INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE: **Department of Civil Engineering**

1. Subject Code: **CEN-501** Course Title: **Environmental Modeling & Simulation**
2. Contact Hours: **L:3 T:1 P:2/2**
3. Examination Duration (Hrs.): **Theory : 3 Practical : 0**
4. Relative Weight: **CWS: 20 PRS: 20 MTE: 20 ETE: 40 PRE: 0**
5. Credits : **04** 6. Semester : **Autumn** 7. Subject Area: **PCC**
8. Pre-requisite: **Nil**
9. Objective : To develop students skills for using computer to analyze, design and control environmental systems.

10. Details of the Course

S.N.	Contents	Contact Hours
1	Introduction to modeling and simulation, development process and applications; Model classification and evaluation; Basics of Environmental System Design; Software Packages	5
2	Lumped and distributed parameter models, solution methods using MATLAB; Simulation methodologies, continuous, discrete, Monte - Carlo, agent-based, game theory, system dynamics	7
3	Design of experiments, Reactor Modeling, kinetics, parameter estimation, RTD studies and flow regimes	5
4	Cluster analysis, ecological modeling, classification of ecological data, stability of complex ecosystems	6
5	Microbial dynamics, mixing in lakes, river self-purification, dynamics of DO, BOD and nutrients	7
6	Modeling transport phenomena, atmospheric and porous media transport and transformation of pollutants	7
7	Environmental risk management, health risk assessment, Uncertainty and information dissemination	5
	Total	**42**

List of Experiments:

1. Introductory exercises on MATLAB and other software
2. Solving lumped and distributed parameter models on MATLAB
3. Simulation using MATLAB – an exercise on a simulation method
4. Design of experiment and modeling of a bioreactor using MATLAB
5. Design problems related to water and wastewater systems using suitable software
6. Analysis of DO, BOD and nutrient dynamics in lake and river self purification
7. Analysis of cluster in ecological modeling and stability of a complex ecosystem
8. Modeling pollutant transport and transformation through atmosphere or porous media.

11. Suggested Books

S.N	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1.	Deaton, M.L and Winebrake, J.J., "Dynamic Modeling of Environmental Systems", Springer-Verlag.	2000
2.	Walter J. Weber, Jr., "Environmental Systems and Processes – Principles", Modeling and Design, Wiley Interscience.	2001
3.	Metcalf and Eddy Inc., "Wastewater Engineering : Treatment and Reuse", 4th Ed., Tata McGraw Hill.	2003
4.	Ramaswami, A., "Integrated Environmental Modeling", John Wiley.	2005
5.	Ramasami, A., "Integrated Environmental Modeling", John Wiley & Sons.	2005

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE: **Department of Civil Engineering**

1. Subject Code: **CEN-502** Course Title: **Water Treatment**
2. Contact Hours : **L: 3 T: 1 P: 0**
3. Examination Duration (Hrs.): **Theory : 3 Practical : 0**
4. Relative Weight**: CWS : 25 PRS : 0 MTE : 25 ETE : 50 PRE : 0**
5. Credits **: 04** 6. Semester**: Autumn** 7. Subject Area**: PCC**
8. Pre-requisite**: Nil**
9. Objective: To familiarize the students with principles, design and operation of various conventional and advanced processes for treatment of water.

10. Details of Course:

S. No.	Contents	Contact Hours
1	Introduction to Unit Operations and Processes Involved in Water Treatment, Natural purification of water	4
2	Coarse Material Removal Operations: Coarse Screens, Fine Bar Screens, Disc and Drum Screens, Pre-Settling Tank Aeration-Iron and Manganese Removal.	4
3	Coagulation and Flocculation: Rapid mixing, Floccultaion, Different Types of Flocculators, Mechanical Mixers. Sedimentation: Theoretical Concepts, Class-1 Clarification, Class-2 Clarification, Zone Settling, Compression, Resuspension of Particles by Turbulence, Short Circuiting and Dispersion, Different Types of Sedimentation Tanks, Tube Settlers.	7
4	Filtration: General Features of Rapid Sand and Deep Bed Filters, Filter Media, Characteristics and Preparation, Different Operating Parameters Affecting the Filtration Performance, Hydraulics of Filtration and Backwashing Cycles, Removal Particles, Removal Mechanisms of Filtration.	6
5	Chemical Precipitation, Hardness Removal- Lime Soda Softening. Adsorption: Different Types of Adsorption, Adsorption Isotherms, Adsorption Kinetics in Batch Reactors, Breakthrough Curve and Design of Fixed Bed Adsorber.	7
6	Principles of different membrane processes: Reverse Osmosis, Electrodialysis, Nanofiltration, Ultrafiltration, Microfiltration. Effect of Operational Parameters, Membrane antifouling techniques. Removal of nitrate, fluoride , iron, manganese, arsenic etc. from water	7
7	Disinfection- Chlorination, UV & Ozonation, Advanced Oxidation Processes. Removal of organics from drinking water: organics in raw water, reactions of organics with disinfections and their health implications, strategies for organic reduction and removal, case studies. Sludge Treatment- Sludge generation & various methods of sludge treatment and disposal from water treatment plants	7
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1.	Weber, W.J., “Physico-chemical Processess”, Wiley Interscience	1983
2.	S. Vigneswaran and C. Visvanathan, “Water Treatment Processes: Simple Options”, CRC Press.	1995
3.	R.L.Droste, “Theory and Practice of Water and Wastewater Treatment”, John Wiley.	1997
4.	S.R. Qasim, Edward and Motley and Zhu, H., “Water Works Engineering – Planning, Design and Operation”, Prentice Hall, India.	2002
5.	Nicholas G. Pizzi, “Water Treatment Operator Handbook”, American Water Works Association.	2005

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE: CIVIL ENGINEERING

1. Subject Code: **CEN-503** Course Title: **Wastewater Treatment**
2. Contact Hours: **L: 3 T: 1 P:0**
3. Examination Duration (Hrs.): **Theory : 3 Practical : 0**
4. Relative Weight**: CWS: 25 PRS : 0 MTE : 25 ETE: 50 PRE: 0**
5. Credits **: 04** 6. Semester**: Autumn** 7. Subject Area**: PCC**
8. Pre-requisite**: Nil**
9. Objective: To familiarize the students with principles, design and operation of various conventional and advanced processes for treatment of water and wastewater.

10. Details of Course:

S. No.	Contents	Contact Hours
1	Introduction: Biological Wastewater Treatment, Biological Sludge Treatment. Biological Systems: Fundamentals of Microbiology and Biochemistry, Bioenergetics and Metabolism, Kinetics of Biological Growth.	5
2	Process Analysis: Reaction Rates, Effect of Temperature on Reaction Rate, Enzyme Reaction and Kinetics, Effect of Temperature on Reaction Rate, Reactor Analysis, Residence Time Distribution.	5
3	Sewerage System: Domestic wastewater characteristics, Flow equalization, population equivalent, Treatment flow chart. Primary, secondary and tertiary treatment of domestic wastewater. Downstream Wastewater Treatment for Reuse and Recycle – Need for downstream processing, Guidelines for wastewater recycling, Small and package plants for wastewater treatment	7
4	Activated Sludge Process: Substrate Utilization and Biomass Growth, Monod's Kinetics, Estimation of Kinetic Parameters, Process Description and its Modification, Process Design, Process Performance Evaluation, Trouble Shooting. Nitrogen Removal-Biological nitrification and Denitrification.	6
5	Activated sludge process design for nutrient removal, Process operation: (F/M), mean cell residence time, oxygen requirement. Biological and Chemical phosphorus removal, Sedimentation of Activated Sludge. Advanced Activated Sludge Process- Sequencing Batch Reactor, Oxidation Ditch and membrane bioreactors	7
6	Biofilm Process: Trickling Filter, Biotower, Rotational Biological Contactor, Integrated Activated Sludge and Biofilm processes. Stabilization Ponds & Aerated Lagoons: Types and their description, Design, Operation and Maintenance	7
7	Anaerobic Processes: Process Description; Process Design, Operation and Maintenance; Sludge Digestion. Sludge Treatment- Thickening, Dewatering- Mechanical and Sludge drying Beds.	5
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1.	Metcalf and Eddy, "Wastewater Engineering", 4th Ed., McGraw Hill.	2003
2.	R.L. Droste, "Theory and Practice of Water and Wastewater Treatment", John Wiley.	1997
3.	S.R. Qasim, "Wastewater Treatment Plants – Planning, Design and Operation", CRC Press, Florida.	1999
4.	Ramalho, R.S., "Wastewater Treatment', Wiley.	1995

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE: **Department of Civil Engineering**

1. Subject Code: **CEN-504** Course Title: **Environmental Chemistry**

2. Contact Hours : **L: 3** **T: 1** **P: 2**

3. Examination Duration (Hrs.): **Theory : 03** **Practical : 0**

4. Relative Weight**: CWS : 15 PRS : 25 MTE : 20 ETE : 40 PRE : 0**

5. Credits**: 05** 6. Semester**: Autumn** 7. Subject Area**: PCC**

8. Pre-requisite**: Nil**

9. Objective: To develop understanding of environmental interactions and measurement of water and wastewater quality parameters.

10. Details of Course:

S. No.	Particulars	Contact Hours
1.	Introduction and Scope – Air-water, Water-sediment / Soil and air – water – sediment – interactions, Physical water quality parameters	5
2.	Chemistry of Natural Waters – Reaction stoichiometry, Basic concepts from equilibrium chemistry, Acid base reactions, Solubility of salts (soil chemistry) and related water quality parameters	14
3.	Nutrients and Organic Impurities in water, Oxidation – Reduction reactions, Water and wastewater quality parameters (ORP, BOD, COD, TOC etc.)	9
4.	Biochemical reactions in water and wastewater , Reaction kinetics, sludge production, Methane output, Oxygen requirement etc.	5
5.	Heavy metals in water, Complex formation, metal speciation	2
6.	Air Chemistry – General concepts of air chemistry, Stratospheric and Tropospheric chemistry	7
	Total	**42**

List of Experiments:

1. Determination of pH, conductivity, TS, TDS, Turbidity, Total coliform, Fecal coliform
2. Determination of major ions : Ca^{++}, Mg^{++}, Na^{+}, HCO_3^{-}, Cl^{-}, SO_4^{--}, Checking correctness of analysis : Ion balance, TDS – EC ratio, Determination of Saturation Index and CCPP
3. Determination of Nutrients, BOD, COD, TOC, UV-absorbance, K_{ow}
4. Determination of Residual Cl_2, Available Cl_2 and Chlorine Demand
5. Analysis of Trace Metals in Water and Wastewater

12. Suggested Books:

S. No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1.	C.N. Sawyer, P.L. McCarty and G.F. Parkin, "Chemistry for Environmental Engineering and Science (Fifth Edition)", Tata McGraw Hill	2003
2.	Davis, M.L. and Cornwell, D.A., "Introduction to Environmental Engineering", McGraw Hill.	2007
3.	G.M. Masters and Ela, "Introduction to Environmental Engineering and Science", 3rd Ed., PHI Learning.	2008
4.	Colin Baird, "Environmental Chemistry (Second Edition)", W.H. Freeman & Co.	1999
5.	S.W. Stumn and J.J. Morgan, "Aquatic Chemistry", Wiley.	1981
6.	Standard Methods of Water and Wastewater Analysis APHA, AWWA.	2005

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE: **Department of Civil Engineering**

1. Subject code: **CEN-505** Course Title : **Environnemental Hydraulics**
2. Contact Hours: **L: 3 T: 1 P: 0**
3. Examination Duration (Hrs): **Theory: 3 Practical: 0**
4. Relative Weight: **CWS: 25 PRS: 0 MTE: 25 ETE 50 PRE: 0**
5. Credits: **04** 6. Semester: **Autumn** 7. Subject Area: **PCC**
8. Pre-requisite: **Fluid Mechanics**
9. Objective : To teach students the basic principles of environmental hydraulics.

10. Details of the Course:

S. No.	Contents	Contact Hours
1	Introduction and scope, review of basic principles of engineering fluid mechanics, continuity, momentum, and energy equations, steady flow through pipes- hydraulic gradient and total energy line, basics of open channel flow; Ground water, well hydraulics, well design and constructions,	7
2	Parallel, compound and equivalent pipes, head losses in pipes, design of pressurized conduits,	2
3	Mixing for environmental engineers, various forms of mixing in the environment, modeling the mixing: advection dispersion equation, Various forms of advection dispersion eq. and its solution. Dispersion,	16
4	Special cases of mixing, density stratified flow, tide, literature review	4
5	Mass transfer in gas liquid and liquid liquid system with special emphasis on aeration, literature review	10
6	Project presentation	3
	Total	**42**

11. Suggested Books:

S.No.	Name of Authors/Book/Publishers	Year of Publication/ Reprint
1	Roberson, J.A., Cassidy, J.J., Chaudhry, M.H. "Hydraulic Engineering", 2nd Edition, Wiley.	1998
2	Chadwick, A., Morfett, J., Borthwick, M. "Hydraulics in Civil and Environmental Engineering", 5th Edition, CRC Press.	2004
3	Lee, C. C., Lin, S.D. "Handbook of Environmental Engineering Calculations", McGraw Hill.	2007
4.	Schnoor, J.L., Environmental Modeling: Fate of Chemicals in Water, Air and Soil, John Wiley & Sons, New York	1996

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE: **Department of Civil Engineering**

1. Subject Code: **CEN-511** Course Title: **Surveying Measurements and Adjustments**
2. Contact Hours : **L: 3** **T : 0** **P: 2**
3. Examination Duration (Hrs) : **Theory : 3** **Practical : 0**
4. Relative Weight : **CWS : 15** **PRS: 25** **MTE: 20** **ETE: 40** **PRE: 0**
5. Credits : **04** 6. Semester: **Autumn** 7. Subject Area : **PCC**
8. Pre-requisite: **Nil**
9. Objective of Course : To introduce the various concept of field surveying.
10. Details of Course :

Sl. No.	Contents	Contact Hours
1.	Principles of surveying, Various maps and their scales, Symbols and colours, Generalisation of information	3
2.	Surveying measuring equipments & techniques - Distance, Height, Angles and Directions. Compass Surveying: Bearings and Azimuths	4
3.	Levelling: Balancing of sights, Differential leveling, profile and cross-section leveling, reducing the levels- Height of Instrument and Rise & Fall method. Contouring	6
4.	Trigonometrical Leveling and Tacheometric surveying	5
5.	Methods of control establishment: Traversing, Traverse computations and adjustments. Triangulation and Trilateration.	7
6.	Plane Table Surveys	3
7.	Modern surveying equipments- Total Station	4
8.	Concept of observation and model, The mathematical model and errors, Random and systematic errors, Purpose of adjustments	4
9.	Least squares adjustment techniques, Adjustment by linear and non-linear functions in the model, Adjustment by observation equation (variation of parameters) and condition equation methods.	6
	Total	**42**

List of Practicals :

1. Study of different types of maps, maps in the making, conventional symbols and map numbering system.
2. Introduction to various surveying equipments – Level and Theodolites.
3. Measurement of magnetic bearing of traverse with at least five sides using Prismatic Compass.
4. Use of Auto level to determine the Reduced Level of at least five different given points (use Height of Collimation method)
5. Use of Auto level to determine the Reduced Level of a number of points by fly levelling and close the network at the given Bench Mark (use Rise and Fall method)
6. Profile and Cross-sectional levelling of a road at an interval of 20m and 2m respectively of the central line of the road using Total Station. Plot the profile and cross section on a graph sheet at a suitable scale.
7. (a) Determine the height of a building using Trigonometric Levelling.
   (b) Layout the traverse with at least five sides using Tacheometric observations.
8. Measurement of horizontal and vertical angles by Repetition and Reiteration Methods.

9. Mount drawing sheet on Plane table and draw 2cm grid on sheet. Plot the traverse on drawing sheet. Plot the details/features.
10. Plot the detail/features and draw elevation contours using Plane Table surveys.
11. Total Station for taking field measurements
12. Use of Total Station for angles and distance measurements.

11. Suggested Books :

Sl. No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1.	Arora, K.R., "Surveying", Vol. 1, 2 & 3, Standard Book House.	2005
2.	Chandra, A.M., "Higher Surveying", New Age International Publications.	2002
3.	Subramanian, R., "Surveying and Levelling", Oxford University Press.	2007
4.	Gopi, S, Sathikumar, R. and Madhu, N., "Advanced Surveying, Pearson Publications.	2007

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE: **Department of Civil Engineering**

1. Subject Code: **CEN-512** Course Title: **Principles of Photogrammetry**
2. Contact Hours : **L: 3 T : 0 P: 2**
3. Examination Duration (Hrs) : **Theory : 3 Practical : 0**
4. Relative Weight : **CWS: 15 PRS: 25 MTE: 20 ETE: 40 PRE: 0**
5. Credits : **04** 6. Semester: **Autumn** 7. Subject Area : **PCC**
8. Pre-requisite: **Nil**
9. Objective of Course : To introduce the various concept of photogrammetry.

1. Details of Course :

Sl. No.	Contents	Contact Hours
1.	Photogrammetry - Types of photographs, Scale determination, Flying Height, Relief and Tilt Displacements	5
2.	Stereovision, Base Lining, Parallax bar, Height determination from stereo-photographs, Flight planning.	6
3.	Porro-Koppe, Reprojection principle, Double reprojection, Equivalent and calibrated focal length of lens and concept of principal distance.	5
4.	Concepts of orientation: Interior, Relative and Absolute Orientation of Aerial Photographs.	5
5.	Optical—Mechanical, Graphical and Numerical methods of Relative orientation, Over-correction factors and its determination.	5
6.	Model deformations, Residual errors and precision of Inner and Relative Orientation, Relative Orientation in hilly terrain and in difficult country.	6
7.	Stereo-plotting Instruments: 1st, 2nd & 3rd order instruments, General principle of calibration, Testing and adjustment of instruments. Photogrammetric mapping: Basic idea of control requirement and photogrammetric extension of control.	5
8.	Fundamentals of close Range Photogrammetry, Application in Engineering and non-topographic fields.	5
	Total	**42**

List of Practicals :

1. Determination of scale and flying Height of an aerial photograph.
2. Use of Stereo Vision Test Card and Base lining of a pair of photographs.
3. Determination of height using Parallax Bar and correction contours.
4. Mapping using Sketch Master.
5. Introduction to various types of Stereo plotting machines.
6. Interior and Relative Orientation of a pair of photograph on Wild A8.
7. Absolute Orientation
8. Map plotting using Wild A8.

2. Suggested Books :

Sl. No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1.	Moffitt, F.H. and Mikhail, E.M., "Photogrammetry", 3rd Ed., Harper and Row Publisher.	1992
2.	Wolf, P.R. and Dewitt, B.A., "Elements of Photogrammetry", McGraw-Hill .	2007
3.	Luhmann, T., Robson, S., Kyle, S. and Beohm, J., "Close Range Photogrammetry and 3D Imaging", Gruyter Inc.	2013
4.	Mikhail, E.M., Bethal, J.S. and McGlove, J.C., "Introduction to Modern Photogrammetry", John Wiley and Sons.	2001

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE: **Department of Civil Engineering**

1. Subject code: **CEN-513** Course Title: **Remote Sensing and Digital Image Processing**
2. Contact Hours: **L: 3** **T: 0** **P: 2**
3. Examination Duration (Hrs): **Theory: 03** **Practical: 0**
4. Relative Weight: **CWS: 15** **PRS: 25** **MTE: 20** **ETE: 40** **PRE: 0**
5. Credits: **04** 6. Semester: **Autumn** 7. Subject Area: **PCC**
8. Pre-requisite: **Nil**
9. Objective : To introduce the concepts of Remote Sensing and Digital Image Processing.

10. Details of Course :

Sl. No.	Contents	Contact Hours
1	Introduction: History of Remote Sensing, Remote sensing components, Sources of Energy, EMS and Radiation, Black body and associated laws Interaction of EMR with Atmosphere—Scattering, Refraction, Absorption, Transmission, Atmospheric windows, Interaction of EMR with Earth Surface—Spectral reflectance curves, Radiation Calculation,	7
2	Platforms and Sensors: Orbit al movement and Earth coverage. Sunsynchronous and Geosynchronous satellites, Active and passive sensors, PAN, Multi High resolution and Hyper spectral Sensors, Thermal and Microwave sensors, Sensors characteristics, Indian Remote Sensing Satellite Programme, Other satellites	7
3	Hard copy Images, Visual image analysis: Image interpretation: Elements, Keys and aids, Basic instrumentation, Visual interpretation of images	3
4	Image Processing software, Digital data products and their characteristics. Digital Image Formats. Colour image generation, Initial data statistics, Histogram and Scatter plot, Mosacing.	7
5	Pre-processing: Atmospheric, Radiometric and Geometric corrections.	3
6	Image enhancement, Contrast stretching, Noise removal, Low and high pass filters, other filters. Edge detection, Texture images	5
7	Ratio and NDVI Images, Taselled cap transformation, PCA and its uses	5
8	Digital image analysis: Supervised and unsupervised image classification methods, Accuracy assessment	5
	Total	**42**

List of Practicals :

1. Introduction to different types of remote sensing data products.
2. Use of spectro-radiometer to collection signature of different earth objects.
3. Training of photo interpretation files.
4. Visual Analysis of a satellite data.
5. Demo on different types of remote sensing based software.
6. Initial Statistics Extraction.
7. Atmospheric Correction.
8. Geometric Correction
9. Image Enhancement
10. Image Transformation

11. Suggested Books :

Sl. No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1.	Chandra, A.M. and Ghosh, S.K., "Remote Sensing and Geographical Information System", Narosa.	2006
2.	Gibson, P.J., "Introductory Remote Sensing – Principles and Concepts", Routledge.	2000
3.	Gibson, P.J. and Power, C.H., "Introductory Remote Sensing – Digital Image Processing and applications", Routledge.	2000
4.	Gonzales, R.C. and Woods, R.E., "Digital Image Processing", 2nd Ed., Pearson Education.	2006
5.	Jain, A.K., "Fundamentals of Digital Image Processing", Prentice Hall.	2004
6.	Lillesand, T.M. and R.W. Kiefer, "Remote Sensing and Image Interpretation", 4th Ed., John Wiley.	2000
7.	Mather, P.M., "Computer Processing of Remotely Sensed Images", John Wiley.	1999
8.	Schowengerdt, R.A., "Remote Sensing – Models and Methods for Image Processing", Academic Press.	1997

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE: **Department of Civil Engineering**

1. Subject Code: **CEN-514** Course Title: **Geodesy and GPS Surveying**
2. Contact Hours : **L: 3 T : 0 P: 2**
3. Examination Duration (Hrs) : **Theory : 3 Practical: 0**
4. Relative Weight : **CWS: 15 PRS: 25 MTE: 20 ETE: 40 PRE: 0**
5. Credits : **04** 6. Semester: **Autumn** 7. Subject Area : **PCC**
8. Pre-requisite: **Nil**
9. Objective of Course : To understand the basics of geodesy and global positioning system which will help to further broaden one's background in the general field of geomatics engineering.

