LIST OF CIVIL ENGINEERING COURSES

CE213A: Introduction to Environmental Science **3-0-0-0 [9]**

Course Contents:

Introduction: Define environmental science as a subject that draws on learning's from natural sciences to investigate human impact on the natural environment. Present concept of hydrosphere, atmosphere, biosphere, and ecosystem. Explain how the scientific method is used to investigate natural phenomena, particularly the interrelationships between organisms and between organisms and their environments; Water: Availability and Pollution. Hydrologic Cycle and Water Bodies, Water Availability and Use, Water Pollution, Water Management; Climate, Weather, and Air Pollution: Explain the components of the atmosphere and the processes that form climate and climate change. Classify sources and types of air pollution. Solid Waste Management: Classify types of solid waste and disposal methods, and explain the associated environmental effects. Analyze the effect of waste and hazardous waste on human health; Environmental Legislation and Policy Development: Examine the need and rationale for environmental legislation; Energy and review of Thermodynamics: Describe energy as a force, the forms of energy, and explain the laws of thermodynamics. Illustrate the principle of conservation of matter; Energy Consumption and Conventional Sources. Summarize data on uses, consumption, and reserves of energy. Fossil fuels;

Presentations by students: Suggested Presentation topics,

- Rationale and effectiveness of strategies to increase the availability of water, conserve water, and purification of water.
- Current Global initiatives to manage/ mitigate climate change impacts
- History of environmental legislation in India and the discussion of environmental issues that need development of policy and legislation.
- Strategies, programs, and policies to reduce the amount of waste and to reduce the harmful effects of waste.

CE241A: Sustainable Built Environment **3-0-0-0 [9]**

Course Contents:

Earth and Environment Definition of environment; origin of earth, lithosphere, hydrosphere, atmosphere, biosphere; Earth Structure, Plate Tectonics theory, geo-morphological features, Geological structures (folds, faults, discontinuity, dike); Engineering and Genetic classification of soils, Weathering and Soils; Rocks, rock cycle, Igneous Rocks, Sedimentary Rocks, Metamorphic Rocks, Rock Properties, Rock-water interaction; Natural disasters: Cyclone, Tornado, Volcanic Eruption, Earthquakes– Generation mechanism, different terminologies, earthquake monitoring and measurements, seismic region of the world, Tsunami, Land Slides; Sustainability and resilience for natural disasters; Hydrosphere; water cycle, surface and groundwater origin and its quality, oceans, ocean currents, ocean water quality; Atmosphere;

components of atmosphere; earth's energy budget; air quality, winds, cloud formation, storms; Biosphere; essential components for life; energy, carbon, water and nutrients and their role in sustaining life; carbon and nutrients recycling; biomes and ecosystems; Natural Resource and Human Civilization; Natural Resources; natural resources for energy, food, shelter, and other human needs ; Human Civilization; link between human civilization, natural resources and environment; Infrastructure: characteristics of modern human civilization and the need for infrastructure; Environmental Impacts of Human Civilization Environmental impacts of population growth, intensive agriculture, land use changes, urbanization, industrialization, mining; Consequences of fossil fuel burning; global warming and climate change ; Loss of biodiversity, desertification, loss of soil fertility, reduction in water availability, land, air and water pollution; Sustainable Development; Concept of Sustainable Development: Bruntdland Report; Modifications for sustainability; reuse and recycle, demand management, innovative supply side Engineering; Sustainable development in various sectors; energy, industry, agriculture, transportation, construction, water resources and land management; Institutional limitations in achieving sustainable development

CE242A: Civil Engineering Materials **3-0-2-0 [11]**

Course Contents:

Properties of construction material and their evaluation (creep, elastic modulus, fatigue, impact, etc.); test methods and specifications; Cement chemical composition, properties such as setting, strength, fineness, hydration; Aggregates sources, properties, chemical reactivity; Concrete constituents, proportioning, properties in fresh and hardened state, characteristic strength, quality control (sampling, acceptance, etc.), transportation and placing, testing (including NDT), porosity; Admixtures chemical, mineral; Steel properties, types of steel, steel in civil engineering; Bricks manufacture, properties and classification; masonry bonds; New materials Fibre reinforced plastics (FRPs), epoxy-coated bars, etc. with performance requirements, test methods, specifications; Bitumen source, composition, characterization, various forms, tests on bitumen; Bituminous mix design; Soil description, engineering geology of soils and their formation, index properties of soil, classification of soils.

CE262A: Engineering Hydraulics **2-0-2-0 [8]**

Course Contents:

Introduction; Review of the basic equations: continuity, momentum, and energy. Flow through closed conduits: Laminar flow, Turbulent flow, Pipes in Series and Parallel, Pipe Networks, Unsteady flow. Flow through open channels: Uniform flow, Critical flow, Gradually Varied flow, Rapidly Varied flow, Spatially Varied flow, Un-steady flow. Flow Measurement: Pressure, Velocity and Discharge measurements. Forces on immersed bodies: Drag and Lift. Basics of Irrigation Engineering: Crop water requirements, Irrigation methods.

CE272A: Structural Analysis **3-0-0-0 [9]**

Course Contents:

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: moment-area 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, slope-deflection equation, moment distribution method. Plane trusses and beams by using direct stiffness method.

CE311A: Environmental Quality and Pollution **3-0-3-0 [12]**

Course Contents:

Introduction and Scope General concept of Environmental Engineering; Ecology and Environment; Impact of pollution on the environment; Environmental Quality Parameters; Various pollutants in different media; Introduction to Environmental Standards; Brief mention of development of environmental standards; Aquatic Chemistry Acid-base chemistry, alkalinity, metal complexation, precipitation, etc; Mass Transfer Inter-media transfer of pollutants e.g. gas-liquid, solid-liquid transfers; Particles in Environment Formation, settling deposition, flocculation; attachment; Pollutant Transport; Mechanisms of Pollutant Transport; Air Pollution Pollutant sources, effects, meteorology as applied to air pollution, air pollution control; Environmental Modeling Pollutant transport equations; Development of analytical/ predictive environmental models for various environmental media; Solid and Hazardous Waste Management; Definition; Control measures; Disposal of Wastes, Management; Environmental Impact Assessment; Concept and importance; Various steps in a EIA study; assessment of impacts; mitigation of adverse impacts; Environmental management plan.

