states, redox chemistry and redox scales, chemical kinetics-first order, second order, pseudo-first order; Introduction to Equilibrium Modeling Software: Visual MINTEQ; Dissolution-precipitation; Oxides and hydroxides, Other solids, Competition between solids, Coexistence of solids and phase rule; Modeling kinetics of nucleation-precipitation; Sorption-Desorption; Introduction to adsorption on mineral surfaces and isotherms, Sorption on organic matrices; chemical partitioning to solids distribution coefficient; sorption in natural and engineered systems, Surface complexation: surfaces and reactions; Surface complexation modeling: double-layer, constant capacitance, and triple-layer models. Experimental techniques for solid-phase investigations; Diffraction: Principle of XRD, Bragg's law, Fundamentals of crystal structures- unit cells, lattice planes and Miller indices, important structure types, phase identification, Scherer equation. Microscopy: Principles and applications of SEM, TEM and associated energy dispersive X-ray spectroscopy (EDXS), Spectroscopy: Principles and applications of X-ray Fluorescence (XRF), Vibrational (IR and Raman), Absorption (XANES, EXAFS).
CE768M	PLASTIC WASTE MANAGEMENT	3-0-0-0-5	This course will introduce students to the fundamental concepts of plastic waste management and the approaches required to create sustainable solutions for communities. The students will be able to 1. understand the Magnitude of the problem on a global scale and in the Indian setting. 2. Comprehend the severity of Pollution from Plastic in the ocean, micro-plastic formation, and its impact on sea life, human health, and the economy 3. Know Current practices of plastic waste management and identify the best way to manage plastic waste and mitigate the risk. Students will understand the trans-disciplinary approach to sustainability, applied science, and social and economic issues. They will learn the basic life cycle assessment (LCA) concepts and apply life cycle assessment methodology using appropriate case studies. The available opportunities and challenges being faced in developing a sustainable model for plastic waste management in India will be

			discussed.
CE770	ADJUSTMENT COMPUTATIONS FOR GEOINFORMATICS-I	1.5-0-1-0-6	Adjustment computations: Introduction, Observation/measurements: True value, Most probable value (MPV) True error, residual, discrepancy, Types and sources of error, Gaussian law of accidental errors, Precision and accuracy, Measures of precision from Gaussian law, Expectation operator, Variance, Covariances, Correlation, Weights and cofactors, Various error measures on 1D, 2D, and 3D standards, Propagation of errors, variance, covariance and cofactors, Pre-analysis, Introduction to Statistical concepts, Probability distributions, Hypothesis testing. Geoinformatics methodology: Mathematical model, Definition, elements and Types of models: stochastic and function, linear, non-linear, over-determined, under-determined, unique, explicit, implicit, observation, condition, combined, Adjustment: Purpose and types, Least squares adjustment: Principle and techniques, Assumptions, Ordinary, weighted, generalized LS, Geometrical interpretation. Observation equations: Model and solution strategy, Adjustment of linear and non-linear forms, Variance-covariance propagation of adjusted data in observations equations method Condition equation: Model and solution strategy, Adjustment of linear and non-linear forms, Variance-covariance propagation of adjusted data in condition equations method. Combined method: Model and solution strategy, Variance-covariance propagation of adjusted data in combined equations method Observation and condition equations as simplification of combined method. Post-analysis of adjusted data: Absolute and relative error ellipse and error ellipsoid, Significance and use in designing projects, outlier/blunder detection, redundancy, redundancy number, reliability, and sensitivity analysis. Applications of adjustment computations: Traversing, Tachometry, EDM, Photogrammetry, GNSS, Network adjustment. Introduction to Geostatistics: Geostatistical tools: Semivariance, Variogram, various models Kriging.
CE771	ADJUSTMENT COMPUTATIONS FOR GEOINFORMATICS-II	1.5-0-1-0-6	Review of Least squares (LS): Adjustment of observations using observation equations, condition equations and combined equations form. Variations to LS methods: LS with constraints, Bayesian LS, treatment of nuisance parameters. Adjustment using Generalized LS. Datum Problem and Free Network Adjustment, rank deficient models. Least squares collocation. Dynamic Mode Filtering and Prediction: Prediction, Filtering, and Smoothing, sequential/recursive/phased adjustment, stacking of normal equations, Helmert-Wolf blocking, Kalman Filtering, comparison of Kalman filter and LS. Similarity (S) transformation, deformation analysis. Applications: Geodesy, Photogrammetry, GNSS, 3D Network adjustment.
CE772M	REFERENCE FRAMES,	3-0-1-0-6	Introduction to Geodesy: Topographic maps, Elements of a map, Map scale, Relief representation, Geodesy

