CIVIL ENGINEERING

Scheme of Instruction for M Tech Civil Engineering program (2021-22)

M Tech Program in Civil Engineering

Semester 1 Common to all students
Core: 18 Credits
CE 201 3:0 Basic Geomechanics
CE 275 3:0 Transportation Systems Modelling
CE 217 3:0 Fluid Mechanics
CE 204 3:0 Solid Mechanics
CE 205 3:0 Finite Element Method
CE 211 3:0 Mathematics for Engineers

a) **To fulfill Major requirement in an Area,** students shall complete minimum 21 course credits (15 core + 6 elective on offer) and 22 Dissertation project credits in the said Area.
b) **For optional Minor in one of the other four Areas**, a student must complete minimum of 12 credits in the said Area. A course can be counted only once for determining the major or minor. For a minor in Dam Engineering, only the * marked courses qualify.

The pending course numbers (currently marked as $$$) will be assigned before Aug 2022

Major in Dam Engineering

Core: 12 Credits (+ 3 credits from term 1)
*CE 285 3:0 Disaster Management for Dams
*CE $$$ 3:0 Dam Safety Surveillance, Instrumentation and Monitoring (From Aug 2022)
CE 260 3:0 Rock mechanics (From Aug 2022)
*CE $$$ 1:2 Integrated Investigation of Dams (From Aug 2022)
CE 299 0:22 Dissertation Project

Major in Geotechnical Engineering

Core: 12 Credits (+ 3 credits from term 1)
CE 202 3:0 Foundation Engineering
CE 295 3:0 Earth Retaining Structures and Earthen Dams
CE 207 3:0 Geoenvironmental Engineering
CE 208 3:0 Ground Improvement and Geosynthetics
CE 299 0:22 Dissertation Project

Major in Structural Engineering

Core: 9 Credits (+ 6 credits from term 1)
CE 209 3:0 Mechanics of Structural Concrete
CE 210 3:0 Structural Dynamics
CE 228 3:0 Continuum Plasticity
CE 299 0:22 Dissertation Project

Major in Water Resources Engineering

Core: 12 Credits (+ 3 credits from term 1)
CE 203 3:0 Surface Water Hydrology
CE 213 3:0 Systems Techniques in Water Resources Engineering
CE 214 3:0 Ground Water Hydrology
CE 215 3:0 Stochastic Hydrology
CE 299 0:22 Dissertation Project

Major in Transportation Systems Engineering

Core: 12 Credits (+ 3 credits from term 1)
CE 262 3:0 Public Transportation Systems Planning
CE 272 3:0 Traffic Network Equilibrium
CE 235 3:0 Optimization Methods
CE 299 0:22 Dissertation Project

Electives in Dam Engineering

*CE $$$ 3:0 Assessing and Managing Risks Associated with Dams (From Aug 2022)
*CE 286 3:0 Sediment Management in Reservoirs
*CE $$$ 3:0 Hydrologic Safety Evaluation of Dams (From Aug 2022)
*CE $$$ 3:0 Dams and Spillways (From Aug 2022)
*CE 295 3:0 Earth Retaining Structures and Earthen Dams
CE 208 3:0 Ground Improvement and Geosynthetics
CE 221 3:0 Earthquake Geotechnical Engineering
CE 227 3:0 Engineering Seismology
CE 279 3:0 Computational Geotechnics
*CE $$$ 3:0 Flood Resilient Transport System (From Aug 2022)
*ST 222 3:0 Basic Concepts of Planning & Design of Hydro-Mechanical Components in Dams

Electives in Geotechnical Engineering

CE 220 3:0 Design of Substructures
CE 221 3:0 Earthquake Geotechnical Engineering
CE 227 3:0 Engineering Seismology
CE 231 3:0 Forensic Geotechnical Engineering
CE 279 3:0 Computational Geotechnics

Electives in Structural Engineering

CE 229 3:0 Non-Destructive Evaluation Methods for Concrete Structures
CE 235 3:0 Optimization Methods

CE 236 3:0 Fracture Mechanics
CE 239 3:0 Stochastic Structural Dynamics
CE 240 3:0 Uncertainty Modeling and analysis
CE 243 3:0 Bridge Engineering
CE 250 3:0 Stability and Design of Steel Structures
CE 280 3:0 Structural System Identification
CE 284 3:0 Plates, Shells, and Geometric Elasticity

Electives in Water Resources Engineering
CE 223 3:0 Hydroclimatology
CE 226 3:0 Open Channel Flow
CE 247 3:0 Remote Sensing and GIS for Water Resources Engineering
CE 249 3:0 Water Quality Modelling
CE 277 3:0 Remote Sensing in Ecohydrology
CE $$$ 3:0 Hydrologic Safety Evaluation of Dams (From Aug 2022)
AS 216 3:0 Introduction to Climate Systems

Electives in Transportation Systems Engineering
CE 269 3:0 Traffic Engineering
CE 271 3:0 Choice Modelling
CE $$$ 3:0 Flood Resilient Transport System (From Aug 2022)
DS 290 3:0 Modelling and Simulation
ST 203 3:0 Technology and Sustainable Development
MG 221 3:0 Applied Statistics

Semester 1 (mandatory for all MTech Civil Engineering students)

CE 201 (AUG) 3:0
Basic Geo-mechanics

Introduction to genesis of soils, basic clay mineralogy; Principle of effective stress, permeability and flow; Fundamentals of Tensors, Introduction to stresses and deformation measures; Mohr-Coulomb failure criteria, soil laboratory tests; Critical state and stress paths. Shear Strength and Stiffness of Sands; Consolidation, shear strength and stiffness of clays

Swetha Veeraraghavan

Wood, D.M., Soil Behaviour and Critical State Soil Mechanics, Cambridge University Press, 1991.
Bolton, M.D. A Guide to Soil Mechanics, Cambridge University Press, 1991.
Salgado, R., The Engineering of Foundations, McGraw Hill, 2008.

CE 275 (AUG) 3:0
Transportation Systems Modelling

Methods – Statistical and econometric methods for transportation data analysis; linear regression for analysis of continuous variable data (assumptions, estimation, specification, interpretation, hypothesis testing, segmentation, non-linear specification, testing of assumptions); discrete outcome models for analysis of categorical data (binary and multinomial choice models, maximum likelihood estimation); entropy methods for analysis of spatial flows; Demand-supply equilibrium; Models of traffic flow; Optimization models to predict traffic volumes;
Applications – analysis of user behaviour in infrastructure systems; travel behaviour, travel demand and supply analysis (modelling the generation, spatial and temporal distribution, modal split, and route choice of travel); analysis of vehicular traffic streams; tools for data analysis and transport modelling.