Laboratory; Introduction to Environmental Engineering Laboratory Tour of the laboratory; Familiarization with glassware and instruments etc.; Measurement of Water and Wastewater Quality Parameters; Alkalinity, pH, solids, anions; Cations, BOD, COD, TKN, P, microbial quality, etc; Demonstration of Air Pollution; Measurement Instrumentation; Ambient particle and gaseous; samplers, stack monitoring, meterology, etc.; Demonstration of Advanced Analytical Instrumentation; Gas and liquid chromatographs, measurement of metals, organic carbon analyzers, and other advanced instruments in Environmental Engineering laboratory

CE331A: Geoinformatics **3-0-2-0 [11]**

Course Contents:

Introduction to surveying, Coordinate systems and datum transformation, Linear measurements, Angle measurement, Vertical control- Leveling and Contouring; Total Station surveys, Errors

and adjustments, Control surveys-Traversing, Triangulation, GNSS survey, Construction surveys.

CE332A: Survey Camp **0-0-0-4 [4]**

Course Contents:

Survey Camp: Reconnaissance and establishing the control stations; GNSS observation for control points, Control network densification and topographic mapping using Total Station, Road profiling, Hand-held GNSS survey for GIS data collection.

CE341A: Civil Engineering Communication Skills **0-0-0-2 [2]**

Course Contents:

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.

CE351A: Soil Mechanics **2-0-2-0 [8]**

Course Contents:

Stresses within a soil, effective stress principle, stress point and stress path, Soil water systems capillarity, flow, Darcy's law, permeability, and tests for its determination, different heads, piping, quicksand condition, seepage, flow nets, Compressibility and consolidation characteristics. Strength of loose and dense sands, NC and OC soils; dilation, pore pressures; Skempton's coefficients, etc.; Compaction characteristics, water content dry unit weight relationships, OMC, maximum dry unit weight, field compaction control, etc.

CE352A: Foundation Design **2-0-1-0 [7]**

Course Contents:

Site investigations, methods of drilling, sampling, in-situ test - SPT, CPT, plate load and dynamic tests, groundwater level, etc. Bearing capacity, general, local and punching shear failures, corrections for size, shape, depth, water table, compressibility, etc., ultimate and allowable stresses, methods based on in situ tests, Settlements of foundations, stress in soils (Boussinesq, Westergaard), Design of foundation, Types of foundations - shallow/deep, isolated, combined, mat, etc., contact pressure distributions, Earth Pressure theories, Coulomb and Rankine approaches, c-f soils, smooth and rough walls, inclined backfill, Deep foundations: pile and well foundations.

CE361A: Engineering Hydrology **2-0-0-0 [6]**

Course Contents:

Introduction: 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 Evapo-transpiration Pan evaporation, empirical equations for estimating evaporation and evapo-transpiration; Transpiration, 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 and Log Pearson Type I II distributions, Rational method, risk, reliability, and safety factor; Hydrologic storage routing Groundwater Hydrology: Types of aquifers and properties, Darcy's law, steady flow in a confined and unconfined aquifer (without recharge), steady flow to a well

CE371A: Design of Steel Structures **2-0-0-0 [6]**

Course Contents:

Steel structures, Limit states and design philosophy; partial safety factors and load combinations; Analysis and design methods; Design of tension members based on net section including shear lag effects, staggered holes and block shear; Design of compression members for flexural and flexural torsional buckling, Column formula, Local buckling and buckling class, End restraints and effective length factor; Role of plate buckling, Plastic hinge, Classification of section: plastic, compact, semi-compact, slender, 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; Effect of axial load on flexure behavior, Cross-section yielding and member instability, PM interaction and moment amplification, Biaxial bending; Design of Bolts and Welds, Strength under combined stresses, Prying action; Common simple and eccentric joints and frame connections, Column bases.

CE372A: Reinforced Cement Concrete Design **2-0-0-0 [6]**

Course Contents:

Reinforced concrete (RC) structures, Loadings, analytical models for analysis and design of RC structures, Design Methodologies: Working Stress Method and Limit State Method; Behaviour of RC members under flexure; Working stress design for common flexural members; Limit state design of beams and slabs (one way and two way) for flexure; Singly and doubly reinforced sections; rectangular and flanged sections; S hear 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 biaxial bending; Slender columns Types of footings; design of isolated /combined footing.

CE382A: Transportation Engineering **3-0-0-0 [9]**

Course Contents:

Introduction; Transportation engineering elements; Geometric design; Traffic flow fundamentals; uninterrupted traffic flow; Interrupted traffic flow; Pavement analysis; Highway maintenance.

CE412A: Water Supply and Wastewater Disposal Systems **3-0-2-0 [11]**

Course Contents:

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.

CE432A: Geographical Information System **3-0-2-0 [11]**

Course Contents:

Introduction; GIS data: spatial and non-spatial, spatial data model: raster, tessellation, vector, 2.5D model; Topology and topological models; Spatial referencing using coordinates and geographic identifiers, metadata; Spatial data acquisition; Attribute data sources; Spatial and attribute data input; Data storage, RDBMS, database operations; Spatial and non-spatial data editing functions; Quality of spatial data; GIS analysis functions: Retrieval, classification, measurement, neighborhood, topographic, interpolation, overlay, buffering, spatial join and query, connectivity, network functions, watershed analysis, view shed analysis, spatial pattern analysis, spatial autocorrelation, trend surface analysis; GIS presentation functions: Visual communication theory, design theory, data visualization methods, exporting data; Modern trends: Internet GIS, 3D GIS, physical modeling under GIS environment.

