## M. Tech. in Earth System Science and Engineering

### SEMESTER - 1

<table>
<thead>
<tr>
<th>Course No.</th>
<th>Course Name</th>
<th>L – T – P – C</th>
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</thead>
<tbody>
<tr>
<td>CE 591</td>
<td>Earth System Dynamics</td>
<td>3 – 0 – 0 – 6</td>
</tr>
<tr>
<td>CE 592</td>
<td>Exploration Geoscience</td>
<td>3 – 0 – 0 – 6</td>
</tr>
<tr>
<td>CE 593</td>
<td>Advanced Remote Sensing</td>
<td>3 – 0 – 2 – 8</td>
</tr>
<tr>
<td>CE XXX</td>
<td>Elective I</td>
<td>3 – 0 – 0 – 6</td>
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<tr>
<td>CE XXX</td>
<td>Elective II</td>
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Total: 15 – 0 – 2 – 32

### SEMESTER – 2

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<thead>
<tr>
<th>Course No.</th>
<th>Course Name</th>
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<tbody>
<tr>
<td>CE 594</td>
<td>Geohazard Science and Engineering</td>
<td>3 – 0 – 0 – 6</td>
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<tr>
<td>CE 595</td>
<td>Advanced Techniques in Geoscience</td>
<td>2 – 0 – 2 – 6</td>
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<tr>
<td>CE XXX</td>
<td>Elective III</td>
<td>3 – 0 – 0 – 6</td>
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<tr>
<td>CE XXX</td>
<td>Elective IV</td>
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<tr>
<td>CE XXX</td>
<td>Elective V</td>
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### SEMESTER – 3

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<td>CE 598</td>
<td>M Tech Project – Phase I</td>
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### SEMESTER – 4

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<th>Course No.</th>
<th>Course Name</th>
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<tbody>
<tr>
<td>CE 599</td>
<td>M Tech Project – Phase II</td>
<td>0 – 0 – 24 – 24</td>
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Total: 0 – 0 – 24 – 24

Annexure-120/4(e) contd……..
## ANEXURE-I

### LIST OF ELECTIVES

<table>
<thead>
<tr>
<th>Course No.</th>
<th>Course Name</th>
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</thead>
<tbody>
<tr>
<td><strong>Elective I</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CE 601</td>
<td>Numerical Methods</td>
<td>3 – 0 – 0 – 6</td>
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<tr>
<td>CE 602</td>
<td>Optimization Methods</td>
<td>3 – 0 – 0 – 6</td>
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<td>CE 513</td>
<td>Statistical Methods in Civil Engineering</td>
<td>3 – 0 – 0 – 6</td>
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<tr>
<td><strong>Elective II, III, IV, V</strong></td>
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<tr>
<td>CE XXX</td>
<td>Geodesy and Mapping</td>
<td>3 – 0 – 0 – 6</td>
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<td>CE XXX</td>
<td>Geostatistics</td>
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<tr>
<td>CE 501</td>
<td>Continuum Mechanics</td>
<td>3 – 0 – 0 – 6</td>
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<tr>
<td>CE 503</td>
<td>Structural Dynamics</td>
<td>3 – 0 – 0 – 6</td>
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<tr>
<td>CE 554</td>
<td>Advanced Fluid Mechanics</td>
<td>3 – 0 – 0 – 6</td>
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<tr>
<td>CE 563</td>
<td>Flow and Transport Processes in Fractured Media</td>
<td>3 – 0 – 0 – 6</td>
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<tr>
<td>CL613</td>
<td>Computational Fluid Dynamics</td>
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<tr>
<td>CE XXX</td>
<td>Petroleum Geology</td>
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<td>CE XXX</td>
<td>Structural Geology</td>
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<tr>
<td>CE XXX</td>
<td>Advanced Image and Spectral Analysis</td>
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<tr>
<td>CE XXX</td>
<td>Precision Remote Sensing</td>
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<td>CE XXX</td>
<td>Geochemistry</td>
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<tr>
<td>CE XXX</td>
<td>Advanced Hydrogeology</td>
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<tr>
<td>CE 646</td>
<td>Rock Mechanics</td>
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<td>CE XXX</td>
<td>Petrophysics</td>
<td>3 – 0 – 0 – 6</td>
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<tr>
<td>CE 642</td>
<td>Subsurface Investigation and Instrumentation</td>
<td>3 – 0 – 0 – 6</td>
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<tr>
<td>CE XXX</td>
<td>Underground Exploration</td>
<td>3 – 0 – 0 – 6</td>
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<tr>
<td>CE 557</td>
<td>Environmental Hydrology</td>
<td>2 – 0 – 2 – 6</td>
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<tr>
<td>CE 564</td>
<td>Stochastic Hydrology</td>
<td>3 – 0 – 0 – 6</td>
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<tr>
<td>CE 565</td>
<td>Introduction to Multiphase Flow</td>
<td>3 – 0 – 0 – 6</td>
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<tr>
<td>CE 568</td>
<td>Environmental Management of Water Resources</td>
<td>3 – 0 – 0 – 6</td>
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<tr>
<td>CE XXX</td>
<td>Pollution and Contaminant Flux in the Environment</td>
<td>3 – 0 – 0 – 6</td>
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<tr>
<td>CE 552</td>
<td>Water Resources Systems Analysis, Planning &amp; Mgt</td>
<td>3 – 0 – 0 – 6</td>
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<tr>
<td>CL633</td>
<td>Applied Statistical Thermodynamics</td>
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<tr>
<td>CE 567</td>
<td>Sediment Dynamics in Fluvial Systems</td>
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<tr>
<td>CE XXX</td>
<td>Engineering Seismology</td>
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<tr>
<td>CE XXX</td>
<td>Earth System Engineering</td>
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<tr>
<td>CE 606</td>
<td>Earthquake Engineering</td>
<td>3 – 0 – 0 – 6</td>
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<tr>
<td>CE XXX</td>
<td>Climate Change: Causes, Effects and Mitigation</td>
<td>3 – 0 – 0 – 6</td>
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<tr>
<td>CE XXX</td>
<td>Landslide Engineering</td>
<td>3 – 0 – 0 – 6</td>
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<tr>
<td>CE XXX</td>
<td>Advanced Geological Engineering</td>
<td>3 – 0 – 0 – 6</td>
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</tbody>
</table>
CE 591    Earth System Dynamics   (3-0-0-6)