Abdul R. Pinjari & Tarun Rambha

J. de D. Ortuzar and L.G. Willumsen. Modelling Transport (4th edition), John Wiley and Sons, 2011.
P. Chakroborty and A. Das. Principles of Transportation Engineering (2nd Edition), PHI Learning Private, Ltd., 2017
F. Koppelman and C.R. Bhat. A Self Instructing Course in Mode Choice Modeling: Multinomial and Nested Logit Models, 2006.

CE 217 (AUG) 3:0
Fluid Mechanics

Vectors and tensors, divergence theorem, pressure, Archimedes principle, fluid mass conservation, heat and contaminant conservation, momentum conservation and Cauchy equation, stress tensor, constitutive relation for Newtonian fluids, Navier-Stokes equations, vorticity, laminar plane couette and open channel flow, Euler equations, potential flow approximation, simple solutions of potential flows, laminar flow in pipes and channels, transition to turbulence Reynolds stress and fluxes, laminar boundary layer, laminar bottom dense flows.

Debsunder Dutta

Kundu, Cohen and Dowling Fluid Mechanics, Sixth Ed., Academic Press, 2016.White, F.M. Fluid Mechanics, F.M., Eighth Edition, McGraw Hill, 2016.

CE 204 (AUG) 3:0
Solid Mechanics

Introduction to tensor algebra and calculus, indicial notation, matrices of tensor components, change of basis formulae, eigenvalues, Divergence theorem. Elementary measures of strain. Lagrangian and Eulerian description of deformation. Deformation gradient, Polar decomposition theorem, Cauchy-Green and Lagrangian strain tensors. Deformation of lines, areas and volumes. Infinitesimal strains. Infinitesimal strain-displacement relations in cylindrical and spherical coordinates. Compatibility. Tractions, body forces, stress at a point, Cauchy's theorem. Piola-Kirchhoff stress tensors. Momentum balance. Symmetry of the Cauchy stress tensor. St. Venant's Principle. Virtual Work. Green's solids, elastic strain energy, generalized Hooke's Law, material symmetry, isotropic linear elasticity in Cartesian, cylindrical and spherical coordinates, elastic moduli, plane stress, plane strain,. Navier's formulation. Airy stress functions. Selected problems in elasticity. Kirchhoff's uniqueness theorem, Betti-Maxwell reciprocal theorem, Principle of stationary potential energy, Torsion in circular and non-circular shafts and thin-walled tubes, warping. Pure bending of thin rectangular and circular plates, small deflection problems in laterally loaded thin rectangular and circular plates. Outline of Mindlin plate theory.

Narayan K. Sundaram

Fung, Y. C. and Pin Tong, Classical and Computational Solid Mechanics, World Scientific, 2001
Boresi, A.P., and Lynn P.P., Elasticity in Engineering Mechanics, Prentice Hall 1974.
Malvern L., Introduction to the Mechanics of a Continuous Medium, Prentice Hall, 1969

CE 205 (JAN) 3:0
Finite Element Method

Concepts of the stiffness method. Energy principles. Continuum BVP and their integral formulation. Variational methods: Raleigh-Ritz, weighted residual methods, virtual work and weak formulations. Finite element formulation of one, two and three dimensional problems, Isoparametric formulation. Computational aspects and applications, Dam structure and foundation stability applications.

J M Chandra Kishen

Zienkiewicz, O.C. and Taylor, R.L., The Finite Element Method: Vol. 1 (The Basis), Butterworth-Heinemann, 2000.
Cook R.D.. Malkus, D. S., Plesha and Witt, R.J., Concepts and Applications of Finite Element Analysis, Fourth edition, John
Wiley and Sons.
J N Reddy, An Introduction to the Finite Element Method, Second Edition, McGraw Hill Inc, 1993.

CE 211 (AUG) 3:0

Mathematics for Engineers

Revision of ordinary linear ODEs, Formal operators, Adjoint operator, Sturm-Liouville theory, eigenvalue problems, Classification of PDEs, Characteristics / first order PDEs, Laplace equation / potential theory, Separation of variables (cartesian, polar), Eigenfunction expansions, Green's functions, Introduction to boundary value problems
Probability space and axioms of probability. Conditional probability. Total probability and Bayes theorems. Scalar and vector random variables. Probability distribution and density functions. Expectation operator. Functions of random variables.
Vector spaces and subspaces, solution of linear systems, Linear independence, basis, and dimension, The four fundamental subspaces, Linear transformations, Orthogonal vectors and subspaces, Cosines and projections onto lines, Projections and least squares, The fast Fourier transform, Eigenvalues and eigenvectors, Diagonalization of a matrix, Difference equations and powers of matrices, Similarity transformations.

C. S. Manohar

Michael Stone, Paul Goldbart, 2009, Mathematics for Physics: A Guided Tour for Graduate Students, Cambridge University Press
Papoulis A and Pillai, S U., 2002, Probability, random variables and stochastic processes, Mc Graw-Hill, Boston
Strang Gilbert, 2013, Linear Algebra and Its Applications, India Edition (4th), CENGAGE LEARNING

<u>Major in Dam Engineering</u>

CE $$$ (JAN) 3:0
Disaster Management for Dams

Overview of disaster management and flood mapping, Flood risk associated with various

types of dams, Dam hazard classification systems, Dam failure modes and assessment of consequences, Dam breach modelling, Hydrologic, Hydraulic and breach outflow routing, Remote Sensing and Geographic Information Systems (GIS) applications for emergency preparedness and flood mapping, Dam hazard classification framework in India, Emergency action plans preparation and implementation.

D Nagesh Kumar & V V Srinivas

Guidelines for Developing Emergency Action Plans for Dams, Dam Safety Rehabilitation Directorate (DSRD), Central Water Commission (CWC), 2016.
Guidelines for Mapping Flood Risks Associated with Dams, DSRD, CWC, 2018.
Heywood, I., Cornelius, S., and Carver, S. An Introduction to Geographical Information Systems, Pearson Education, 1998.
Lillesand T.M. and Kiefer R.W. Remote Sensing and Image Interpretation, John Wiley & Sons, 2000.
Singh, V. P. Dam Breach Modeling Technology, Springer Science & Business Media, 2013.

CE $$$ (AUG) 3:0
Dam Safety Surveillance, Instrumentation and Monitoring

Dam safety: Overview of dam inspection for dam safety; Dam safety inspection program; Inspecting embankment dams, concrete & masonry dams; Inspecting spillways, outlets and mechanical equipment; Inspection using ROVs.
Instrumentation & Monitoring: Instrument types and their uses; Instrumentation system planning- Embankment, concrete and masonry dams, seismic monitoring; Hydrometeorological instrumentation – data collection and management, data organization & analysis, automation

M Sekhar & K S Nanjunda Rao

Guide to Hydrological Practices, Volume I, Hydrology – From Measurement to Hydrological Information, WMO-No. 168.
Technical Specifications of Hydro-meteorological, Geodetic, Geotechnical and Seismic Instruments, Dam Safety Rehabilitation Directorate, Central Water Commission,2018.
Guidelines for Safety Inspection of Dams (2018), DRIP, Central Water Commission, Government of India, New Delhi.
Guidelines for Instrumentation of Large Dams (2018), DRIP, Central Water Commission, Government of India, New Delhi.

CE 260 (AUG) 3:0
Rock Mechanics

Physical properties of intact rocks, stresses and strains, engineering properties of rocks and rock masses, theory of elasticity, rock discontinuities, in situ stresses, structural geology, strike, dip, bedding plane, types of fractures: joints, faults, folds, unconformity, formation and classification of joints, faults and folds, effects of joints, faulting, folding, geological exploration - bore holes, methods of drilling, rock strength and rock mass strength, rock failure criteria, rock mass classification: rock mass rating, geophysical methods, geology of dam sites and reservoirs, Importance of geology in dam construction, rock slope stability. numerical and computer methods in rock mechanics and under-ground excavations.

Jyant Kumar and Tejas Murthy

John A. Hudson and John P. Harrison. Engineering Rock Mechanics
John Jaeger, N. G. Cook, and Robert Zimmerman. Fundamentals of Rock Mechanics
Goodman, R. E. Introduction to Rock Mechanics. John Wiley & Sons.
Ömer Aydan. Rock Mechanics and Rock Engineering.

CE $$$ (AUG) 1:2
Integrated Investigation of Dams – Laboratory Course

Laboratory Tests: Grain Size Analysis, Atterberg Limits, Specific Gravity, Compaction, Shear Strength, Consolidation, Compressibility, Permeability and Characterization of Soils. Rock Triaxial tests.
Field Investigations: Standard Penetration Test, Dynamic Core Penetration Test, Static Cone Penetration Test, Plate Bearing Test, Pressure meter Test, Vane Shear Test, Field Density Test, Pocket Penetrometer, In-situ permeability test.
Geophysical Methods: Geophysical testing of dam, Ground penetrating radar survey, Multichannel analysis of surface testing, Seismic borehole tests down/up and cross hole testing, Electric resistivity survey, Remote operated vehicle for under dam monitoring. Case studies of dam investigations and interpretations.

P Anbazhagan & P Raghuveer Rao

An-Bin Huang, Paul W Mayne, Geotechnical and Geophysical Site Characterization, CRC Press, 2008.
Head, K.H., Manual of Soil Laboratory Testing. Vols. 1 to 3, 1981.
Compendium of Indian Standards on Soil Engineering Parts 1 and II, 1987 - 1988.

Major in Geotechnical Engineering

CE 202 (JAN) 3:0
Foundation Engineering

Subsurface investigations, Bearing capacity of shallow foundations, penetration tests, plate load tests. Settlement of shallow foundations, elastic and consolidation settlements; settlement, estimates from penetration tests, settlement tolerance. Allowable bearing pressure. Foundations on problematic soils. Principles of foundation design. Introduction of deep foundations. Bearing capacity and settlement of piles and pile groups in soils. Machine foundations. Reinforced soil beds.

Tejas G Murthy

Bowles, J.W., Foundation Analysis and Design, 5th Edn., McGraw-Hill, 1996.
Das, M. B., Principles of Foundation Engineering, Brooks/Cale Engineering Division, 1984.

CE 206 (JAN) 3:0
Earth Retaining Structures and Earthen Dams

Earth retaining structures, lateral earth pressure coefficients, Rankine and Coulomb theories, passive earth pressure computation with curved rupture surfaces, stability of gravity and cantilever retaining walls, stability of vertical cuts, braced excavations, cantilever and anchored sheet piles, stability of infinite slopes and finite slopes, different methods of slices for the analysis of finite slopes and embankments, stability analysis of earth and rock dams, forces/loads to be considered, different load cases, factors of safety in different conditions, filters for earthen dams, seepage analysis, software application.

Jyant Kumar

Terzaghi, K., Theoretical Soil Mechanics, John Wiley, 1965.
Taylor, D.W., Fundamentals of Soil Mechanics, John Wiley, 1948.
Bowles, J.W., Analysis and Design of Foundations, 4th and 5th Ed., McGraw-Hill, 1988 & 1996.
Lambe, T.W. and Whitman, R.V., Soil Mechanics, Wiley Eastern Limited, 1976.
Earth and earth-rock dams: Engineering problems of design and construction. James L. Sherard, Wiley, 1963.

CE 207 (JAN) 3:0
Geo-environmental Engineering

Sources, production and classification of wastes, Environmental laws and regulations, physico-chemical properties of soil, ground water flow and contaminant transport, contaminated site characterization, estimation of landfill quantities, landfill site location, design of various landfill components such as liners, covers, leachate collection and removal, gas generation and management, ground water monitoring, end uses of landfill sites, slurry walls and barrier systems, design and construction, stability, compatibility and performance, remediation technologies, stabilization of contaminated soils and risk assessment approaches.

G L Sivakumar Babu

Sharma, H.D., and Reddy, K.R., Geoenvironmental Engineering: Site Remediation, Waste Containment and Emerging Waste Management Technologies, John Wiley & Sons, Inc., Hoboken, New Jersey, 2004.
Rowe, R. Kerry, Quigley, Robert M., Brachman, Richard W. I., and Booker, John R. Barrier Systems for Waste Disposal Facilities , 2nd edn 2004. Spon Press, Taylor & Francis Group, London.
Tchobanoglous, G., Theisen, H. and Vigil, S.A., Integrated Solid Waste Management - Engineering Principles and Management Issues, McGraw Hill (1993).

CE 208 (JAN) 3:0
Ground Improvement and Geosynthetics

Principles of ground improvement, mechanical modification. Properties of compacted soil. Hydraulic modification, dewatering systems, preloading and vertical drains, electro-kinetic dewatering, chemical modification, modification by admixtures, stabilization using industrial wastes, grouting, cutoff walls, underpinning, soil nailing, soil reinforcement principles, properties of geo-synthetics, applications of

geo-synthetics in bearing capacity improvement, slope stability, retaining walls, embankments on soft soils and dams, filtration, drainage and seepage control with geo-synthetics, landfills and other applications of geo-synthetics, case studies.

G Madhavi Latha

Hausmann, M.R., Engineering Principles of Ground Modification, McGraw-Hill, 1990.
Jones, C.J.E.P., Reinforcement and Soil Structures, Butterworth Publications, 1996.
Koerner, R. M., Designing with Geosynthetics, Prentice Hall Inc. 1998.

Major in Structural Engineering

CE 209 (JAN) 3:0
Mechanics of Structural Concrete

Introduction, Limit state design philosophy of reinforced concrete, Stress-strain behavior in multi-axial loading, failure theories, plasticity and fracture, ductility, deflections, creep and shrinkage, Strength of RC elements in axial, flexure, shear and torsion, RC columns under axial and eccentric loading, Beam-column joints, Strut and Tie modelling, Yield line theory of slabs, Seismic resistant design, Methods for predicting the behavior of pre-stressed concrete members and structures.