	COORDINATE SYSTEMS AND MAP PROJECTIONS		definition, branches, and history. Coordinate systems in Geodesy: Horizontal and vertical datum: Important reference surfaces in Geodesy: Geoid, Ellipsoid and Topographical surface, Everest, WGS84 and GRS80 Ellipsoids, Geoid, Indian Mean Sea Level, Level Surfaces and plumb line, Deflection of Vertical and Geoid Undulations. Geometrical Relationships of an Ellipsoid: Geometrical relationship of an ellipse, Radius of curvature along the meridian and the prime vertical sections, Mean radius of curvature, Curves on an ellipsoid of revolution: Normal section azimuths and Geodesics, Direct/Inverse problems in Geodesy. Terrestrial Reference Systems: Terrestrial coordinate systems – Geocentric and Topocentric, Various geocentric coordinate systems and reference frames: Cartesian, Ellipsoidal, Natural and Geodetic Coordinate Systems and their inter-relationships, WGS84, IGS and ITRF Reference frames, Polar motion and Earth rotation. Map projections: Map projections: Introduction to Map Projections, Purpose and methods of map projections and their classification, Conformal projections – Special reference to Lambert Conformal Conic, Stereographic and Transverse Mercator, Equivalent and Equidistant projections, Indian Grid System, UTM Projection, Methods of map projection transformations.
CE773M	GEODETIC ASTRONOMY AND INTRODUCTION TO SATELLITE GEODESY	3-0-1-0-6	Geodetic Astronomy: Celestial Sphere, Definition of terms in Astronomy, Solution of Astronomical Triangle Celestial coordinate systems and their inter-transformations Variation in Celestial Coordinates: Precession, Nutation, Polar Motion, Physical effects and Proper motion Time Systems: Solar, Sidereal, Ephemerides, Atomic and Rotational Time Systems: UT0, UT1, UT2 and UTC, Polar Motion CIO, Earth Rotation, Leap Second, Determination of Astronomic Azimuth, Latitude and Longitude. Satellite Geodesy: Introduction to Satellite Geodesy, Keplerian Laws of satellite motion, Geometry of Ellipse and Keplerian ellipse in Space, Transformation of Coordinates from Keplerian elements to Earth Centered Earth Fixed (ECEF) coordinate system, Perturbed satellite motion, Lagrangian and Gaussian forms of Perturbation equations, Gravitational and non-gravitational perturbing forces, Introduction to GNSS, SLR, VLBI and Satellite altimetry, Geodetic applications of satellite missions.
CE736	FLOOD MODELLING	3-0-0-0-9	Depth-Averaging of conservation laws, Approximation of Shallow Water Equation: Kinematic Wave, Diffusive Wave, Local Inertia, Full Dynamic Models; Solution Techniques: Basics of Finite Difference and Finite Volume Methods, convergence, consistency, stability, implicit and explicit schemes, Method of Characteristics; Channel Networks: Distributed Flow Routing; Unsteady flows in open channels; Sediment Transport.