Course Content:
Definition and scope of earth system sciences; fundamental concepts of the five spheres (lithosphere, hydrosphere, atmosphere, biosphere and cryosphere); interactions between the five spheres; carbon cycle; hydrologic cycle; fundamental geoscience concepts; functional components; earth system: the physical and chemical processes; unifying concepts of geosciences to examine surface and internal processes in the earth including weathering; plate tectonics, earthquake; volcano; orogeny; palaeoclimate.

Texts/ References:

CE 592    Exploration Geosciences   (3-0-0-6)

Course Content:
Distribution of ore deposits in space and time; stages of exploration and objectives; prospecting
criteria and selection of areas for exploration during reconnaissance and initial follow-up; introduction to geophysical exploration techniques, gravity and magnetic methods, principles and methods of gravity and magnetic prospecting, geological setting and prospecting criteria for important deposits; petroleum resources, gold deposits, massive sulfide deposits, porphyry copper deposits; underground sampling and calculation of blocked reserves; seismic exploration theory and geometry of seismic waves, seismic sources and equipment, reflection and refraction field method, seismic stratigraphy, seismic interpretation, hydrocarbon indicators, resistivity methods; well logging techniques and data processing, applications and limitations of various geophysical techniques in solving geological, hydrogeological, geotechnical, and environmental problems, with an emphasis on mineral and hydrocarbon exploration.

Texts/References:


CE 593 Advanced Remote Sensing (3-0-2-8)

Course Content:

Fundamentals of remote sensing; Interaction of EMR with the atmosphere and the earth surface; types of remote sensor and platforms; types of resolution; active and passive remote sensing; introduction to panchromatic, multispectral and hyperspectral data; basics of optical and microwave remote sensing.