CE441b: Construction Management **3-0-0-0 [5], modular**

Course Contents:

Stakeholders in construction projects – client, consultant, contractor, financial institutions, regulators, Private Public Partnership, Environmental Impact Assessment; Planning and scheduling (PERT), resource leveling, 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, labor 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

CE451A: Application of Geotechnical Engineering **3-0-0-2 [11]**

Course Contents:

Earth and Earth retaining structures: Slope stability analysis, 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.

CE462A: Hydraulic and Hydrologic Design **3-1-0-0 [11]**

Course Contents:

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 water distribution network, Analysis and design of rigid boundary channels; Tractive-force concepts in channel design, Design of canal head works, distribution works, and cross drainage works; Design of gravity dams, spillways, and energy dissipators.

CE471A: Special Topics in Structural Design **3-0-0-2 [11]**

Course Contents:

Elements of Pre-stressed concrete; Introduction to seismic design; Introduction to design of masonry structures; Case studies in design of RC Structures (RC water tank, Building frame, etc.), Case studies in design of steel structures (Industrial buildings, towers, chimneys, Plate girder, chimneys)

CE481A: Transportation Facilities Design **3-0-0-2 [11]**

Course Contents:

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; at grade intersections; terminals.

CE491A: Undergraduate Project I **0-0-0-9 [9]**

Course Contents:

The course may consist of reading, laboratory work, modeling, theoretical development etc., depending on the problem of research; total hours to be spent for this course is expected to be 9 per week. Course content is variable according to the research problem chosen.

CE492A: Undergraduate Project II **0-0-0-9 [9]**

Course Contents:

The course may consist of reading, laboratory work, modeling, theoretical development etc., depending on the problem of research; total hours to be spent for this course is expected to be 9 per week. Course content is variable according to the research problem chosen.

CE493A: Undergraduate Project III **0-0-0-9 [9]**

Course Contents:

The course may consist of reading, laboratory work, modeling, theoretical development etc., depending on the problem of research; total hours to be spent for this course is expected to be 9 per week. Course content is variable according to the research problem chosen.

CE603A: Mathematics for Civil Engineers **1.5-0-0-0 [5]**

Course Contents:

Linear Differential Equations; Homogeneous Linear Equations of Second Order; Second-Order Homogeneous Equations with Constant Coefficients; Case of Complex Roots, Complex Exponential Function; Non-homogeneous Equations; Solution by Undetermined Coefficients; Solution by Variation of Parameters; Fourier Integrals; Fourier Cosine and Sine Transforms; Fourier Transform and Properties; Dirac Delta Function; Convolution Theorem; Parseval's Theorem; Fourier integral to Laplace transfoms; Partial Differential Equations; Basic Concepts; Modelling: Vibrating String, Wave Equation; Separation of Variables, Use of Fourier Series; Modelling: Membrane, Two-Dimensional Wave Equation; Rectangular Membrane, Use of Double Fourier Series; Linear 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.

CE604A: Numerical Methods for Civil Engineers **1.5-0-0-0 [5]**

Course Contents:

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 QR-Factorization; 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; Crank-Nicholson method for parabolic equation; upwind scheme for first order wave equation; direct discretization and time lumping schemes for second order wave equation.

CE605A: Probability and Statistics for Civil Engineers **1.5-0-0-0 [5]**

Course Contents:

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.

CE606a: Optimization Methods for Civil Engineers **3-0-0-0 [5], modular**

Course Contents:

Introduction to the course and its importance; Optimization methods: problem formulation, solution techniques for linear and integer problems (both unconstrained and constrained), sensitivity analysis; Introduction to non-linear problems; Introduction to non-traditional optimization methods. Case studies from Civil Engineering.

CE610A: Advanced Hydrology **3-0-0-0 [9]**

Course Contents:

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, stream flow hydrographs, base flow separation, index, ERH & DRH, algorithm for abstraction using Green Ampt equation, SCS method, overland and channel flow modeling, time area concepts, and stream net works; Unit Hydrograph: General hydrologic system model, response functions of a linear hydrologic 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, S-Curve, IUH; Subsurface Water: Soil moisture, porosity, saturated and unsaturated flow; Richards' equation, infiltration, Horton's, Philip's, and Green Ampt methods, parameter estimation, ponding time concepts; 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 into confined and unconfined wells; Unsteady flow in a confined aquifer.

CE611A: Advanced Hydraulics **3-0-0-0 [9]**

Course Contents:

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.

CE612A: Fluid Mechanics Laboratory **2-0-3-0 [9]**

Course Contents:

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; Venturi-meter and orifice meter; Energy loss in bends; Ground water flow/ well abstraction; Hydrogen bubble flow visualization; Hydraulic jump; Flow past a cylinder.

CE613A: Computer Methods in Hydraulics and Hydrology **2-0-3-0 [9]**

Course Contents:

Basics: Introduction to computer programming and computation with Matlab. Open channel flow : Estimation of normal and critical depth; uniform flow computations; computation of water surface profile (WSP) gradually varied flow estimation using standard step and direct step methods, WSP in presence of hydraulic structures; unsteady flow Saint Venant equation, kinematic wave routing, diffusion routing, overland flow; steady and unsteady modeling using HECRAS. Closed conduit flow: Steady and unsteady state modeling; pipe network analysis; introduction to EPANET/WaterCAD. Surface water hydrology: Estimation of Unit hydrographs; lumped and distributed flow routing; hydrologic statistics parameter estimation, time series analysis, frequency analysis, geo-statistics; hydrologic modeling using HECHMS. Groundwater hydrology: Solving groundwater flow equation saturated and unsaturated flow, Richards' equation, Green Ampt infiltration model; introduction to MODFLOW; Application of soft computing methods and GIS in Hydraulic and Hydrologic modeling. Laboratory: Programming exercises for the related topics.