10. Details of the Course

S. N.	Contents	Contact Hours
1	Introduction to geodesy & its development	2
2	Earth and its size & shape, Earth and its motions- annual, spin, precession, nutation, polar motion	8
3	Earth and its gravity field – anomaly, gravity potential, geoid & deflection to vertical	5
4	Earth and its atmosphere – physical properties, wave propagation through atmosphere, temporal variations, gravitational field of the atmosphere.	5
5	Introduction to GPS- its components, Instruments & processing software, GPS signals. GPS data collection, Planning & Methods	7
6	GPS observables- Pseudo range and carrier phase; Parameter Estimations	6
7	Data Handling- Cycle slip detection and correction, Ambiguity resolution, GPS data processing, Errors in GPS data – Satellite Geometry, Multipath errors & corrections; Accuracy of GPS data	7
8	Datum transformation	2
	Total	**42**

List of Practicals :

1. Demonstration, hands-on practice and temporary adjustments of a Gravimeter.
2. Demonstration, hands-on practice and collection of data using navigational GPS receiver. Further, download and process the data using software.
3. Demonstration, hands-on practice and collection of data using Geodetic GPS receivers. Further, download and process the data using software.
4. To determine the relative as well as absolute gravity of some stations and along a profile of 100meter at an interval of 5 meter. Find the location of the stations as well as plot the profile using GPS receivers.
5. To determine the height of a tower using a Gravimeter and verify the result with that by using GPS receiver.
6. To determine the variations of gravity with elevation. Determine the elevation of the stations using GPS receiver.
7. To determine the gravity anomaly profile in the IITR campus having absolute locations of the stations using GPS receivers.

11. Suggested Books :

Sl. No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1.	Bomford, G., “Geodesy”, Clarendon Press, Oxford.	1980
2.	Hoffmann-Wellenhoff, B., “GPS Theory & Practice”, Springer.	2001
3.	Leick, A., “GPS Satellite Surveying”, John Wiley.	2005
4.	Torge, W., “Geodesy : An Introduction”, Walter de Gruyter, Berlin.	1980
5.	Vanicek, Peter and Krakiwsky, E.J., “Geodesy : The Concepts”, Elsevier.	1986

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

1. Subject Code : **CEN-521** Course Title : **Advanced Numerical Analysis**
2. Contact Hours : **L: 3 T : 0 P: 2**
3. Examination Duration (Hrs) : **Theory : 3 Practical : 0**
4. Relative Weight : **CWS : 15 PRS: 25 MTE: 20 ETE: 40 PRE: 0**
5. Credits : **04** 6. Semester: **Autumn** 7. Subject Area : **PCC**
8. Pre-requisite: **Nil**
9. Objective of Course: To impart knowledge of various numerical techniques to solve the problems of geotechnical engineering.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	Introduction, roots of a non-linear equation and roots of a polynomial of n^{th} degree [incremental search method, method of successive approximations, Newton's method, bisection method, secant method, Müller's method, synthetic division, Bairstow's method] and convergence study	10
3.	Solution of (non-homogeneous) linear algebraic equations, review of matrix algebra, Gauss elimination method, Cholesky's decomposition method, householder method, Gauss-Siedal iterative method	06
4.	Solution of non-linear algebraic equations, method of successive approximation, Newton's method, modified Newton – Raphson method, secant method	04
5.	Eigen values and Eigen vectors, reduction of generalized Eigen value problem to the standard Eigen value problem, methods for obtaining Eigen values and Eigen vectors [polynomial method, vector iteration method, Mises power method, Jacobi method]	08
6.	Time marching schemes for solution of problems in time domain, numerical integration (2 – D) [Newton – Cotes method, Gauss – Legendre method]	04
7.	Solution of ordinary and partial differential equations, Euler's method, Runge – Kutta method, finite difference method, applications to problems of beam and plates on elastic foundation, Laplacian equation, consolidation equation, laterally loaded piles etc	10
	Total	**42**

List of Practicals:

1. Development of algorithms/codes by considering different methods for: roots of equations
2. Solution of simultaneous equation (linear-nonlinear),
3. Eigen value and Eigen vectors
4. Numerical integration
5. Solution of differential equation

11. Suggested Books:

S. No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1.	Chapra, S. C. and Canale R. P., "Numerical Methods for Engineers", Tata McGraw hill	2003
2.	Carnahan, B., Luther, H. A. and Wilkes, J. O., "Applied Numerical Methods", John Wiley	1969
3.	Heath, M. T. ,"Scientific Computing : An Introductory Survey", McGraw hill	1997
4.	Douglas Faires, J. and Richard Burden, "Numerical Methods", Thomson	2003
5.	Rajasekaran, S., "Numerical Methods in Science and Engineering", S. Chand	1999

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

1. Subject Code : **CEN-522** Course Title : **Advanced Soil Mechanics**
2. Contact Hours : **L: 3 T : 1 P: 2/2**
3. Examination Duration (Hrs) : **Theory : 3 Practical : 0**
4. Relative Weight : **CWS :20 PRS: 20 MTE: 20 ETE: 40 PRE: 0**
5. Credits : **04** 6. Semester: **Autumn** 7. Subject Area : **PCC**
8. Pre-requisite: **Nil**
9. Objective of Course : To give advanced knowledge of mechanics governing the behaviour of soils to students so that they are able to understand the behaviour of foundations and structures constructed in/on them.

10. Details of Course :

S. No.	Contents	Contact Hours
1.	Fundamental aspects of soil mechanics, characteristics of soil, particulate nature, weight volume relationship	02
2.	Flow of water through soils, permeability, flownets	02
3.	Theory of elasticity, few aspects of elasticity, plane stress and plane strain problems	05
4.	Pore water pressure, undrained loading, determination of pore water pressure parameters	05
5.	Consolidation, Terzaghi's 1-D consolidation theory, layered soils, time dependent loading, 2-D problems, 3-D consolidation (axisymmetric problems, vertical drains), creep/secondary consolidation and basic of rheological models	09
6.	Shear strength, stresses in soils, Mohr's circle, stress paths, UU, CU, CD tests, drained and undrained stress-strain relationships and shear strength	09
7.	Critical state theory, normal consolidation line, critical state line, Roscoe surface, Hvorslev surface, no tension line	04
8.	Constitutive laws for soils	06
	Total	**42**

List of Practicals:

1. Determination of relative density
2. Vane shear test
3. Consolidation tests
4. Direct shear and tri-axial compression test – UU, CU, CD tests
5. Influence of strain rate
6. Stress path testing etc.

11. Suggested Books:

S. No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1.	Das, Braja, M., "Advanced Soil Mechanics", Taylor & Francis	1983
2.	Lambe, T. William and Whitman, Robert V., "Soil Mechanics", John Wiley.	2000
3.	Craig, R.F., "Soil Mechanics", Chapman & Hall.	1993
4.	Suklje, L., "Rheological Aspects of Soil Mechanics", John Wiley.	1969
5.	Terzaghi, K. and Peck, R.B., "Soil Mechanics in Engineering Practice", John Wiley.	1967
6.	Davis, R.O. and Selvadurai, E.P.S. "Elasticity and Geomechanics", Cambridge University Press.	1995

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

1. Subject Code : **CEN-523** Course Title : **Engineering Behaviour of Rocks**
2. Contact Hours : **L: 3 T : 1 P: 2/2**
3. Examination Duration (Hrs) : **Theory : 3 Practical : 0**
4. Relative Weight : **CWS :20 PRS: 20 MTE: 20 ETE: 40 PRE: 0**
5. Credits : **04** 6. Semester: **Autumn** 7. Subject Area : **PCC**
8. Pre-requisite: **Nil**
9. Objective of Course : To impart to students the knowledge of the basic mechanics which governs the behaviour of rocks and rock masses so that they can understand the mechanics of structures constructed in/on them.

10. Details of Course :

S. No.	Contents	Contact Hours
1.	Introduction, definitions, development of rock mechanics, activities and applications of rock mechanics and rock engineering	3
2.	Properties of intact rocks, types of specimens for testing-,uniaxial compressive strength tests- tolerance limits and requirements, preparation of specimens , factors affecting UCS, modes of failures, stress strain curves, post failure behaviour	6
3.	Tensile strength, direct methods, indirect methods, miscellaneous methods	2
4.	Shear tests, single shear test, double shear test, punch test, direct shear test, oblique shear test, triaxial strength of rocks - triaxial strength test, Coulomb's theory, Mohr envelopes and p-q plots	4
5.	Strength criteria for intact rocks, rock strength criteria by Coulomb-Navier, Griffith's (1924), Mcclintock and Walsh (1962), empirical failure criteria by Bieniawski (1974), Hoek and Brown (1980), Ramamurthy (1993), Singh and Singh (2005)	8
6.	Classification of intact rocks, geological classification, geotechnical classification, classification of jointed rocks, Terzaghi (1946), Deere (1968), RQD, RMR, Q-systems, BGD, J_f concept, RMI, GSI, strength behaviour of jointed rocks, scale effect, classification approaches	8
7.	Deformational behaviour of jointed rocks, definitions, computation of modulus of deformation through RMR, Q, GSI and J_f, constitutive modeling	7
8.	Flow through jointed rock mass, hydraulic conductivity and flow nets, ground water flow in fractured rocks, measurement of water pressure, field tests	4
	Total	**42**

List of Practicals:

1. Physical properties
2. Uniaxial compression test
3. Brazilian test
4. Point load strength index test
5. Triaxial compression test
6. Oblique shear test
7. Sonic wave velocity
8. Permeability test
9. Field shear test
10. Schmidt hammer test.

11. Suggested Books

S. No.	Name of Authors/Books/Publishers	Year of Publication / Reprint
1.	Hudson, J.A. and Harrison, John P., "Engineering Rock Mechanics- An Introduction to the Principles", Elsevier.	2000
2.	Jaeger, J.C. and Cook, N.G.W., "Fundamentals of Rock Mechanics", Mathew & Co. Ltd.	1979
3.	Singh, B. and Goel, R.K., "Rock Mass Classification- A Practical Engineering Approach", Elsevier.	2006
4.	Hoek, E., "Practical Rock Engineering", Rock Science.	2000
5.	Ramamurthy, T., "Engineering in Rocks", PHI Learning Pvt. Ltd.	2008

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

1. Subject Code : **CEN-524** Course Title : **Soil Dynamics and Machine Foundations**
2. Contact Hours : **L: 3 T : 1 P: 0**
3. Examination Duration (Hrs) : **Theory : 3 Practical : 0**
4. Relative Weight : **CWS :25 PRS: 0 MTE: 25 ETE: 50 PRE: 0**
5. Credits : **04** 6. Semester: **Autumn** 7. Subject Area : **PCC**
8. Pre-requisite: **Nil**

9. Objective of Course : To impart to students the basic knowledge in theory of vibrations and behaviour of soils under dynamic loads so that foundations for various types of machines could be designed.

10. Details of Course :

S. No.	Contents	Contact Hours
1.	Theory of vibrations, single, two and multiple degree of freedom systems, vibration isolation, vibration absorbers, vibration measuring instruments	10
2.	Strength characteristics, factors affecting, philosophy of design of equipments, studies by dynamic tri-axial and oscillatory shear equipments	06
3.	Liquefaction, mechanism, factors affecting, studies by dynamic tri-axial testing, oscillatory shear box, shake table and blast tests, assessment of liquefaction potential	06
4.	Dynamic earth pressure, analytical and graphical methods, displacement analysis of retaining walls, seismic stability of slopes : modified Swedish circle and Taylor's method, concept of yield acceleration and evaluation of displacement of embankment	06
5.	Machine foundations, types and basic requirements, analysis and design of foundations for reciprocating and impact type machines, introduction to the design of T.G. Foundations	06
6.	Determination of dynamic elastic constants, various methods including block resonance tests, cyclic plate load tests, wave propagation tests, oscillatory shear box test, soil liquefaction test	08
	Total	**42**

11. Suggested Books

S. No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1.	Das, B.M., "Fundamentals of Soil Dynamics", Elsevier.	1983
2.	Steven Kramer, "Geotechnical Earthquake Engineering", Pearson.	2008
3.	Prakash, S., "Soil Dynamics", McGraw Hill.	1981
4.	Kameswara Rao, N.S.V., "Vibration Analysis and Foundation Dynamics", Wheeler.	1998
5.	Saran, S., "Soil Dynamics and Machine Foundations", Galgotia.	2006

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

1. Subject Code : **CEN-531** Course Title : **Advanced Hydrology**
2. Contact Hours : **L: 3** **T : 1** **P: 0**
3. Examination Duration (Hrs) : **Theory : 3** **Practical : 0**
4. Relative Weight : **CWS : 25** **PRS: 0** **MTE: 25** **ETE: 50** **PRE: 0**
5. Credits : **4** 6. Semester: **Autumn** 7. Subject Area : **PCC**
8. Pre-requisite: **Nil**
9. Objective: To introduce the fundamentals of hydrological system and mathematical models in surface hydrology.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Hydrologic system and hydrologic budget, fundamental laws of hydrology; atmospheric water vapor.	5
2.	**Hydrologic Inputs:** Precipitation and its forms, snowfall and rainfall; measurement techniques and space-time characteristics	5
3.	**Hydrologic Abstractions:** Infiltration, depression, storage, evapotranspiration; measurement techniques and their modeling	6
4.	**Stream flow:** Measurement techniques, space-time characteristics, rating curves	5
5.	**System Approach:** Unit Hydrograph, IUH, GIUH	6
5.	**Mathematical Modeling**: Linear and Nonlinear models, Physically based models	7
6.	**Hydrological routing**: Flood forecasting, Advance regression and correlation analysis.	5
7.	**Advanced Method of Frequency Analysis**: Outliers, Time series analysis.	3
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1.	Chow, V.T., Maidment, D.R. and Mays, W.L., "Applied Hydrology", McGraw Hill.	1988
2.	Ojha, C.S.P., Berndtsson, R. and Bhunya, P., “Engineering Hydrology”, Oxford University Press.	2008
3.	Wanielista, M., Kersten, R. and Eaglin, R., “Hydrology”, John Wiley.	1997

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

1. Subject Code : **CEN-532** Course Title : **Advanced Fluid Mechanics**
2. Contact Hours : **L: 3** **T : 1** **P: 2/2**
3. Examination Duration (Hrs) : **Theory : 3** **Practical : 0**
4. Relative Weight : **CWS : 20** **PRS: 20** **MTE: 20** **ETE: 40** **PRE: 0**
5. Credits : **4** 6. Semester: **Autumn** 7. Subject Area : **PCC**
8. Pre-requisite: **Nil**
9. Objective: To introduce the governing equations, laminar flow, turbulent flow and measurements of turbulence.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Kinematics of Flow:** Equation of continuity in cartesian, polar and cylindrical coordinates, rate of deformation, dilation, vorticity	3
2.	**Standard 2D Flow Patterns:** Source, sink, doublet and their combinations, construction of flows by superposition, D'Alembert's paradox	5
3.	**Laplace Equation:** Solution by graphical and relaxation methods, conformal mapping, solution by separation of variables	4
4.	**Laminar Flow:** Derivation of Navier-Stokes equations – exact solutions for flow between parallel plates, Couette flow, flow near a suddenly accelerated plate and an oscillating plate.	8
5.	**Boundary Layers:** Similarity solutions of boundary layer equations, Falkner-Skan Wedge flows, Karman's momentum integral equations, Karman-Puhlhausen approximate solution, separation in boundary layer under adverse pressure gradient, turbulent boundary layer.	8
6.	**Turbulent Flows:** Reynolds equations of motion, semi-empirical theories of turbulence, velocity profiles for inner, outer and overlap layers, equilibrium boundary layers.	8
7.	**Measurement of Turbulence and Statistical Theory of Turbulence:** Isotropic and homogeneous turbulence, probability density functions, correlation coefficients, decay of isotropic turbulence.	6
	Total	**42**

List of Practicals:

1. To study the surface profile and the total head distribution in a forced vortex flow.
2. To study the flow behavior in a pipe bend and to calibrate the pipe bend (i.e., bend or elbow meter) for discharge measurement.
3. To study the boundary layer velocity profile, and to determine the exponent in the power law of velocity distribution, boundary layer thickness and displacement thickness.
4. To study the velocity distribution in an open channel and to estimate the energy and momentum correction factors.
5. To study the characteristics of a hydraulic jump.
6. To study the velocity distribution downstream of an expansion (with and without splitter plates) in a channel.

11. Suggested Books

S. No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1.	White, F.M., "Fluid Mechanics", McGraw-Hill.	1979
2.	Schlichting, H., "Boundary Layer Theory", McGraw-Hill.	1979
3.	Garde, R.J., "Turbulent Flow", Wiley Eastern Limited.	1994
4.	Pope, S. B., "Turbulent Flows", Cambridge University Press.	2000
5.	Rouse, H., "Advanced Mechanics of Fluids", John Wiley.	1959
6.	Ojha, C.S.P., Berndtsson, R. and Chandaramouli, P.N., “Fluid Mechanics”, Oxford University Press.	2010

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

1. Subject Code : **CEN-533** Course Title : **Free Surface Flows**
2. Contact Hours : **L: 3** **T : 1** **P: 0**
3. Examination Duration (Hrs) : **Theory : 3** **Practical : 0**
4. Relative Weight : **CWS : 25** **PRS: 0** **MTE: 25** **ETE: 50** **PRE: 0**
5. Credits : **4** 6. Semester: **Autumn** 7. Subject Area : **PCC**
8. Pre-requisite: **Nil**
9. Objective: To introduce the concepts of free surface flow and its applications in flood control, design of drainage and water ways.
10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Free surface flows, velocity distribution, resistance relationships, specific energy and specific force, normal and critical depths computations, governing equation and computation of gradually varied flows.	6
2.	**Hydraulic Jump:** Elements of hydraulic jump, hydraulic jump in variety of situations including contracting and expanding geometries and rise in floor levels, control of hydraulic jump using baffle walls and cross jets.	6
3.	**Supercritical Flows:** Flow past deflecting boundaries, oblique shock waves.	4
4.	**Spatially Varied Flows:** Flows past side weirs, De Marchi equations, design of side weirs, flow past bottom racks, trench weirs and waste water gutters.	6
5.	**Aerated Flows:** Bulking of flow, mechanism of air entrainments, modelling of aerated flows, development of self-aerated flows, uniform aerated region, aeration over spillway.	6
6.	**Stratified Flows:** Thermal stratification in water bodies including reservoirs, modelling of stratified flows.	4
7.	**Unsteady Flows:** St. Venant's equations and their solution using method of characteristics and finite difference schemes; dam break problem, hydraulic flood routing.	6
8.	**Channel Transitions:** Sub-critical and supercritical.	4
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1.	Chow, V.T., "Open Channel Hydraulics", McGraw Hill.	1959
2.	Choudhary, M.H., "Open-Channel Flows", Prentice-Hall.	1994
3.	Ranga Raju, K.G., "Flow Through Open Channels, Tata McGraw Hill.	2003
4.	Chanson, H., "The Hydraulics of Open Channel Flow: An Introduction", Elsevier.	2004
5.	French, R.H., "Open-Channel Hydraulics", McGraw-Hill.	1994
6.	Wood, I.R., "Air Entrainment in Free-Surface Flows", A.A. balkema.	1991

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

1. Subject Code : **CEN-534** Course Title : **Modelling, Simulation and Optimization**
2. Contact Hours : **L: 3** **T : 1** **P: 0**
3. Examination Duration (Hrs) : **Theory : 3** **Practical : 0**
4. Relative Weight : **CWS : 25** **PRS: 0** **MTE: 25** **ETE: 50** **PRE: 0**
5. Credits : **4** 6. Semester: **Autumn** 7. Subject Area : **PCC**
8. Pre-requisite: **Nil**
9. Objective: To introduce the fundamentals of modeling, simulation and optimization techniques in Civil Engineering
10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Systems and Models:** Fundamentals of systemic approach, system modeling, classification of models, model structure, Linear, non-linear, time-invariant, time variant models, State-space models, Distributed parameter models, System Synthesis, Direct and inverse problems, Role of optimization, Role of computers, examples from hydrology/water resources engineering	8
2.	**Regression Analysis:** Linear and Multiple Regression analysis, analysis of residues, tests of goodness of fit, Parsimony criterion, role of historical data, examples from hydrology / water resources engineering.	4
3.	**Spatial Distribution**: Polynomial surfaces, Kirging, Spline functions, Cluster Analysis	4
4.	**Time Series Analysis:** Auto-cross correlation analysis, identification of trend, spectral analysis, identification of dominant cycles, smoothening techniques, Filters, time series of rainfall and stream flow.	6
6.	**Random variables:** Basic concepts, probability density distribution functions, Expectation and standard deviation of discrete and continuous random variables and their functions, covariance and correlation, commonly used theoretical probability distributions (uniform, normal, binomial, poisson's and negative exponential), Fitting distributions to raw data, Chi-square and Kolmogrov-Smirnov;s tests of the goodness of fit, Central limit theorem, various algorithms for generation of random numbers	7
7.	**Monte Carlo simulation:** basic concepts, generation of synthetic observations, statistical interpretation of output, Evaluation of definite integrals,	4
8.	Optimization: Introduction, Classical methods, Linear Programming, Dynamic Programming, Nonlinear optimization, Constrained optimization techniques	9
	Total	**42**

11. Suggested Books

S. No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1.	Law, A.M. and Kelton, W.D., "Simulation Modeling and Analysis", Tata McGraw Hill.	2007
2.	Daniel, C. and Wood, P.S., "Fitting Equations to Data", John Wiley.	1980

3.	Ljung, L., "System Identification Theory for the Users", Prentice Hall.	1999
4.	Rao S. S., "Engineering Optimization,Theory and Pratice", New Age International Publishers.	2012
5	Deb, K., "Optimization for Engineering design", Prentice Hall of India.	2006
6	Vedula S. and Mujumdar P. P. "Water Resources Systems", Tata McGraw Hill.	2005

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

1. Subject Code : **CEN-535** Course Title : **Ground Water Engineering**
2. Contact Hours : **L: 3** **T : 1** **P: 0**
3. Examination Duration (Hrs) : **Theory : 3** **Practical : 0**
4. Relative Weight : **CWS : 25** **PRS: 0** **MTE: 25** **ETE: 50** **PRE: 0**
5. Credits : **4** 6. Semester: **Spring** 7. Subject Area : **PEC**
8. Pre-requisite: **Nil**

9. Objective: To introduce fundamentals of groundwater hydrology, groundwater assessment and groundwater development.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Definition of groundwater, role of groundwater in hydrological cycle, groundwater bearing formations, classification of aquifers, flow and storage characteristics of aquifers, Darcy's law, anisotropy and heterogeneity.	5
2.	**Governing Equations for Groundwater Flow:** Dupuit-Forchheimer assumptions, general differential equations governing groundwater flows, analytical solutions.	6
3.	**Wells and Well Hydraulics:** Different types of wells, construction of wells, steady and unsteady state solutions for confined, unconfined and leaky aquifers, effect of boundaries, method of images, pumping test analysis.	8
4.	**Groundwater Conservation:** Regional groundwater budget; resource assessment; estimation of recharge, Indian practice, artificial recharge	5
5.	**Groundwater Quality:** General problem of contamination of groundwater, sources, remedial and preventive measures, seawater intrusion in coastal aquifers.	6
6.	**Groundwater Flow Modelling:** Role of groundwater flow models, reference to hydraulic, Hele-Shaw and analog models, introduction to numerical modeling.	6
7.	**Planning of Groundwater Development:** constraints on the development, role of flow models, optimal groundwater development.	6
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/Books/Publisher	Year of Publication/ Reprint
1.	Bear, J., "Hydraulics of Ground Water", McGraw.	1979
2.	Walton, W.C., "Ground Water Resources Evaluation", McGraw Hill.	1970
3.	Freeze and Cherry, "Ground Water", Prentice Hall.	1979
4.	Driscoll, F.G., "Ground Water and Wells", Johnson Division.	1986
5.	Raghunath, H. M., "Ground Water", New Age International (P) Limited.	2007

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

1. Subject Code : **CEN-541** Course Title : **Matrix Structural Analysis**
2. Contact Hours : **L: 3** **T : 0** **P: 2**
3. Examination Duration (Hrs) : **Theory : 3** **Practical : 0**
4. Relative Weight : **CWS : 15** **PRS: 25** **MTE: 20** **ETE: 40** **PRE: 0**
5. Credits : **04** 6. Semester: **Autumn** 7. Subject Area : **PCC**
8. Pre-requisite: **Nil**
9. Objective: To equip students with different methods of linear and non-linear analysis using matrix approach and expose them to write small utility programs and use of commercial packages for computer aided analysis of common 2D and 3D structures

10. Details of Course:

S. No.	Contents	Contact Hours
1	Basic methods of analysis, different indeterminacies, stiffness and flexibility approach	04
2	Flexibility method using member approach	06
3	Stiffness matrix for prismatic, non-prismatic and curved members, shear deformations	08
4	Linear analysis of different 2D and 3D structures	08
5	Techniques for enhancing computing power: solution algorithm, substructuring	04
6	Non linear analysis: types and different techniques, convergence criteria	08
7	Development of codes and introduction to different software packages	04
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/Books/Publisher	Year of Publication/ Reprint
1	William Weaver Jr & James M Gere, “Matrix Analysis of Framed Structures”, 2nd Ed., CBS Publishers, New Delhi	1986
2	Madhu B Kanchi, “Matrix Methods of Structural Analysis”, 2nd Ed., Wiley Eastern Ltd.	1993
3	Majeed K I, “Non Linear Structure Analysis”, Butterworth Ltd. London.	1973

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

1. Subject Code : **CEN-542** Course Title : **Continuum Mechanics**
2. Contact Hours : **L: 3** **T : 1** **P: 0**
3. Examination Duration (Hrs) : **Theory : 3** **Practical : 0**
4. Relative Weight : **CWS :25** **PRS: 0** **MTE: 25** **ETE: 50** **PRE: 0**
5. Credits : **04** 6. Semester: **Spring** 7. Subject Area : **PEC**
8. Pre-requisite: **Nil**

9. Objective of Course : To impart to students the basic knowledge in theory of vibrations and behaviour of soils under dynamic loads so that foundations for various types of machines could be designed.