Hyperspectral remote sensing: causes of absorption feature in the spectra, hyperspectral image and spectral measurement techniques (in laboratory, field and space), atmospheric correction techniques, pre-processing of hyperspectral images (geometric correction, data dimensionality reduction and noise whitening), processing of measured lab/field spectra; endmember extraction; sub-pixel classification and information extraction; Thermal Remote Sensing: introduction to thermal remote sensing, available spaceborne thermal sensors, Temperature-Emissivity Separation (TES) techniques, information extraction, advance quantitative analyses of thermal imagery and accuracy assessment (confusion matrix); application of quantitative hyperspectral and thermal remote sensing techniques in earth and planetary exploration, and civil engineering.
Texts/References:


CE 594 Geohazards Science and Engineering (3-0-0-6)

Course Content:

Introduction to risks and geohazards; different types of hazards: natural disasters, landslides, tornados, earthquakes, acute and chronic health effects; long-term societal effects due to environmental change: sea level rise and global warming; physical principles of hazardous phenomena and quantitative methods for hazard assessment; methods of risk mitigation; risk control and management; geological hazard management, hazard forecasting system, and applications.

Texts/References:


CE 595 Advanced Techniques in Geoscience (2-0-2-6)

Course Content:

Generation of structural geology and lithology map; interpretation of subsurface geology from geological data; preparation and interpretation of gravity and magnetic anomaly maps; preparation of geological maps from aerial photographs; preparation of geological maps and lineaments maps from satellite imagery; geophysical and geochemical processes; study on interactions of various processes by using observations from field data and remote sensing data operation of analytical instruments such as mass spectrometers; xrf; spectrophotometers; experimental design; standardization and calibration; analysis and integration of geological, geochemical and geophysical data; resistivity survey and interpretation of resistivity data; seismic data interpretation; well logging and core data analysis and interpretation for petroleum reserves; calculation of ore reserves from given geological map and data from ore microscopy.
and fluid inclusion; calculation of grade and averaging of assay value and demarcation of ore bearing zones; preparation and interpretation of geochemical anomaly and maps.

Texts/References:

ELECTIVE COURSES

Elective I

CE 601 Numerical Methods (3-0-0-6)

Course Content:
Linear equations and Eigen value problems; Accuracy of approximate calculations; Nonlinear equations; interpolation; differentiation and evaluation of single and multiple integrals; initial and boundary value problems by finite difference method; Newton’s method, variation and weighted residual methods; introduction to finite element methods; fundamental of statistical distribution.

Texts/References:

CE 602 Optimization Methods (3-0-0-6)

Course Content:
Basics of engineering analysis and design, need for optimal design, formulation of optimal design problems, basic difficulties associated with solution of optimal problems, classical optimization methods, necessary and sufficient optimality criteria for unconstrained and constrained problems, Kuhn-Tucker conditions, global optimality and convex analysis, linear optimal problems, Simplex method, Introduction to Karmarkar’s algorithm; numerical methods
for nonlinear unconstrained and constrained problems, sensitivity analysis, linear post optimal analysis, sensitivity analysis of discrete and distributed systems; introduction to variational methods of sensitivity analysis, shape sensitivity, introduction to integer programming, dynamic programming, stochastic programming and geometric programming, introduction to genetic algorithm and simulated annealing.

**Texts/References:**


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**CE 513 Statistical Methods in Civil Engineering (3-0-0-6)**

**Course Content:**

Charts and diagrams; measures of central tendency and measures of dispersions and their applications in civil engineering; percentile ranks and percentiles; concept of standardization; applications of scatter plots; covariance; correlation coefficients and their properties in field data; curve fitting and least square techniques and their use in the experimental methods in civil engineering; concept of regressions; regression curve in bivariate frequency distributions; introduction to probability and set theory; probabilistic measures; conditional probability and Bayes' theorem; discrete and continuous random variables; probability density functions; probability distributions of single and multiple random variables; discrete & continuous distributions; chi-square test; Kolmogorov-Smirnov test; analysis of variance; conditional distributions and independence; expectations and moments and their applications in random vibrations and other fields of Civil engineering; random processes and their properties; some important random processes and their applications in Civil engineering.

**Texts/References:**


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**Elective II-V**

**CE 635 Geodesy and Mapping (3-0-0-6)**
Course Content:
Astronomy and Geometric Geodesy: Celestial Sphere, Definition of terms in Astronomy, Celestial coordinate systems, Variations in Celestial coordinates; Precession and Nutation; Time systems--Sidereal time, Ephemerides time, Atomic time; Rotational Time systems: UT0, UT1, UT2, CIO and Polar motion, Earth Rotation parameters and Leap second; Coordinate Systems in Geodesy, Geodetic reference systems: ICRF and ITRF, Datums-Horizontal & Vertical, GRS-80, WGS-84; Transformation of Coordinates from one datum to another; Mean Sea level, Geoid and MSL in India; Geometry of Ellipsoid, Level Surface and Plumb Line, Deflection of vertical, Geoidal Separation, Natural Coordinates, Astrogeodetic deflection; satellite geodesy: Introduction to Satellite Geodesy, Keplerian Motion, Geometry of ellipse, Kepler ellipse in space; Introduction to GNSS satellite systems, Satellite Laser ranging, Satellite Altimetry; Map Projection: Introduction to Map projection, Purpose and methods of Map projection and their classification; Conformal Map projections: LCC and Transverse Mercator Projections; Indian Grid System and UTM.