CE614A: Stochastic Hydrology **3-0-0-0 [9]**

Course Contents:

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 modeling, time series modeling of annual and periodic hydrologic time series (including AR, ARMA, ARIMA, and DARMA models), multivariate modeling of hydrologic time series, practical considerations in time series modeling applications.

CE615A: Introduction to AI Techniques **3-0-0-0 [9]**

Course Contents:

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, feed forward and feedback networks, supervised and unsupervised learning methods standard back-propagation (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 operators selection, crossover, and mutation, binary and real coded GAs, constraint handling in GAs, and selected case studies involving GA applications to engineering.

CE616A: Sediment Transport **3-0-0-0 [9]**

Course Contents:

Properties of sediment, incipient motion, bed load, suspended load, total load, sediment measurements, regime concept, bed form mechanics, plan form and stream bed variations of rivers, reservoir sedimentation, erosion and deposition, sediment control, sediment transport in pipes.

CE617A: Advanced Modeling of Subsurface Flow and Transport **3-0-0-0 [9]**

Course Contents:

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.

CE618A: Vadose Zone Hydrology **3-0-0-0 [9]**

Course Contents:

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

CE619A: Ecohydrology **3-0-0-0 [9]**

Course Contents:

Introduction: Origin and scope of ecohydrology. Ecohydrological processes: Interactions between physical, chemical and biological processes at basin scale soil water dynamics, land surface energy budgets; scales of interactions; ecohydrological optimality theory; ecohydrological controls on nutrient cycle; Landscape connectivity morphological, ecological and hydrological connections. Techniques in ecohydrological measurements: Measuring energy and water fluxes in atmosphere, soil and vegetation; atmosphere latent, sensible and CO_2 fluxes, distribution of wind, temperature and humidity; soil moisture, soil respiration and soil heat flux; vegetation leaf area index, stomatal conductance and transpiration. Ecohydrological modeling: Governing equations; mathematical models stochastic and deterministic models; process based and empirical models; calibration and validation of models; scale issues in ecohydrological modeling. Applications of ecohydrology: Use of ecohydrogical principles in paleo-hydrology and climate change studies; ecohydrological approach for sustainable management of floods and droughts; case studies from tropical river basins and dry land ecosystems.

CE620A: Structural Dynamics **3-0-0-0 [9]**

Course Contents:

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.

CE621A: Engineering Mechanics **3-0-0-0 [9]**

Course Contents:

Stress analysis: forces and moments, theory of stress, principal stresses and stress invariants, compatibility equations, equilibrium equations; Strain: deformation and velocity gradients, Lagrangian and Eulerian description and finite 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. Venant's principal, linear elasticity and generalized Hook's law, Stokesian and Newtonian fluids, Navier-Stokes equations, Bernoulli equation, linear viscoelasticity, yield criteria; Applications: Airy stress function, two-dimensional elastostatics problems, torsion.

CE622A: Stability of Structures **3-0-0-0 [9]**

Course Contents:

Criteria for design of structures: stability, strength, and stiffness; Classical concept of stability; Stability of discrete systems: linear and nonlinear behavior; Stability of continuous systems: stability of columns: axial–flexural buckling, lateral bracing of columns, combined axial-flexural-torsion buckling; Stability of frames: member buckling versus global buckling, slenderness ratio of frame members; Stability of beams: lateral-torsion buckling; Stability of plates: axial-flexural buckling, shear flexural buckling, buckling under combined loads; Introduction to inelastic buckling and dynamic stability.

CE623A: Experimental Methods in Structural Engineering **2-0-3-0 [9]**

Course Contents:

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; Instrumentation: mechanical, electrical, electronic system and their calibration, various types of sensors for displacement, velocity, acceleration, pressure, loads, strains, full-field 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 behavior of beams, columns, joints, and frames under various loads, mode shapes, natural frequency, damping factors from free and forced vibrations, shake table tests.

CE625A: Masonary Structures **3-0-0-0 [9]**

Course Contents:

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 masonry walls: vertical loads, vertical loads and moments –

eccentricity & kern distance, lateral loads - in-plane, out-of-plane; 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 & vertical reinforcement, 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 - in-situ, non-destructive testing; Construction practices and new materials.

CE626A: Bridge Engineering and Design **3-0-0-0 [9]**

Course Contents:

Introduction to Bridge Engineering: Components on bridge structures, Planning of bridges (traffic, hydro-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

CE627A: Advanced Design of Steel Structures **3-0-0-0 [9]**

Course Contents:

Properties of steel: mechanical properties, hysteresis, ductility; Hot-Rolled Sections: compactness and non-compactness, 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, P-M interaction, bi-axial bending, joint panel zones; Drift criteria: P-Δ effect, deformation-based design; Connections: types – welded, bolted, location - beam-column, column-foundation, splices.

CE628A: Durability of Concrete Structures **3-0-0-0 [9]**

Course Contents:

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 macro cell 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.

CE629A: Earthquake Analysis and Design of Structures **3-0-0-0 [9]**

Course Contents:

Characteristics of earthquakes; Earthquake response of structures; Concept of earthquake resistant design; Code provisions of design of buildings; Design of liquid storage tanks; Liquefaction; Non-engineered construction; Special topics: bridges, dams, strengthening of existing buildings.

CE630A: Rock Mechanics **3-0-0-0 [9]**

Course Contents:

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.

CE631A: Advanced Geotechnical Engineering **3-0-0-0 [9]**

Course Contents:

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

CE632A: Foundation Analysis and Design **3-0-0-0 [9]**

Course Contents:

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.