CE737	MOMENT ANALYSIS FOR CONTAMINANT FATE AND TRANSPORT	3-0-0-0-9	Introduction to solute transport models, Laplace transform of solute transport models, Fourier transform of solute transport models, Transfer function approaches, temporal and spatial moment analysis of solute plume behavior, moment generating differential functions, moment analysis for compounds undergoing sequential decay
CE738	HYDROMETRY	2-0-3-0-9	Introduction to measurement system; types and characteristics of instruments; measurement uncertainties; sensor calibration; principles, instruments and methods for measuring hydrological variables; data acquisition systems; data processing, storage and dissemination.
CE739	IRRIGATION SYSTEMS	3-0-0-0-9	Introduction to irrigation systems; soil-plant-water relations; estimation of evaporation and transpiration; crop water requirement; irrigation water requirement; irrigation methods; crop models; irrigation scheduling; irrigation efficiencies; irrigation advisories.
CE775M	INTRODUCTION TO ROAD SAFETY MODELLING	3-0-0-1-5	Overview of road safety analysis; elements of crash data; review of concepts of probability and statistics (discrete and continuous distribution, law of total variance, Bayes' rule, sample means/variances, correlations); linear regression (estimation, model selection, impact of violations of assumptions); count data models (poisson/negative binomial regression, extensions); hotspot identification methods; analysis; expansion and modeling of traffic counts; before-after studies; overview of machine learning application in safety analysis; surrogate safety assessment; emerging trends in road safety analysis.
CE780	LABORATORY COURSE IN TRANSPORTATION ENGINEERING	0-0-6-3-9	Experiments on road surface characterization; Relationship between viscosity and some of its measures; Experiments on Bituminous mixes; Sub-grade improvement techniques for pavements; Experiments on traffic flow characterization; Computer aided analysis and design techniques in transportation engineering; Equipment demonstration/explanation of working principle of some equipments relevant to highway industry
CE781M	TRAFFIC SIMULATION	3-0-2-0-6	Basics about traffic simulation; Discrete and continuous distributions; Random number generators; Generating random variants; Creation of a road network; Vehicle placement and vehicle movement on road network; Simulation of single and multi-lane traffic flow; Calibration and validation; Simulating disorderly traffic; Applications of traffic simulation.
CE783M	ANALYSIS OF CONCRETE PAVEMENT	3-0-0-0-5	Analysis of beam on elastic foundation; infinite, semi-infinite and finite beams; various types of foundations; analysis of plates on elastic foundation; analysis of concrete pavement – load stress and thermal stress; dynamic loading analysis
CE784	MACHINE LEARNING	3-0-0-2-11	Introduction to machine learning and data analytics in

	AND DATA ANALYTICS FOR CIVIL ENGINEERING APPLICATIONS		civil engineering: fundamentals, tools, history necessities, machine learning in modern civil engineering; recapitulation of linear regression, logistic regression; supervised algorithms such as k-nearest neighbor, support vector machines, neural networks fundamentals and backpropagation, applications to structural damage detection, soil classification, etc.; unsupervised clustering algorithms such as hierarchical clustering, k-means and DBSCAN, applications on transportation mode inference, level of service of roads; convolutional neural networks introduction and fundamentals, image classification and object detection, applications to camera-based classification and object detection related to structural health monitoring, vehicle detection, etc.; recurrent neural networks, long-short term memory, applications to traffic state prediction (speed/volume), soil strength prediction, rainfall-runoff modelling, etc.; variational autoencoder, generative adversarial networks, applications to sensor data generation and imputation such as traffic sensors, fault diagnostics in structural health monitoring, etc.; map-reduce fundamentals (key-value), interface, algorithms (matrix multiplication, sorting, etc.), relevant tools such as apache pig, hive, spark fundamentals, spark streaming, applications to large-scale traffic trajectory data analysis, building information modelling in construction industry, etc.; large-scale data visualization using Tableau, Power BI; deep learning tools such as keras, pytorch. Students will carry out a project applying the tools/algorithms covered in the course on a topic of their choice of interest.
CE785M	PAVEMENT MATERIALS	3-0-0-0-5	Characterization of pavement materials; Concepts of bituminous mixture design; Unbound layers in pavements – Material properties and design considerations; Surface energy concepts; Improving structural properties of unbound and subgrade layers – Soil stabilization concepts and mix design considerations.
CE786	ANALYSIS AND DESIGN OF BITUMINOUS PAVEMENTS	3-0-0-0-9	Mechanical modeling of pavement materials - bound and unbound materials, stress-dependent and time-dependent response (with reference to modeling of bituminous mix, aggregates and soil). Analysis of elastic half-space; analysis of bituminous pavement - load stress and thermal stress. Introduction to design concepts. Structural design of bituminous pavement (as new pavement and overlay). Cost and reliability considerations. Distresses in bituminous pavements, evaluation, maintenance measures.
CE787	COMPUTATIONAL TOOLS FOR TRANSPORTATION ENGINEERING	3-0-2-0-11	Overview of different computational tools and applications in transportation engineering, Integrated Developing Environment (IDE) in R/Python, different data types and dataframes in R/Python and their applications in transportation engineering (vehicle counts, mode choices, etc.), Different looping techniques, operators,