Ananth Ramaswamy

Nilson, A. H., Darwin, D. and Dolan, C. W., Design of concrete structures, McGraw Hill, 2004
Lin and Burns, Design of Prestressed concrete structures, John Wiley and Sons, 2006
Agarwal and Shrikhande- Earthquake resistant design of structures, Prentice-Hall of India Pvt. Ltd. New Delhi, 2006.

CE 210 (JAN) 3:0
Structural Dynamics

Equations of motion. Degrees of freedom. D' Alembert principle. SDOF approximation to vibrating systems. Energy storage elements: mass, stiffness and damper. Undamped free vibration. Natural frequency. Damped free vibration. Critical damping. Forced response under periodic and aperiodic excitations. Support motions. Resonance. Impulse response and complex frequency response functions. Duhamel integral. Vibration isolation: FTR and DTR. Multi-DOF systems. Normal modes and natural frequencies. Orthogonality of normal modes. Natural coordinates. Uncoupling of equations of motion. Repeated natural frequencies. Proportional and non proportional damping. Damped normal modes. Principle of vibration absorber. Continuous systems. Vibration of beams. Forced response analysis by eigenfunction expansion. Moving loads and support motions. Effect of axial loads. Approximate methods for vibration analysis. Rayleigh's quotient. Rayleigh-Ritz method. Method of weighted residual. Method of collocation. Galerkin's method.

C S Manohar

Meirovich, L., 1984, Elements of vibration analysis, McGraw-Hill, NY
Clough R W and J Penzien, 1993, Dynamics of structures, McGraw-Hill, NY
Rao,S S 2004, Mechanical Vibrations, 4th Edition, Pearson Education, New Delhi.

CE 228 (JAN) 3.0
Continuum Plasticity

Brief reviews of finite deformation kinematics and constitutive closure; introduction to rational thermodynamics and formulation of constitutive theories; internal variables; dissipation inequality; physics of yielding; plastic flow and hardening; notion of yield surface; classical models for yielding; plastic flow and hardening; additive and multiplicative splitting of kinematic quantities; solutions of simple BVPs; FEM for small deformation plasticity; yield free plasticity models; linearization and computational schemes; introduction to damage mechanics.

Prerequisites: A graduate level course in solid mechanics or continuum mechanics.

Debasish Roy

A S Khan, S Huang, 1995, Continuum Theory of Plasticity, John Wiley, NY
J Lubliner, 2008. Plasticity theory. Courier Corporation.
M E Gurtin, L Anand, 2012, The Mechanics and Thermodynamics of Continua, Cambridge University Press, UK
Simo, J. C., & Hughes, T. J., 2006, Computational inelasticity, Springer Science & Business Media.

Major in Water Resources Engineering

CE 203 (JAN) 3:0
Surface Water Hydrology

Review of basic hydrology, hydrometeorology, infiltration, evapotranspiration, runoff and

hydrograph analysis. Flood routing – lumped, distributed and dynamic approaches, `hydrologic statistics, frequency analysis and probability, introduction to environmental hydrology, urban hydrology. Design issues in hydrology.

P P Mujumdar

Bedient, P. B., and Huber, W. C., Hydrology and Floodplain Analysis, Prentice Hall, 2002.
Chow, V.T., Maidment, D.R. and Mays, L.W,. Applied Hydrology, McGraw-Hill 1988.
Linsley, R.K., Kohler, M.A. and Paulhus, J.L.H., Hydrology for Engineers, McGraw Hill, 1985.

CE 213 (JAN) 3:0
Systems Techniques in Water Resources Engineering

Optimization Techniques - constrained and unconstrained optimization, Kuhn-Tucker conditions, Linear Programming (LP), Dynamic Programming (DP), Multi-objective optimization, applications in water resources, water allocation, reservoir sizing, multipurpose reservoir operation for hydropower, flood control and irrigation. Review of probability theory, stochastic optimization. Chance constrained LP, stochastic DP. Surface water quality control. Simulation - reliability, resiliency and vulnerability of water resources systems.

D Nagesh Kumar

Loucks, D.P., Stedinger, J.R. and Haith, D.A., Water Resources Systems Planning and Analysis, Prentice Hall, Englewood Cliffs, N.J, 1981.
Vedula, S. and Mujumdar, P. P., Water Resources Systems: Modelling Techniques Tata-McGraw Hill, 2005.
Srinivasa Raju, K and Nagesh Kumar, D., Multicriterion Analysis in Engineering and Management, PHI Ltd., New Delhi, 2010.

CE 214 (JAN) 3:0
Ground Water Hydrology

Ground water and hydrological cycle. Ground water movement and balance. Ground water monitoring. Equations of flow. Well hydraulics - analysis of aquifer tests and models. Regional groundwater resource evaluation and numerical modeling. Groundwater recharge estimation. Base flow analysis and models. Ground water quality. Mass transport in ground water. Tracer tests and scale effects of dispersion. Solute transport modeling.

M Sekhar

Freeze, A. R. And Cherry, J. A. Groundwater, Prentice Hall, 1979.
Fetter, C. W. Applied Hydrogeology, Prentice Hall, 1988.
Domenico, P. A., and Schwartz, F. W. Physical and Chemical Hydrogeology, John Wiley, 1990.
Fetter, C. W. Contaminant Hydrogeology, Prentice Hall, 1993.

CE 215 (JAN) 3:0
Stochastic Hydrology

Introduction to random variables, statistical properties of random variables. Commonly used probability distributions in hydrology. Fitting probability distributions to hydrologic data. Probability plotting and frequency analysis. Data generation. Modeling of hydrologic uncertainty - purely stochastic models, first order Markov processes. Analysis of hydrologic time series – linear and nonlinear correlations, Fourier analysis and spectral density functions, Wavelets. Applications to hydrologic forecasting.

V V Srinivas

Bras, R.L. and Rodriguez-Iturbe, Random Functions and Hydrology, Dover Publications, New York, USA, 1993.
Hann, C.T., Statistical Methods in Hydrology, First East-West Press Edition, New Delhi, 1995.
Ang, A.H.S. and Tang, W.H., Probabilistic concepts in Engineering Planning Design, Vol. 1, Wiley, New York, 1975.
Clarke, R.T., Statistical Models in Hydrology, John Wiley, Chinchester, 1994

Major in Transportation Systems Engineering

CE 262 (JAN) 3:0
Public Transportation Systems Planning

Modes of public transportation and application of each to urban travel needs; comparison of transit modes and selection of technology for transit service; transit planning, estimating demand in transit planning studies, demand modeling, development of generalized cost, RP & SP data and analysis techniques; functional design and costing of transit routes, models for planning of transit routes, scheduling; management and operations of transit systems; integrated public transport planning; operational, institutional, and physical integration; models for integrated planning; case studies.