Texts/References:

CE 636 Geostatistics (3-0-0-6)

Course Content:
Introduction to probability, statistics and set theory; observations and mathematical model, precision and accuracy, rejection of observations, weights and cofactors, correlation and covariance, propagation of errors and variance-covariance; Least squares adjustment computations; Sequential processing and Kalman Filtering, Variance-covariance of adjusted data, error ellipse and error ellipsoid; Statistical analysis of adjusted data; methods of interpolation: Variogram, Semivariogram, Kriging; Applications of adjustments computations for geospatial data analysis.

Texts/References:

CE 501  Continuum Mechanics (3-0-0-6)

Course Content:
Basic concepts of the theory of continuous media; introduction to tensor algebra; Elementary introduction to Cartesian tensors and tensor operations, theory of stresses; infinitesimal and finite strains; strain-displacement relationships; compatibility; stress-strain relationships; plane stress and plane strain case; stress function approaches; plane problems in Cartesian and polar coordinates; spatial (Eulerian) and material (Lagrangian) description of motion of deformable bodies, boundary value problem in elasticity elements of plasticity; yield criteria; flow rule and hardening; strain displacement relationship, strain rate tensor, time rate of change of volume and line integrals, stress tensor, continuity and equilibrium equations, constitutive equations, boundary value problems, Navier equations, conservation laws, yielding of material, plastic flow theory, derivation of Navier-Stoke’s equation and its applications.

Texts/References:

CE 503  Structural Dynamics (3-0-0-6)

Course Content:
CE 554    Advanced Fluid Mechanics    (3-0-0-6)
Course Content:
Elementary introduction to Cartesian tensors and tensor operations; notion of a continuum and
definition of fluid, scalar and vector fields; spatial (Eulerian) and material (Lagrangian)
description of motion of deformable bodies, rotation and vorticity; strain rate tensor; time rate of
change of volume and line integrals; Reynold’s transport theorem; stream function; irrotational
flow and velocity potential, internal, external and surface contact forces, stress tensor, continuity
and equilibrium equations, constitutive equations, derivation of Navier-Stoke’s equation; plane
Poiseuille flow and Couette flow; Hagen-Poiseuille flow; Stokes’ flow; slow flow and Hele-Shaw
flow; flow in convergent-divergent channels; introduction to laminar flow; Blasius equation;
Karman momentum equation; description of turbulent flow; Kelvin-Helmholtz instability; mean
flow equations; Prandtl’s mixing length; turbulent Poiseuille flow; jets and wakes.

Texts/References:

CE 563    Flow and Transport Processes in Fractured Media (3-0-0-6)
Course Content:
Fractured rock systems; hydrogeologic characterization methods; channeling; fracture network;
point and non-point sources of pollutants; conservative and reactive solute transport; fracture
flow and transport models.

Texts/References:
Dordrecht.
2. Committee on Fracture Characterization and Fluid Flow, Rock Fractures and Fluid Flow:

CE 637 Petroleum Geology (3-0-0-6)

Course Content:

Origin and composition of petroleum and natural gas, geology of petroleum basins; petroleum system: source rocks, reservoir rocks and traps; geographic and stratigraphic distributions of oil and gas; Oil migration; structural and tectonic aspects of petroliferous basins; types of petroliferous basins and their relation to hydrocarbon potential; Methods and techniques for petroleum exploration; Sub-surface geological methods and brief idea about geologic interpretations of seismic data; well-logs; drilling techniques; production and development geology.

Texts/References:


Annexure-120/4(e) contd…….