			regular expressions, user-defined functions in R/Python, Basics of structured data processing in R/Python and applications in transportation engineering such as time-series data processing, Unstructured data processing fundamentals including images and geo-spatial data, data visualization techniques and applications such as GPS traces, crash locations visualizations, Basics of linear modeling, assumptions, and applications in transportation such as crash rates modelling, etc. Introduction to MATLAB, matrices and operators, Combining and transforming matrices, Arithmetic operations in matrix, Introduction to functions, Function I/O, Built-in functions, Introduction to object-oriented programming, Class, Subclass, Objects, Methods and attributes and their properties, Encapsulation, Inheritance and polymorphism, Data structures (structure array, cell array, linked list, trees, etc.), Algorithmic complexity, Error handling.
CE788M	TRANSPORTATION INFRASTRUCTURE MANAGEMENT	3-0-1-0-5	Maintenance decision-making; statistical techniques for estimating performance prediction models (linear regression, stochastic duration models); facility and network-level optimization for limited resource allocation allocation (Markov decision processes, dynamic programming, linear programming).
CE789	TRANSPORTATION NETWORK ANALYSIS	3-0-0-0-9	i) static traffic assignment (user equilibrium, system optimal assignment, Braess' paradox, extensions of user equilibrium), ii) dynamic traffic assignment (node and link models, queue models, cell transmission model, link transmission model, time-dependent shortest paths), iii) combinatorial optimization problems (shortest path problem, minimum spanning tree, traveling salesman problem, vehicle routing problem)
CE791	LITERATURE SEARCH AND REVIEW	0-0-0-5-5	Basics of literature review: Introduction, identifying appropriate search engines Writing style: Styles of citation and referencing Referencing various types of sources: journal articles, conference proceedings, technical reports, online portals, news paper articles Ethics in writing review reports: Plagiarism, use of figure or data from published report, giving proper credit to authors.
CE792	SCIENTIFIC WRITING SKILLS	0-0-0-5-5	Basics of scientific writing Subjects/Actions, Cohesion, Emphasis, Simplicity; Parts of a Scientific papers Abstract, Introduction, Body, Conclusion, Acknowledgements, Reference; Writing styles: Referencing, Citation, Language Making and Handling Figures and Tables Ethics in writing.
CE793	SCIENTIFIC PRASENTATION SKILLS	0-0-0-5-5	Basics of scientific presentation Visuals: choice of type and size of fonts, color combination, styles, use of sketch and pictures Delivering impressive presentation: Usage of language, clarity, simplicity, speed, explaining Figures and Tables Parts of a Scientific presentation Title, motivation, objectives, body, findings, summary, acknowledgements Ethics in using contents from other