Ashish Verma

A. Verma and T. V. Ramanayya, Public Transport Planning and Management in Developing Countries, CRC Press, 2014
VuchicVukan R., Urban Transit: Operations, Planning and Economics, Prentice Hall, 2005.
Gray G. E., and Hoel L. A., Public Transportation, Prentice Hall, 1992.

CE 272 (JAN) 3:0
Traffic Network Equilibrium

Traffic assignment; Fixed points and Variational inequalities; Fundamentals of convex optimization; Shortest path algorithms; Wardrop user equilibrium; System optimum and Price of Anarchy; Link-based algorithms (Method of successive averages, Frank-Wolfe); Potential games; Variants of the traffic assignment problem (Multiple-classes, Elastic demand); Path-based algorithms; Origin-based methods; Sensitivity analysis.

Tarun Rambha

Sheffi, Y. Urban Transportation Networks: Equilibrium Analysis with Mathematical Programming Methods. Prentice Hall, 1985.
Patriksson, M. The traffic assignment problem: models and methods. Courier Dover Publications, 2015.

CE 235 (JAN) 3:0
Optimization Methods

Basic concepts, Kuhn-Tucker conditions, linear and nonlinear programming, treatment of discrete variables, stochastic programming, Genetic algorithm, simulated annealing, Ant Colony and Particle Swarm Optimization, Evolutionary algorithms, Applications to various engineering problems.

Ananth Ramaswamy

Arora, J.S. Introduction to Optimization, McGraw-Hill (Int. edition)1989.
Rao, S.S., Optimization: Theory and Applications. Wiley Eastern, 1992
Current Literature.

Electives in Dam Engineering

CE $$$ (AUG) 3:0
Assessing and Managing Risks Associated with Dams

Overview of Dams Risk Assessment and Management, Role of Probability and Statistics in Engineering, Fundamentals of Probability Models, Analytical Models of Random Phenomena, Functions of Random Variables, Numerical and Simulation Methods in Probability, Statistical Inferences from Observational Data, Determination of Probability Distribution Models, Regression and Correlation Analyses, Bayesian Approach, Elements of Quality Assurance and Acceptance Sampling, Basis for a Risk-Informed Dam Safety Management Program for India, Initial Risk-Based Screening, Identification of Failure Modes, Semi-Quantitative Risk Analysis, Quantitative Risk Assessment, Risk Evaluation (Quantitative Risk Assessment), Portfolio Risk Management, Risk Governance, Institutional Framework in Dam Safety.

G L Sivakumar Babu

Dam Safety Rehabilitation Directorate (2019) Guidelines for Assessing and Managing Risks Associated with Dams, Government of India Central Water Commission Central Dam Safety Organisation.
Ang, A H S and W. H Tang (2006) Probability Concepts in Engineering: Emphasis on Applications to Civil and Environmental Engineering.
Current Literature

CE $$$ (JAN) 3:0
Sediment Management in Reservoirs

Introduction to sediment management; Erosion and sedimentation in drainage basins; Reservoir sedimentation process; Predictive methods for reservoir sedimentation; Mitigation of reservoir siltation; Reservoir sedimentation in India; Sediment management in Indian reservoirs: Good practices and problems; Discussion on case studies.

M Sekhar & K S Nanjunda Rao

Handbook for Assessing and Managing Reservoir Sedimentation (CWC, February 2019).
Morris, G. L. and Fan, J. 1998. Reservoir Sedimentation Handbook, McGraw-Hill Book Co., New York.
Graf, W. H. (1971). Hydraulics of Sediment Transport. McGraw-Hill Book Co., New York.

Dey, S. (2014). Fluvial Hydrodynamics: Hydrodynamic and Sediment Transport Phenomena. Springer-Verlag, Berlin.

CE $$$ (AUG) 3:0
Hydrologic Safety Evaluation of Dams

Significance of hydrologic safety evaluation and modeling uncertainty in hydro-meteorological processes; Standard project storm and Probable maximum precipitation (PMP); Design flood estimation - Hydro-meteorological approach: unit hydrograph construction, design storm depth estimation from PMP Atlas, storm transposition and adjustment, estimation of loss rate, base flow and time distribution coefficients, HEC-HMS model; Flood frequency analysis approach: At-site and regional frequency analysis using commonly used probability distributions in hydrology, Probability plotting and Goodness of fit tests; Reservoir sedimentation, Reservoir rule curve.

V V Srinivas

Chow, V.T., Maidment, D.R. and Mays, L.W., Applied Hydrology, McGraw-Hill, 1988.
Handbook for Assessing and Managing Reservoir Sedimentation, Dam Safety Rehabilitation Directorate, Central Water Commission, 2019.
Hosking, J. R. M., and Wallis, J. R., Regional Frequency Analysis: An Approach Based on L-Moments, Cambridge University Press, 1997.
Manual on Estimation of Probable Maximum Precipitation (PMP), World Meteorological Organization, 2009.

CE $$$ (AUG) 3:0
Dams and Spillways

Basic concepts and design considerations – area capacity curves, fixation of different hydraulic levels and capacities; Diversion arrangements – design of diversion tunnels and channels; Spillways – types, hydraulics, profiles and spillway capacity, types and design of EDA; Foundation design; Stability Analysis; Design, Construction methods and treatments for Concrete, RCC, CFRD and arch dams, barrages, thermal analysis, physical and numerical model studies; Design of related structures including piers, spillway bridges, galleries, staircase, lift, retaining walls, Software analysis with case study.

J. M. Chandra Kishen and V V Srinivas

Robert Jansen (Ed), Advanced Dam Engineering for Design, Construction, and Rehabilitation, Van Nostrand Reinhold, New York 1988.
New York State Dept. of Environmental Conservation, Guidelines for design of Dams, 1989
Central Water Commission, New Delhi, Manual for Assessing Structural Safety of existing Dams, 2020.
Khatsuria, R. M. (2004). Hydraulics of spillways and energy dissipators. CRC Press.
Pereira, G. M. (2020). Spillway Design-Step by Step. CRC Press.

CE $$$ (JAN) 3:0
Basic Concepts of Planning & Design of Hydro-Mechanical Components in Dams

Introduction and Types of Gates, Selection of Hydraulic gates, Hydraulic gates design & weight estimation, Hydro-dynamic forces, Gate operating systems, Materials, Fabrication, Erection, Testing and Commissioning, Hydraulic Gates for Dam Safety, Social and environment impacts of dam structures, Design of fish pass and alternate gate structures, Dam removal and the sediment effect.

Punit Singh

Design of Small Dams-A Water Resources Technical Publication, United States Department of The Interior, Bureau of Reclamation, Third edition - 1987
Bandyopadhyay, J. (2017). Restoration of ecological status of Himalayan rivers in China and India: The case of the two mother rivers—The Yellow and the Ganges. In Environmental Sustainability from the Himalayas to the Oceans (pp. 69-98). Springer, Cham.
Bandyopadhyay, J. (2018). Why we need a new perspective on rivers. The Third Pole, 25.
Emil Mosonyi, Waterpower development, Hardcover – 2009, ISBN-10: 8185240841
Giesecke, Wasserkraftanlagen, Springer Verlag
Knauss, J. (1987). Swirling flow problems at intakes: Hydraulic structures design manual. Rotterdam, The Netherlands: AA Balkema.
Schwartz, H. I, (1964). Projected Nappes subjected to harmonic pressures. Proceedings of the Institution of Civil Engineers, 28(3), 313-326.

<u>Electives in Geotechnical Engineering</u>

CE 220 (AUG) 3:0

Design of Substructures

Design considerations, field tests for bearing capacity and settlement estimates, selection of design parameters. Structural design considerations. Codes of practice. Design of spread footings, combined footings, strap footings, ring footings, rafts, piles and pile caps and piers.

P Raghuveer Rao

Bowles, J.E. Foundation analysis and design. 5th Edn., McGraw Hill, 1996
Indian Standard Codes

CE 221 (AUG) 3:0
Earthquake Geotechnical Engineering

Introduction to engineering seismology, Plate tectonics, Seismic wave propagation, Earthquake magnitude, Ground motion, Seismic hazard analysis, Ground response analysis, Soil-structure interaction, Local site effects, Dynamic properties of soils, Liquefaction phenomena, analysis of pore pressure development. Laboratory and in-situ testing for seismic loading, analysis and design of slopes, foundations, earth retaining structures and dams for seismic loading, Case histories, Earthquake hazard mitigation techniques .

G Madhavi Latha

Geotechnical Earthquake Engineering By Steven L. Kramer, Pearson Education, 2003. Geotechnical Earthquake Engineering Handbook, Robert W. Day, McGraw-Hill, 2002.

CE 227 (JAN) 3:0
Engineering Seismology

Introduction to earthquake hazards. Strong ground motions, tsunamis, landslides, liquefaction. Overview of plate tectonics and earthquake source mechanisms. Theory of wave propagation. Body waves and surface waves. Concepts of seismic magnitudes and intensity. Seismic station. Sensors and data loggers, mechanical and digital sensors. Interpretation of seismic records – acceleration, velocity and displacement. Regional seismicity and earthquakes in India. Seismic zonation – scales, macro and micro, attenuation, recurrence relation. Seismic hazard analysis - deterministic and probabilistic. Site characterization – different methods and experiments. Local site effects, ground motion amplifications. Development of response/design spectrum. Liquefaction hazard assessments. Integration of hazards using GIS. risk and vulnerability Studies.

P Anbazhagan

Earthquake Engineering – From Engineering Seismology to Performance Based Engineering, Edited by Bozorgnia, Y. and Bertero, V.V., CRC Press Washington 2004.
Leon Reiter, Earthquake hazard Analysis – Issues and Insights, Columbia University Press New York 1990.
Steven L Kramer, Geotechnical Earthquake Engineering, Pearson Education, 2003.

CE 231 (AUG) 3:0
Forensic Geotechnical Engineering

Introduction, Definition of a Forensic Engineer, Types of Damage, Planning the Investigation, investigation methodology, Collection of Data, Distress Characterization, Development of Failure, Hypothesis, Diagnostic Tests, Back Analysis, Technical Shortcomings, Legal Issues Reliability Aspects, Observation Method of Performance Evaluation, Case Histories related to settlement of Structures, lateral movement, backfill settlements, causes due to soil types such as collapsible soil, expansive soil, soluble soils, slope Failures and landslides, debris flow, slope softening and creep, trench collapses, dam failures, foundation due to earthquakes, erosion, deterioration, tree roots, groundwater and moisture problems, groundwater problems, retaining failures problems, pavement failures and issues, failures in soil reinforcement and geosynthetics, development of codal provisions and performance based analysis procedures.

G L Sivakumar Babu

Bolton M (1991) A Guide to Soil Mechanics, Universities Press
Robert W. Day (2011) Forensic Geotechnical and Foundation Engineering, Second Edition, McGraw-Hill Companies, Inc.
Rao, V.V.S. and Sivakumar Babu, G.L (2016) Forensic Geotechnical Engineering, Springer Nature.

CE 279 (JAN) 3:0
Computational Geotechnics

Introduction to numerical modelling with focus on geotechnical aspects, basics of continuum mechanics, introduction to finite difference and finite element methods, constitutive modelling

of linear elastic and elasto-plastic behaviour of soils, static & dynamic loads and boundary conditions applicable to dams and other structures, coding of finite element and finite difference problems using MATLAB, examples of solving for dam's response using the commercial Geotech software FLAC.

Swetha Veeraraghavan

Bathe, K.J., Finite Element Procedures in Engineering Analysis, Prentice-Hall,
Englewood Cliffs, NJ, 1982.
Wood, D.M., Soil Behavior and Critical State Soil Mechanics, Cambridge University
Press, New York, 1990.
Hai-Sui Yu, Plasticity and Geotechnics, Springer, 2006
Desai, C.S. and Christian, J.T. Eds. Numerical Methods in Geotechnical Engineering,
McGraw-Hill, 1977.

Electives in Structural Engineering

CE 229 (JAN) 3:0
Non-Destructive Evaluation Methods for Concrete Structures

Planning and interpretation of in-situ testing of concrete structures; Surface hardness methods; Fundamental bases and methodologies of non-destructive evaluation (NDE) techniques related to concrete structures; NDE methods for concrete testing based on sounding: Acoustic emission (AE) testing of concrete structures; NDE methods for concrete testing based on sounding: Ultrasonic pulse velocity (UPV) methods; Partially destructive strength tests related to concrete; cores; Examples of UPV corrections for reinforcement; examples of evaluation of core results

R Vidya Sagar

J. H. Bungey and S. G. Millard (1996) Testing of concrete in structures. Blackie Academic & Professional, 1996, chapman & Hall publishers.
V. M. Malhotra and N. J. Carino (2005) Handbook on Nondestructive Testing of Concrete Ed. by V.M. Malhotra and N.J. Carino., CRC publishers.
C. V. Subramanian (2016) Practical Ultrasonics., Narosa publishers
C. U. Gross and M. Ohtsu (2008) Acoustic Emission Testing., Springer-Verlag Berlin Heidelberg
JSNDI (2016) Practical Acoustic Emission testing. Springer Japan 2016.

CE 235 (JAN) 3:0
Optimizatin Methods

Basic concepts, Kuhn-Tucker conditions, linear and nonlinear programming, treatment of discrete variables, stochastic programming, Genetic algorithm, simulated annealing, Ant Colony and Particle Swarm Optimization, Evolutionary algorithms, Applications to various engineering problems.