10. Details of Course :

S. No.	Contents	Contact Hours
1.	Vector and Tensors Algebra, Lineariziation and Directional Derivatives, Stress and Equilibrium, Analysis for Stresses, Translational and Rotational Equilibrium, Principal Stresses and Principal Planes in 3D, Stress Invariants, Cauchy and Kirchhoff Stress Tensor, Deviatoric and Volumetric Components, Work Conjugancy, Octahedral and von-Mises stresses.	
2.	Kinematics, Linearized Kinematics, Strain Quadric of Cauchy, Principal Strains, Invariants, Equations of Compatibility, Finite Deformation, Material (Lagrangian) and Spatial (Eulerian) Descriptions, Deformation Gradient, Polar Decomposition, Volume change, Distortional Component of Deformation Gradient, Area Change.	
3.	Equations of Elasticity,Hooke's Law, Generalized Hooke's Law, Anisotropic, Orthotropic and Isotropic Elasticity Tensor, Plane Stress and Strain Problems, Airy Stress Functions for Two-Dimensional Problems, Airy Stress Function in Polar Coordinates, Isotropic Hyper elasticity, Three-Dimensional Elasticity.	
4.	Elasto-Plastic Behavior of Material, Elasto-Plastic Formulations, Material Yield Criteria- von Mises, Tresca, Mohr-coulomb, Ducker-Pager, Isotropic and Kinematic Hardening, Normality Principle, Plastic Flow Rule, Plastic Potential, Elasto-Plastic Stress-Strain Relations, Prandtl-Rauss Equations, Levy-Mises Relations, Hardening Modulus, Generalized Elasto-Plastic Stress-Strain Relations	
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1.	Finite element analysis in Geotechnical Engineering theory, By David M Potts and Lidija Zdravkovic, Thomas Telford	1999
2.	Mechanics of Materials and Interfaces: The Disturbed State Concept, By C S Desai, CRC Press LLC	2000
3.	Mechanics of Geomaterial Interfaces, By A.P.S. Selvadurai, M.J. Boulon, Elsevier	1995

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

1. Subject Code : **CEN-543** Course Title : **Advanced Concrete Design**
2. Contact Hours : **L: 3** **T : 0** **P: 2**
3. Examination Duration (Hrs) : **Theory : 3** **Practical : 0**
4. Relative Weight : **CWS : 15** **PRS: 25** **MTE: 20** **ETE: 40** **PRE: 0**
5. Credits : **04** 6. Semester: **Autumn** 7. Subject Area : **PCC**
8. Pre-requisite: **Nil**
9. Objective: To give a consistent and sound theoretical background to the force and stress distributions in reinforced and pre-stressed concrete. To introduce the concepts of yield line analysis, strut-tie models and other state of art analysis techniques and to connect these with the extant design ideologies in the building codes. To study advanced concepts of creep/rheology & crack widths in reinforced and prestressed concrete and creating numerical models of these. To develop a clear theoretical understanding of the underlying reasons behind codal details as ductile detailing, reinforcement placement etc.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	Plastic Section Theory for Reinforced Concrete including interaction of flexure-Shear-Axial effects	5
2.	Upper bound and lower bound plastic theorems	2
3.	Application of plastic analysis to frames – instantaneous centre of rotations	4
4.	Introduction to Pushover Analysis	3
5.	Introduction to Strut-Tie Models	2
6.	Strut-Tie Models for Deep Beams, Beam-Column Joints& Shear walls	5
7.	Introduction to Yield line analysis and application for slabs, raft foundations etc.	4
8.	Introduction to Pre-stressed concrete and behaviour for simple elements	8
9.	Modelling of creep/shrinkage and long term effects for RCC and prestressed concrete	5
10.	Calculation of crack widths and crack control designs	4
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1.	Reinforced Concrete: Mechanics and Design, 6th Ed., McGregor & White	2011
2.	Reinforced Concrete: A Fundamental Approach, 6th Ed., Edward Nawy	2008
3.	Design of Prestressed Concrete, 2nd Ed., Arthur H. Nilson	1987
4.	Darwin & Dolan, “Design of Concrete Structures”, 14th Ed., Nilson,	2009
5.	Prestressed Concrete: A Fundamental Approach, 5th Ed., Edward Nawy	2005
6.	J Schlaich, K Schaefer, and M. Jennewin, “Toward a Consistent Design of Structural Concrete”, PCI Journal V. 32, No. 2, pp. 72-150.	1987
7.	Kennedy & Goodchild, “Practical Yield Line Design”, The Concrete Centre, TCC/03/3.	2004

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

1. Subject Code : **CEN-544** Course Title : **Structural Dynamics**
2. Contact Hours : **L: 3** **T : 1** **P: 0**
3. Examination Duration (Hrs) : **Theory : 3** **Practical : 0**
4. Relative Weight : **CWS : 25** **PRS: 0** **MTE: 25** **ETE: 50** **PRE: 0**
5. Credits : **04** 6. Semester: **Autumn** 7. Subject Area : **PCC**
8. Pre-requisite: **Nil**
9. Objective: To understand the response of structures to earthquakes requires study of structural dynamics. Therefore, Single Dynamic Degree of Freedom Systems are first introduced, then two and three DOF system are covered. Finally the earthquake effects on structures are covered.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	Overview of Structural Dynamics, Single Degree of Freedom Systems – Analysis of Free Vibrations – undamped and damped systems, estimation of damping by logarithmic decrement method.	3
2.	Formulation of equation of motion for generalized SDOF dynamic problems using virtual work method.	3
3.	Response of SDOFS systems to Harmonic, Periodic, Impulse Loads	3
4.	Formulation of equation of motion for two/three DOF systems. Finding mode shapes and frequencies by solving the determinantal equation, and iterative techniques. Use of sweeping matrices for obtaining higher modes. Proof of Convergence. Modal superposition and Response Spectrum Methods.	12
5.	Response of single and multiple DOFS systems to Earthquake Loading using Time-Stepping Methods based on Forward Cauchy Euler, Backward Cauchy Euler and Trapezoidal Rule. Accuracy, stability and algorithmic dampingin step-by-step methods.	6
6.	Earthquake response analysis of Multi-DOF systems subjected to earthquake ground motion. Concept of modal mass and mode participation factors, etc.	6
7.	Newark & Hall's linear and inelastic response spectra for earthquakes	6
6.	Introduction to IS code provisions regarding earthquake.	3
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1.	Ray W. Clough & Penzien, "Dynamics of Structures", Mc Graw Hill.	1993
2.	Anil Chopra, "Dynamics of Structures ", Mc Graw Hill.	2001

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

1. Subject Code : **CEN-545** Course Title : **Finite Element Analysis**
2. Contact Hours : **L: 3** **T : 0** **P: 2**
3. Examination Duration (Hrs) : **Theory : 3** **Practical : 0**
4. Relative Weightage : **CWS : 15** **PRS: 25** **MTE: 20** **ETE: 40** **PRE: 0**
5. Credits : **04** 6. Semester: **Spring** 7. Subject Area : **PCC**
8. Pre-requisite: **Nil**
9. Objective: To introduce the concept of domain discretisation and a variational framework of the equations of mechanics. Application of these methodologies to a wide range of engineering problems and connection with the laws of continua.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	Basic Concepts, Discretization; Displacement, Force and Hybrid Models	02
2.	Interpolation Functions for General Element Formulations: Compatibility and Completeness, Polynomial Forms: One Dimensional Elements, Geometric Isotropy, Triangular Elements, Rectangular Elements, Three Dimensional Elements, Isoperimetric Formulations, Axisymmetric Elements; Numerical Integration.	08
3.	Applications in Solid Mechanics: Plane Stress/Strain: FE Formulation: CST, LST; Stiffness Matrix, Load Matrix Formation Rectangular Element Isoparametric Formulation: Plate Elements and Shell Elements, Three Dimensional Elements FE Formulation: Axisymmetric Stress Analysis, Torsion, Interface Elements, Infinite Elements	08
4.	Application in Structural Dynamics and Vibrations: Mass (Consistent and Diagonal) and Damping Matrices; Modal Analysis, Time History Analysis, Explicit Direct Integration/ Implicit Direct Integration and Mixed Methods.	06
5.	Introduction to Nonlinear Problems: Geometric and Material (Elasto-plastic), Solution Methods: Newton Ralphson Method, Modified Newton-Ralphson Method, Arc Method, A Problem of Geometric Nonlinearity.	08
6.	Stationary Principles, Rayleigh Ritz Method and Interpolation; Weighted Residual Methods and Variational Methods, Numerical Errors and Convergence	06
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1.	David Hutton, “Fundamentals of Finite Element Analysis”, Tata McGraw Hill	2005
2.	R. D. Cook, Malkus and Plesha, “Concepts and Applications of Finite Element Analysis”, 3rd Ed., John Wiley.	1989
3.	T. J. R. Hughes, “The Finite Element Method : Linear Static and Dynamic Analysis”, Prentice Hall.	1987
4.	Klaus Juergen Bathe, “Finite Element Procedures”, Prentice Hall of India.	2003
5.	O. C. Zienkiewicz., R. L. Taylor & J. Z. Zhu., “The Finite Element Method Its Basis & Fundamentals”, Elsivier Publications.	2007

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

1. Subject Code : **CEN-561** Course Title : **Traffic Engineering & Modeling**
2. Contact Hours : **L: 3 T : 1 P: 0**
3. Examination Duration (Hrs) : **Theory : 3 Practical : 0**
4. Relative Weight : **CWS : 25 PRS: 0 MTE: 25 ETE: 50 PRE: 0**
5. Credits : **04** 6. Semester: **Autumn** 7. Subject Area : **PCC**
8. Pre-requisite: **Nil**
9. Objective: To introduce the advances in traffic engineering and to make the students conversant with relevant modeling approaches.

10. Details of Course:

S. No.	Contents	Contact Hours
1	Introduction: Elements of traffic engineering, issues for traffic engineers; road users, vehicles, highways and control devices, modelling concepts.	04
2.	Traffic Stream Characteristics: Traffic stream parameters, Time Space diagram, relationship among q,k,u, Macroscopic Fundamental Diagrams (MFD).	04
3.	Traffic Studies: Traffic volume studies, speed, travel time and delay studies, parking studies, RSI Survey, WTP Survey, accident data collection, pedestrian studies.	06
4.	Traffic design: Capacity analysis concepts – urban streets and rural highways, design of parking facilities, street design.	06
5.	Statistical application in Traffic Engineering: Overview of Probability Functions and Statistics, Normal Distribution and application, Confidence Bounds, Sample Size, Binomial Distribution, Poisson Distribution, Hypothesis Testing.	08
6.	Traffic Flow Theory: Models of Uninterrupted Flow, Queuing Theory, Shock Wave Theory.	04
7.	Time Series Analysis: Basic Components of Time Series, Smoothening and Decomposition Methods, Data Filters, Auto Correlations and Moving Averages.	04
8.	Management Techniques: Traffic calming; Congestion and road user pricing; priority movements; traffic regulations and control systems; use of intelligent systems.	06
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1.	William R. Mcshane and Roger P. Roess, "Traffic Engineering", Pearson (4th Edition).	2013
2.	Kadiyali, L.R., "Traffic Engineering and Transport Planning", Khanna Publishers.	2012
3.	C A O'Flaherty, Ed , "Transport Planning and Traffic Engineering", Butterworth Heinemann, Elsevier, Burlington, MA	2006
4.	May, A.D., "Fundamentals of Traffic Flow", Prentice Hall, Inc. 2nd Ed.	1990
5.	Carlos F. Daganzo. "Fundamentals of Transportation and Traffic Operations", Pergamon	1997
6.	Simon P. Washington, Matthew G. Karlaftis and Fred L. Mannering, "Statistical and Econometric Methods for Transportation Data Analysis", 2nd Edition, CRC Press	2011

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

1. Subject Code : **CEN-562** Course Title : **Pavement Analysis and Design**
2. Contact Hours : **L: 3 T : 1 P: 0**
3. Examination Duration (Hrs) : **Theory : 3 Practical : 0**
4. Relative Weight : **CWS : 25 PRS: 0 MTE: 25 ETE: 50 PRE: 0**
5. Credits : **04** 6. Semester: **Autumn** 7. Subject Area : **PCC**
8. Pre-requisite: **Nil**
9. Objective: To impart knowledge to students related to analysis and design of pavements with respect to Highways and Airports.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction :** Components of pavement structure, importance of subgrade soil, properties on pavement performance. Functions of subgrade, subbase, base course and wearing course.	6
2.	**Stresses in Flexible Pavements:** Stresses in homogeneous masses and layered systems, deflections, shear failures, equivalent wheel and axle loads.	6
3.	**Elements in Design of Flexible Pavements :** Loading characteristics-static, impact and repeated loads, effects of dual wheels and tandem axles, area of contact and tyre pressure, modulus or CBR value of different layers, equivalent single wheel load, equivalent stress and equivalent deflection criterion; equivalent wheel load factors, climatic and environmental factors.	6
4.	**Design Methods for Flexible Pavements:** California bearing ratio (CBR) method, U.S. Navy method. Triaxial method, Mcleod method, Boussinesq's and Burmister's analysis and design method, Triaxial method, Design of flexible pavements, IRC method for Flexible Pavement Design.	6
5.	**Rigid Pavements:** Wheel load stresses, Soil subgrade, Westergaard's analysis, Bradbury's approach, Arlington test, Pickett's corner load theory and influence charts.	6
6.	**Temperature Stresses:** Westergaard's and Thomlinson's analysis of warping stresses, Combination of stresses due to different causes, Effect of temperature variation on Rigid Pavements.	6
7.	**Reinforced Concrete Slabs:** Prestressed concrete slabs-general details. Design of Tie Bars and Dowel Bars.	6
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1	Yoder, E.J. and Witczak, M.W., "Principles of Pavement Design 2nd Ed", John Wiley & Songs, Inc.	1975
2	O'Flaherty, A. Coleman, "Highways : The Location, Design, Construction and Maintenance of Road Pavements", 4th Ed., Elsevier	2006
3	Fwa, T.F., "The Handbook of Highway Engineering", CRC Press Taylor & Francies	2006

	Group.	
4	Khanna, S.K. and Justo, C.E.G., “Highway Engineering”, Nem Chand Jain & Bros.	2005
5	Papagiannakis, A.T. and Masad, E.A., “Pavement Design and Materials, John Wiley & Sons Inc.	2008

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

1. Subject Code : **CEN-563** Course Title : **Planning, Design and Construction of Rural Roads**
2. Contact Hours : **L: 3 T : 1 P: 0**
3. Examination Duration (Hrs) : **Theory : 3 Practical : 0**
4. Relative Weight : **CWS : 25 PRS: 0 MTE: 25 ETE: 50 PRE: 0**
5. Credits : **04** 6. Semester: **Autumn** 7. Subject Area : **PCC**
8. Pre-requisite: **Nil**
9. Objective of Course: To introduce the concepts of Planning, Geometric Design, Pavement Design, Construction and Maintenance of Rural Roads
10. Details of the Course.

S. No.	Contents	Contact Hours
01	**Planning of Rural Roads**: Classification of Roads, Brief introduction to earlier 20 year Plans, System's Approach, NATPAC Model, Gravity Model, CRRI Model, FBRNP Model, Concepts of PMGSY	08
02	**Geometric Design**: Geometric Design Standards for Rural Roads with special reference to PMGSY, Hill Road Standards.	04
03	**Pavement Design:** Various pavement design methods for Rural roads including Flexible and Rigid pavements using IRC:SP-20, IRC-72, IRC-37, IRC:SP-62, CRRI Nomograms	04
04	**Mix Design Methods:** CRRI Method, Triangular Chart Method, Fuller's Method, Rothfuch method, PI based Method	06
05	**Materials:** Brief introduction to conventional materials, Marginal and Waste Materials including Fly Ash, GBFS, BFS, SMS, Bagasse, CRMB, etc	06
06	**Construction:** Case Studies of Waste Material Utilization in Rural Roads, Low Cost Techniques for Rural Road Construction, Tractor Bound Technology, Special Considerations for Hill Areas	06
07	**Drainage:** Transverse and Longitudinal Drainage, Design of drains, Minor CD Works, Filter Design etc.	04
08	**Maintenance:** Type and Causes of Failures, Remedies	04
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1	Rural Roads Manual , SP-20, IRC	2002
2	Document on Rural Road Development, Vol I & II, CRRI	1990
3	PMGSY Operation Manual, NRRDA, Govt of India	2005
4	Specifications for Rural Roads, MoRD, IRC	2004
5	Khanna S.K., Justo C.E.G, "Highway Engineering", Nem Chand & Bros, Roorkee	2004
7	L R Kadiyali, "Traffic Engineering and Transport Planning", Khanna Publishers, Delhi	1999
8	Quality Assurance Handbook for Rural Roads, NRRDA, Govt. of India	2007

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

1. Subject Code : **CEN-564** Course Title : **Geometric Design**
2. Contact Hours : **L: 3 T : 1 P: 0**
3. Examination Duration (Hrs) : **Theory : 3 Practical : 0**
4. Relative Weight : **CWS : 25 PRS: 0 MTE: 25 ETE: 50 PRE: 0**
5. Credits : **04** 6. Semester: **Autumn** 7. Subject Area : **PCC**
8. Pre-requisite: **Nil**
9. Objective: To introduce concepts and design procedures for different types of roads and associated facilities.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Design Controls - Topography and physical features, traffic, vehicular characteristics, speed and safety; Space standards for urban, rural and hill roads, Sight distance requirements, Access controls	6
2.	**Cross-section Elements :** Single lane, Two lane, Multi-lane highways, Expressways, Urban roads; Street design concepts, bicycle tracks, pedestrian facilities, street furniture, Design of Speed Breaker	6
3.	**Alignment :** Horizontal Alignment - Curve design, Super-elevation design, Transition curve design, Attainment of super-elevation, Pavement widening, Sight distance on horizontal curves; Vertical Alignment - Gradients, Grade compensation, Design of vertical curves, Combination of horizontal and vertical alignment, vertical clearance for underpasses and elevated structures	6
4.	**Highway Capacity:** Two lane, Four lane, Six lane non-urban highways, Urban roads, Expressways, HCM USA and IRC Specifications	8
5.	**Intersection Geometry:** Visibility requirements, Principles of channelization, Layout design for types of intersections, on-ramps and off-ramps (flyovers and Access controlled facilities), Acceleration and deceleration lanes, Two-way turn lanes,	6
6.	**Design of Facilities:** Design of on-street and off-street parking facilities, multi-storyed Parking; Design of bus shelters and bus lay-bye, Bus terminal, Truck terminals and truck lay-bye, Container terminal, Toll Plaza, Foot-over bridge and sky-walk	10
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1.	Wright, P.H. & Dixon, K.K., "Highway Engineering", 7th Ed., John Wiley & Sons.	2004
2.	Transportation Research Board (TRB), Highways Capacity Manual, National Research Council, Washington D.C.	2010
3.	Khisty, C.J. and Lal, B.K., "Transportation Engineering - An Introduction", Prentice Hall of India Pvt. Ltd.	2006
4.	Kadiyali, L.R., "Traffic Engineering and Transport Planning", Khanna Publishers.	2008

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE: **Department of Civil Engineering**

1. Subject code: **CEN-601** Course Title: **Air Pollution and Control**
2. Contact Hours: **L: 3 T: 1 P: 2/2**
3. Examination Duration (Hrs): **Theory: 3 Practical: 0**
4. Relative Weight: **CWS: 20 PRS : 20 MTE : 20 ETE : 40 PRE : 0**
5. Credits: **04** 6. Semester: **Spring** 7. Subject Area: **PEC**
8. Pre-requisite: **Nil**
9. Objective : To impart the knowledge and understanding of causes and effects of air pollution and their controlling mechanisms.

10. Details of the Course:

S. No.	Contents	Contact Hours
1.	Introduction and scope, emission sources, stationary and mobile sources, types of air pollutants (criteria air pollutants, air toxics, green house gases and noise), effects of pollutants on man, material and plants.	6
2.	Meteorology, transport, dispersion and transformation of pollutants in air, plume rise, effect of buildings and topography on the fate of air pollutants.	7
3.	Monitoring of indoor and ambient air quality, emission inventory, air pollution dispersion models, point, line and area source models, receptor modeling, stochastic models, compartment/box model.	7
4.	Carrying capacity of air sheds, local, regional and global issues of air pollution, summer and winter smog, acid rain and climate change.	7
5.	Air pollution control techniques, equipments and their design, design of stacks, control of particulate matter and gaseous pollutants.	7
6.	Air pollution emission standards, air quality standards, control laws, regulations and legislations - national and international, technology and policy options for controlling air pollution, economics of air pollution control, case studies.	8
	Total	**42**

List of Practicals :

i) Tailpipe emission measurements
ii) Stack emission measurements
iii) Sampling and analysis of SO_2, NO_2, SPM, and RSPM
iv) Measurements of CO and HC
v) Measurements of noise

11. Suggested Books:

S. No.	Name of Authors/Book/Publishers	Year of Publication/ Reprint
1	Wark, K., Warner, C.F., and Davis, W.T., "Air Pollution: Its Origin and Control", Addison-Wesley Longman.	1998
2	Boubel, R.W., Fox, D.L., Turner, D.B., Stern, A.C., "Fundamentals of Air Pollution", Academic Press.	2005
3	Seinfeld, J.H., Pandis, S.N., "Atmospheric Chemistry and Physics", John Wiley.	2006
4	Lodge, J.P. (Ed.), "Methods of Air Sampling and Analysis", CRC Press.	1988
5	Gurjar, B.R., Molina, L., Ojha, C.S.P. (Eds.), "Air Pollution: Health and Environmental Impacts", CRC Press.	2010

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE: **Department of Civil Engineering**

1. Subject code: **CEN-602** Course Title: **Water Quality Management**
2. Contact Hours: **L: 3 T: 1 P: 0**
3. Examination Duration (Hrs): **Theory: 3 Practical: 0**
4. Relative Weight: **CWS: 25 PRS: 0 MTE: 25 ETE : 50 PRE: 0**
5. Credits: **04** 6. Semester: **Spring** 7. Subject Area: **PEC**
8. Pre-requisite: **Nil**
9. Objective: To impart understanding of various aspects related to quality, pollution and remediation of natural water resources

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Source and nature of water pollution, strategy for water quality management, water quality standards, laws and regulations.	02
2.	**Rivers and Streams:** River hydrology and river pollution, spills and continuous discharge of residual material from point and non-point sources, initial mixing, oxygen demanding wastewaters, nutrients VOCs Streeter-Phelps model and other models, fate of bacteria (indicator bacteria pathogens and viruses, restoration and management strategy).	13
3.	**Lakes and Reservoirs:** Physical and hydrologic characteristics, natural processes, water quality models (completely mixed, vertical, two dimensional), eutrophication, phytoplankton models, phytoplankton – nutrient – DO relationships, restoration and management strategy.	13
4.	**Ground Water:** Introduction, natural ground water quality, sources and ground water pollution, transport processes (sorption, decay, combined) transport models for instantaneous and continuous point sources and non-point sources, non-aqueous phase liquids, remediation strategy.	08
5.	**Wetlands and Watersheds:** Introduction, natural and constructed wetlands, wetland hydrology, water generated pollutant loads, urban and agricultural water sheds, air sheds.	04
6.	**Estuaries, Bays and Harbors:** Estuarine hydrology, tides and tidal currents, water quality in estuaries, water quality models.	02
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/Book/Publishers	Year of Publication/ Reprint
1.	Thomann, R.V., Mueller, J.A., ”Principles of Surface Water Quality Modelling and Control”, Harper and Row Publishers.	1987
2.	Chin, David A., “Water Quality Engineering in Natural Systems”, Wiley – Interscience.	2006
3.	Masters, G.M. and Ela, “Introduction to Environmental Engineering and Science”, PHI Learning.	2008

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE: **Department of Civil Engineering**

1. Subject code: **CEN-603** Course Title: **Industrial and Hazardous Waste Management**
2. Contact Hours: **L: 3 T: 1 P: 0**
3. Examination Duration (Hrs): **Theory: 3 Practical: 0**
4. Relative Weight: **CWS: 25 PRS: 0 MTE: 25 ETE: 50 PRE: 0**
5. Credits: **04** 6. Semester: **Spring** 7. Subject Area: **PEC**
8. Pre-requisite: **Nil**
9. Objective: This course aims at developing in students understanding of industrial and hazardous waste management practices.

10. Details of the Course:

S. No.	Contents	Contact Hours
1.	Introduction, industrial waste surveys, sampling and characterization.	4
2.	Waste management strategies and programs.	3
3.	Green technologies, zero waste discharge units, environmentally balanced industrial complex (EBIC).	3
4.	Introduction to ISO: 9000 and ISO: 14000 series of standards for environmental management.	3
5.	Waste treatment technologies, CEPTs, co-disposal with municipal waste.	5
6.	Case studies of distillery, pulp and paper, tannery, sugar, textile, steel, oil refinery, chemicals and industrial complexes, etc.	9
7.	Hazardous waste management rules, classification of hazardous wastes, storage and handling requirements, risk assessment, on-site and off-site emergency preparedness planning.	6
8.	Hazardous waste treatment and disposal practices, stabilization and solidification, incineration, land filling, deep-well injection, underground disposal, encapsulation; site remediation.	9
	Total	**42**

11. Suggested Books

S. No.	Name of Authors/Book/Publishers	Year of Publication/ Reprint
1.	Nemerow, N.L., "Industrial Waste Management", McGraw Hill.	2007
2.	Eckenfelder, W.W., "Industrial Water Pollution Control", McGraw Hill.	2004
3.	Grega, La, M.D., Buckingham, P.L. and Evans, J.C., "Hazardous Waste Management", McGraw Hill.	2001
4.	Liu, O.H.F. and Liptak, B.G., "Solid and Hazardous Waste Management", Lewis Publishers.	2000
5.	Wentz, C.A., "Hazardous Waste Management", McGraw-Hill.	1995

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE: **Department of Civil Engineering**

1. Subject code: **CEN-604** Course Title: **Environmental Impact and Risk Assessment**
2. Contact Hours: **L: 3 T: 1 P: 0**
3. Examination Duration (Hrs): **Theory: 3 Practical: 0**
4. Relative Weight: **CWS: 25 PRS: 0 MTE: 25 ETE: 50 PRE: 0**
5. Credits: **04** 6. Semester: **Spring** 7. Subject Area: **PEC**
8. Pre-requisite: **Nil**
9. Objective: To develop understanding of the environment and impact on it due to various projects and actions.
10. Details of Course:

S. No.	Particulars	Contact Hours
1.	Introduction (Preliminary Assessment), Overview and Introduction to the Course, The Environmental Impact Assessment Process, Basic Steps in EIA Process, EIA Notifications of MoEF, Project Screening and scoping for EIA, Initial Environmental Examination, public participation in environmental decision making	5
2.	Prediction and Assessment of Impacts on the Air Environment: Air Pollutants Emission, Ambient Air Quality and Standards, Emission Inventories, Meteorological Data, Mass Balances, Dispersion Models , Pollutant Emissions Minimization - Case Study	5
3.	Prediction and Assessment of Impacts on the Surface Water Environment: Quality Impacts, Quantity Impacts, Water Quality Index, Mass Balances, Quantitative Modeling, Water Conservation - Case Study. Prediction and Assessment of Impacts on the Groundwater Environment: Hydrogeological Information, Vulnerability Mapping, Subsurface Transport and Fate	6
4.	Prediction and Assessment of Impacts on the Noise Environment: Terminology, Noise Propagation from Point and Line Sources, Mitigation Measures - Case Study	4
5.	Biological Impact Prediction and Assessment: Identifications, Related laws, Biological indices & Mitigation measures	4
6.	Prediction and Assessment of Impacts on the Socioeconomic Environment: Selection of Factors, Risk and Health, Socioeconomic Gains versus Biophysical Losses.	4
7.	Prediction and Assessment of Impacts on the Land Environment: Soil & Geological properties, Universal Soil Loss equation, mitigation measures	4
8.	Risk Assessment: Hazard Identification, Effect Assessment, Risk characterization, Risk Reduction	4
9.	Environmental audit. Case studies of EIA	6
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/Book/Publishers	Year of Publication/ Reprint
1.	Jain R.K., Urban, L.V. and Stacey, G.S., "Environmental Impact Analysis", Van Nostrand Reinhold.	2003
2.	Weathern, P., "Environmental Impact Assessment – Theory and Practice", Unwin Hyman, London.	1982
3.	Canter, L.W., "Environmental Impact Assessment", McGraw Hill.	2006
4.	Charles, H., "Environmental Impact Assessment", CRC Press.	2011
5.	Morris, Peter and Riki, "Methods of Environmental Impact Assessment", Spon Press, London.	2001

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE: **Department of Civil Engineering**

1. Subject code: **CEN-605** Course Title: **Solid Waste Management**
2. Contact Hours: **L: 3 T: 1 P: 0**
3. Examination Duration (Hrs): **Theory: 3 Practical: 0**
4. Relative Weight: **CWS: 25 PRS: 0 MTE: 25 ETE : 50 PRE: 0**
5. Credits: **04** 6. Semester: **Spring** 7. Subject Area: **PEC**
8. Pre-requisite: **Nil**
9. Objective: To impart knowledge of planning of municipal solid waste management systems for environmental health and sustainable development.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	Introduction: Development of solid waste management (SWM) program, issues in solid waste management, integrated solid waste management, legislations and regulations.	3
2.	Sources and Types of Solid Waste: Residential, commercial and industrial wastes, waste generation, sampling and analysis.	4
3.	Collection and Transport: Source separation, handling, storage, collection services, analysis of collection system, route optimization, transfer and transport.	5
4.	Processing and Material Separation Techniques: Receiving Area, Conveyors, Shredders, manual separation, screening, air classification, magnetic and eddy current separation techniques.	6
5.	Transformation of Solid Waste: Biological Processes: Composting and anaerobic Digestion, Waste to Energy Conversion: Emission control and ash management.	6
6.	Disposal of Solid Waste: Natural attenuation and containment landfills, Siting, Design and construction of landfills, gas, leachate, storm-water movement and control, closure of landfills, environmental monitoring, incineration, pyrolysis and gasification.	8
7.	Environmental Impact Assessment: EIA of landfills and other treatment methods.	2
8.	Case Studies: Overview of solid waste management practices in India.	4
	Total	**42**

List of Practicals :

i) Solid Waste Characterization
ii) Biodegradation and end products measurement

11. Suggested Books:

S. No.	Name of Authors/Book/Publishers	Year of Publication/ Reprint
1.	Tchobanoglous G., Theisen, H. and Vigil, S., "Integrated Solid Waste Management : Engineering Principles and Management Issues", McGraw Hill.	2011
2	McBean E. A., "Solid Waste Landfill Engineering and Design", Prentice Hall.	1995
3	CPHEEO Manual of Solid Waste Management, GOI Publication.	2001
4	Cheremisinoff, N.D., "Handbook of Solid Waste Management and Waste Minimization Technologies", Butterworth, London.	2003

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE: **Department of Civil Engineering**

1. Subject Code: **CEN-611** Course Title: **Analytical and Digital Photogrammetry**
2. Contact Hours : **L: 3 T : 0 P: 2**
3. Examination Duration (Hrs) :**Theory : 3 Practical : 0**
4. Relative Weight : **CWS: 15 PRS: 25 MTE: 20 ETE: 40 PRE: 0**
5. Credits : **4** 6. Semester: **Spring** 8. Subject Area : **PEC**
8. Pre-requisite: **Principles of Photogrammetry**
9. Objective of Course : To provide enhanced knowledge on analytical and Digital Photogrammetry.

10. Details of Course :

Sl. No.	Contents	Contact Hours
1	Introduction, Historical development from conventional to analytical and digital photogrammetry, Applications of analytical and digital photogrammetry	4
2	Coordinate systems, Condition equations, Orthogonal transformation matrices and methods of construction, Approximate orthogonal matrix, Measurement of image coordinates from hard copy and soft copy; Instruments	5
3	Digital images and their properties, Direct and indirect methods of acquisition of digital images - CCD, Digitizers and photogrammetric scanners, Comparative merits, Storage and compression of digital imagery, Loss of data & image quality, Corrections to observed image coordinates	5
4	Analytical orientation, Relative, Absolute and Exterior orientation methods, Analytical plotter and its functioning, Automatic image matching techniques - signal based and feature based matching, Comparative merits and demerits,	5
5	Digital correlation, Least square matching, Multipoint matching etc., Model formation using digital stereo pairs, Automatic generation of DEM, Digital orthophotos,	7
6	Digital photogrammetric system - Potential, Capabilities and characteristics features, Design consideration, Add-on devices	6
7	Analytical aerial triangulation, Independent model triangulation, Strip and block triangulation and adjustment, Bundle block adjustment. Various applications	10
	Total	**42**

List of Practicals :
1. Introduction to Digital Photogrammetric System.
2. Preparation of Digital Photo
3. Interior Orientation.
4. Relative Orientation.
5. Relative Orientation.
6. Absolute Orientation
7. 3D Model generation
8. Generation of Digital orthophotograph.
9. Aero triangulation

11. Suggested Books

Sl. No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1.	Ghosh, Sanjib K., "Analytical Photogrammetry", Concept Publishing Co.	1987
2.	"Manual of Photogrammetry", American Society of Photogrammetry.	1995
3.	Linder, Wilfried, "Digital Phgotogrammetry", Springer.	2009
4.	Egals, Yves and Kasser, Michel, "Digital Photogrammetry", Taylor and Francis.	2002

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE: **Department of Civil Engineering**

1. Subject Code: **CEN-612** Course Title: **Advanced Digital Image Processing**
2. Contact Hours: **L: 3 T: 0 P: 2**
3. Examination Duration (Hrs): **Theory: 03 Practical: 0**
4. Relative Weight: **CWS: 15 PRS: 25 MTE: 20 ETE: 40 PRE: 0**
5. Credits: **4** 6. Semester: **Spring** 7. Subject Area: **PEC**
8. Pre-requisite: **Remote Sensing and Digital Image Processing**
9. Objective : To introduce the concepts of multi and hyper-spectral remote sensing.
10. Details of Course :

Sl. No.	Contents	Contact Hours
1	Various types of images: PAN, Mutispectral, Hyperspectral and High resolution images, Feature and intensity based image registration of images, Open Source Image Processing software and image data	4
2	Advanced Spatial Filtering techniques—Spatial and Frequency domain (e.g., Fourier, wavelets), Texture Images	6
3	Image compression, Pixel and sub-pixel level target detection and classification, Data fusion methods and applications.	5
4	DEM generation from stereo-satellite images, CARTOSAT DEM, SRTM DEM, ASTER DEM, Parameter extraction	5
4	Empirical modelling of biophysical parameters from multi and hyperspectral remote sensing data, 3D visualisation of data	8
5	ANN, Fuzzy Logic, Object based classification from satellite images	8
6	Applications of multi and hyperspectral remote sensing data in water resources, forestry, earth sciences, resource management and planning, military target detection.	6
	Total	**42**

List of Practicals :
1. Study of different types of remote sensing data
2. Hands on experience on images processing modules
3. Data visualization tools – study of images
4. Feature and intensity based image registration of images
5. Spatial enhancement of remote sensing images
6. Data dimensionality reduction using feature selection and feature extraction methods
7. Advanced pattern recognition algorithms for extraction of information from images
8. Derivation of biophysical parameters from multi and hyperspectral remote sensing images

11. Suggested Books :

Sl. No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1.	Chen, C.H., “Information Processing for Remote Sensing”, World Scientific.	1999
2.	Cheng, Chein I., “Hyperspectral Imaging : Techniques for Spectral Detection and Classification”, Kluwer Academic.	2003

3.	Landgrebe, D., “Signal Theory Methods in Multi-spectral Remote Sensing”, John Wiley.	2003
4.	Richards, John A. and Xiuping, Jia., “Remote Sensing Digital Image Analysis : An Introduction”, Springer-Verlag.	1999
5.	Varshney, P.K. and Arora, Manoj K., “Advanced Image Processing Techniques for Hyperspectral Remote Sensing Data”, Springer-Verlag.	2004

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE: **Department of Civil Engineering**

1. Subject Code: **CEN-613** Course Title: **Thermal, Microwave and Hyperspectral Remote Sensing**
2. Contact Hours : **L: 3 T : 0 P: 2**
3. Examination Duration (Hrs) : **Theory : 3 Practical : 0**
4. Relative Weight : **CWS : 15 PRS : 25 MTE : 20 ETE : 40 PRE : 0**
5. Credits : **4** 6. Semester: **Spring** 7. Subject Area : **PEC**
8. Pre-requisite: **Nil**
9. Objective of Course : To provide enhanced knowledge on the use of thermal, microwave and hyperspectral remote sensing data and their analysis for various engineering and other applications.

9. Details of Course :

Sl. No.	Contents	Contact Hours
1.	Brief review of thermal and microwave remote sensing, their utility, merit and demerits. Introduction to spectral characteristics of remote sensing data. Optical radiation models. Summary of Visible to Shortwave region models. Thermal sensors and their characteristics.	4
2.	Thermal infrared region models. Interpretation of thermal images – day and night images. Emmissivity consideration. Thermal inertia considerations. Factors affecting analysis of thermal images..	5
3.	Estimation of land surface temperature from thermal images. Applications of thermal remote sensing.	3
4.	Introduction to Microwave Remote Sensing - Active and Passive Systems, Platforms and Sensors.	5
5.	Passive Microwave Systems: Background, Mathematical formulation for microwave radiation and simulation, Measurement and analysis of Brightness Temperature, Applications in various fields— Oceanography and Meteorology.	4
6.	Active Microwave Systems: Basic principles of Radar, Radar Equation, Resolution, Range, Phase and Angular measurements, Microwave Scattering and its measurement, Relationships between Scene and Sensor parameters, Imaging systems – RAR and SAR. SAR Imagery—their characteristics and interpretation. Applications of microwave remote sensing.	6
7.	SAR Interferometry for DEM generation. Differential SAR Interferometry for surface displacement studies. Applications in land subsidence, landslide movements, glacier movements etc. Polarimetry in Radar Remote Sensing. Basic equations. Propagation of waves and wave polarization. HH, VV, HV and VH polarization data and their applications.	4
8.	Principles of Hyperspectral Remote Sensing, Spectral Cube, Airborne and spaceborne hyperspectral sensors	4
9.	Smile effect and correct, instrument calibration: geometric and spectral calibration, continuum removal, red edge and blue shift concepts	3
10.	Spectral mixing theory, waveform characterization, spectral mapping methods: spectral feature filtering (SFF), Linear Spectral Unmixing (LSU), Mixture Tuned Matched Filtering (MTMF). Spectral Angle Mapper (SAM)	4
	Total	**42**

List of Practicals :

1. Familiarisation with various thermal and microwave remote sensing data products
2. Hands on experience on thermal data and microwave data processing modules in an image processing software
3. Study and collection of emmissivity data pertaining to various earth surface features from different sources.
4. Visual image interpretation of thermal images.
5. Digital image interpretation of thermal images.
6. Land surface temperature estimation from thermal images
7. Study and implementation of brightness temperature estimation models for passive microwave remote sensing data
8. Study and implementation of backscatter estimation models for active microwave remote sensing data
9. Visual and Digital image interpretation of SAR images.
10. Use of Differential SAR Interferometry for surface displacement studies.
11. Collection of spectral signatures and study of hyperspectral image
12. Classification of hyperspectral data

11. Suggested Books :

Sl. No.	**Name of Authors/Books/Publishers**	**Year of Publication/ Reprint**
1.	Henderson, F.M. and Anthony, J.L., "Principles and Applications of Imaging Radar", Manual of Remote Sensing, Vol. 2. John Wiley.	1998
2.	Manual of Remote Sensing, Vol. 1 to 5, American Society of Photogrammetry and Remote Sensing.	2003
3.	Schowengerdt, R.A., "Remote Sensing Models and Methods in Image Processing", Academic Press.	2006
4.	Matzler, C., "Thermal Microwave Radiation: Application for Remote Sensing", Institute of Electrical Engineers (IEE).	2008
5.	Chang, Chein, I., "Hyperspectral Data Processing", John Wiley and Sons.	2013

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE: **Department of Civil Engineering**

1. Subject Code: **CEN-614** Course Title: **Theory and Applications of GIS**
2. Contact Hours: **L: 3 T: 0 P: 2**
3. Examination Duration (Hrs): **Theory : 3 Practical : 0**
4. Relative Weight : **CWS : 15 PRS : 25 MTE : 20 ETE : 40 PRE : 0**
5. Credits: **4** 6. Semester : **Spring** 7. Subject Area: **Civil Engineering**
8. Pre-requisite : **Nil**
9. Objective of Course: The course objective is to provide basic knowledge of GIS theory and engineering applications using the existing state-of-the-art GIS software. The course shall be taught using a combination of lectures, demonstrations, and hands-on, interactive practicals in the classroom.

10. Details of Course:

Sl. No.	Contents	Contact Hours
1	Introduction, Geographical concepts and Terminology, Difference between Image Processing system and GIS, Utility of GIS.	4
2	Various GIS packages and their salient features, Essentials components of GIS, Data acquisition through scanners and digitizers	5
3	Raster and Vector Data: Introduction, Descriptions: Raster and Vector data, Raster Versus Vector, Raster to Vector conversion, Remote Sensing Data in GIS, Topology and Spatial Relationships, Data storage verification and editing	7
4	Data preprocessing, Georeferencing, Data compression and reduction techniques, Runlength encoding, Interpolation of data, Database Construction, GIS and the GPS, Data Output	7
5	Database structure, Hierarchical data, Network systems, Relational database, Database management, Data manipulation and analysis	4
6	Spatial and mathematical operations in GIS, Overlay, Query based, Measurement and statistical modelling, Buffers, Spatial Analysis, Statistical Reporting and Graphing	5
7	Programming languauges in GIS, Virtual GIS, Web GIS	5
8	Application of GIS to various natural resources mapping and monitoring and engineering problems	5
	Total	**42**

List of Practicals :

1. Demo on various GIS software and their salient features.
2. Scanning and digitization (on screen).
3. Registration of various maps and digitization and editing of features.
4. Database creation and management.
5. Buffer and overlay analysis.
6. Map preparation and composition.
7. Spatial and Mathematical operations.
8. Area and query based analysis
9. Customized application in GIS.
10. Web publishing of GIS layers.

11. 3D GIS.
12. Demo on various GIS based application.

11. Suggested Books

Sl. No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1	Burrough, P.A. and Mc Donnel, R.A., "Principles of Geographic Information System", Oxford University Press.	2000
2	Chrisman, Nicholas R., "Exploring Geographic Information Systems", John Wiley.	2002
3	Demers, Michael N., "Fundamentals of Geographic Information System", 2nd Ed. Wiley.	2008
4	Ghosh, S.K. and Chandra, A.M., "Remote Sensing and GIS", Narosa Publishing House.	2008
5	Lo, C.P. and Young, A.K.W., "Concepts and Techniques of Geographical Information System", Prentice Hall India.	2002
6	Longley, Paul A, Goodchild, Michael F., Maguire, David J. and Rhind, David W., "Geographic Information Systems and Science", Wiley	2001

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE: **Department of Civil Engineering**

1. Subject code: **CEN-615** Course Title: **Geoinformatics for Natural Disasters**
2. Contact Hours: **L: 3** **T: 0** **P: 2**
3. Examination Duration (Hrs): Theory: **3** Practical: **0**
4. Relative Weight: CWS: **15** PRS: **25** MTE: **20** ETE: **40** PRE: **0**
5. Credits: **4** 6. Semester: **Spring** 7. Subject Area: **PEC**
8. Pre-requisite: **Nil**
9. Objective : To introduce the applications of remote sensing, GIS and GPS tools for disaster mitigation and management.

10. Details of Course :

Sl. No.	Contents	Contact Hours
1	Introduction to various types of disasters. Manmade and natural – earthquakes, volcanoes, landslides, floods, cyclones, tsunamis, anthropogenic, industrial, chemical and environmental, fire etc. Stages of a disaster mitigation plan- pre-disaster planning, disaster preparedness, monitoring phase, emergency response or damage assessment, recovery and relief phase.	4
2	Various Geomatics tools – Total Station, GPS, RS, GIS, Digital Elevation model Generation extraction of parameters and their uses.	2
3	Earthquakes – Causative factors, hazard assessment, selection of factors, SAR Interferometry for estimation of ground displacement, creation of thematic data layers, preparation of seismic hazard zonation maps, regional risk assessment, Geomatics tools for risk mitigation plans. Case studies. Damage Assessment.	5
4	Landslides – Causative factors, hazard assessment, selection of factors – triggering and non-triggering, creation of thematic data layers, preparation of landslide hazard zonation maps, regional and site specific risk assessments, Modeling for risk mitigation plans. Case studies	6
5	Cyclones and Flooding: Cyclone: cyclone related parameters and effects on land and sea – damage assessment. Flooding: causes, identification of factors, space-time integration, GIS data layers, flood prone area demarcation, analysis and management, risk assessment. Damage Assessment. Case studies, Damage assessment.	5
6	Drought and Desertification: Types of droughts, factors influencing droughts, identification of variables, development of vegetation index, assessment of land use and ground water level changes, delimiting drought prone areas, processes of desertification, over utilization of water and land resources. GIS data layer creation – Management strategies. Case studies.	4
7	Anthropogenic Disasters: Atmospheric Disasters : Ozone layer depletion, green house / global warming – acid rain – snow melt – sea level rise – related problems. GIS data layer creation. Case studies. Marine Disasters: oil spill and chemical pollution, coastal erosion and deposition, factor identification, GIS analysis, management strategies. Case studies.	5
8	Biodiversity Disasters: Ecological degradation – nuclear disaster and biodiversity loss. Identification of parameters (mapping of forest types, protected areas and natural forests) – population extinction – conserving bio-diversity (species and subspecies). Soil erosion, coral / mangrove depletion, forest fire-mining. Geomatics tools for preparation	5

	of ecological degradation maps, erosion maps, deforestation maps etc. GIS in environmental modeling. Case studies.	
9	Forest Fire: estimation of forest fire, extent – NBR (Normal Burnt Ratio), use of geomatics tools for monitoring and management, Damage assessment.	3
10.	Tsunami - Introductory concepts, Geomatics tools and systems for monitoring and management, damage assessment.	3
	Total	**42**

List of Practicals :

1. Familiarisation with various remote sensing data products at different spectral, spatial and temporal resolutions
2. Hands on experience on Total Station
3. Hands on experience on GPS.
4. Hands on experience on an image processing and GIS software.
5. Digitization of Thematic layers.
6. Collection of data from different sources for a given natural hazard
7. Collection of field data using Total Station and/or GPS survey for the natural hazard selected
8. Use of GIS for preparation of thematic data layers for the natural hazard selected
9. Use of GIS for hazard zonation using probabilistic or any other method
10. Use of GIS for risk zonation and assessment.
11. Flood plan mapping using temporal satellite data (pre and post flood).
12. Use of Differential SAR Interferometry for surface displacement studies.

11. Suggested Books :

Sl. No.	**Name of Authors/Books/Publishers**	**Year of Publication/ Reprint**
1.	Andrew, Skeil, "Environmental Modeling with GIS and Remote Sensing", John Willey.	2002
2.	Ariyabandu, M. and Sahni P. (Eds), "Disaster Risk Reduction in South Asia", Prentice-Hall.	2003
3.	Bossler, J.D., "Manual of Geospatial Science and Technology", Taylor and Francis, London.	2001
4.	Demers, Michael N., "Fundamentals of Geographic Information Systems", John Willey.	2000
5.	Matthews, John A., "Natural Hazards and Environmental Change", Bill McGuire, Ian Mason.	2002

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE: **Department of Civil Engineering**

1. Subject Code: **CEN-616** Course Title: **Geoinformatics for Land Use Surveys**
2. Contact Hours: **L: 3** **T: 0** **P: 2**
3. Examination Duration (Hrs): **Theory: 3** **Practical: 0**
4. Relative Weight: **CWS: 15** **PRS: 25** **MTE: 20** **ETE: 40** **PRE: 0**
5. Credits: **4** 6. Semester: **Spring** 7. Subject Area: **PEC**
8. Pre-requisite: **Nil**
9. Objective of Course : To impart advanced knowledge on the use of remote sensing data in optical region for preparation of land use land cover maps and their usage in urban planning

10. Details of Course :

Sl. No.	Contents	Contact Hours
1	Introduction. Land use land cover— definition and its significance in engineering projects. History of land use land cover. Modern land use land cover surveys and classification systems. Utility of remote sensing data for land use land cover mapping at various scales.	4
2	Land use land cover analysis based on spectral characteristics of remote sensing data - Visible, Near Infrared and Shortwave Infrared wavelength regions, Thermal Infrared regions and active microwave region, high resolution images, various vegetation indices.	8
3	Land use land cover analysis based on spatial characteristics of remote sensing data – utility of IFOV, land parcel sizes, minimum mapping unit, map scale, Land use land cover analysis based on temporal characteristics of remote sensing data – temporal resolution of remote sensing data, application based temporal requirements, land use land cover change detection – visual and digital change detection algorithms. Principles of land use land cover mapping. Visual image interpretation techniques for land use cover map preparation.	8
4	Digital image classification for land use land cover map preparation. Per pixel classification – statistical, artificial neural network and other machine learning approaches. Object based image classification. Concept of mixed pixel. Sub pixel classification – linear mixture modeling, fuzzy set based classification, artificial neural network and other machine learning approaches.	9
5	Classification accuracy assessment – accuracy of per pixel and sub-pixel classification. Sampling design issues, design of error matrix and fuzzy error matrix. Statistical testing.	4
6	Issues in urban and regional planning – objectives and planning processes, data requirements. Physical planning and statistical methods. Mapping of parcels and individual buildings, Utility of land use land cover in urban planning.	4
7	Role of remote sensing and GIS for urban planning, management, and growth assessment. Study of cropping pattern and resources. Utility/service planning. Transportation planning and management. Infrastructure planning.	5
	Total	**42**

List of Practicals :

1. Familiarization with various photographic and digital remote sensing data products used for land use land cover mapping.
2. Study of spectral reflectance characteristics of various land use land cover features using Spectro-Radiometer.
3. Preparation of land use land cover classification scheme for an area.
4. Study of image interpretation elements through image interpretation keys for visual analysis of land use land cover. Preparation of a land cover map from the given FCC. Take minimum mapping unit as 5 mm x 5 mm. Compute areas of various land cover classes mapped using digital planimeter.
5. Training on image classification module of ERDAS Imagine. Practice for selection of training areas and their quality assessment using histogram and separability analyses.
6. Comparative assessment of various statistical image classifiers for land use land cover mapping. Practice for selection of testing areas based on different sampling schemes for classification accuracy assessment in ERDAS Imagine.
7. Preparation of a land use land cover map using back propagation neural network algorithm (use either Matlab, IDRISI or ENVI software).
8. Preparation of land use land cover map at sub-pixel level using soft classification techniques (use either ERDAS, IDRISI or ENVI software).
9. Preparation of land parcel and building map from high resolution satellite image.
10. Development of a computer program to implement an advanced image classification algorithm (e.g., decision tree classifier, evidential reasoning or any other).
11. Preparation of a land use land cover change detection map using various image change detection algorithms (use either ERDAS, IDRISI or ENVI software).

11. Suggested Books :

Sl. No.	**Name of Authors/Books/Publishers**	**Year of Publication/ Reprint**
1.	Campbell, J. B., "Introduction to Remote Sensing", Guilford Press.	2002
2.	Lillesand, T.M. and R.W. Kiefer, "Remote Sensing and Image Interpretation", 4th Ed., John Wiley.	2000
3.	Mather, Paul M., "Computer Processing of Remotely-Sensed Images", John Wiley.	1999
4.	Rencz, Andrew B. (Editor-in-Chief), "Remote Sensing for Natural Resource Management and Environmental Modeling", Manual of Remote Sensing, Vol. 4. John Wiley.	2004
5.	Rencz, Andrew B. (Editor-in-Chief), "Remote Sensing of Human Settlements", Manual of Remote Sensing, Vol. 5, John Wiley.	2004

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE: **Department of Civil Engineering**

1. Subject Code: **CEN- 617** Course Title: **Satellite Geodesy**
2. Contact Hours: **L: 3 T: 0 P: 2**
3. Examination Duration (Hrs): **Theory: 3 Practical: 0**
4. Relative Weight: **CWS: 15 PRS: 25 MTE: 20 ETE: 40 PRE: 0**
5. Credits: **4** 6. Semester: **Spring** 7. Subject Area: **PEC**
8. Pre-requisite: **Nil**
9. Objective of Course : To provide enhanced knowledge on satellite geodesy and its applications in GPS.

10. Details of Course :

Sl. No.	Contents	Contact Hours
1	Introduction, Fundamentals: Reference coordinate systems, Time, Signal Propagation.	7
2	Satellite Orbital Motion: Fundamental of Celestial Mechanics, Purturbed Satellite Motion, Orbit determination, Satellite Orbit & Orbital Maneuvers	8
3	Basic Observation Concepts and Geodetic Satellites: Satellite Geodesy for parameter estimation, Observables and basic concepts, Satellites used in geodesy, GNSS systems-GPS, GLONASS, Galelio etc	9
4	Satellite Altimetry – basics, satellites & missions, Measurements, corrections, Data Processing and Accuracy, determination of mean sea surface.	5
5	Laser Ranging- Systems and components; Measurements, corrections, Data Processing and Accuracy; Applications	5
6	Planned Missions and Special Methods – VLBI.	3
7	Applications of Geodetic Satellite Methods – Positioning, Gravity Field and Earth Models, Navigation, Geodynamics.	5
	Total	**42**

List of Practicals :

1. Demonstration, hands-on practice and collection of data using Geodetic GPS receivers. Further, download and process the data using commercial software.
2. Demonstration, hands-on practice and analysis of 7 days GPS data using BERNESE software.
3. Demonstration, hands-on practice and analysis of 7 days GPS data using GAMIT software.
4. To determine the different orbit and satellite parameters from GPS data.
5. Process and analyse laser ranging data.
6. Process and analyse VLBI data.

11. Suggested Books :

Sl. No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1.	Kaula, W.A., “Theory of Satellite Geodesy”, Dover Pub. Inc. NY	2000
2.	Seeber, Gunter, “Satellite Geodesy: Foundations”, Methods and Applications. Walter De Gruyter, NY.	2006
3.	Mueller, I.I., “Introduction to Satellite Geodesy”, Ungar Pub.	1964
4.	Tishchenko, A.P., “Geometrical Methods of Space Geodesy”, NASA Pub.	1971

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE: **Department of Civil Engineering**

1. Subject Code: **CEN-618** Course Title: **Modeling and Analysis of Geo-Spatial Data**
2. Contact Hours: **L: 3 T: 0 P: 2**
3. Examination Duration (Hrs): **Theory: 3 Practical: 0**
4. Relative Weight: **CWS: 15 PRS: 25 MTE: 20 ETE: 40 PRE: 0**
5. Credits: **4** 6. Semester: **Spring** 7. Subject Area: **PEC**
8. Pre-requisite: **Nil**

9. Objective of Course : To introduce various modeling and error analysis techniques for processing of geo-data acquired from surveying, photogrammetry, GPS, remote sensing and GIS.

10. Details of Course :

Sl. No.	Contents	Contact Hours
1.	**Types of Geo-spatial Data**: Ratio, Categorical and Ordinal Data. Spatial and Non-spatial data. Vector and Raster Data. Primary and Secondary Data.	5
2.	**Multi Criterion Decision Making:** Standardisation of weights, Analytical Hierarchical Process (AHP), Spatial Decision Support System	4
3.	**Coordinate Transformations:** Two-Dimensional, Conformal, Affine, Projective Coordinate Transformation. Three-Dimensional Conformal Coordinate Transformation. Map models and Map Projection Systems	5
4.	**Geo-spatial Data Structures and Database Management Systems**: Data Compression Models, DBMS and Relational DBMS. File Formats for various GIS Data Types. Digital Remote Sensing Data: File Formats.	6
5.	**Measurements and Analysis**: Sample versus Population. Graphical Representation of Geo-spatial Data. Measures of Central Tendency – Mean, Median, Mode. Mean Vector. Measures of Variation in Data - Variance Covariance and Correlation Matrices.	5
6.	**Error in Geo-spatial Data and Error Modeling**: Error Sources, Types of Errors – Gross, Systematic and Random Errors. Precision, Accuracy and Uncertainty. Errors in Geospatial data and measurements, Propagation of Random Errors.	4
7.	**Principles of Least Squares**. Observation Equations. Systematic Formulation of the Normal Equations. Using Matrices to Form the Normal Equations. Least Squares Solution of Nonlinear Systems. Least Squares Fit of Points to a Line or Curve. Concept of Adjustment of Errors. Least Squares Adjustment Using Conditional Equations and Observation Equations	5
8.	**Confidence Intervals and Statistical Testing**: Sampling Distributions. Sampling Schemes and Sample Sizes. Confidence Interval for the Mean: *t* Statistic. Confidence Interval for a Population Variance. Confidence Interval for the Ratio of Two Population Variances. Hypothesis Testing. Uses of Statistical Testing in Geo-spatial Data Processing.	5
9.	**Uncertainty Modeling of Geo-spatial Data**: Uncertainties in various Geo-spatial Data, Fuzzy set, Monte Carlo Simulations. Error Ellipse for Uncertainty Quantification.	3
	Total	**42**

List of Practicals :

1. Familiarity with different types of Geodata: Ratio, Categorical and Nominal
2. Understanding raster and vector data
3. Familiarization with various 2D and 3D coordinate transformations and Map Projection Systems.
4. Working on a DBMS software
5. Introduction to a Statistical Software for various applications, namely,
   - i) Generation of random error data
   - ii) Error modeling
   - iii) Least Squares adjustment
   - iv) Statistical Testing
   - v) Uncertainty modeling

11. Suggested Books :

Sl. No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1.	Bossler, J. D., "Manual of Geospatial Science and Technology", Taylor and Francis.	2002
2.	Freund, J. E., "Mathematical Statistics", Prentice Hall of India.	1998
3.	Law, A. M. and Kelton, W. D., "Simulation, Modeling and Analysis", Tata McGraw Hill.	2003
4.	Mikhail, Edward M. and Gracie, Gordon, "Analysis & Adjustment of Survey Measurements", Van Nostrand Reinhold.	1981

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

1. Subject Code : **CEN**-621 Course Title : **Advanced Geotechnical Exploration and Testing**
2. Contact Hours : **L: 3 T : 1 P: 0**
3. Examination Duration (Hrs) : **Theory : 3 Practical : 0**
4. Relative Weight : **CWS :25 PRS: 0 MTE: 25 ETE: 50 PRE: 0**
5. Credits : **04** 6. Semester: **Spring** 7. Subject Area : **PEC**
8. Pre-requisite: **Nil**
9. Objective : To impart knowledge of advanced methods of testing of geological materials like soil, rocks and rock masses
10. Details of Course :

S. No.	Contents	Contact Hours
1.	**Pressure Meter Testing of Soils and Weak Rocks:** Menard pressure meter equipment, Probe calibration and corrections, Limit pressure, Creep pressure, Tests in soils and weak rocks, Interpretation of test data, Pressure meter modulus of soils & weak rocks	05
2.	**Dilatometer Testing of Soils:** Equipment and procedure of testing, Interpretation of test data, Geotechnical parameters of clay- OCR, k_0, un-drained shear strength, soil stiffness, coefficient of consolidation, Geotechnical parameters of clay- friction angle, state parameter, soil stiffness, Application to problems of settlement of shallow foundations, laterally loaded piles, soil liquefaction etc.	05
3.	**Stress Path Testing of Soils:** Influence of stress history on behavior of soils, Stress paths for hydrostatic compression (HC), Direct shear (DS), Conventional tri-axial compression (CTC), Conventional tri-axial extension (CTE), True tri-axial compression (TTC), drained and un-drained situations, analysis and interpretation of test data on NC and OC clays	07
4.	**Post Failure Testing of Rocks:** Servo-controlled uni-axial and tri-axial testing of different rock types, effect of confining pressure, brittle-ductile transition, effect of L/D ratio, Cyclic testing of rock cores, analysis and interpretation of test data	06
5.	**Electrical Resistivity Methods:** Principle, Resistivity of soils and rocks, Resistivity Technique- Wenner and Schlumberger arrangements, Electrical Soundings, Methods of electrical resistivity profiling, Analysis and interpretation of field test data	07
8.	**In-situ shear Strength of Jointed Rocks:** Equipment and test procedure, interpretation for peak and residual strength of rock mass	02
6.	**Measurement of In-situ Stresses in Rocks:** Flat jack technique, Hydro-fracturing method	04
7.	**In-situ Deformation Modulus of Jointed Rocks :** Goodman Jack test, Plate jacking test, Plate jacking test down the drill hole, radial jacking test etc., interpretation of test data.	06
	Total	**42**

List of Practicals :

1. Pressure meter testing of soils during boring and its variation with depth
2. Stress path testing of soils under hydro-static compression
3. Stress path testing of soils in conventional tr-axial compression
4. Stress path testing of soils under true tr-axial compression
5. Servo-controlled uni-axial testing of rock specimens
6. Servo-controlled tri-axial testing of rock specimens
7. Demonstration of electrical resistivity profiling method
8. Demonstration of Goodman jack test for deformation modulus of rocks

11. Suggested Books :

S. No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1.	Singh Alam, "Soil Engineering in Theory and Practice", Asia Pub. House.	1981
2.	Atkinson, J.H., Bransby, P.L., " The Mechanics of Soils- An Introduction to Critical State Soil Mechanics", McGraw Hill Book Co., UK.	1978
3.	Schnaid, F., " In Situ Testing in Geomechanics", Taylor and Francis.	2009
4.	Hudson, J. A., Harrison, J. P., "Engineering Rock Mechanics", Pergamon Press	1997
5.	Ramamurthy, T., " Engineering in Rocks for Slopes, Foundations and Tunnels", Prentice Hall.	2007

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

1. Subject Code : **CEN-622** Course Title : **Advanced Foundation Engineering**
2. Contact Hours : **L: 3 T : 1 P: 2/2**
3. Examination Duration (Hrs) : **Theory : 3 Practical : 0**
4. Relative Weight : **CWS :20 PRS: 20 MTE: 20 ETE: 40 PRE: 0**
5. Credits : **04** 6. Semester: **Spring** 7. Subject Area : **PEC**
8. Pre-requisite: **Nil**

9. Objective of Course: To impart knowledge of methods of analysis and design of various foundations.

10. Details of Course :

S. No.	Contents	Contact Hours
1.	Planning of soil exploration for different projects, methods of subsurface exploration, methods of borings along with various penetration tests	05
2.	Shallow foundations, requirements for satisfactory performance of foundations, methods of estimating bearing capacity, settlements of footings and rafts, proportioning of foundations using field test data, IS codes, pressure – settlement characteristics from constitutive laws	06
3.	Pile foundations, methods of estimating load transfer of piles, settlements of pile foundations, pile group capacity and settlement, laterally loaded piles, pile load tests, analytical estimation of load- settlement behaviour of piles, proportioning of pile foundations, lateral and uplift capacity of piles	06
4.	Well foundation, IS and IRC codal provisions, elastic theory and ultimate resistance methods	05
5.	Tunnels and arching in soils, pressure computations around tunnels	04
6.	Open cuts, sheeting and bracing systems in shallow and deep open cuts in different soil types	06
7.	Coffer dams, various types, analysis and design	03
8.	Foundations under uplifting loads	04
9.	Soil-structure interaction	03
	Total	**42**

List of Practicals:

1. Exploratory borings by different methods including auger boring
2. Wash boring
3. Percussion drilling and rotary drilling etc. followed by - planning of soil exploration for different projects,
4. Standard penetration tests
5. Dynamic cone penetration tests
6. Static cone penetration tests
7. Plate load tests
8. Load tests on piles

11. Suggested Books:

S. No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1.	Bowles, Joseph E., "Foundation Analysis and Design", Mc-Graw Hill.	1996
2.	Das, Braja M., "Principles of Foundation Engineering", PWS Publishing.	1998
3.	Som, N, N. and Das S. C., "Theory and Practice of Foundation Design", Prentice Hall.	2003
4.	Poulos, H. G. and Davis, F. H., "Pile Foundation Analysis and Design", Wiley and Sons.	1980
5.	Saran, S., "Analysis and Design of Substructures", Oxford and IBH.	2006

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

1. Subject Code : **CEN-623** Course Title : **Stability Analysis of Slopes**
2. Contact Hours : **L: 3** **T : 1** **P: 0**
3. Examination Duration (Hrs) : **Theory : 3** **Practical : 0**
4. Relative Weight : **CWS :25** **PRS: 0** **MTE: 25** **ETE: 50** **PRE: 0**
5. Credits : **04** 6. Semester: **Spring** 7. Subject Area : **PEC**
8. Pre-requisite: **Nil**

9. Objective of Course : Landslides is a very common phenomenon in hilly regions and results in loss of life and property. The course is designed to identify various modes of failures and study their safety aspects including provision of remedial measures.

10. Details of Course :

S. No.	Contents	Contact Hours
1.	Introduction, classification of natural slopes and excavation failures, slope stability – mechanics of slope failure, failure modes	04
2.	Collection and analysis of geological data, field survey and testing, graphical presentation of geological data and evaluation of potential slope problems	06
3.	Seepage analysis, in-situ permeability tests, two dimensional flow – Laplace equation and it's solution, graphical method, determination of phreatic line, flow nets in homogeneous and zoned earth dams under steady seepage and draw-down conditions, seepage control in earth dams, influence of seepage on slope stability	06
4.	Soil slopes, infinite slope, method of slices, friction circle methods etc., Bishop's modified method, Bishop's rigorous method, Janbu's method, Morgenstern and Price, Spencer's method, stability analysis of dam body during steady seepage	08
5.	Rock slopes, methods of slope stability analysis, plane failure, wedge failure, over toppling failure, Hoek & Bray's charts, three dimensional wedge analysis, seismic considerations, computer programs, use of non-linear failure criterion in rock slope stability analysis	10
6.	Strengthening measures, stabilization of slopes by drainage methods, surface and subsurface drainage, use of synthetic filters, retaining walls, stabilization and strengthening of slopes, shotcreting, rock bolting and rock anchoring	06
7.	Instrumentation and monitoring of slopes, slope movements, warning devices, maintenance of slopes	02
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/Books/Publisher	Year of Publication/ Reprint
1.	Hoek, E. and Bray, J.W., "Rock Slope Engineering" Institution of Mining Engineering.	1981
2.	Giani, G.P., "Rock Slope Stability Analysis", A A Balkema.	1992
3.	Wyllie Duncan C and Christofer W Mah," Rock Slope Engineering" Spon Press, Taylor and Francis Group.	2004
4.	Singh, B. and Goel, R.K.,"Software for Engineering Control of Landslides and Tunneling Hazards", A A Balkema.	2002
5.	Harr M.E.," Ground Water and Seepage", McGraw Hill.	1962
6.	Chowdhary Robin and Chowdhary Indrajit , "Geotechnical Slope Analysis", CRC Press.	2009

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

1. Subject Code : **CEN-624** Course Title : **Design of Underground Excavations**
2. Contact Hours : **L: 3 T : 1 P: 0**
3. Examination Duration (Hrs) : **Theory : 3 Practical : 0**
4. Relative Weight : **CWS :25 PRS: 0 MTE: 25 ETE: 50 PRE: 0**
5. Credits : **04** 6. Semester: **Spring** 7. Subject Area : **PEC**
8. Pre-requisite: **Nil**
9. Objective of Course : To impart knowledge of methods of analysis and design of underground excavations in rocks and jointed rock masses for hydro-power projects and large underground storages for various purposes.

10. Details of Course :

S. No.	Contents	Contact Hours
1.	Introduction, planning of and exploration for various underground construction projects	04
2.	Stereographic projection method, principle and its application in underground excavation design	04
3.	Elastic stress distribution around tunnels, stress distribution for different shapes and under different in-situ stress conditions, Greenspan method, design principles, multiple openings, openings in laminated rocks, elasto-plastic analysis of tunnels, Daemen's theory	08
4.	Application of rock mass classification systems, ground conditions in tunneling, analysis of underground openings in squeezing and swelling ground, empirical methods, estimation of elastic modulus and modulus of deformation of rocks; uni-axial jacking / plate jacking tests, radial jacking and Goodman jacking tests, long term behaviour of tunnels and caverns, New Austrian Tunneling Method (NATM), Norwegian Tunneling Method (NTM), construction dewatering	09
5.	Rock mass-tunnel support interaction analysis, ground response and support reaction curves, Ladanyi's elasto-plastic analysis of tunnels, design of various support systems including concrete and shotcrete linings, steel sets, rock bolting and rock anchoring, combined support systems, estimation of load carrying capacity of rock bolts	08
6.	In-situ stress, flat jack, hydraulic fracturing and over coring techniques and USBM type drill hole deformation gauge, single and multi-point bore hole extensometers, load cells, pressure cells, etc	05
7.	Instrumentation and monitoring of underground excavations, during and after construction, various case studies	04
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors /Books/Publishers	Year of Publication / Reprint
1.	Hoek, E and and Brown, E. T.," Underground Excavations in Rocks", Institute of Mining Engineering.	1983
2.	Obert, L. and Duvall, W.I., "Rock Mechanics and Design of Structures in Rocks", John Wiley.	1967
3.	Singh, B. and Goel, R.K.,"Rock Mass Classification- A Practical Engineering Approach", Elsevier.	2006
4.	Singh, B. and Goel, R.K., "Tunnelling in Weak Rocks", Elsevier.	2006
5.	Ramamurthy, T., "Engineering in Rocks", PHI Learning.	2008

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

1. Subject Code : **CEN-625** Course Title : **Ground Improvement Engineering**
2. Contact Hours : **L: 3 T : 1 P: 0**
3. Examination Duration (Hrs) : **Theory : 3 Practical : 0**
4. Relative Weight : **CWS :25 PRS: 0 MTE: 25 ETE: 50 PRE: 0**
5. Credits : **04** 6. Semester: **Spring** 7. Subject Area : **PEC**
8. Pre-requisite: **Nil**

9. Objective of Course: To apprise the students about treatment of poor soil conditions for development activities and tell them about state of art in this area by case studies.

10. Details of Course :

S. No.	Contents	Contact Hours
1.	Introduction, typical situations where ground improvement becomes necessary, historical review of methods adopted in practice, current status and the scope in the Indian context	05
2.	Methods of ground improvement, mechanical compaction, dynamic compaction, impact loading, compaction by blasting, vibro-compaction; pre-compression, dynamic consolidation, design aspects of stone columns, use of admixtures, injection of grouts, design guidelines and quality control, design examples on preloading with sand drains, road designs with geosynthetics	09
3.	Reinforced earth, basic mechanism, constituent materials and their selection; engineering applications – shallow foundations on reinforced earth, design of reinforced earth retaining walls, reinforced earth embankments structures, wall with reinforced backfill, analysis and design of shallow foundations on reinforced earth	10
4.	Geotextiles, selection and engineering applications, design examples, stabilisation/improvement of ground using geomembranes, geocells, geonets, geosynthetic walls	08
5.	Soil nailing, construction of underground structures, landslide controls, deep vertical cuts, contiguous piles	04
6.	Problematic soils, use of ply soils, improvement of saline soils, improvement of black cotton soils	06
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/Books/Publisher	Year of Publication/ Reprint
1.	Moseley, M. P. and Kirsch K.,"Ground Improvement", Spon press.	2004
2.	Mittal, Satyendra, "Ground Improvement Engineering", Vikas publishing house	2010
3.	Koerner, R.M., "Designing with Geosynthetics"' Prentice hall.	1990
4.	Saran, S., "Reinforced Soil and Its Engineering Applications", I.K. international	2005
5.	Rao, G.V., Geosynthetics – An Introduction, Sai Master geoenvironmental services.	2007
6.	Jones, CJFP, "Earth Reinforcement and soil structure", Thomas Telford	1996
7.	Shukla, S.K., Yin, Jian-Hua, "Fundamentals of Geosynthetic Engineering", Taylor & Francis.	2006

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

1. Subject Code : **CEN-626** Course Title : **Foundations on Weak Rocks**
2. Contact Hours : **L: 3 T : 1 P: 0**
3. Examination Duration (Hrs) : **Theory : 3 Practical : 0**
4. Relative Weight : **CWS :25 PRS: 0 MTE: 25 ETE: 50 PRE: 0**
5. Credits : **04** 6. Semester: **Spring** 7. Subject Area : **PEC**
8. Pre-requisite: **Nil**
9. Objective of Course : This course is designed to impart knowledge for design of foundations of structures in hill regions and methods for treatment of weak foundations to make them stable.

10. Details of Course :

S. No.	Contents	Contact Hours
1.	Engineering properties of weak rocks, different rock mass classification systems, relative merits and demerits	02
2.	Failure criteria for weak rocks, bi-linear Mohr-Coulomb failure criterion, Hoek and Brown criterion and modified Hoek and Brown failure criterion etc.	02
3.	Effect of structural planes on rock foundations, possible modes of failure of foundations on rocks/ rock masses, determination of in-situ shear strength of rocks and rock masses	04
4.	Requirements for satisfactory performance of foundations, bearing capacity of foundations on rocks and rock masses, allowable bearing pressure of rock foundations using a nonlinear failure criterion, monotonic and cyclic plate load tests	07
5.	Pressure-settlement characteristics, effect of layering, anisotropy, heterogeneity and in-elasticity	06
6.	Shallow foundations, shallow foundations on sloping ground, raft foundations, stilt foundations, foundations for suspension bridges, transmission line towers, framed buildings etc, treatment of foundations - open joints, solution cavities, weak seams	08
7.	Piles in weak rocks, bearing capacity and settlement of piles, piles in stratified rock masses, field load tests on piles in weak rocks, behaviour of bored / driven piles in soft / weathered rocks, case studies	06
8.	Dam foundations, stability analysis, 3D wedge analysis of abutments of arch dams, dam-foundation interaction problems, influence of discontinuities like faults, fault zones, shear zones, seams etc on stability of dams, seepage below dam foundations etc., treatment of dam foundations- shear keys, dental treatment of faults, seams, grouting of cavities, grout curtains, cable anchors etc	07
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/Books/Publisher	Year of Publication/ Reprint
1.	Wyllie Duncan C.," Foundations on Rock: Engineering Practice", E&FN Spon, Taylor and Francis.	2005
2.	Singh, B. and Goel, R.K.,"Rock Mass Classification- A Practical Engineering Approach", Elsevier .	2006
3.	Hudson, J. A.(Chief Ed.), "Comprehensive Rock Engineering: Principles-Practice & Project," Vols. 1-5, Pergamon press.	1993
4.	Hoek, E., "Practical Rock Engineering", Rock science.	2000
5.	Ramamurthy, T., "Engineering in Rocks", PHI learning.	2008

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

1. Subject Code : **CEN-627** Course Title : **Landslide Analysis and Control**
2. Contact Hours : **L: 3 T : 1 P: 0**
3. Examination Duration (Hrs) : **Theory : 3 Practical : 0**
4. Relative Weight : **CWS :25 PRS: 0 MTE: 25 ETE: 50 PRE: 0**
5. Credits : **04** 6. Semester: **Spring** 7. Subject Area : **PEC**
8. Pre-requisite: **Nil**

9. Objective : To impart knowledge of advanced methods of testing of geological materials like soil, rocks and rock masses

10. Details of Course :

S. No.	Contents	Contact Hours
1.	Landslide hazard and risk	03
2.	Landslides in earth systems	03
3.	Earthquake and seismically induced landslides	03
4.	Stability analysis soil and rock slopes	03
5.	Rainfall analysis and rainfall induced landslides	03
6	Risk assessment	03
7	Landslide hazard zonations	03
8	Numerical modelling of landslides	03
9	Remote sensing techniques	03
10	Groundwater system analysis for landslides	03
11	Remediation techniques	03
12	Early warning systems	03
12	Disaster Mitigation	03
14	Sustainability and environmental issues	03
	Total	**42**

11. Suggested Books :

S. No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1.	**Landslides: Analysis and Control,** Volume 176 of Special report - Transportation Research Board, National Research Council, National Research Council (U.S.). Transportation Research Board	1978
2.	Singh, B. and Goel, R.K., "Rock Mass Classification – A Practical Engineering Approach", Elsevier	2006
3.	Hoek, E. and Bray, J.W., "Rock Slope Engineering", Institute of Mining Engg.	1981
4.	Giani, G.P., "Rock Slope Stability Analysis", A.A. Balkema	2002
5.	Singh, B. and Goel, R.K., "Software for Engineering Control of Landslide and Tunneling Hazards", A.A. Balkema	2002
6.	Deoja, B., Dhital, M., Thapa, B., Wagner, A., "Mountain Risk Engineering Handbook", ISIMOD, Kathmandu	2002

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

1. Subject Code : **CEN-628** Course Title : **Constitutive Models for Geological Materials**
2. Contact Hours : **L: 3 T : 1 P: 0**
3. Examination Duration (Hrs) : **Theory : 3 Practical : 0**
4. Relative Weight : **CWS :25 PRS: 0 MTE: 25 ETE: 50 PRE: 0**
5. Credits : **04** 6. Semester: **Spring** 7. Subject Area : **PEC**
8. Pre-requisite: **Nil**
9. Objective of Course : To important knowledge in respect of various constitutive models for soil and rock involving stress-strain relationships.

10. Details of Course :

S. No.	Contents	Contact Hours
1.	Role of constitutive modeling	02
2.	Importance of Laboratory Testing with Relation to Constitutive Modeling;	02
3.	Elasticity: Linear, quasilinear, anisotropic;	04
4.	Plasticity basics: Yield criteria, Flow rule, Plastic Potential, Hardening/ softening;	06
5.	Rate Independent Plasticity: Mohr-Coulomb, Non-linear failure criteria, Drucker-Prager, and Cap models	06
6.	Critical State Soil Mechanics: Critical state concept, Cam-clay models,	06
7.	Constitutive model for rocks	04
8.	Simulation of single element test using cam-clay: consolidation, drained and undrained triaxial test,	04
9.	Stress-dilatancy theory	02
10.	Work Hardening Plasticity Theory Formulation and implementation	02
11.	Applications of Elasto-plastic models	02
12.	Special Topics: Hypoelasticity-plasticity, Disturbed state concept	02
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1.	Hicher and Shao, “Constitutive Modeling of Soils and Rocks”, John Wiley.	2008
2.	N. Schofield and C. P. Wroth, “Critical State Soil Mechanics”, McGraw-Hill.	1968
3.	C.S. Desai and H. J. Siriwardane, “Constitutive Laws for Engineering Materials with Emphasis on Geologic Materials”, Prentice-Hall, Inc., New Jersey.	1984
4.	David M Potts and Lidija Zdravkovic, “Finite Element Analysis in Geotechnical Engineering Theory”, Thomas Telford.	1999
5.	C.S. Desai, “Mechanics of Materials and Interfaces : The Disturbed State Concept”, CRC Press LLC.	2000
6.	A.P.S. Selvadurai, M.J. Boulon, “Mechanics of Geomaterial Interfaces, Elsevier.	1995

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

1. Subject Code : **CEN-631** Course Title : **Fluvial Hydraulics**
2. Contact Hours : **L: 3** **T : 1** **P: 0**
3. Examination Duration (Hrs) : **Theory : 3** **Practical : 0**
4. Relative Weight : **CWS : 25** **PRS: 0** **MTE: 25** **ETE: 50** **PRE: 0**
5. Credits : **4** 6. Semester: **Spring** 7. Subject Area : **PEC**
8. Pre-requisite: **Nil**
9. Objective: To introduce the flow characteristics in an alluvial channel with erodible boundary.
10. Details of Course:

S. No.	Contents	Contact Hours
1.	The sediment problems, properties of sediments, incipient motion of uniform and non-uniform sediments.	8
2.	Bed forms and channel resistance.	5
3.	Bed load and suspended load transport for uniform and non-uniform bed material, total load equations, sediment sampling.	10
4.	Stable channel design and sediment control.	4
5.	Bed level variations, local scour, degradation, aggradation and reservoir sedimentation.	7
6.	Physical and mathematical models.	4
7.	Design of guide bunds and other river training banks.	4
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/Books/ Publisher	Year of Publication/ Reprint
1.	Garde, R.J., “River Morphology”, New International Publishers.	2006
2.	Julien, P.Y., “Erosion and Sedimentation”, Cambridge University Press.	1998
3.	Jansen, P.P.H., “Principals of River Engineering”, VSSD Publications.	1994
4.	Garde, R.J. and Ranga Raju, K.G., "Mechanics of Sediment Transportation and Alluvial Stream Problems", Wiley Eastern Limited.	2006

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

1. Subject Code : **CEN-632** Course Title : **Hydraulic Structures**
2. Contact Hours : **L: 3** **T : 1** **P: 0**
3. Examination Duration (Hrs) : **Theory : 3** **Practical : 0**
4. Relative Weight : **CWS : 25** **PRS: 0** **MTE: 25** **ETE: 50** **PRE: 0**
5. Credits : **4** 6. Semester: **Spring** 7. Subject Area : **PEC**
8. Pre-requisite: **Nil**

9. Objective: To introduce various hydraulic structures and their hydraulic design.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	Introduction: Hydraulic structures for water resources projects.	2
2.	Embankment Dams: Types, design considerations, seepage analysis and control, stability analysis, construction techniques.	8
3.	Gravity Dams: Forces acting on failure of a gravity dam, stress analysis, elementary profile, design of gravity dam, other functional features of a gravity dam.	8
4.	Dam Outlet Works: Types of outlet structures, ogee spillway, chute spillway, siphon spillway, side channel spillway, Labyrinth and Pianokey weir.	8
5.	Terminal Structures: Hydraulic jump types, stilling basin, roller bucket, ski jump basin, baffled spillway, drop structure	7
6.	Hydraulic Modeling: Basic principles, dimensional analysis, modeling free-surface flows, design of physical models	9
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/Books/Publisher	Year of Publication/ Reprint
1.	Peterka, A.J, “Hydraulic Design of Stilling Basins and Energy Dissipators”, USBR Engineering Monographs No. 25”.	1984
2.	"Design of Small Dams", Third Edition, Water Resources Technical Publication – US Bureau of Reclamation.	1987
3.	Singh, B., and Varshney, R.S., "Embankment Dam and Engineering", Nem Chand and Brothers.	2004
4.	Chanson, H., “The Hydraulics of Open Channel Flow : An Introduction”, Elsevier Scientific Publications.	2004
5.	Novak, P. and Nalluri, C., “Hydraulic Structures”, Edition 4, Taylor & Francis.	2007
6.	Creager, Justin and Hinds, “Engineering for Dams”, Vol. I and II, John Wiley.	

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

1. Subject Code : **CEN-633** Course Title : **Systems Engineering**
2. Contact Hours : **L: 3** **T : 1** **P: 0**
3. Examination Duration (Hrs) : **Theory : 3** **Practical : 0**
4. Relative Weight : **CWS : 25** **PRS: 0** **MTE: 25** **ETE: 50** **PRE: 0**
5. Credits : **4** 6. Semester: **Spring** 7. Subject Area : **PEC**
8. Pre-requisite: **Nil**

9. Objective: To introduce basic concepts of systems, system modeling, system synthesis and optimization.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	Definitions and components of a system, system control, systems modelling and model development.	10
2.	System synthesis. economic analysis, conflicts and role of optimization in their resolution.	6
3.	Unconstrained optimization – analytical and numerical.	3
4.	Constrained optimization – analytical and numerical.	3
5.	Integer programming.	2
6.	Geometric programming.	2
7.	Linear programming.	10
8.	Dynamic programming.	3
9.	Stochastic programming.	3
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/Books/Publisher	Year of Publication/ Reprint
1.	Aguilera, R.J., "Systems Analysis and Design", Prentice Hall.	1973
2.	Ossenbruggen, P. J., "Systems Analysis for Civil Engineering", John Wiley.	1984
3.	de Neufrille, R., "Systems Analysis for Engineer" , McGraw Hill.	1971
4.	Rao, S.S., "Engineering Optimization – Theory and Practice", New Age International (P) Ltd.	1999
5.	Hamdy, A.T., "Operations Research – An Introduction", Prentice Hall.	1997

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

1. Subject Code : **CEN-634** Course Title : **Water Resources Systems Planning**
2. Contact Hours : **L: 3** **T : 1** **P: 0**
3. Examination Duration (Hrs) : **Theory : 3** **Practical : 0**
4. Relative Weight : **CWS : 25** **PRS: 0** **MTE: 25** **ETE: 50** **PRE: 0**
5. Credits : **4** 6. Semester: **Spring** 7. Subject Area : **PEC**
8. Pre-requisite: **Nil**

9. Objective: To introduce various aspects of systemic water resource planning and the relevant mathematical tools.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Water resources planning process, multi-objective planning.	3
2.	**Evaluation of Water Plans:** Basic concepts of engineering economics, welfare economics, economic comparison of alternatives.	4
3.	**Water Plan Optimization:** Plan formulation, objective functions and constraint, analytical optimization, numerical optimization, linear programming, dynamic programming, simulation, planning under uncertainty.	10
4.	**Deterministic River Basin Modeling:** Stream flow modeling, estimation of reservoir storage requirements – dead storage, active storage for water supply/ irrigation / power generation, flood storage, optimal allocation.	10
5.	**Conjunctive Use/Groundwater Management Models:** LP based conjunctive use modeling, aquifer response models, link - simulation, embedded, matrix response based models, soft modeling.	10
6.	**Water Quality Management Models:** Basic water quality modeling, objectives of management, control alternatives, optimal plans.	5
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/Books/Publisher	Year of Publication/ Reprint
1.	Hall, W.A. and Dracup, J.A., "Water Resources Systems Engineering", McGraw Hill Book Company.	1970
2.	Loucks, D.P., "Water Resource Systems Planning and Analysis", Prentice Hall.	1981
3.	Maass et al., "Design of Water-Resource Systems", Harvard University Press.	1962
4.	Vedula S. and Mujumdar, P.P., "Water Resources Systems", Tata McGraw Hill.	2005

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

1. Subject Code : **CEN-635** Course Title : **Irrigation and Drainage**
2. Contact Hours : **L: 3** **T : 1** **P: 0**
3. Examination Duration (Hrs) : **Theory : 3** **Practical : 0**
4. Relative Weight : **CWS : 25** **PRS: 0** **MTE: 25** **ETE: 50** **PRE: 0**
5. Credits : **4** 6. Semester: **Spring** 7. Subject Area : **PEC**
8. Pre-requisite: **Nil**
9. Objective: To introduce concepts of irrigation engineering including drainage and salt balance / leaching aspects.
10. Details of Course:

S. No.	Contents	Contact Hours
1.	Introduction, objectives of irrigation, type of irrigation and suitability; selection of irrigation method.	3
2.	Irrigation requirement, water balance, soil water relationships, water storage zone, infiltration.	6
3.	Flow of moisture through root zone, soil physical and chemical properties, crop evaporative and drainage requirements, irrigation efficiency and uniformity.	4
4.	Surface irrigation systems, types of surface systems, basin irrigation, border irrigation, furrow irrigation, field measurement techniques, flow measurement, flumes, weirs, irrigation events, advance, wetting, depletion and recession phases.	7
5.	Infiltration, infiltrometer, ponding methods, soil water, tensiometers, neutron probe, time domain reflectometer, evapotranspiration, crop coefficient, leaf area index, FAO guide lines on evapotranspiration estimation.	6
6.	Fundamentals of surface irrigation hydraulics, continuity equation, momentum equation	3
7.	Hydrodynamic model, zero inertia model, kinematic wave model.	4
8.	Drainage principles, need for drainage, steady state equations, Hooghoudt, Kirkham, Dagan and Ernst equations.	6
9.	Salt balance, water and salt balance of the root zone, salt equilibrium equation and leaching requirement, leaching efficiency.	3
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1.	Walker, W.R., and Skogerboe, G.V., "Surface Irrigation Theory and Practice", Prentice Hall, INC.	1987
2.	Drainage Principles and Applications, "International Institute for Land Reclamation and Improvement", Wageningen.	1973
3.	Michael, A.M., "Irrigation: Theory and Practice", Vikas Publishing House.	1978
4.	Asawa, G.L., "Irrigation Engineering", New Age International Publishers.	1996
5.	Majumdar, D.K., “Irrigation Water Management”, PHI Learning.	2009
6.	Luthin, J.N., "Drainage Engineering", John Wiley.	1966

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

1. Subject Code : **CEN-636** Course Title : **Hydro Power Engineering**
2. Contact Hours : **L: 3** **T : 1** **P: 0**
3. Examination Duration (Hrs) : **Theory : 3** **Practical : 0**
4. Relative Weight : **CWS : 25** **PRS: 0** **MTE: 25** **ETE: 50** **PRE: 0**
5. Credits : **4** 6. Semester: **Spring** 7. Subject Area : **PEC**
8. Pre-requisite: **Nil**
9. Objective: To introduce fundamentals of hydropower, transient analysis and various components of a hydropower plant.
10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Water Power:** Introduction, sources of energy, role of hydropower in a power system.	3
2.	**Estimation of Water Power Potential:** Flow duration curves of gauge and ungauge streams, load curve, load factor, capacity factor, utilization factor, diversity factor, load duration curve, firm power, secondary power, prediction of load.	7
3.	**Types of Hydro-power Plants:** Run of river plants, general arrangement of run of river plants, valley dam plants, diversion canal plants, high head diversion plants, storage and pondage, pumped storage power plants.	4
4.	**Penstocks:** General classification, design criteria, economical diameter, losses, anchor blocks, valves, bends and manifolds.	6
5.	**Trash racks:** Types, losses, design, stability.	4
6.	**Intakes:** Types, losses, air entrainment, anti-vortex device, air vent, power channels, forebay, tunnel.	6
7.	**Turbines:** Introduction, types of turbines, hydraulics of turbines, velocity triangles, draft tubes, cavitation in turbines, turbine model testing, characteristics of turbines.	6
8.	**Water Hammer and Surges:** Introduction, water hammer, transients caused by turbine, load acceptance and rejection, resonance in penstocks, surge tanks, channel surges.	6
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1.	Dandekar, M.M., and Sharma, K.H., "Water Power Engineering", Vikas Publishing House Pvt. Ltd.	2000
2.	Barrows, H.K., "Water Power Engineering", Tata McGraw Hill Publishing Company Ltd.	1943
3.	Varshney, R.S., "Hydro Power Structures", Nem Chand & Bros.	2001
4.	Nigam, P.S., "Hydro Electric Engineering", Nem Chand & Bros.	2001
5.	Choudhary, M.H., "Applied Hydraulic Transients", Van Nostrand Reinhold Company	1987
6.	Streeter, V.L., and Wylie, B., "Fluid Transients", McGraw-Hill Book Company.	1967
7.	Warnick, C.C., "Hydropower Engineering", Prentice-Hall.	1984
8.	Norwegian Institute of Technology: Hydropower Development: Vols. 3, 4, 5 & 6, Division of Hydraulic Engineering.	1992-93

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

1. Subject Code : **CEN-637** Course Title : **Computational Methods in Fluid Mechanics**
2. Contact Hours : **L: 3** **T : 1** **P: 0**
3. Examination Duration (Hrs) : **Theory : 3** **Practical : 0**
4. Relative Weight : **CWS : 25** **PRS: 0** **MTE: 25** **ETE: 50** **PRE: 0**
5. Credits : **4** 6. Semester: **Spring** 7. Subject Area : **PEC**
8. Pre-requisite: **Nil**
9. Objective: To introduce various numerical techniques and their applications to transient pipe flow, open channel flow and groundwater flow and contaminant transport.
10. Details of Course:

S. No.	Contents	Contact Hours
1.	Review of numerical techniques like method of characteristics, finite difference method.	7
2.	Finite element method.	6
3.	Modelling of steady state flow and hydraulic transients in pipes.	6
4.	Modelling of non-uniform, transient spatially varied flows in open channels.	7
5.	Numerical solutions for Navier-Stokes, boundary layer and Reynolds equations.	8
6.	Modelling of groundwater flow and contaminant transport in groundwater.	8
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1.	Anderson, "Computational Fluid Mechanics and Heat Transfer", McGraw Hill.	1984
2.	Chung, T. J., "Finite Element Analysis in Fluid Dynamics", McGraw Hill.	1978
3.	Anderson, & Weessner, "Applied Groundwater Modelling", Academic Press.	1992
4.	Chaudhary, H. M., "Applied Hydraulic Transient", McGraw Hill.	1976
5.	Streeter and Wylie, "Fluid Transients", McGraw Hill.	1976
6.	Smith, G.D., "Numerical Solution of Partial Differential Equations-FDM".	1985

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

1. Subject Code : **CEN-641** Course Title : **Behaviour and Design of Steel Structures**
2. Contact Hours : **L: 3** **T : 0** **P: 2**
3. Examination Duration (Hrs) : **Theory : 3** **Practical : 0**
4. Relative Weight : **CWS : 15** **PRS: 25** **MTE: 20** **ETE: 40** **PRE: 0**
5. Credits : **04** 6. Semester: **Autumn** 7. Subject Area : **PEC**
8. Pre-requisite: **Nil**

9. Objective: To introduce basic concepts of stability of structures and illustrate it's application in thin walled structures along with advanced topics in analysis and design of steel structures

10. Details of Course:

S. No.	Contents	Contact Hours
1	Concepts of Stability, Introduction to Buckling Behaviour of Columns	03
2	Stability ofBeam-Columns and Frames	03
3	Lateral Instability of Beams	03
4	Local Buckling and Post Buckling Behaviour of Plates	03
5	Behaviour and Design of Cold Formed Thin Walled Structures Subjected to Flexure and Compression	10
6	Plastic Analysis and Design of Steel Structures, LRFD approach	04
7	Advanced Topics in Bolted and Welded Connections	05
8	Behaviour of Steel Concrete Composite Construction and Introduction to Brittle Fracture and Fatigue.	03
9	Design of Steel Truss Bridges	08
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1.	S.P. Timoshenko and J.M. Gere, "Theory of Elastic Stability" McGraw-Hill.	1963
2	A.S. Arya and J.L. Ajmani, "Design of Steel Structures" Nem Chand & Bros.	2000
3.	N. Subramanian, "Design of Steel Structures", Oxford University Press.	2008
4.	M.L. Gambhir, "Stability Analysis and Design of Structures", Springer.	2005

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

1. Subject Code : **CEN-642** Course Title : **Analysis and Design of Bridges**
2. Contact Hours : **L: 3** **T : 0** **P: 2**
3. Examination Duration (Hrs) : **Theory : 3** **Practical : 0**
4. Relative Weight : **CWS : 15** **PRS: 25** **MTE: 20** **ETE: 40** **PRE: 0**
5. Credits : **4** 6. Semester: **Spring** 7. Subject Area : **PEC**
8. Pre-requisite: **Nil**
9. Objective: To introduce bridge deck behavior with the help of classical and numerical analysis approaches and impart knowledge needed for design of R.C. and pre-stressed concrete bridges.