			sources
CE794	SCIENTIFIC DATA ANALYSIS, PRESENTATION AND INTERPRETATION	0-0-0-5-5	Basics of data: Primary data, secondary data, data sources and reliability Tools for data analysis: Identifying the right tool based on the project requirement (eg. Matlab, R, MSExcel, Access, ArcGIS, etc) Presentation of data: Graphical, tabular, and descriptive, Use of graphing tools in programs including Matlab, R, and MSExcel. Interpretation: Interpretation of results and documenting.
CE797	PHD SEMINAR I	0-0-0-0-0	Each Ph.D. student registered for CE797 will give a 45-60 minute seminar based on his/her research work. In addition, they will be expected to attend all CE797 seminars scheduled that semester. In addition to registered Ph.D students, other researchers from within and outside the Institute may be invited to give seminars as a part of CE797. Grading for CE797 shall be in the S/X mode and based on the quality of the seminar presented by the student and his/her attendance in other CE797 seminars. CE DPGC Convener will be the nominal instructor for the course. However, grades will be given in consultation with thesis supervisor(s) and program committee members of the concerned student.
CE798	PHD SEMINAR II	0-0-0-0-0	Each Ph.D. student registered for CE798 will give a 45-60 minute seminar based on his/her research work. In addition, they will be expected to attend all CE798 seminars scheduled that semester. In addition to registered Ph.D students, other researchers from within and outside the Institute may be invited to give seminars as a part of CE798. Grading for CE798 shall be in the S/X mode and based on the quality of the seminar presented by the student and his/her attendance in other CE798 seminars. CE DPGC Convener will be the nominal instructor for the course. However, grades will be given in consultation with thesis supervisor(s) and program committee members of the concerned student..
CE799	PHD THESIS	0-0-0-9-9	Ph. D. Thesis
CE897	MS RESEARCH SEMINAR I	0-0-0-0-0	Each MS (Research) student registered for CE897 will give a 45-60 minute seminar based on his/her research work. In addition, they will be expected to attend all CE897 seminars scheduled that semester. In addition to registered MS (Research) students, other researchers from within and outside the Institute may be invited to give seminars as a part of CE897. Grading for CE897 shall be in the S/X mode and based on the quality of the seminar presented by the student and his/her attendance in other CE897 seminars. CE DPGC Convener will be the nominal instructor for the course. However, grades will be given in consultation with thesis supervisor(s) of the concerned student.
CE898	MS RESEARCH SEMINAR II	0-0-0-0-0	Each MS (Research) student registered for CE898 will give a 45-60 minute seminar based on his/her research

			work. In addition, they will be expected to attend all CE898 seminars scheduled that semester. In addition to registered MS (Research) students, other researchers from within and outside the Institute may be invited to give seminars as a part of CE898. Grading for CE898 shall be in the S/X mode and based on the quality of the seminar presented by the student and his/her attendance in other CE898 seminars. CE DPGC Convener will be the nominal instructor for the course. However, grades will be given in consultation with thesis supervisor(s) of the concerned student.
CE899	MS - RESEARCH THESIS	0-0-0-9-9	MS(R) Thesis
CE999	DIIT Project	0-0-0-9-9	DIIT Project
CE714	Traffic Dynamics and Simulation	3-0-0-0 [9]	This course will provide a basic understanding of macroscopic models such as the firstorder and higher-order traffic flow models, model characteristics, and numerical schemes. Microscopic models such as car-following and lane-changing models will be discussed. Development of traffic simulation, calibration, and validation of simulation will be presented. Finally, the course discusses disordered traffic, macroscopic and microscopic models for disordered traffic, and its implementation in traffic simulation.
CE715M	Contract Management	3-0-0-0 [5]	The course introduces the brief process of execution of works and procurement of materials through contracts with emphasis on different modes of execution, types of bids, parties for the contract and the required ethics. Present a brief overview of the applicable laws like Indian Contract Act, Arbitration and Reconciliation Act etc Present the structure and broad content of the bid documents in relation with the applicable laws. Present the following processes being followed by various departments with case studies: • Bid evaluation • Entering into the contract • Managing contracts • Managing the change requests • Dispute resolution
CE704	Analysis of Transportation Systems	3-0-0-0 [9]	Course Description: Objectives: This PG course aims to cover mathematical foundations for analysis of transportation systems. In the beginning, basics of optimization will be covered and after that important combinatorial optimization problems with transportation applications will be discussed. Finally, there will be focus towards traffic assignment or infrastructure management problems. Contents: Module 1 (Compulsory): 20 lectures