Debraj Ghosh

Arora, J.S. Introduction to Optimization, McGraw-Hill (Int. edition)1989.
Rao, S.S., Optimization: Theory and Applications. Wiley Eastern, 1992
Current Literature.

CE 236 (AUG) 3:0
Fracture Mechanics

Introduction; Linear Elastic Fracture Mechanics; Design based on LEFM; Elasto-Plastic Fracture Mechanics; Mixed Mode Crack Propagation; Fatigue Crack Propagation; Finite Elements in Fracture Mechanics.

R Vidya Sagar

T. L. Anderson, Fracture Mechanics, CRC press, Fourth Edition, 2017, Boca Raton, Florida
David Broek, Elementary Fracture Mechanics, Sijthoff and Noordhoff, The Netherlands.
Prashanth Kumar, Elements of Fracture Mechanics, Wheeler Publishing, New Delhi.
J. F. Knott, Fundamentals of Fracture Mechanics, Butterworths, London.

CE 239 (JAN) 3:0
Stochastic Structural Dynamics

Introduction to random variables and processes: probability, random variables. Transformations of random variables. Stationary, ergodic and non-stationary stochastic processes. Linear transformation of stationary-ergodic stochastic processes. Normal Gaussian Stochastic processes. PSD functions. Wiener processes and an introduction to Ito calculus. Response of SDOF and MDOF oscillators under random inputs. Oscillators subject to white noise excitations.

Input-output relations in time and frequency domains under the assumption of response stationarity. Handling non-stationarity in the response. level crossing and first passage problems. Nonlinear oscillators under random inputs: sources of non-linearity. Equivalent linearization and perturbation methods. Numerical integration and Monte Carlo simulations: Ito-Taylor expansions. Stochastic Euler and Heun methods. Higher order implicit and explicit methods. Errors in Monte-Carlo simulations. Variance reduction techniques.

Debasish Roy

Lin, Y K, Probabilistic Structural Dynamics, McGraw-Hill
Kloeden, P.E. and Platen, E., Numerical Solutions of Stochastic Differential Equations, Springer
Ghanem, R.G and Spanos, P D, Stochastic Finite Elements: A Spectral Approach, Springer-Verlag.

CE 240 (AUG) 3:0
Uncertainty Modeling and analysis

Deterministic vs nondeterministic perspectives. Sources of uncertainty. Epistemic vs. aleatoric uncertainty. Data driven vs. physics driven uncertainty modelling. Different approaches such as probabilistic, interval, fuzzy. Introductory probability and statistics, point estimation, hypothesis testing, time series. Modelling: connecting data to the probabilistic models. Discretization of random fields. Tools for uncertainty propagation. Computational aspects of uncertainty propagation.

Debraj Ghosh

Applied Statistics and Probability for Engineers by Douglas C. Montgomery & George C. Runger, John Wiley and Sons, 2010
Current literature

CE 243 (AUG) 3:0
Bridge Engineering

Bridge types, aesthetics, general design considerations and preliminary design, IRC / AASHTO design loads, concrete bridge design - reinforced and prestressed girder bridges, steel bridge design Composite bridges, design of bridge bearings, Pier, Abutment and foundation; seismic and wind load analysis, analysis of cable supported bridge systems, bridge inspection and maintenance.

Ananth Ramaswamy

Barker and Puckett Design of Highway Bridges, John Wiley and Sons 2007

CE 250 (Jan) 3:0
Stability and Design of Steel Structures

Concepts and principles of stability of beam-columns- Differential equations for beam-columns, effects of concentrated lateral loads, effects of different end conditions such as built-in or elastic supports; continuous beams and columns with axial loads, torsion in Thin walled sections, Lateral buckling of beams, elastic buckling of rigid frames, arches; influence of material inelasticity and imperfections in the structural stability of member ; application of energy and numerical methods in critical buckling load assessments; design of structural steel thin walled members and built up sections.

Ananth Ramaswamy

Timoshenko, S. and Gere, J., "Theory of Elastic Stability" McGraw Hill.
Wai-Fa Chen and Lui, E.M., "Structural Stability: Theory and Implementation" Elsevier.
Bazant , Z.P.,and Cedolin, Luigi "Stability of Structures:. Elastic, Inelastic, Fracture and Damage Theories", Dover Publications.

CE 280 (Aug) 3:0
Structural System Identification

Time invariant system identification. Bayesian formulations and computation using MCMC samplers. Bayesian dynamic state space models. Kalman filter and its variants. Combined state and parameter estimation. UKF and particle filters. Model selection. Inverse senstivity analysis. Review of signal processing tools: FFT algorithm. Short time Fourier transform and wavelet transform. Supervised and unsupervised learning. Notion of digital twins.

C S Manohar

C R Farrar and K Worden, 2012, Strctural health monitoring: a machine learning perspective, John Wiley and Sons.
A Doucet, et al., 2001, Sequential Monte Carlo methods in practice, Springer, New York.
K P Murphy, 2012, Machine learning: a probabilistic perspective, MIT Press.

CE 284 (AUG) 3:0:

Plates, Shells, and Geometric Elasticity

Brief review of elasticity and variational principles. Classical plate theories: Elements of plate deformation; pure bending of thin circular and rectangular plates under various boundary conditions; Navier and Lévy solutions; introduction to plates of general shapes; problems in combined lateral and membrane loading in thin rectangular and circular plates. Introduction to Mindlin-Reissner shear plates; elements of large deflection of thin plates and the Fóppl-von Kármán equations. Introduction to stability and plate buckling. Applications of plate theories. Brief introduction to the differential geometry of surfaces; First and second fundamental forms; principal curvatures; Gauss curvature. Shell theories: General Kirchhoff-Love linear theory of thin shells; membrane theory of shells for cylindrical shells and shells of revolution; engineering applications. Introduction to computational methods for shell and plate problems.Other topics as time permits (orthotropic plates; plates on elastic foundation; thermal stresses).

Narayan K. Sundaram

Ventsel and Krauthammer, Thin Plates and Shells: Theory, Analysis and Applications
Timoshenko and Woinowsky-Krieger, Theory of Plates and Shells
Villagio, Mathematical Models for Elastic Structures
Historical and current literature

Prerequisites:
Graduate-level solid mechanics (CE 204 / ME 242 or equivalent), or instructor consent.

Electives in Water Resources Engineering

CE 223 (JAN) 3:0
Hydroclimatology

Introduction to Hydroclimatology; Hydroclimate temporal variation - El-Nino southern oscillation (ENSO), Global impact of ENSO, ENSO forecasting, other oscillations (NAO and PDO), Identification of ENSO-streamflow teleconnection; Hydroclimate simulation and forecasting - Prediction versus forecasting, Uncertainty in prediction, General Circulation Models, Coupled Model Inter-comparison Projects; Forecast verification measures; Weather forecasts and downscaling techniques; Climate information based streamflow forecasting; Long-term water balance - Budyko's Framework, Linear watershed model ('abcd' model), Data assimilation, Ensemble Kalman Filter (EnKF), application of EnKF on linear watershed model; Impact of Climate change on hydroclimate variables.