CE 638 Structural Geology (3-0-0-6)

Course Content:

Dynamic and kinematic analyses of rocks in two dimensions, stress and strain; Folds: classification, mechanism of folding; Biot’s law; strain within buckled layer; similar fold and shear fold; kink bands; chevron folds and conjugate fold; cleavage; lineation; boudinage; deformation of linear structures by flexural slip folding and shear folding; deformation of planar structures by flexural slip folding and shear folding; superimposed folding: Type 1, 2 and 3 interference pattern; faults and ductile shear zone.

Texts/References:

CE 639   Geochemistry   (3-0-0-6)

Course Content:
Chemical composition of the Earth and its constituent reservoirs; meteorite evidence; elementary
statistics for geochemistry; major, minor and trace elements including rare earth elements; element
partitioning between minerals and melts; oxide-element conversions; radioactivity and
geochronology; chemical and isotopic fractionation; application of Rb-Sr and Sm-Nd isotope
geochemistry to rock dating, petrogenesis, and crust-mantle evolution; mixing phenomena in
elements and isotopes; laws of thermodynamics; internal energy, heat capacity, enthalpy and
entropy; Gibbs free energy and chemical potential; fugacity and activity; Raoult's law and Henry's
law; ideal and non-ideal solutions aqueous solutions and solubility equilibria; activities of ionic
species; construction of Eh-pH diagrams.

Texts/References:

CE 640   Advanced Image and Spectral Analysis   (3-0-0-6)

Pre Requisite: CE 593 : Advance Remote Sensing

Course Content:
Fundamentals of hyperspectral remote sensing; origin of spectral absorption features; characteristic
absorption features of natural and manmade materials; hyperspectral sensors (present and future);
atmospheric correction techniques; data dimensionality reduction (PCA, MNF, ICA); digital image
enhancement and filtering techniques.

Introduction to spectroradiometers, calibration of spectroradiometers, spectral acquisition in
controlled environment, up-scaling of lab/field scale information to the satellite scale,
characterization of measured spectra, fundamentals of linear and non-linear spectral deconvolution;
spectral unmixing using library and field spectra; Extraction of image “Endmembers” in N-dimension space, characterization of derived Image Endmembers using spectral repository, sub-pixel classification using image derived Endmembers and lab measured spectra (Binary Encoding, Spectral Angle Mapper, Linear Unmixing, Mixture Tuned Matched Filtering), and accuracy assessment; Case studies: Application of imaging spectroscopy.

Texts/References:


CE 652  Precision Remote Sensing (3-0-0-6)

Course Content:

Global Positioning Systems; Surveying with GPS; Planning and field observations; GIS and GPS integration.

LiDAR: Physics and spectral characteristics of laser and its interaction with objects; Airborne Altimetric LiDAR: principle; topographic and bathymetric LiDAR; multiple return; full wave digitization; components of a LiDAR system, calibration and flight planning; LiDAR geolocation models; Accuracy and error propagation; error analysis and removal; data classification techniques; LiDAR data integration with spectral data; LiDAR applications; Photogrammetry: Metric and non-metric cameras; geometry of photographs; heights and tilt distortions; rectification and orthophotographs; stereoscopy, parallax equation and stereo measurements for height determination; orientation: interior, exterior, relative, and absolute; mathematical model relating images, model and object space; image matching techniques (signal and feature-based, relational, cross-correlation and least squares matching); strip and block triangulation and adjustment; automatic DTM and orthophoto production, flight planning.

Texts/References:

CE 653   Advanced Hydrogeology    (3-0-0-6)

Course Content:
Basic concept of hydrology and hydrogeology; Water Cycle; Water balance and hydrological processes; environment and water; Physical, chemical and biological quality of natural surface water and groundwater; Organic and inorganic pollutants in water and wastewater; water quality criteria for drinking, municipal, industrial, agricultural, recreational, wildlife and aquatic organisms; specific refractory substances in water and its impact on water usage; effluent discharge standards; The continuum approach to transport in subsurface hydrology; Darcy’s law and its generalization; flow through saturated and unsaturated porous formations; well hydraulics; analysis of pumping test data; groundwater recharge; water logging and salinity; infiltration and exfiltration from soils in presence and absence of a water table; modeling contaminant transport porous media; dispersion, adsorption and decay, volatilization; applications of numerical models in hydrogeology; model conceptualization, discretization and calibration, initial and boundary conditions, use of Dirichlet and Neumann boundaries, modeling strategy, pitfalls and limitations; Management of groundwater resources, development of management model, incorporation of simulation model with the optimization model; Applications: pollution control, mining and construction dewatering, saltwater intrusion, wetland protection from dewatering.