S. No.	Broad Title	Topics	No. of Lectures
1(i)	Basics of optimization	Motivating optimization formulations, types of decision variables (continuous vs discrete), constraints as sets, functions as objectives,	10
1(ii)	Combinatorial network optimization problems and solution approaches	Computational complexity, applications of network optimization problems (shortest path algorithms, minimum spanning tree, travelling salesman problem, vehicle routing problems, facility location, knapsack problems), approximation algorithms, heuristic and metaheuristic algorithms, integer programming algorithms such as branch-and-bound	10

After covering the basics of optimization, any one of the two modules listed below will be taught in a given semester.

Module 2 (Traffic assignment): 20 lectures

S. No.	Broad Title	Topics	No. of Lectures
2(i)	Introduction to traffic assignment	Beckmann's formulation, equivalency flonditions, system-optimum formulation, Braess' paradox, convex combinations method, network loading models	7
2(ii)	Stochastic user equilibrium	Discrete choice models, stochastic network loading, stochastic user equilibrium	5

2(iii)	Dynamic user equilibrium	Link transmission model, node models, dynamic network loading models, time-dependent shortest path problems, dynamic user equilibrium	8

Module 3 (Infrastructure management): 20 lectures

S. No.	Broad Title	Topics	No. of Lectures
3(i)	Introduction to infrastructure management	Overview of maintenance rehabilitation and reconstruction (MR&R) decision-making and the associated sub-problems: network-level and facility-level optimization, performance models, inspection and data considerations; motivating the need for life cycle cost optimization, user vs agency costs; serviceability vs distress metrics, discrete vs continuous indices	4
3(ii)	Performance models	Deterioration and maintenance effectiveness models for discrete and continuous condition indices	4

3(iii)	Facility-level optimization problems	Optimizing decision-making for continuous and discrete condition states at the facility-level, dynamic programming, applications in maintenance optimization	6
3(iv)	System-level optimization problems	Finite horizon and infinite planning horizon problems; applications in budget allocation problems for pavement and bridge management.	6

Pre-requisites: Basic knowledge of calculus, probability, statistics and linear algebra. Basic programming skills.

Short summary for including in the Courses of Study Booklet: The course presents a systems perspective of transportation network operations and management. The course will cover the fundamental of optimization techniques and their applications in transportation engineering. After covering the basics of optimization, any one of the following two modules will be covered i) traffic assignment: introduction to traffic assignment, stochastic user equilibrium and dynamic user equilibrium ii) infrastructure management: modeling and optimization methods and their application to inspection, performance prediction and maintenance decision-making for the management of infrastructure systems such as highways, bridges, airfield pavements, railway tracks, etc.

Recommended Books
Textbook: None

References:
1) Sheffi, Y., 1985. Urban transportation networks (Vol. 6). Prentice-Hall, Englewood Cliffs, NJ. (Publicly accessible at http://web.miteclu/sheffi/wwwlselectedMediaisheffi urban trans networks.bdf)
2) Boyd, S. and Vandenberghe, L., 2004. Convex optimization. Cambridge university press. (Publicly accessible at https://web.stanford.edul—boydicvxbooki)
3) Simchi-Levi, ID., Chen, X. and Brame!, J., 2005. The logic of logistics. Theory, algorithms, and applications for

			logistics and supply chain management. 4) Cormen, T.H., Leiserson, C.E., Rivest, R.L. and Stein, C., 2022. Introduction to algorithms. MIT press. 5) Winston, W.L., 2004. Operations research: applications and algorithm. Thomson Learning, Inc. 6) Papadimitriou, C.H. and Steiglitz, K., 1998. Combinatorial optimization: algorithms and complexity. Courier Corporation. 7) Bertsimas, D., & Tsitsiklis, J. N. 1997. Introduction to linear optimization. Athena Scientific. 8) Washington, S., Karlaftis, M. G., Mannering, F., & Anastasopoulos, P. (2020). Statistical and econometric methods for transportation data analysis. CRC Press.
CE716	Project Management and Control	3-0-0-0[9]	**Objectives** A construction project requires significant investment in terms of time, money, and resources. This necessitates a need for effective construction project management skills that facilitate completing the projects within the stipulated time and budget limits while adhering to safety and quality standards. This course aims to equip students with the skills required for planning, scheduling, budgeting, coordinating, and supervising large-scale projects. Specific objectives include: • To introduce students to basic project management concepts with a focus on applications in Civil engineering. • To expose students to complexities involved in managing large-scale construction projects and provide them with the right tools and methods to manage these complexities. • To provide students with a platform to sharpen the skills learned by applying these concepts on a real-life construction project
CE718	Water resources systems analysis	3-0-0-0 [9]	**Objectives**The course introduces optimization and simulation techniques that are used in planning and management of water resources systems. The course will include application of these techniques to problems such as reservoir design and operations, river basin management, water allocation to multiple sectors, decision making under uncertainty and multi-criteria decision making
CE719	Hydrometeorology	3-0-0-0 [9]	**Objectives** The objective of this course is to provide a conceptual understanding of the physical processes involved in the transfer of water and energy between the land surface and the lower atmosphere. The course will focus on fundamental concepts such as laws of thermodynamics and mass, momentum, and energy conservation principles to explain hydrometeorological processes such as rainfall, cloud formation, evapotranspiration, winds and development of pressure systems. The understanding of these processes will further be applied to explain hydrometeorological phenomena such as extreme rainfall, thunderstorms,

			floods, droughts and heatwaves
CE729	Hydropower and turbomachines	3-0-0-0 (9)	**Objectives:** Learning the basics of hydropower and hydraulic turbomachines is essential for a civil engineer, particularly those graduating with a degree in water resource engineering. The proposed course is designed as an elective course to acquaint postgraduate or senior undergraduate students in civil engineering with the basic principles of hydropower plants and hydraulic turbomachines. Students will learn about the basic requirements and layout of hydropower plants, as well as the functioning of various hydraulic turbines and pumps**.**
CE726	Design and Analysis of Underground Excavations	3-0-0-0-(9)	**Objectives**: The students would learn the analysis of underground structures in rocks and soil of different qualities considering the elastic and elastoplastic stress-strain behaviour of geomaterials. The implementation of different design methods, including empirical, analytical and numerical approaches, would be covered in this course. Further, the use of codes and standards in the design of underground structures and the practical aspects of tunnelling including instrumentation and support design will be covered.
CE642	Laboratory Course in Infrastructure Engineering and Management	3-0-0-0-(9)	The objective of this course is to provide hands-on experience for students in the different area of Infrastructure Engineering and Management. The laboratory course will focus on four broad areas: a) Project Management Software: Computational exercises relevant to project management and controls (MSP, Primavera, AutoCAD). b) Quantity Estimation and Planning: Quantity estimation & take-off, Bar bending schedule, planning & design of formwork. c) Productivity Measurement and Assessment: Productivity calculation & workforce estimation, Construction equipment and machinery estimation. d) Construction Engineering: Site layout planning, Quality and safety planning and relevant tools, Applications and need of Building Information Modelling (BIM) in Construction projects, Experiments related to Repair and Rehabilitation of Concrete
CE706	Slope Stability and Landslides Analysis	3-0-0-0-9	The identification of the stable state of a sloping ground is important to control the geohazards owing to landslides, where a large variety of geomaterials such as rock, debris, and soil move rapidly downward or outward of the sloping ground located in hilly and mountainous regions. This course is designed to provide: (i) an understanding of the mechanism of the instability of slopes leading to landslides; (ii) to understand the importance of geological, geotechnical, hydrological, topographical, meteorological, seismological, and anthropogenic factors towards the instability of slopes and landslides; (iii) to have an idea about monitoring and controlling techniques for identification and prevention of landslides.
CE401	Hydraulic Turbomachines	2-0-0-0 [6]	This course is designed as an elective course to acquaint an undergraduate student in civil engineering with the

			basic principles of Hydraulic Turbomachines. Students will learn about the functioning of pumps, compressors and turbines and their classifications. They willalso learn the designing and optimization of Hydraulic Turbomachines.
CE442M	Pavement Engineering Laboratory	5 (3-0-1-0)	Currently, the Undergraduate Level (UG) students in the Dept. of Civil Engg. heavily lacks exposure on the experimental part of Transportation Engg. Therefore, this course is designed to provide them with the necessary exposure on the key experimental part of transportation engineering with particular orientation towards pavement engineering part as per the state-of-the-art practice.
CE728	Subsurface Environmental Flows	3-0-0-0-9	The porous subsurface is crucial for various energy and environmental applications, including groundwater resources and carbon sequestration. This proposed course aims to introduce postgraduate and senior undergraduate students to the fundamental concepts of flow processes involved in these applications. We will specifically focus on five key areas: carbon sequestration, subsurface hydrogen storage, geothermal energy recovery, groundwater contamination, and subsurface nuclear waste storage. In this course, students will learn how to use the concepts of porous media flows for predicting flow behaviour in these contexts.
CE444	Advanced topics in mechanics and analysis of skeletal structures	9 (3-0-0-0)	**Objectives:** Skeletal structures such as trusses, frames, etc., are widely used in structural engineering applications such as buildings, bridges, long span roofs, reticulated shells etc. Design of these structural systems require advanced knowledge in structural mechanics, and matrix structural analysis covering material and geometric nonlinear behavior. This course aims to cover the necessary structural mechanics theories, and their implementation using matrix method for the analysis of skeletal structures.
CE659	Computational Fluid Mechanics for Civil Engineering Applications	3-0-0-0 (9)	**Overview of the Course:** This course provides an introduction to the computational modelling techniques for hydrodynssamic data acquisition from the flow field. The computational modelling covers the basic concepts of the Partial Differential Equations (PDEs), different types of PDEs, conservative and nonconservative forms, characteristics analysis/solution for 1st order and 2nd order linear and quasi-linear PDEs, harmonic functions and mean value theorem, Eulerian and Lagrangian approaches, fundamentals of numerical modelling, numerical stability, consistency and convergence criteria, finite difference and finite volume methods (FDM and FVM), Taylor series and discretization, solution techniques and numerical schemes for different types of PDEs, first and second order discretization techniques, numerical algorithms (SIMPLE, PIMPLE, PISO), numerical stability and convergence, matrix factorization and inversion techniques, tri-diagonal and penta-

			diagonal matrices, Kolmogorov's theory, turbulence modelling, steady and unsteady Reynolds Averaged Navier Stokes (RANS) equations, turbulence closure models (k-ε, k-ω, RST), Large Eddy Simulation (LES), Smagorinsky model, Direct Numerical Simulation (DNS), structured and unstructured meshing, boundary conditions, development of computational framework using MATLAB and OpenFOAM, implementation of CFD in various Civil Engineering applications. This course briefly covers the basic post-processing algorithms of acquired data from computational studies including time-averaging of data, Reynolds stress and shear velocity estimation, frequency response analysis.