CE633A: Reinforced Earth Structures **3-0-0-0 [9]**

Course Contents:

Reinforcing materials, Advantage of RE, behavior 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 geo-textiles, geo-grids, geo-nets, and geo-membranes.

CE634A: Ground Improvement Techniques **3-0-0-0 [9]**

Course Contents:

Engineering properties of soft, weak and compressible deposits; Principles of treatment loading (static and Dynamic); Accelerated flow; Reinforcement; Drainage and filters, Injections, thermal, electrical and Chemical Methods; Preloading; Dynamic Consolidation; Vertical drains; Granular piles; Soil nailing; Anchors; Design methods and case studies.

CE635A: Foundation Dynamics **3-0-0-0 [9]**

Course Contents:

Dynamics of elastic systems; Single and multi degrees of freedom systems; Empirical and semi-empirical 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.

CE636A: Geotechnical Earthquake Engineering **3-0-0-0 [9]**

Course Contents:

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 ground motion; Liquefaction: evaluation of liquefaction hazards, effects of liquefaction; Case studies.

CE637A: Constitutive Modeling of Soils **3-0-0-0 [9]**

Course Contents:

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 un-drained triaxial test; Stress dilatancy theory; Work hardening plasticity theory: formulation and implementation; Applications of elasto-plastic models; Special Topics: hypoelasticity-plasticity, disturbed state concept.

CE638A: Geotechnical Measurements and Explorations **2-0-3-0 [9]**

Course Contents:

Subsurface exploration planning; drilling and sampling techniques, field and laboratory tests, instrumentation and monitoring of field data, report preparation.

CE639A: Analytical and Numerical Methods in Geomechanics **3-0-0-0 [9]**

Course Contents:

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.

CE640A: Infrastructure Asset Management **2-0-0-0 [6]**

Course Contents:

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

CE641a: Project Management **3-0-0-0 [5], modular**

Course Contents:

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

CE642A: Laboratory Course in Infrastructure Engineering and Management 1-0-6-0 [9]
Course Contents:
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]

CE643b: Infrastructure Financing 3-0-0-0 [5], modular
Course Contents:
Overview: Demand for infrastructure; infrastructure sectors; role of private sectors and PPPs; Greenfield vs. Brownfield investments; sources of revenue and financing; competition and Regulation; Decision making on infrastructure projects: Cost benefit analysis, engineering economics and capital budgeting; assessment of projects; decision making framework; business process; financial records; accounting principles and conventions; financial statements; depreciation; determining cash flows; estimation of capital costs; estimation of operating costs; taxes and royalties; working capital, case studies; Evaluating capital projects: Time value of money; interest and interest rates; evaluation criteria for investment decisions; mutually exclusive, replacement and independent projects; practical issues in evaluation of projects; sensitivity, scenario, and other decision analysis techniques; case studies; Risk assessment: Returns; certainty and uncertainty; portfolio risk,; diversification; cost of capital; interest rates and cost debt; Weighted average cost capital, leverage and debt financing; opportunity cost of investment; sources of uncertainty; probability method; risk adjusted discount rate; certainty equivalent method; risk adjustment practices; Monte Carlo simulation; decision tree analysis; utility theory and risk; real options analysis; case studies; Financing of capital projects: Sources of finance; financial securities; financial markets; equity and debt financing; financing

engineering for capital projects; project finance; PPP and funding of public infrastructure; case studies

CE645A: Basic Quality and Safety Management in Construction 1.5-0-0-0 [5]

Course Contents:

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, labor 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), tunneling, bridges (*not all need be covered*)

CE647A: Construction Methods 1.5-0-0-0 [5]

Course Contents:

Earthwork (soil and aggregate) related equipments: Aggregate production crushers and their types, feeders, screens and handling equipment. Tractors, motor graders, scrapers, front-end waders, dozer, excavators, rippers, loaders, trucks and hauling equipment, compacting equipment, finishing equipment, handling and transportation operations (such as forklifts and related equipment, portable material bins, conveyors, cranes, trucks, etc.,); Asphalt construction: Asphalt pavers, compactors for asphalt concrete and other construction methods; Concrete construction: Mixing and placement-pumps, ready-mix concrete trucks, plant operational equipment, concrete paving technology, continuous concreting operation of various shapes & varying sections; Pre-cast concrete and steel construction: Launching techniques for heavy decks, handling & erecting components on tall structures, in-situ pre-stressing in high-rise structures and others; Pre-stressed concrete construction: Post-tensioning of slab-aerial transporting and others; Special construction: Tunnel, underwater, offshore, tall buildings, large-span bridges or structures and others.

CE648A: Repair and Rehabilitation of Concrete Structures **1.5-0-0-0 [5]**

Course Contents:

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; 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.

CE651A: Special Concretes **3-0-0-0 [9]**

Course Contents:

Introduction to portland cement concrete**:** Concrete production operations – Indian Standard and ACI Mix design of concrete – Fresh and hardened properties of concrete – Durability of concrete – Role of ingredients in concrete – Physical and chemical characteristics of pozzolans – Role of admixtures and additives in concrete – Experimental test parameters and measurements during concrete testing; Special cements: Need – Classifications – Blended cements, modified hydraulic cements, calcium aluminate cements, calcium sulfate based binders, calcium sulfo-

aluminate cements, GGBS based cements, shrinkage compensating (or) expansive cements – Other special cements: macro-defect free cements, phosphate cements, expansive cements, fast-setting cements, oil well cements – Performance and prescriptive specifications; Special concretes: Importance and need – high performance concrete and property based classifications. Special concretes: Mass concrete, self-compacting or self-consolidating concrete, fiber reinforced concrete, high strength concretes, roller compacting concrete. Other concretes or composites for special properties: high-volume fly ash concretes, geo-polymer concrete, pervious concrete, light weight concrete, aerated concrete, polymer or polymer modified concretes, ultra-high performance concretes, etc. Mixture proportioning and parameters in the development of special concretes; Special concreting operations: Guniting and shotcreting, pre-placed aggregate, anti-washout concretes, concrete pumping, tremie placement for underwater applications and others;

CE664A: Physicochemical Principles and Processes **3-0-0-0 [9]**

Course Contents:

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;

CE665A: Ecological and Biological Principles **3-0-0-0 [9]**

Course Contents:

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.