Rajarshi Das Bhowmik

Shelton ML. Hydroclimatology: perspectives and applications. Cambridge: Cambridge University Press; 2009.
Wilks DS. Statistical methods in the atmospheric sciences. Academic Press; 2011 Jun 3.
Maraun D, Widmann M. Statistical downscaling and bias correction for climate research. Cambridge University Press; 2018 Jan 18.

CE 226 (AUG) 3:0
Open Channel Flow

Basic Concepts of Fluid Mechanics; Introduction to Open-channel Flow; Uniform Flow; Non-uniform Flow: Gradually Varied, and Rapidly Varied flows; Spatially Varied Flow; Unsteady Flow; Pollutant Transport in Open Channels.

Rajarshi Das Bhowmik

Chow, Ven Te. Open-channel hydraulics. Vol. 1. New York: McGraw-Hill,1959.

Chaudhry, M. Hanif. Open-channel flow. Springer Science & Business Media, 2007.

Srivastava, Rajesh. Flow through open channels. Oxford Higher Education, 2008.

CE 247 (AUG) 3:0
Remote Sensing and GIS for Water Resources Engineering

Basic concepts of remote sensing. Airborne and space borne sensors. Digital image processing. Geographic Information System. Applications to rainfall - runoff modeling. Watershed management. Irrigation management. Vegetation monitoring. Drought and flood monitoring. Environment and ecology. Introduction to digital elevation modeling and Global Positioning System (GPS). Use of relevant software for remote sensing and GIS applications.

D Nagesh Kumar

Lillesand T.M. and Kiefer R.W. Remote Sensing and Image Interpretation, John Wiley & Sons, 2000.

Sabins, F.F. Remote Sensing - Principles and Interpretation, Freeman & Co., New York, 1986. Heywood, I., Cornelius, S., and Carver, S. An Introduction to Geographical Information Systems, Pearson Education, 1998.

CE 249 (AUG) 3:0
Water Quality Modeling

Basic characteristics of water quality, stoichiometry and reaction kinetics. Mathematical models of physical systems, completely and incompletely mixed systems. Movement of contaminants in the environment. Water quality modeling in rivers and estuaries - dissolved oxygen and pathogens. Water quality modeling in lakes and ground water systems.

M Sekhar

Chapra, S.C., Surface Water Quality Modeling, McGraw Hill, 1997.
Tchobanoglous, G., and Schroeder, E.D., Water Quality, Addison Wesley, 1987.

CE 277 (JAN) 3:0

Remote Sensing in Ecohydrology

Introduction to ecohydrology, fundamentals of exchange of energy and water in terrestrial ecosystems, soil temperature and moisture, surface energy fluxes, modeling leaf photosynthesis and stomatal conductance, introduction to plant canopies and radiation regime, soil, plant atmosphere continuum, fundamentals of optical remote sensing, remote sensing of vegetation composition, structure and function, applications of remote sensing to coupled water and carbon cycles in terrestrial ecosystems.

Debsunder Dutta

Ecological Climatology, 3rd Edition, Gordon Bonan, Cambridge University Press. An Introduction to Environmental Biophysics, 1998, G.S. Campbell, J. Norman, Springer. Remote Sensing and Image Interpretation, 2015, Lilliesand, Thomas and Chipman, John Wiley & Sons. Some current and previous literature on remote sensing and modeling.

<u>Electives in Transportation Systems Engineering</u>

CE 269 (AUG) 3:0
Traffic Engineering

Traffic flow elements and its characterization: vehicle characteristics, human factors, infrastructure elements, capacity and LoS concepts, Highway Capacity Manual (HCM) methods. Uninterrupted Traffic Flow: speed-flow-density relationships, multi-regime models, car-following, lane-changing, simulation framework. Interrupted Traffic Flow: signal design, shock-wave theory, gap-acceptance behavior, delay and queue analysis. Design of traffic facilities: expressways, signalized and un-signalized intersections, interchanges, parking, signs and markings.

Tarun Rambha

Roess, R.P., Prassas E.S. & McShane, W.R. (2010), Traffic Engineering, Prentice Hall, USA.
May, A. D. (1990), Traffic Flow Fundamentals, Prentice Hall, USA.
Highway Capacity Manual (2010), Transportation Research Board, USA.
Kadiyali, L. R. (2000), Traffic Engineering and Transport Planning, Khanna Publishers, India.
Salter, R J. & Hounsell, N. B. (1996), Highway Traffic Analysis and Design, Macmillan Education, UK.

CE 271 (JAN) 3:0
Choice Modeling

Individual choice theories; Binary choice models; Unordered multinomial choice models (multinomial logit and multinomial probit); Ordered response models (ordered logit, ordered probit, generalized ordered response; rank-ordered data models); Maximum likelihood estimation; Sampling based estimation (choice-based samples and sampling of alternatives); Multivariate extreme value models (nested logit, cross-nested logit); Mixture models (mixed logit and latent class models); Mixed multinomial probit; Integrated choice and latent variable models; Discrete-continuous choice models with corner solutions; Alternative estimation methods (EM, analytic approximations, simulation); Applications to travel demand analysis.

Abdul R. Pinjari

F. Koppelman & C.R. Bhat. A Self-Instructing Course in Mode Choice Modeling: Multinomial and Nested Logit Models, 2006.
K. Train. Discrete Choice Methods with Simulation (2nd edition), Cambridge University Press, 2009.

M. Ben-Akiva & S.R. Lerman. Discrete Choice Analysis: Theory and Application to Travel Demand, MIT Press, 1985.

CE $$$ (AUG) 3:0
Flood Resilient Transport System

Introduction to principles of resilient transport system and development of evacuation plans; Transport network planning and design; Measures/policies for adaptation of transport system to flooding situation; Modelling, simulation, and geo-spatial analysis methods to design resilient transport system and robust evacuations plans; Integrated macro and micro traffic simulation models for scenario analysis and development of evacuation plans; Exposure to soft computing tools for transport modelling and simulation

Ashish Verma

M A P Taylor, Climate Change Adaptation for Transportation Systems (1st Edition), Elsevier, 2020.
Vajjarapu, H., Verma, A., & Hemanthini AR., Evaluating climate change adaptation policies for urban transportation in India, International Journal of Disaster Risk Reduction, 47, 101528, 2020.
Jan F. Feenstra, Ian Burton, Joel B. Smith, Richard S. J. TOI, Handbook on methods for climate change impact assessment and adaptation strategies, UNEP, 1998.