10. Details of Course:

S. No.	Contents	Contact Hours
1	Structural Forms and Design Loads for Bridges	03
2	Effective Width Concept and Load Distribution in Multi-Beam Bridges	05
3	Grillage Analogy	03
4	Design of R.C. and Pre-Stressed Concrete Slab Bridges	06
5	Design of R.C. and Pre-Stressed Concrete Girder Bridges	09
6	Behaviour of Box-Girder Bridges, Introduction to Arch Bridges, Suspension and Cable Stayed Bridges	09
7	Different Types of Bearings and Design of Elastomeric Bearings	03
8	Introduction to Secondary Effects, Temperature, Shrinkage, Creep. Construction Techniques and Effects of Construction Sequence on Design.	04
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1	N. Rajagopalan, “Bridge Superstructure”, Narosa Publishing House.	2010
2.	D.J. Victor, “Essentials of Bridge Engineering” Oxford & IBH Publishing.	2001
3.	Code of Practice for Concrete Road Bridges - IRC:112-2011, Indian Road Congress.	2011
4.	Standard Specifications and code of Practice for Bridges, Section II- Loads and Stresses - IRC:6-2010, Indian Road Congress.	2010
5.	E.C. Hambly, “Bridge Deck Behaviour”, Chapman and Hall, London.	1976

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

1. Subject Code : **CEN-643** Course Title : **Analysis and Design of High-Rise Buildings**
2. Contact Hours : **L: 3** **T : 0** **P: 2**
3. Examination Duration (Hrs) : **Theory : 3** **Practical : 0**
4. Relative Weight : **CWS : 15** **PRS: 25** **MTE: 20** **ETE: 40** **PRE: 0**
5. Credits : **4** 6. Semester: **Spring** 7. Subject Area : **PEC**
8. Pre-requisite: **Nil**
9. Objective: To introduce the analysis and design of tall buildings subjected to different loading conditions and detailing of various components.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	Structural systems for multi-storey buildings, gravity and lateral loads on buildings, analysis of multi-storey frames. Behaviour of framed tube, tube-in-tube systems, and bundled tube systems	6
2.	Importance of symmetry and regularity in plan, and regularity in elevation. Analysis for torsion in buildings	6
3.	Design of buildings with shear walls and coupled shear walls	6
4.	Design and detailing of various members and beam-column joints for ductility. The capacity design principle. Performance based design philosophy	6
5.	Design of floor slabs, raft and pile foundations	9
6.	Application of MS-Excel, ETABS and SAFE software	9
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1.	U.H.Varyani, "Structural Design of Multi-storeyed Buildings", 2nd Ed., South Asian Publishers, New Delhi.	2002
2.	V.L. Shah & S.R.Karve, "Illustrated Design of Reinforced Concrete Buildings", (GF+3storeyed), Structures Publications, Pune.	2013
3.	Design of Multi Storeyed Buildings, Vol. 1 & 2, CPWD Publications.	1976
4.	Bungale S. Taranath, "Structural Analysis and Design of Tall Buildings", Mc-Graw Hill.	1988
5.	Bryan S. Smith and Alex Coull, "Tall Building Structures", Wiley India.	1991
6.	Wolfgang Schueller, "High Rise Building Structures", Wiley.	1986

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

1. Subject Code : **CEN-644** Course Title : **Analysis and Design of Plates and Shells**
2. Contact Hours : **L: 3** **T : 0** **P: 2**
3. Examination Duration (Hrs) : **Theory : 3** **Practical : 0**
4. Relative Weight : **CWS : 15** **PRS: 25** **MTE: 20** **ETE: 40** **PRE: 0**
5. Credits : **4** 6. Semester: **Spring** 7. Subject Area : **PEC**
8. Pre-requisite: **Nil**
9. Objective: To analyze and design of plate and shell structures
10. Details of Course:

S. No.	Contents	Contact Hours
1	Classification of Plates	01
2	Governing Equations	03
3	Boundary Conditions	01
4	Analysis of Rectangular and Circular Plates	08
5	Grid Floor as Orthotropic Plate	03
	Buckling of Plates	01
	Design Criteria and Code Specification	02
	Classification of Shells	01
6	Membrane Theory for Shells of Revolution with Axisymmetric and Non-Axisymmetric Loadings	04
7	Bending Analysis of Shells of Revolution for Axisymmetric Loadings	02
8	Membrane and Bending Theories of Cylindrical Shells	03
9	Theory of Edge Beams	02
10	Doubly Curved Shells	02
11	Membrane Theory and Design of Hyperbolic Shells	02
12	Buckling of Shells	01
13	Design Applications, Analysis and Design of Folded plates, Cooling towers, Silos and Bunkers,	04
14	Codal Specifications, Practical Considerations, Computer Applications	02
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1.	S.P. Timoshenko and S. Woinowsky-Krieger, "Theory of Plates and Shells", 5th Ed., McGraw- Hill.	1959
2.	J.N. Reddy, "Theory and Analysis of Elastic Plates", 2nd Ed., Taylor & Francis.	2006
3.	B.K. Chatterjee, "Theory and Design of Concrete Shells", 3rd Ed., Chapman and Hall.	1988
4.	V.S. Kelker and R.T. Sewell, "Fundamentals of the Analysis and Design of Shell Structures", 1st Ed., Prentice Hall.	1987
5.	R. Szilard, "Theory and Analysis of Plates : Classical and Numerical Methods, 1st Ed., Prentice Hall.	1973

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

1. Subject Code : **CEN-645** Course Title : **Mechanics of Composites**
2. Contact Hours : **L: 3** **T : 1** **P: 0**
3. Examination Duration (Hrs) : **Theory : 3** **Practical : 0**
4. Relative Weight : **CWS : 25** **PRS: 0** **MTE: 25** **ETE: 50** **PRE: 0**
5. Credits : **4** 6. Semester: **Spring** 7. Subject Area : **PEC**
8. Pre-requisite: **Nil**

9. Objective: To analyze and design Laminated composite structures

10. Details of Course:

S. No.	Contents	Contact Hours
1.	Introduction-Classification and Characteristics of Composite Materials, Basic Terminology, Uses of Fibrous Composites	02
2.	Behaviour of Lamina Stress-Strain Relationship for Anisotropic, Orthotropic and Isotropic Material.	04
3.	. Transformation of Elastic Constants	02
4.	Failure Criteria for an Orthotropic Lamina	02
5.	Introduction to Micromechanics: Laws of Mixture	03
6.	Behavior of Laminate: Classical Lamination Theory, Stress-Strain Relationship for a Laminate, Extensional, Bending and Coupling Stiffness, Different Configurations and Corresponding Stiffness	06
7.	Strength of Laminates	02
8.	Inter-laminar Stresses	02
9.	Shear Deformation Theories	02
10.	Behaviour and Analysis of Laminated Plates Subjected to Bending, Buckling and Vibrations	07
11.	Thin Walled Laminated Structures and Sandwich Constructions	03
12.	Behaviour of laminated composite Joints	03
13.	Examples on Practical Applications	04
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1.	R.M. Jones, "Mechanics of Composite Materials", 2nd Ed., Taylor & Francis.	1998
2.	I.M. Daniel & Ori Ishai, "Engineering Mechanics of Composite Materials", 2nd Ed., Oxford University Press.	2013
3.	Autar K. Kaw, "Mechanics of Composite Materials", 2nd Ed., CRC Press.	2005
4.	R.F. Gibson, "Principles of Composite Mechanics", 2nd Ed., CRC Press.	2007
5.	B.D. Agarwal, L.J. Broutman, L.J. Broutman, "Analysis and Performance of Fibre Composites", 2nd Ed., John Wiley.	1990

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

1. Subject Code : **CEN-646** Course Title : **Engineering Design Optimization and Reliability**
2. Contact Hours : **L: 3** **T : 0** **P: 2**
3. Examination Duration (Hrs) : **Theory : 3** **Practical : 0**
4. Relative Weight : **CWS : 15** **PRS: 25** **MTE: 20** **ETE: 40** **PRE: 0**
5. Credits : **4** 6. Semester: **Spring** 7. Subject Area : **PEC**
8. Pre-requisite: **Nil**

9. Objective: This course is designed to introduce graduate students to concepts and applications of structural reliability and design optimization. Upon completion of this course, students will be able to: (a) Compute first- and second-order estimates of failure probabilities of engineered systems; (b) Compute sensitivities of failure probabilities to assumed parameter values; (c) Measure the relative importance of the random variables associated with a system; (d) Update reliability estimates based on new observational data; (e) Identify the relative advantages and disadvantages of various analytical reliability methods, as well as Monte Carlo simulation; (f) Use reliability tools to calibrate simplified building codes

10. Details of Course:

S. No.	Contents	Contact Hours
	Introduction to Design Optimization; Optimal Design Problem Formulation; Graphical Optimization and Basic Concepts	3
	Optimum Design Concepts: Optimality Conditions; Optimal Design with MATLAB	5
	Numerical Methods for Unconstrained Design Optimization; Numerical Methods for Constrained Design Optimization; Practical Applications of Optimization	8
	Genetic Algorithm for Optimum Design; Multi-objective Optimum Design Concepts and Methods	8
	Fundamentals of probability theory; Common probabilistic models	2
	General component reliability; First-order second-moment methods; First and Second-order reliability method	9
	Importance measures and parameter uncertainty; Sampling techniques; Surrogate Modelling	4
	Development of reliability based design codes; System reliability	3
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1.	Jasbir S. Arora, "Introduction to Optimum Design", 3rd Ed., Academic Press.	2012
2.	Achintya Halder and Sankaran Mahadevan, "Probability, Reliability, and Statistical Methods in Engineering Design", John Wiley.	2000
3.	O. Ditlevsen, and H. O. Madsen, "Structural Reliability Methods", Internet Edition 2.3.7, John Wiley. http://www.web.mek.dtu.dk/staff/od/books.htm	2007
4.	A.H.S. Ang and W. H. Tang, "Probability Concepts in Engineering Planning and Design", Vol. I : Basic Principles, Wiley.	1975
5.	R. E. Melchers, "Structural Reliability Analysis and Prediction", 2nd Ed., Wiley.	1999

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

1. Subject Code : **CEN-647** Course Title : **Condition Assessment and Retrofitting of Structures**
2. Contact Hours : **L: 3** **T : 0** **P: 2**
3. Examination Duration (Hrs) : **Theory : 3** **Practical : 0**
4. Relative Weight : **CWS : 15** **PRS: 25** **MTE: 20** **ETE: 40** **PRE: 0**
5. Credits : **4** 6. Semester: **Spring** 7. Subject Area : **PEC**
8. Pre-requisite: **Nil**

9. Objective: To introduce the application of different techniques for evaluation and retrofitting of buildings

10. Details of Course:

S. No.	Contents	Contact Hours
1	Deterioration of Concrete Buildings: Embedded Metal Corrosion, Disintegration Mechanisms, Moisture Effects, Thermal Effects, Structural Effects, Faulty Construction	08
2	Evaluation of Concrete Buildings: Visual Investigation, Destructive Testing Systems, Non-Destructive Testing Techniques, Semi-Destructive Testing Techniques, Chemical Testing.	08
3	Surface Repair & Retrofitting Techniques: Strategy & Design, Selection of Repair Materials, Surface Preparation, Bonding repair Materials to Existing concrete, Placement Methods,	08
4	Epoxy Bonded Replacement Concrete, Preplaced Aggregate Concrete, Shotcrete/ Gunite, Grouting, Injection Grouting, Micro concrete.	06
5	Strengthening Techniques: Strengthening Techniques, Beam Shear Capacity Strengthening, Shear Transfer Strengthening between Members, Column Strengthening, Flexural Strengthening, and Crack Stabilization	08
6	Guidelines for Seismic Rehabilitation of Existing Buildings, Seismic Vulnerability and Strategies for Seismic Retrofit.	04
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1	Emmons, P.H., “Concrete Repair and Maintenance”, Galgotia Publication.	2001
2	Bungey, S., Lillard, G. and Grantham, M.G., “Testing of Concrete in Structures”, Taylor and Francis.	2001
3	Malhotra, V.M. and Carino, N.J., “Handbook on Non-destructive Testing of Concrete”, CRC Press.	2004
4	Bohni, H., “Corrosion in Concrete Structures”, CRC Press.	2005
5	FEMA 273; NEHRP Guidelines for the Seismic Rehabilitation of Buildings.	1997
6	ATC- 40: Seismic Evaluation and Retrofit of Concrete Buildings, Vol. 1 & 2.	1997
7	M.J.N., Seible, F. and Calvi, G.M., “Seismic Design and Retrofit of Bridges by Priestley”, John Wiley.	1996

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

1. Subject Code : **CEN-648** Course Title : **Concrete Technology**
2. Contact Hours : **L: 3** **T : 0** **P: 2**
3. Examination Duration (Hrs) : **Theory : 3** **Practical : 0**
4. Relative Weight : **CWS : 15** **PRS: 25** **MTE: 20** **ETE: 40** **PRE: 0**
5. Credits : **4** 6. Semester: **Spring** 7. Subject Area : **PEC**
8. Pre-requisite: **Nil**
9. Objective : The objective of this course is to provide detailed knowledge about concrete and its composition.
10. Details of Course:

S. No.	Contents	Contact Hours
1.	Ingredients of Concrete: Review of Cements including Blended Cements, Manufacture, Chemical Composition, Aggregates: Review of Types; Elementary Mineralogy and Petrology; Sampling and Testing; Effects on Properties of Concretes, Chemical and Physical Processes of Hydration. Mineral Admixtures: Pulverized Fly Ash, Ground Granulated Blast Furnace Slag and Silica Fume; Chemical Composition,Physical Characteristics,Chemical and Physical Processes of Hydration and Interaction,Effects on Properties of Concretes.	8
2.	Admixtures:Review of Types and Classification, Chemical Composition,Effects on Properties of Concretes.	2
3.	Fresh-Concrete: Rheology of Mortars and Concretes; Workability, Segregation and Bleeding, Theory and Principles governing the correct transportation, Placing, Compaction and Curing of Concrete. Plastic Settlement and Plastic Shrinkage,Exothermic Characteristics:Early Age Thermal Movements,Strength Development,Maturity, Accelerated Curing,Hot and Cold Weather Concreting.	8
4.	Properties of Hardened Concrete: Strength,Deformation under Load,Elasticity,Creep,Drying Shrinkage and other volume Changes. Thermal Properties.	5
5.	Durability of Concrete and Concrete Construction: Durability Concept,Pore Structure and Transport Processes,Reinforcement Corrosion, Fire Resistance,Frost Damage, Sulfate Attack,Alkali Silica Reaction,Methods of Providing Durable Concrete.	7
6.	Concrete Mix Design: The process of Mix Selection, Factors governing the selection of Mix Proportions, Combining Aggregates to obtain Specified Grading, Different Methods of Mix Design, Concepts of Statistical Quality Control of Concrete Construction.	6
7.	Special Concretes: Lightweight Concrete,No-Fines Concrete, High Performance Concrete,High Density and Radiation-Shielding Concrete,Polymer Concrete,Fibre-Reinforced Concrete,Self Compacting Concrete, Roller Compacted Concrete, High Volume Fly Ash Concrete, Ready Mixed Concrete.	6
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1.	A.M. Neville and J.J. Brooks, “Concrete Technology”, 1st Ed.	2002
2.	P.K. Mehta and Paulo J.M. Monteiro, “Concrete: Microstructure, Properties and Materials”, 3rd Ed.	2006

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

1. Subject Code : **CEN-649** Course Title : **Fracture Mechanics in Quasi-brittle Materials**
2. Contact Hours : **L: 3** **T : 1** **P: 0**
3. Examination Duration (Hrs) : **Theory : 3** **Practical : 0**
4. Relative Weight : **CWS : 25** **PRS: 0** **MTE: 25** **ETE: 50** **PRE: 0**
5. Credits : **4** 6. Semester: **Spring** 7. Subject Area : **PEC**
8. Pre-requisite: **Nil**
9. Objective: To introduce the mechanics of fracture and their applications to anisotropic and heterogeneous quasi-brittle materials
10. Details of Course:

S. No.	Contents	Contact Hours
1	**Basic concepts:** Basic modes of fracture, Elasticity solution to infinite and finite plate with a crack: Westergaard complex function and Muskhelishvili potential, Effect of free boundary, 3-Dimensional crack problems	5
2	**Linear elastic fracture mechanics(LEFM) based design concepts:** Energy release rate, Griffith's energy balance criterion, Crack resistance, Stress intensity factors, Small scale yielding, plastic zone corrections	6
3	**Elastic plastic fracture mechanics (EPFM) based design concepts:** J-integral, Crack tip opening displacement, Crack growth resistance concepts	3
4	**Introduction to fracture mechanics in Quasi-brittle material:** Trends in Fracture of quasi-brittle materials, Fracture process zone, Size effect: Sources, experimental evidence, statistical and energetic size effect	6
5	**Non-linear fracture mechanics:** Fictitious and Effective elastic crack approach, Nonlocal continuum modelling of damage localization	4
6	**Application of fracture mechanics to concrete structures:** Size effect on nominal strength, Tension of reinforced concrete members, Bending of reinforced concrete members, Shear in reinforced concrete beams, Fibre-reinforced concrete, Bi-material interface, Concrete dams	8
7	**Fatigue and fracture in concrete:** Introduction, Conventional methods of fatigue analysis, Fatigue crack propagation approach, Crack propagation models for constant and variable amplitude loading, Overload effect, Crack closure	5
8	**Finite elements in fracture mechanics:** Modelling of crack tip singularity, Approaches for the extraction of stress intensity factor, Discrete and smeared crack approach, Application to problems of LEFM and EPFM	5
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1	Broek, D.,Springer, "Elementary Engineering Fracture Mechanics", 3rd Ed.,.	1982
2	Kumar, P., "Elements of Fracture Mechanics", Wheeler Publishing.	1999
3	Anderson, T.L., "Fracture Mechanics: Fundamentals and Applications", 3rd Ed., CRC Press.	2005
4	Shukla, A., "Practical Fracture Mechanics in Design", 2nd Ed., CRC Press.	1989
5	Shah, S. P., Swartz, S. E. and Ouyang, "Fracture Mechanics of Concrete: Applications to Concrete, Rock and other Quasi-brittle Materials", C., John Wiley.	1995
6	Bazant, Z. P., and Planas, J., "Fracture and Size Effect in Concrete and Other Quasi-brittle Materials", CRC Press.	1997

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

1. Subject Code : **CEN-650** Course Title : **Design of Bridge Substructures**
2. Contact Hours : **L: 3** **T : 0** **P: 2**
3. Examination Duration (Hrs) : **Theory : 3** **Practical : 0**
4. Relative Weight : **CWS : 15** **PRS: 25** **MTE: 20** **ETE: 40** **PRE: 0**
5. Credits : **4** 6. Semester: **Spring** 7. Subject Area : **PEC**
8. Pre-requisite: **Nil**

9. Objective: To introduce the behaviour and design of bridge substructures.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	Hydraulic calculations related to bridge design	04
2.	Analysis and design of piers and pier caps	06
3.	Seismic restrainers	01
4.	Analysis and design of abutments	04
5.	Analysis and design of well foundations	15
6.	Analysis and design of pile foundations	12
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1.	Vijay Singh, “Wells and Cassions” Nem Chand & Sons.	1981
2.	S. Saram, “Analysis and Design of Substructures”.	2012
3.	Ponnuswamy, “Bridge Engineering”.	1986
4.	D. J. Victor, “Essentials of Bridge Engineering”.	2001
5.	Rakshit, “Design and Construction of Highway Bridges”.	2004

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

1. Subject Code : **CEN-651** Course Title : **Wind Engineering**
2. Contact Hours : **L: 3** **T : 0** **P: 2**
3. Examination Duration (Hrs) : **Theory : 3** **Practical : 0**
4. Relative Weight : **CWS : 15** **PRS: 25** **MTE: 20** **ETE: 40** **PRE: 0**
5. Credits : **4** 6. Semester: **Spring** 7. Subject Area : **PEC**
8. Pre-requisite: **Nil**
9. Objective: To introduce the theoretical and experimental approaches available to analyze the effect of wind loading on various wind sensitive structures

10. Details of Course:

S. No.	Contents	Contact Hours
1	Atmospheric Pressure and Gradient Wind, Wind Climate and Structure, Peak 3-sec, 10 min and Hourly Mean Wind Speeds. Low Cycle Energy and Large Scale Pressure Systems, Wind Energy and Turbulence, Spectral Distribution and Boundary Layer (ABL) & its Characteristics.	07
2	Aerodynamics of Bluff Bodies, Vortex Shedding and Associated Unsteady Along and Across Wind Forces. Peak Factor and Gust factor Estimation. Buffeting and Ovalling, Galloping and Flutter. Extreme Winds, Correlation and Spectral Function.	07
3	Random Vibration Theory, Auto Correlation Function, Power Spectral Density, Narrow and Wide Band Random Processes. Response of SDF in the Frequency Domain to Random Excitation. Application to MDF Systems.	06
4	Experimental Procedures for Response Studies. Wind Tunnel and its Salient Features, ABL Simulation. Basic Wind Tunnel Instrumentation for the Measurement of Flow Parameters, Forces, Displacements and Strains. Use of Statistical Methods for the Analysis of Measured Data and its Interpretation. Analytical Procedures for Along Wind and Across Wind Forces.	08
5	Wind Effects on Buildings, Chimneys, Towers and Bridges. Pressure Coefficients and Internal Pressures, Case Studies.	08
6	Codal Provisions, Design Wind Velocities, Wind Resistant Design- Indian Codes and other International Codes of Practice.	06
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1	E. Simiu and R.H. Scanlan, “Wind Effects on Structures”, Wiley.	1996
2	E. Simiu and T. Miyata, “Design of Buildings and Bridges for Wind”, Wiley.	2006
3	J.D. Holmes, “Wind Loading on Structures”, F & FN Spon.	2001

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

1. Subject Code : **CEN-661** Course Title : **Advanced Highway Materials and Construction**
2. Contact Hours : **L: 3** **T : 1** **P: 2/2**
3. Examination Duration (Hrs) : **Theory : 3** **Practical : 0**
4. Relative Weight : **CWS : 20** **PRS: 20** **MTE: 20** **ETE: 40** **PRE: 0**
5. Credits : **04** 6. Semester: **Spring** 7. Subject Area : **PEC**
8. Pre-requisite: **Nil**
9. Objective of Course: To introduce the advances in use of highway materials in construction of different layers of a pavement.

10. Details of the Course.

S. No.	Contents	Contact hours
1	**Aggregates:** Classification, physical and strength characteristics, Proportioning of aggregates, Aggregate texture and skid resistance, polishing of aggregates.	06
2	**Soil:** Classification, Structural and Constructional problems in soil subgrade, Identification and strength tests, Soil-moisture movement, Sub-soil drainage, Soil stabilization.	06
3	**Bitumen:** Bitumen sources and manufacturing, Bitumen constituents, structure and Rheology, Mechanical and engineering properties of bitumen, Tests on bitumen, Emulsions – Properties, types, modifications, Durability of bitumen, Adhesion of bitumen, Modified bitumen.	10
4	**Bituminous Mixes:** Desirable properties of mixes, Design of bituminous mixes, Tests on bituminous mixes, Fillers, Theory of fillers and specifications.	06
5	**Cement Concrete Mixes:** Constituents and their requirements, Physical, plastic and structural properties of concrete, Factors influencing mix design, Design of concrete mixes.	06
6	**Road Construction:** Bituminous road construction procedures and specifications, Quality control requirements. Concrete Road construction: Construction methods, Quality control requirements, Joints in cement concrete pavements, Reinforced cement concrete road construction.	08
	Total	**42**

List of Practicals:

01. Identification tests on soils (Atterburg limits); Heavy compaction test on subgrade soil
02. Triaxial test on pure subgrade soil
03. Aggregate polishing and skid resistance test (demonstration); GSB mix design
04. Test for aggregate durability; Preparation of mix for SDBC
05. Elastic recovery test on binder
06. Marshall Bituminous Mix design, Rheometer test
07. Bitumen viscosity test (Rotational viscometer); Retained stability test
08. Concrete Mix design

11. Suggested Books**:**

S. No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1	Krebs, Robert D. and Walker, R. D., "Highway Materials", McGraw Hill Book Co., New York	1971
2	Her Majesty's Stationery Office, "Soil Mechanics for Road Engineers", Ministry of Transport, Road Research Laboratory, UK	1966
3	Her Majesty's Stationery Office, "Bituminous Materials in Road Construction", Ministry of Transport, Road Research Laboratory, UK	1966
4	Her Majesty's Stationery Office, "Concrete Roads Design and Construction", Ministry of Transport, Road Research Laboratory, UK	1966
5	Read, J. and Whiteoak, D., "The Shell Bitumen Handbook", 5th Edition, Shell Bitumen, Thomas Telford Publishing, London	2003
6	Relevant IRC and IS codes	

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

1. Subject Code : **CEN-662** Course Title : **Intersection Design and Analysis**
2. Contact Hours : **L: 3** **T : 1** **P: 0**
3. Examination Duration (Hrs) : **Theory : 3** **Practical : 0**
4. Relative Weight : **CWS : 25** **PRS: 0** **MTE: 25** **ETE: 50** **PRE: 0**
5. Credits : **04** 6. Semester: **Spring** 7. Subject Area : **PEC**
8. Pre-requisite: **Nil**
9. Objective of Course: To discuss various methods of designing and analyzing the different types of road intersections and interchanges.

10. Details of Course :

Sl. No.	Contents	Contact Hours
1	Types of intersections, Principles of design, types of maneuvers, relative speed, conflict points and area, Intersection geometrics and their influence on design/operation	10
2	Concept of capacity and LOS, Operational analysis of two-way and all-way stop controlled intersections and Roundabouts by US and Indian methods, mini roundabouts	8
3	Analysis of signal controlled intersections by US, British and Swedish methods, delay and its evaluation	12
4	Types of signals, Design of signals by Indian, US and British methods, signal coordination	6
5	Grade separated intersections and interchanges, weaving sections and their operational evaluation, Intersection signs, marking and lighting	6
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1	Transportation Engineering & Planning, by C. S. Papacostas and P. D. Prevedouros, Prentice Hall of India Private Limited, New Delhi	2001
2	Principles of Highway Engineering and Traffic Analysis, by Fred L Mannering, Walter P. Kilareski and Scott S. Washburn, Wiley India Edition	2007
3	Transportation Engineering, by C. Jotin Khistya and B. Kent Lall Prentice Hall of India Private Limited, New Delhi	2006
4	Transport Planning and Traffic Engineering, by C A O Flaherty, Hodder Headline Group, London	1997
5.	Highway Capacity Manual of US, Transportation Research Board, Washington DC	2010

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

1. Subject Code : **CEN-663** Course Title : **Pavement Evaluation and Management**
2. Contact Hours : **L: 3** **T : 1** **P: 0**
3. Examination Duration (Hrs) : **Theory : 3** **Practical : 0**
4. Relative Weight : **CWS : 25** **PRS: 0** **MTE: 25** **ETE: 50** **PRE: 0**
5. Credits : **04** 6. Semester: **Spring** 7. Subject Area : **PEC**
8. Pre-requisite: **Nil**
9. Objective: To provide knowledge related to evaluation and management of pavements with respect to Highways and Airports.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Pavement Evaluation and Performance:** General concept of pavement evaluation, evaluation of pavement performance, evaluation of pavement structural capacity, evaluation of pavement distress, evaluation of pavement safety.	6
2.	**Types of Distress:** Structural and functional, serviceability, fatigue cracking, pavement deformation and low temperature shrinkage cracking, Factors affecting performance, relation between performance and distress.	6
3.	**Pavement Evaluation & Measuring Equipments:** Functional & Structural Evaluation, Functional Parameters such as Roughness, Distress, Rutting, Skid Resistance etc. Structural Parameters such as Structural Capacity. Benkelman Beam, Bump Integrator, dynaflect. Demonstration of equipments for dynamic testing of pavements. Digital ultrasonic concrete tester. Pavement skid resistance measuring equipments, fatigue testing equipments.	8
4.	**Pavement Overlays:** Flexible overlays and determination of overlay thickness. Rigid overlays and determination of overlay thickness. Design of Overlay by Benkelman Beam and Falling Weight Deflectometer.	8
5.	**Design Alternatives – Analysis, Evaluation and Selection:** Framework for pavement design, design objectives and constraints, Basic structural response models, characterization of physical design inputs, Generating alternative pavement design strategies. Economic evaluation of alternative pavement design strategies, analysis of alternative design strategies. Predicting distress, predicting performance, selection of optimal design strategies.	8
6.	**Pavement Management System:** Introduction to Pavement Management System (PMS) & Maintenance Management System (MMS), construction, maintenance and rehabilitation. Feedback data system. Examples of Working Design and Management Systems. Implementation of a pavement management system.	6
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1	Hass, R., Hudson, W.R. and Zaniewski, J. "Modern Pavement Management" Krieger.	1994
2	Fwa, T.F., "The Handbook of Highway Engineering", CRC Press, Taylor & Francies Group.	2006
3	Shain, M.Y., "Pavement Management for Airports, Roads and Parking Lots", Kluwer Academic Publishers Group.	2004
4	Khanna, S.K. and Justo, C.E.G., "Highway Engineering" Nem Chand & Bros, Roorkee (U.A.) 8th Ed.	2005
5	Hudson, W.R., Haas, R. and Uddin, W., "Infrastructure Management", McGraw Hill.	1997
6	Hass R. & Hudson, W.R., "Pavement Management System", Mc Graw Hill Company, Inc. New York	1978

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

1. Subject Code : **CEN-664** Course Title : **Urban Mass Transit Systems**
2. Contact Hours : **L: 3 T : 1 P: 0**
3. Examination Duration (Hrs) : **Theory : 3 Practical : 0**
4. Relative Weight : **CWS : 25 PRS: 0 MTE: 25 ETE: 50 PRE: 0**
5. Credits : **04** 6. Semester: **Spring** 7. Subject Area : **PEC**
8. Pre-requisite: **Nil**
9. Objective of Course: To introduce the students to urban mass transit systems, their types, suitability, planning, operation and management aspects.
10. Details of the Course:

S. No.	Contents	Contact hours
1	**Introduction**: Mass transit systems, Elements / components of transit systems; Urban Mass Transit systems, types, characteristics, suitability and adaptability of these systems; Evolution of urban transportation.	03
2	**Transit System Planning**: Planning needs; Short-range and long-range planning; Planning procedures and methodology, Data collection; Medium performance transit systems and high-performance transit systems; trends in transit planning.	08
3	**Transit Demand Estimation and Evaluation:** Transit demand forecasting; transit mode evaluation; comparison and selection of most suitable transit mode.	10
4	**Transit System Operations:** Basic operational elements; transit travel characteristics; transit scheduling; transit line analysis – planning objectives, geometry, types and their characteristics, capacity of transit lines, system procedures for improving transit line capacity.	09
5	**Transit Networks and System Analysis:** Transit networks – types and their characteristics; transfers in transit networks; system analysis in transit – conceptual models, modeling procedures; terminal or station location planning – issues, objectives, station spacing decisions.	06
6	**Economics and Financing of Transit Systems:** Transit system performance and economic measures; transit fares – structure, collection and levels; financing of transit services; public and private integration of transit services.	06
	Total	**42**

11. Suggested Books:

S. No	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1	Vukan R. Vuchic, "Urban Transit – Operations, Planning and Economics", John Willey and Sons, Inc., USA	2004
2	John W. Dickey and others, "Metropolitan Transportation Planning", Tata McGraw-Hill Book Company Ltd., New Delhi	1980
3	C A O'Flaherty, 'Transport Planning and Traffic Engineering', Butterworth-Heinemann, Burlington	2006
4	C Jotin Khisty and B Kent Lall, "Transportation Engineering" Prentice-Hall of India	2003

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

1. Subject Code : **CEN-665** Course Title : **Road Traffic Safety**
2. Contact Hours : **L: 3** **T : 1** **P: 0**
3. Examination Duration (Hrs) : **Theory : 3** **Practical : 0**
4. Relative Weight : **CWS : 25** **PRS: 0** **MTE: 25** **ETE: 50** **PRE: 0**
5. Credits : **04** 6. Semester: **Spring** 7. Subject Area : **PEC**
8. Pre-requisite: **Nil**
9. Objective: To introduce the concepts of traffic safety on highways and to make students familiar with related analytical methods and remedial measures.

10. Details of course:

S. No.	Contents	Contact Hours
01	Introduction: Road traffic accidents scenario in India, characteristics of accidents, accident vs. crash, effect of human factors, planning for road network, land use and road environment for safety, designing for road safety – links and junctions, road safety engineering, road safety improvement strategies, elements of a road safety plan.	06
02	Crash investigation and analysis: Steps in treatment of crash locations, diagnosing crash problem and solutions, accident report form, storing of data, using and interpreting crash data, identifying and prioritizing hazardous locations, condition and collision diagrams; Vulnerable road users: crashes related to pedestrian and bicyclists, their safety, provision for disabled; Crash reconstruction: understanding basic physics, calculation of speed for various skid, friction, drag, and acceleration scenarios.	08
03	Statistical analysis of accidents: Descriptive statistics, confidence interval, hypothesis testing, models related to accident frequency, accident severity, accident duration, various methodological issues – over/under dispersion, time-varying explanatory variables, unobserved heterogeneity, endogeneity, under-reporting, spatial and temporal correlation, etc; Accident prediction model.	08
04	Before -after methods in crash analysis: Before and after study, before and after study with control sites, comparative parallel study, before, during and after study, Empirical Bayes method.	04
05	Economic analysis of accidents: Accident costing-economic appraisal, EUAC, PWOC, B/C ratio, IRR, NPV.	04
06	Traffic management system: Traffic flow improvements, expressway patrol, public transit, ridesharing, mobility rest areas, park-and-ride lots, bus bays, signage, markings; ITS applications - vehicular navigation, crash avoidance system, incident management, traffic management centre, highwayside communication.	06
07	Road safety audits: Procedure, aims and objectives, roles and responsibility, history of road safety audit, design standards, tasks, various stages of safety audits; common identifiable problems, structuring of report, identifying common problems.	06
	Total	**42**

11. Suggested books

S. No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1	American Association of State Highway and Transportation Officials (AASHTO), "Highway Safety Manual", 1st Edition, AASHTO.	2010
2	Simon P. Washington, Matthew G. Karlaftis, Fred L. Mannering, "Statistical and Econometric Methods for Transportation Data Analysis", 2nd Edition, Chapman &Hall/CRC Press,	2010
3	Ezra Hauer, "Observational Before -After Studies in Road Safety", Pergamon Press.	1997
4	Limpert, Rudolf. "Motor Vehicle Accident Reconstruction and Cause Analysis", 5th Edition, Lexas Publishing, Charlottesville, VA.	1999
5	Indian Roads Congress, "Highway Safety Code", IRC: SP-44:1996	1996
6	Indian Roads Congress, "Road Safety Audit Manual", IRC:SP-88-2010	2010

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

1. Subject Code : **CEN-666** Course Title : **Transport Economics**
2. Contact Hours : **L: 3** **T : 1** **P: 0**
3. Examination Duration (Hrs) : **Theory : 3** **Practical : 0**
4. Relative Weight : **CWS : 25** **PRS: 0** **MTE: 25** **ETE: 50** **PRE: 0**
5. Credits : **04** 6. Semester: **Spring** 7. Subject Area : **PEC**
8. Pre-requisite: **Nil**
9. Objective of Course: The course provides an outline of demand and supply side concepts and their application to transport policy and planning issues.
10. Details of the Course.

S. No.	Contents	Contact Hours
01	**Introduction and Overview: B**asic components of transport, economic development and urban development. Economic theory, transport as an economic activity, demand and supply issues in transportation sector, demand - supply equilibrium, cost and pricing of transport, law of diminishing returns, elasticity and consumer surplus, costs, pricing and subsidy policies, elements of engineering economics.	06
02	**Transportation Demand and Congestion:** Demand - Demand forecasting methods, factors influencing transport demand, direct and cross - price elasticity of demand, factors that cause shifts in demand function; Congestion - Main causes of traffic congestion, Mechanisms to deal with traffic congestion - congestion pricing, road space rationing, capacity expansion.	07
03	**Transport Supply and Regulation:** Supply - Supply of transport services, development of systems supply function; Regulation - Command and control type of regulation, fiscal measures such as road pricing and environmental taxation, safety and economic regulations in the context of transport services provided by public, issues of social, geographical and temporal equity.	06
04	**Transport Costs and Pricing:** Costs-Direct and external costs of transport, concept of generalized costs, social aspects of transport, joint and common costs of infrastructure, average and marginal cost principle, short-term and long-term costs of supply, congestion costs, external costs, Road User Cost and it's components; Pricing- Pricing principles, the marginal cost pricing rule, efficient pricing, cost complexities and cost recovery, peak-load pricing, second-best pricing, Transport subsidies, price discrimination.	10
05	**Appraisal and Evaluation of Transportation Projects:** Feasibility and evaluation, cost, impacts and performance levels, evaluation of alternatives, analysis techniques, cost-benefit analysis, social and financial benefits, Internal Rate of return method for economic and financial viability, valuation of time, measures of land value and consumer benefits from transportation projects, prioritization of projects, multi-criteria decision assessment.	08
06	**Funding and Financing of Transportation Projects:** Methods for raising funds for maintenance, improvement and expansion of transportation networks, taxation and user fee, financing through loans, bonds, PPPs and concessions.	05
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1	Mccarthy, P.S., "Transportation Economics – Theory and Practice : A Case Study Approach", Blackwell Publishing.	2001
2	E. Quinet, R. Vickerman and R. W. Vickerman, "Principles of Transport Economics", Edward Elgar Publishing.	2004
3	Button, K. J., "Transportation Economics", 3rd Ed., Edward Elgar Publishing.	2010

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

1. Subject Code : **CEN-667** Course Title : **Airport Planning and Design**
2. Contact Hours : **L: 3** **T : 1** **P: 0**
3. Examination Duration (Hrs) : **Theory : 3** **Practical : 0**
4. Relative Weight : **CWS : 25** **PRS: 0** **MTE: 25** **ETE: 50** **PRE: 0**
5. Credits : **04** 6. Semester: **Spring** 7. Subject Area : **PEC**
8. Pre-requisite: **Nil**
9. Objective of Course: To familiarize students on various techniques related to airport planning and design.
10. Details of the Course.

S. No.	Contents	Contact Hours
1	**Airport Planning:** Airport master plan, aircraft characteristics related to airport planning, air traffic demand analysis, planning surveys, airport zoning.	08
2	**Geometric Design:** Airport classification, runway and taxiway geometric standards, exit taxiways, separation and clearances.	06
3	**Terminal Areas:** Facilities, space requirement, number and size of gate positions, aircraft parking system.	06
4	**Visual Aids :** Airport day time markings, airport lighting, visibility, visual aids	03
5	**Structural design of airport pavements:** Design Factors, Design of flexible and rigid pavements	06
6	**Airside capacity and delay:** mathematical models for capacity and delay, space time concept, models for mixed traffic	06
7	**Air Traffic Control: I**mportance of flight rules, navigational aids, air traffic controls, obstruction and clearance requirements	04
8	**Airport Drainage :** Design run-off, inlet size and location design, surface and subsurface design	03
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1	Robert Horonjeff and Francis X. McKelvey, “Planning & Design of Airports, McGraw Hill, Inc,	1993
2	S. K. Khanna, M. G. Arora and S. S. Jain, “Airport Planning & Design”, Nem Chand and Bros. Roorkee	2004
3	Ashford, N. and Wright, P. H., “Airport Engineering”, John Wiley & Sons, NY.,	1992
4	ICAO, “Aerodrome Design Manual”, International Civil Aviation Organization, Montreal, Canada	1983

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

1. Subject Code : **CEN-668** Course Title : **Transportation Systems Analysis**
2. Contact Hours : **L: 3 T : 1 P: 0**
3. Examination Duration (Hrs) : **Theory : 3 Practical : 0**
4. Relative Weight : **CWS : 25 PRS: 0 MTE: 25 ETE: 50 PRE: 0**
5. Credits : **04** 6. Semester: **Spring** 7. Subject Area : **PEC**
8. Pre-requisite: **Nil**
9. Objective of Course: To introduce the students to the analysis of different transportation systems, their components, operations, systems analysis approaches and economics.

10. Details of the Course.

S. No.	Contents	Contact Hours
1	**Introduction**: Scope of transportation and impact on society; System planning process and problem solving process; transportation problems.	06
2	**Transportation Technologies**: Transportation technologies, suitability and adaptability; Transportation system components; Transportation system characteristics – technological and operational; Path – vehicle interaction; Volume – Density relationship for containers.	10
3	**Analysis of Systems:** Generation of alternatives; Performance evaluation of system and performance functions; Operational planning and analysis of components; Transportation network analysis and Minimum path algorithms; Travel in space and time; Planning for non-motorized transportation; Freight transportation planning– models and methods; Residential location choice models, Car-ownership models; transportation software.	12
4	**Transportation Economics:** Transportation demand and supply; Equilibrium between supply and demand, transportation system equilibrium; Elasticity – direct and cross; concept of consumer surplus; transport demand models – sketch planning, incremental demand model, transportation cost, travel – market equilibrium.	08
5	**Sustainable Transportation Planning:** Sustainable transportation – issues and principles; non-motorized transportation planning; Impact evaluation and impact models.	06
	Total	**42**

Suggested Books:

S. No	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1	Marvin L Manheim, “Fundamentals of Transportation Systems Analysis”, The MIT Press, Cambridge, Massachusetts	1980
2	Adib Kanafani, “Transportation Demand Analysis”, McGraw Hill Inc, New York, U.S.A.	1983
3	Steenbrink, P.A., Optimization of Transport Network, John Wiley & Sons, NY.	1974
4	Konstadinos G Goulias, “Transportation System Planning – Methods and Applications”, CRC Press, London	2002

5	C Jotin Khisty and B Kent Lall, “Transportation Engineering – An Introduction”, Prentice Hall of India Pvt Ltd., New Delhi	2003
6	Thomas A Domencich and Daniel McFadden, “Urban Travel Demand – A Behavioural Analysis”, North-Holland Publishing Company, Amsterdam	1975

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

1. Subject Code : **CEN -669** Course Title : **Transportation Planning**
2. Contact Hours : **L: 3 T : 1 P: 0**
3. Examination Duration (Hrs) : **Theory : 3 Practical : 0**
4. Relative Weight : **CWS : 25 PRS: 0 MTE: 25 ETE: 50 PRE: 0**
5. Credits : **04** 6. Semester: **Spring** 7. Subject Area : **PEC**
8. Pre-requisite: **Nil**
9. Objective of Course: To introduce the concept of travel demand modeling using four-stage sequential transportation planning.

10. Details of the Course.

S. No.	Contents	Contact Hours
1	**Introduction to Transportation**: Fields of Transportation, Role in Society, System-Environment Ensemble, Transportation Problems	05
2	**Planning Process**: Hierarchical Structure; Characteristics and objectives of planning, Problem solving and its morphology, Planning methodologies; Overview of urban transportation planning; Urban structure interaction and concepts.	08
3	**Transportation Data:** Data needs and sources; Survey methodology, Quality v/s quantity, Errors, Data collection methods, Attitudinal surveys, Questionnaire design and standardization, Study area and analysis zones, Sample size, Sampling units, frames and techniques.	07
4	**Trips:** Aggregate and disaggregate analysis, Definitions, Types of trips, Factors affecting trip generation, Methods of trip generation, Methods of trip distribution – Growth Factor methods, Synthetic methods, merits and demerits.	08
5	**Modal Analysis and Assignment:** Mode choice sets, Modal split models – First and second generation, Stochastic models, Choice theories, Discrete choice analysis, Logit models, Model specification, estimation and validation; Network analysis, Route or tree building algorithms, Network assignments methods.	08
6	**Sustainable Transportation:** Issues and Guidelines of sustainable transportation, Planning for Mass Transit systems, Planning for Non-Motorized vehicles.	06
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1	B. G. Hutchinson, "Principles of Urban Transport Systems Planning" Scripta Book Co., Washington	1974
2	Anthony J. Richardson, Elizabeth S. Ampt and Arnim H. Meyburg, "Survey Methods for Transport Planning" Eucalyptus Press, Australia.	1995
3	Roy Thomas, "Traffic Assignment Techniques", Avebury Technical, Aldershot, England	1991
4	C A O'Flaherty, ed , "Transport Planning and Traffic Engineering", Butterworth Heinemann, Elsevier, Burlington, MA	2006