CE666A: Air Pollution and its Control **3-0-0-0 [9]**

Course Contents:

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.

CE667a: Principles of Environmental Management **3-0-0-0 [5], modular**

Course Contents:

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;

CE668A: Environmental Quality and Pollution Monitoring Techniques **2-0-4-0 [10]**

Course Contents:

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 sulfur, carbon monoxide, hydrocarbon; Introduction to advanced instruments for environmental analysis

CE669A: Atmospheric Physics and Chemistry **3-0-0-0 [9]**

Course Contents:

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's scattering by aerosols and clouds; Models for global warming and cooling.

CE671A: Introduction to Remote Sensing **3-0-2-0 [11]**

Course Contents:

Remote sensing system; Physics of remote sensing, EMR characteristics and interaction in atmosphere and with ground objects; Sensor types characteristics: types of resolution, FOV, IFOV, PSF; RS satellites and data products; Image processing, interpretation elements; Classification; Geometric and radiometric distortions, Geo-referencing, re-sampling methods; Atmospheric errors and removal; Satellite orbits and characteristics; Applications of optical and microwave remote sensing techniques in Civil Engineering.

CE672A: Machine Processing of Remotely Sensed Data **3-0-0-0 [9]**

Course Contents:

Image processing system; Preprocessing of remotely sensed data; Radiometric and Geometric distortions and corrections; Image enhancement; Image transformations; Pattern recognition;

CE673A: Instrumentation, Laboratory and Field Practices in Geoinformatics **0-0-0-9 [9]**

Course Contents:

Use of automatic and digital levels, electronic theodolites, total stations; Control surveys using GNSS, Total station and traversing methods (adjustment and computations of coordinates); Laser Scanning for mapping, Multi-sensor surveying, Cartography and report writing.

CE674A: Global Navigation Satellite System, 3-0-2-0 [11]

Course Contents:

Overview of GNSS and Introduction to GPS, GLONASS, GALILEO, COMPASS, IRNSS systems; GPS: Basic concepts, signal structure and code modulation Pseudo-range measurements and navigation position; Errors and biases in GPS measurements, 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., SBAS, GAGAN) and Ground based augmentation systems (e.g., WASS, EGNOS); GPS Carrier Phase measurements: Signal Differencing, Double Differencing and Triple Differencing in GPS measurements. Ambiguity resolution, multi path and other observational errors, Doppler effect on GPS signals, Code and Phase combinations for Ionosphere free, Geometry free, Multipath reduction, Ambiguity resolution, Code smoothing, Cycle slip detection and repair; GPS data processing, sequential solutions, Kalman filtering and adjustment computation for GPS; Surveying with GNSS: Point positioning, Relative positioning, Static and Kinematic positioning; Planning and field observations, Networking, Data Post processing, GIS and GPS integration; GNSS applications to Earth Systems, IGS and IERS services.

CE676A: Laser Scanning and Photogrammetry 2-0-3-0 [9]

Course Contents:

Altimetric LiDAR: Physics of laser, spectral characteristics of laser, laser interaction with objects; Airborne Altimetric LiDAR: principle: topographic and bathymetric LiDAR, multiple return, full wave digitization; Components of a LiDAR system, INS technology, INSGPS integration, measurement of laser range, calibration; Flight planning; LiDAR geo-location models; Accuracy of various components of LiDAR and error propagation, error analysis of data and error removal; Data classification techniques, raw data to bald earth DEM processing, uses of return intensity and full waveform in information extraction, LiDAR data integration with spectral data; LiDAR applications: building, tree, powerline extraction; LiDAR data visualization; Photogrammetry: metric and non-metric cameras; Geometry of near vertical and tilted photographs, heights and tilt distortions; Rectification and ortho-photographs; Stereoscopy, parallax equationand stereo measurements for height determination; Orientation interior, exterior, relative, and absolute, Mathematical model relating image, model and object space; Collinearity and coplanarity conditions, DLT; Image matching techniques; Strip and block triangulation and adjustment; Automatic DTM and Ortho-photo production.

CE677A: Geospatial Data Processing 3-0-0-0 [9]

Course Contents:

Geodetic reference systems: ICRF and ITRF, Geodetic datums, Earth ellipsoid; basic geometric geodesy; Coordinate systems and transformation; Map projections, geoid and geoidal heights and

undulations; Observations and mathematical model, precision and accuracy, rejection of observations, weights and cofactors, correlation and covariance, propagation of errors and variance covariance; Least squares adjustment computations; Sequential processing and Kalman Filtering; Variance covariance of adjusted data, error ellipse and error ellipsoid; Statistical analysis of adjusted data; Introduction to GPS; Code and phase measurements; Models for single point positioning and relative positioning using code and phase data; Methods of interpolation; Geo-statistical tools: variogram and krigging.