Texts/References:

Annexure-120/4(e) contd…….

CE 646   Rock Mechanics    (3 0 0 6)

Course Content:
Geological formation of rocks, Structural Geology, Classification of rocks, Physico-mechanical properties of rocks, Laboratory and field tests, Stress-strain behaviour, Failure criteria for intact rock and rock masses, Fracture mechanism, Analysis and design of underground openings,
Instrumentation in tunnels, Rock support and reinforcement, Foundations on rock, Rock blasting.

Texts/References:

CE 654  Petrophysics  (3-0-0-6)

Course Content:
The study of petroleum reservoirs; fundamentals of petrophysics; interrelation between petrophysical parameters; the borehole environment; hydrocarbon mobility; invasion profiles and invasion characteristics; acquisition and presentation of petrophysical data (well logging); interpreting logging parameters (porosity, permeability, electrical resistivity, capillary pressure, relative permeability); study of rock properties (porosity, compressibility, gas permeability, liquid permeability); study of fluid properties; behavior of reservoir fluids, oil properties, gas properties, brine properties permeability correlations; permeability averaging and heterogeneity; study of fluid-rock interaction properties such as saturation and wettability; surface and interfacial tension.

Texts/References:
1. George, B.A., Charles, R.G., Basic Well Log Analysis, AAPC.

CE 642  Subsurface Investigation and Instrumentation  (3 0 0 6)

Course Content:
Problems and phases of foundation investigations; Geophysical, sounding, drilling and accessible explorations; Sample requirements, sampling methods and equipment; Handling, preservation and transportation of samples; Sample preparation, laboratory tests, analysis of results and interpretation, importance of in-situ testing; Performing various in situ tests; Precautions and interpretation; Field Instrumentation; Investigation below sea/river bed; offshore investigation; Site evaluation and reporting.

Texts/References:


CE 655 Underground Exploration (3 0 0 6)

Course Content:

Theory and practice of rock fragmentation by drilling and blasting; introduction to explosives and initiation systems; design of surface and underground blasts; machine excavation systems for tunneling and stopping; environmental impacts, safety, and risk assessment; underground environment: dust suppression, ventilation, lighting, communication, fire protection; underground openings: dimensions, shape, structural response, sequence of excavation, rock conditions, stress distribution and failure prediction, caving and subsidence, failures in underground excavation; Structurally control instability, influence of geometry, in-situ stress, pillar design and failure, fracture propagation, stiffness, energy and stability, static and dynamic response of rock material during excavations; explosives and Charging Systems; Initiating Devices and Systems; Production Bench Blasting; Over break Control and Secondary Blasting; Damage Control; Safety and Accident Prevention; design and construction of large excavation: hydro-power station caverns, metro-railways, large diameter trenches, water carrying.

Annexure-120/4(e) contd……..

CE 557 Environmental Hydrology (2-0-2-6)

Course Content:
Basic concepts of environmental hydrology; water cycle, water balance and hydrological processes; environment and water; hydrology and climate, physical and biological interactions; water-related environmental problems; hydrological characteristics of India; drinking water, drinking water regulation and standards, water testing; forest hydrology, hydrological processes in forested area; urban hydrology, urbanization and hydrological processes, runoff process and flood; storm water storage and infiltration, reconstruction of urban water cycle; domestic, industrial, commercial, agriculture, and public water uses; water rights and development; water pollution and water quality policy, point and non-point source pollution and control, self-purification; sewage treatment; groundwater pollution, background and measurements of groundwater contamination, sources and fate of contaminants, organic solvents, phosphate and nitrate, remediation; Laboratory: Experiments to complement/supplement theoretical topics including physicochemical and bacteriological testing of surface and groundwater (majorcations-anions, total coliform and faecal coliform, Fluoride, Arsenic, Phosphorous, Nitrogen).