CE678A: Introduction to Geodesy **3-0-0-0 [9]**

Course Contents:

Geometric geodesy: Datums Horizontal & Vertical, GRS80, WGS84, ITRF; Transformation of Coordinates from one datum to another. Mean Sea level, Geoid and MSL in India. Coordinate Systems in Geodesy, Geometry of Ellipsoid, level Surface and Plumb Line, Deflection of vertical, Geoidal Separation, Natural Coordinates, Astrogeodetic deflection. Physical geodesy: Fundamentals of potential theory, Laplace Equation in spherical coordinates, Solution of Laplace Equation, Brun's formula, Fundamental equation of Physical Geodesy, Stokes' Formula, Gravity, Gravitational Potential and Gravity potential, Anomalous Gravity field, Gravity Anomaly, Gravity reductions: Free Air, Bouger and Isostatic reduction, Earth Gravity Models, Potential number and different height systems. Map Projection: Introduction to Map projection, Purpose and methods of Map projection and their classification. Conformal Map projections; LCC and Transverse Mercator Projections; Indian Grid System and UTM; Astronomy: Celestial Sphere, Definition of terms in Astronomy, Celestial coordinate systems, Variations in Celestial coordinates. Precession and Nutation; Time systems; Sidereal time, Ephemeries time, Atomic time; Rotational Time systems: UT0, UT1, UT2, CIO and Polar motion, Earth Rotation parameters and Leap second. Satellite geodesy: Introduction to Satellite Geodesy, Keplerian Motion, Geometry of ellipse, Kepler ellipse in space; perturbed satellite motion, Lagrange's and Gaussian form of perturbation equations. Introduction to GNSS satellite systems; Satellite Laser ranging, Satellite Altimetry; VLBI;

CE680A: Traffic Flow Modeling and Simulation **3-0-0-0 [9]**

Course Contents:

Traffic flow characteristics; Deterministic and stochastic models of stream flows; Car following models; Stability and diffusion phenomena in traffic; Boltzmann models; Signalized and un-signalized intersections; Coordination and optimization of network of signalized intersections; Pedestrian flow problems; Fundamentals of traffic simulation modeling; Simulation methodologies and model design; Simulation languages; Study of large scale simulation models.

CE681A: Characterization of Pavement Materials **3-0-0-0 [9]**

Course Contents:

Characterization of pavement materials; bituminous mix, aggregates, sub-grade, cemented materials and cement concrete; Experimental methods; Material modeling; Fatigue and Permanent deformation; Material inter phase and interactions; Surface energy concepts; Moisture and temperature sensitivity; Mix design concepts and approaches; Evaluation and use of recycled materials.

CE682A: Analysis of Pavement Structures **3-0-0-0 [9]**

Course Contents:

Review of basic principles of theory of elasticity. Mechanical modeling of pavement materials-bound and unbound materials, stress-dependant and time-dependent response (with reference to modeling of bituminous mix, aggregates and soil). Beams on elastic foundation; Analysis of concrete pavement - load stress and thermal stress; Elastic half-space; Analysis of bituminous pavement - load stress and thermal stress.

CE683A: Traffic Engineering **3-0-0-0 [9]**

Course Contents:

Microscopic and macroscopic traffic parameters; Traffic flow models including car following models; 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.

CE684b: Pavement Design **3-0-0-0 [5], modular**

Course Contents:

Concept of structural, functional and drainage design of pavement structure; Design of bituminous and concrete pavement – various approaches; Cost and reliability considerations; Pavement distresses, distress evaluation, maintenance measures, and network level maintenance strategy.

CE685a: Urban Transportation **3-0-0-0 [5], modular**

Course Contents:

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).

CE686A: Transportation Economics **3-0-0-0 [9]**

Course Contents:

Basics of microeconomics: demand and supply, and consumer surplus; Transport and the economy. Transport and local economic development; Transportation demand: aggregate models and disaggregate models; Costs and benefits of transportation systems; Regulation, competition, and efficiency in transportation; Investment and financing in transportation infrastructure; Revenues in transportation; Transportation project evaluation, forecasting; Economic impact assessment in transportation projects; Transportation and land use

CE687A: Traffic Safety **3-0-0-0 [9]**

Course Contents:

Introduction; Traffic Safety related issues; 4 Es of traffic safety; Areas of influence for engineers and planners; Vehicle and Human Characteristics; Vehicle related characteristics; human factors; Non-motorist road users; Engineering Components; Road design standards; pavement properties; Signs and signal design; traffic calming; Traffic Safety Audits: introduction; description; significance; Institutional framework; Case studies; Field visit; Data and its significance: crash data, traffic data, planning data, design data; Crash analysis: temporal and spatial distributions; Problem identification and selection of countermeasures: engineering, enforcement and educational treatments; Feasibility; Evaluation of safety improvement projects: mathematical and statistical techniques; Case studies; Traffic safety in planning stage: safety conscious planning, incorporation of traffic safety in planning process, pedestrians and bicyclists' safety and transportation planning; Application of advanced technologies in traffic safety; Decision support system in analyzing data.

CE688A: Airport Systems Planning and Design **3-0-0-0 [9]**

Course Contents:

Air Transport structure and organization, the challenges and the issues, Forecasting air travel demand trend forecasts and analytical methods; Air freight demand, Characteristics of the aircraft as they affect airport; Airport planning requirements: site selection, layout plan and financial plan; Air traffic control lighting and signing; Airport capacity and configuration; Geometric design of runway, taxiway and aprons; passenger terminal functions, passenger and baggage flow, design concepts, analysis of flow through terminals, parking configurations and apron facilities; Air cargo facilities flow through cargo terminals, unitized systems; Airport drainage and pavement design; Airport access problem; Environmental impact of airports.

CE689A: Characterization and Use of Aggregates in Pavement Systems 3-0-0-0 [9]

Course Contents:

Aggregate usage, Classification, Aggregate characterization – Physicochemical and Engineering properties; Unbound aggregate bases (UAB) – Permanent deformation, UAB design considerations, Drainage layer; Aggregates in Hot Mix Asphalt (HMA) – Properties, Gradation requirements, Mix design requirements, Fines in HMA; Aggregate in Portland cement concrete (PCC) – Properties, Aggregate concrete interactions, Requirements for mix design; Sub-grade soils – Classification, Characterization; Improving structural properties of unbound layers – Stabilization concepts and methods, Stabilizer selection, Use of traditional stabilizers, Mix design considerations; Use of recycled aggregates in pavement construction

CE697A: M. Tech Seminar I 0-0-0-0 [0]

Course Contents:

Each M.Tech student registered for CE697A 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 CE697A. 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 CE697A 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.

CE698A: M. Tech. Seminar II 0-0-0-0 [0]

Course Contents:

Each M. Tech. student registered for CE698A will give a 45-60 minute seminar based on his/her research work. In addition, they will be expected to attend all CE698A 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 CE698A. Grading for CE698A 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 CE698A 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.

CE699A: M. Tech Thesis 0-0-0-9 [9]

CE 721A: Random Vibrations **3-0-0-0 [9]**

Course Contents:

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.

CE723A: Finite Element Methods for Civil Engineering Applications **3-0-0-0 [9]**

Course Contents:

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; Formulation of three dimensional brick elements, Applications to stress analysis in dam, earthen embankment, tunnel, etc.; Nonlinear static and dynamic problems; geometric and material nonlinearity, P-delta effects in tall buildings, elasto-plastic 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 3-D elastic problems, consolidation, seepage, transport 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.

CE 724A: Reliability Analysis and Design of Structure **3-0-0-0 [9]**

Course Contents:

Review of the basic probability theory, Introduction to risk analysis, Structural reliability, First order reliability methods, First order reliability analysis with correlated and non-normal stochastic variables, Second order reliability methods, Simulation based reliability methods (Monte Carlo and its variants), Reliability evaluation of systems, Reliability based design of structures: Level I methods, Code Calibration and partial safety factor, Load combinations, Time-variant reliability, Reliability updating

CE725b: Vibration-based Structural Health Monitoring for CE App. 3-0-0-0 [5], modular
Course Contents:
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-to-noise 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.

CE730A: Soil-Structure Interactions 3-0-0-0 [9]
Course Contents:
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.

CE731A: Risk and Reliability in Geotechnical Engineering 3-0-0-0 [9]
Course Contents:
Introduction: Sources and types of uncertainties associated with geotechnical analysis, importance of probabilistic 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 auto correlation and auto covariance 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

CE732A: Unsaturated Soil Mechanics **3-0-0-0 [9]**

Course Content:

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.

CE733A: Geo-Environmental Design Aspects of Solid Waste **3-0-0-0 [9]**

Course Contents:

Identification, characterization and regulatory requirements for disposal of hazardous, nonhazardous and domestic wastes; waste management recycling, composting, incineration and various disposal methods; site selection and geo-environmental 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, geo synthetics amended soils and other admixtures. Leachate collection and detection system; Landfill construction; Construction quality control and performance monitoring; Application of ge-osynthetics in waste disposal design;

CE734A: Plastic Equilibrium in Soils **3-0-0-0 [9]**

Course Contents:

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 stress-strain 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.

CE760a: Surface Water Quality Modeling **3-0-0-0 [5], modular**

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.

CE761b: Subsurface Pollutant Fate and Transport **3-0-0-0 [5], modular**

Course Contents:

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

CE762b: Atmospheric Modeling **3-0-0-0 [5], modular**

Course Contents:

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.

CE763a: Solid and Hazardous Waste Management **3-0-0-0 [5], modular**

Course Contents:

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

CE764a: Environmental Toxicology and Risk Assessment **3-0-0-0 [5], modular**

Course Contents:

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

CE765b: Industrial Waste Management **3-0-0-0 [5], modular**

Course Contents:

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.

CE766A: Agricultural Sustainability and Climate Change **3-0-0-0 [9]**

Course Contents:

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. Policies of Indian; 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, **t**rends over time, current focus, future predictions. International treaties and Initiatives worldwide; Modeling Environmental fate and transport of agrochemicals; 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.

CE780A: Laboratory Course in Transportation Engineering **0-0-6-3 [9]**

Course Contents:

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

CE791A: 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.

CE792A: Scientific Writing Skills **0-0-0-5 [5]**

Course Contents:

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

CE793A: Scientific Presentation Skills **0-0-0-5 [5]**

Course Contents:

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

CE794A: Scientific Data Analysis, Presentation and Interpretation **0-0-0-5 [5]**

Course Contents:

Basics of data: Primary data, secondary data, data sources and reliability; Tools for data analysis: Identifying the right tool based on the project requirement (e.g., Matlab, R, MS Excel, Access, Arc GIS, etc); Presentation of data: Graphical, tabular, and descriptive, Use of graphing tools in programs including MS Excel, R, and MS Excel; Interpretation: Interpretation of results and documenting.

CE797A: PhD Seminar I **0-0-0-0 [0]**

Course Contents:

Each Ph.D. student registered for CE797A will give a 45-60 minute seminar based on his/her research work. In addition, they will be expected to attend all CE797A 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 CE797A. Grading for CE797A 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 CE797A 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.

CE798A: PhD Seminar II **0-0-0-0 [0]**

Course Contents:

Each Ph.D. student registered for CE798A will give a 45-60 minute seminar based on his/her research work. In addition, they will be expected to attend all CE798A 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 CE798A. Grading for CE798A 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 CE798A 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.

CE799A: Ph.D Thesis **0-0-0-9 [9]**

CE897A: MS (Research) Seminar I **0-0-0-0 [0]**

Course Contents:

Each MS (Research) student registered for CE897A will give a 45-60 minute seminar based on his/her research work. In addition, they will be expected to attend all CE897A 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 CE897A. Grading for CE897A 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 CE897A 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.

CE898A: MS (Research) Seminar II **0-0-0-0 [0]**

Course Contents:

Each MS (Research) student registered for CE898A will give a 45-60 minute seminar based on his/her research work. In addition, they will be expected to attend all CE898A 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 CE898A. Grading for CE898A 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 CE898A 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.

CE899A: MS (Research) Thesis **0-0-0-9 [9]**