Texts/References:

Annexure-120/4(e) contd…….
CE 564   Stochastic Hydrology   (3 0 0 6)

Course Content:
Review of fundamentals of probability and statistics, concepts of conditional probability, random variables and their transformations; concepts of moments and quantiles; commonly used probability distribution functions; principles of hypotheses testing; principles of Monte Carlo simulation and estimation theory; methods of maximum likelihood and least squares minimization; theory of random processes, estimation of linear static systems, random fields and stochastic-dynamic systems; Kalman filter and its applications in hydrologic real-time forecasting, stochastic characterizations and geostatistics; temporally and spatially variable subsurface flow analysis; theoretical approaches and applications of stochastic modeling to transport processes in heterogeneous porous media.

Texts/References:

CE 565   Introduction to Multiphase Flow   (3-0-0-6)

Course Content:
Introductory concepts of the physics and mathematics of multiphase flow; flow of immiscible fluids in porous media; pore level characterization; pore networks; invasion percolation in drainage and imbibitions; capillary pressures and relative permeability; upscaling; Buckley-Leverett theory of two- and three-phase immiscible displacements.

Texts/References:

Annexure-120/4(e) contd…….
CE 568  Environmental Management of Water Resources  (3 0 0 6)

Course Content:
Environmental management- principles, problems and strategies; water resources management; Review of political, ecological and remedial actions; future strategies; multidisciplinary environmental strategies, the human, planning, decision-making and management dimensions; environmental impact assessment (EIA), definitions and concepts, rationale and historical development of EIA, sustainable development, Initial environmental examination, environmental impact statement, environmental appraisal, environmental impact factors and areas of consideration, measurement of environmental impact, organization, scope and methodologies of EIA, status of EIA in India; Environmental audit, definitions and concepts, environmental audit versus accounts audit, compliance audit, methodologies and regulations; introduction to ISO and ISO 14000; Life cycle assessment.

Texts/References:

CE 572 Pollution and Contaminant Flux in Water Environment    (3-0-0-6)

Course Content:
Low temperature geochemical reactions in aqueous environments; chemical kinetics; thermodynamics, mixing and dilution, mineral stability, chemical composition of surface water, stable isotopes; contaminants and contaminants transporting near-surface environments; fluid – sediment interaction; fluid portioning; stability and mobility of groundwater contaminants; multi-phase systems; sampling considerations and overview of analytical techniques; flocculation, deposition and re-suspension of sediments; physicochemical processes at sediment water interface; fate and effects of sediment bound contaminants; partitioning of contaminants in water-sediment systems; bio assessment of sediment and water quality; effects of sediment mixing; parameterizing models for contaminated sediment transport; fluxes between trophic levels and through the water-sediment interface.
**Texts/References:**


**CE 552 Water Resources Systems Analysis, Planning & Management (3-0-0-6)**

**Course Content:**

Basic concepts of systems, need for systems approach in water resources, system design techniques, problem formulation; optimization techniques, LP, NLP, dynamic programming, genetic algorithm, sensitivity analysis, capacity expansion; reservoir operation problems, simulation, case studies; planning, role of a planner, National water policies, public involvement, social impact, economic analysis.

**Texts/References:**

2. Loucks, D.P., van Beek, M., Water Resource Systems Planning and Management: An Introduction to Methods, Models and Applications; UNESCO.

**CE 567 Sediment Dynamics in Fluvial Systems (2-0-2-6)**

**Course Content:**

Fluvial sediments; transportation and entrainment; physical & chemical characteristics; grain size distribution; chemical sedimentology; environmental chemistry of sediments; minerals in sediments, physical and chemical properties; texture, grain size, shape, sorting, surface features, packing, orientation, textural maturity, density, porosity, permeability, adsorption properties; Mechanical analysis of sediments: grade scale, frequency distribution and
interpretation, laser particle distribution analysis, X-ray diffractometry, Atomic Absorption Spectrophotometry and scanning electron microscopy; shape analysis and their significance, graphical methods of representation of results; 

particulate nutrient and contaminant flux; modeling approach to sediment flux and concentration; Laboratory: Experiments to complement/ supplement theoretical topics including sediment studies in XRD, SEM, LPA and AAS.

Texts/References:

CE 657 Engineering Seismology (3-0-0-6)

Course Content:
Earthquake Genesis: Type of earthquakes, Plate tectonic theory, Earthquake faults and mechanisms, Seismic gap theory; Seismic Wave Propagation: Type of waves, Attenuation of wave amplitude with distance, directivity pulse; Measurement of Earthquakes: Location and size of earthquake event, Seismograph and Accelerometer; Data Processing: Filtering and baseline correction, Spectrum-compatible ground motion; Strong Motion Characterization: Peak ground acceleration, Strong motion duration, Response spectrum, Fourier spectrum, Power spectral density function, Ground motion intensity measure; Seismic Hazard Assessment: Identification of seismic sources, Magnitude-Recurrence relationship, Factors affecting ground motion characteristics at a site, Attenuation laws, Seismic hazard evaluations in a given time interval, Seismic zonation maps; Local Site Conditions: Effect of site conditions on ground motion characteristics, Evaluation of site effects using statistical correlations and analytical techniques; Design Response Spectrum: PGA and response spectrum shape method, direct statistical correlations; Ground Motion Simulation: Fourier transform based simulation, Wavelet transform based simulation.
CE 658  Earth System Engineering  (2-0-2-6)

Pre Requisite: Earth System Dynamics

Course Content:
Introduction to modeling; Develop model components and to evaluate the role of Earth system components such as energy balances, atmospheric and oceanic circulation; ocean-atmosphere; land-atmosphere coupling; hydrologic cycle; carbon cycle; Anthropocene; Developing model components from experiments; experimental design; standardization and calibration; Study on interactions of various processes by using observations from field data and remote sensing data; Modelling of geophysical and geochemical processes; operation of analytical instruments such as mass spectrometers; gas chromatographs; spectrophotometers; analysis and integration of geological; geochemical and geophysical data and modeling natural system related to hydrology; climate and tectonics.

Texts/ References:

CE 606  Earthquake Engineering  (3 0 0 6)

Pre-requisites: Structural Dynamics (CE504)

Course Content:
Earthquakes: Causes, Magnitude and Intensity, Ground Motions, Site effects, Sensors; Response spectrum: Construction, Characteristics, Design Response spectrum; Linear
Earthquake analysis: Idealization of structures, Response spectrum analysis, Torsionally coupled systems, Frequency domain analysis, Time domain analysis; Nonlinear Earthquake analysis: Force-deformation relationships, Equation of motion, Controlling parameters, Ductility demand, Allowable ductility; Earthquake resistance design: philosophy ductility based design, Detailing provisions, Codal Provisions, Concepts of passive controls; Geotechnical aspects: Dynamic properties of soil, dynamic earth pressures, Liquefaction and ground improvement techniques; Retrofitting and strengthening of Buildings and Bridges.

Annexure-120/4(e) contd……..

Texts/References:

CE 659 Climate Change: Causes, Effects and Mitigation (3-0-0-6)

Course Content:
Introduction to Climate Change; History and Trends of Climate: Paleoclimatology and Climate archives; Climate Forcers: Internal, External and Human; Direct and Indirect Climate forcing: Green house gases, Clouds and Aerosols; Energy Balance; Overview of Climate models: Simplest models to Global Climate Models (GCMs); Biogeochemical cycles; Mitigation Strategies: Transportation, Energy supply, Buildings, Industry, Agriculture, Forestry and Other Land use; Economics, Environmental Laws and Politics of Climate Change; Special Topics: Case studies, Ocean currents, Ocean acidification; and Climate impacts on Precipitation and Evapotranspiration at the earth’s surface.

Texts/References:
CE 660 Landslide Engineering (3-0-0-6)

Course Content:
Introduction to landslide geohazard; socio-economic impacts of landslides; importance of landslide engineering: classification of landslides, landslide triggering factors; hillslope geomorphology and hydrology factors for rainfall induced landslides: earthquake induced landslides; landslide mechanisms and characteristics: influencing parameters; in-situ and laboratory investigations for landslide analyses; methods for assessment of slope stability; landslide susceptibility analysis; landslide hazard assessment; instrumentation for landslide monitoring and early warning systems; landslide mitigation measures.

Texts/References:

CE 666 Advanced Geological Engineering (3-0-0-6)

Course Content:
Geological Engineering, technological aspects in Geological Engineering (structural constructions, bridges and pavements, earthworks); characterization of the subsurface; surface mapping, drilling, and geophysics; surface and subsurface exploration methods; collection, evaluation and organization of data; exploratory drilling-methods, pattern and sequence, logging of drill hole data; planning of exploration drilling holes; geostatistical estimation of ore reserves; application of remote sensing and statistical analyses in mineral, groundwater and petroleum exploration; application of different geophysical and geochemical surveys and exploration strategies.

Texts/References: