Indian Institute of Technology Kanpur

COURSES OF STUDY

2026





Indian Institute of Technology Kanpur
KANPUR-208016

EARTH SCIENCE

Template for BS Program in Earth Sciences

Semester 1	Semester 2	Semester 3	Semester 4	Semester 5	Semester 6	Semester 7	Semester 8
SCHEME-1 (9) ELC111/ELC112/ ELC113 *	ETH111 (3) **	SCHEME-2: EME (09-11)/ES208(9)^	SCHEME-3: HSS-I (11)	SCHEME HSS-II (09)	SCHEME HSS-II (09)	SCHEME: HSS-II (09)	ES402 (04):
MTH 111 (6)	MTH 113 (6)	ESO201 (11):	ESC201 (14)	ESO204 (11):	ES304 (09):	ES401 (09):	DE-3 (09)
MTH 112 (6)	MTH 114 (6)	ESO213 (09):	ES204 (09):	ES301 (06):	ES305 (06):	DE-1 (09) / ES497: UGP-II (09)	DE-4 (09)
PHY 115 (11)	PHY 112 (11)	ES201 (11):	ES205 (09):	ES302 (09):	ES306 (06):	DE-2 (09)	DE-5 (09) / ES498: UGP-III (09)
PHY 111 (3)	CHM 111 (3)	ES202 (09):	ES206 (11):	ES303 (09):	ES496: UGP-I (0) (Extra credits)	OE-4 (09)	OE-5 (09)
TA 111 (9)	ESC 111 (7)	ES203 (06):	ES207 (04):	OE - 1 (09)	OE-2 (09)		OE-6 (09)
CHM 112 (4)	ESC 112 (7) §§				OE-3 (09)		
CHM 113 (4)	LIF111 (6)						
PE111 (3)	PE112 (3)						
55	52	55-57	56-58	53	48	45	49

Note: OEs and DEs can be swapped across semesters based on the availability of the desired courses, provided the total credits for the DEs and OEs remain the same as in the template.

^ES208(9) is compulsory EME course from Y24 and onward batch students only.

Credit table for BS program in Earth Sciences		
Course type	Allowable Credit range	Credit in the department template
Institute Core (IC)	112	112
E/SO	18-45	31
Department	144-179	162 (117 DC + 45 DE)
Open electives (OE)	51-57	54
SCHEME	54-58	54-58
Total for 4-year BT/BS	391-420	413-417

Template for BSH program in Earth Sciences

Template for 3rd to 8th semester BSH program in Earth Sciences					
Semester 3	Semester 4	Semester 5	Semester 6	Semester 7	Semester 8
SCHEME-2: EME (09-11) / ES2028(9)^	SCHEME-3: HSS-I (9-11)	SCHEME HSS-II (09)	SCHEME HSS-II (09)	SCHEME: HSS-II (09)	ES402 (04): Field Geology - III
ESO201 (11): Thermodynamics	ESC201 (14)	ESO204 (11): Fluid Mechanics	ES304 (09): Fundamentals of Remote Sensing and GIS	ES401 (09): Exploration Geophysics	DE-3 (09)
ESO213 (09): Fundamental of Earth Sciences	ES204 (09): Fundamentals of Geophysics	ES301 (06): Fundamentals of Stratigraphy	ES305 (06): Geochemistry	ES497: UGP-II (09) Compulsory	ES498: UGP-III (09) Compulsory
ES201 (11): Crystallography & Mineralogy	ES205 (09): Sedimentology	ES302 (09): Ore Geology	ES306 (06): Field Geology - II	DE-2 (09)	DEH-2 (9)
ES202 (09): Physical Hydrology	ES206 (11): Igneous & Metamorphic Petrology	ES303 (09): Structural Geology	ES496: UGP-I (0) (Extra credits)	OE-4 (09)	DEH-3 (9)
ES203 (06): Geomorphology	ES207 (04): Field Geology - I	OE - 1 (09)	DE-1 (09)	DEH-1 (9)	OE-5 (09)
			OE-2 (09)		OE-6 (09)
			OE-3 (09)		
55-57	56-58	53	57	54	58

- CPI Criteria for BSH: ≥ 8.5
- Student should take 27 credits of DEH courses from the Honours Course Basket. Any ES course with course number ES6xx and/or ES7xx can be considered and included within the Honours Course Basket
- ^ES208(9) is compulsory EME course from Y24 and onward batch students only.
- UG-2 and UGP-3 are mandatory UGPs for BSH

Template for BSM program in Earth Sciences

Template for 3rd to 8th semester BSM program in Earth Sciences					
Semester 3	Semester 4	Semester 5	Semester 6	Semester 7	Semester 8
SCHEME-2: EME (09-11)/ES208(9)^	SCHEME-3: HSS-I (11)	SCHEME HSS-II (09)	SCHEME HSS-II (09)	SCHEME: HSS-II (09)	ES402 (04): Field Geology - III
ESO201 (11): Thermodynamics	ESC201 (14)	ESO204 (11): Fluid Mechanics	ES304 (09): Fundamentals of Remote Sensing and GIS	ES401 (09): Exploration Geophysics	DE-2 (09)
ESO213 (09): Fundamental of Earth Sciences	ES204 (09): Fundamentals of Geophysics	ES301 (06): Fundamentals of Stratigraphy	ES305 (06): Geochemistry	DE-1 (09)	MTB-4 (09)
ES201 (11): Crystallography & Mineralogy	ES205 (09): Sedimentology	ES302 (09): Ore Geology	ES306 (06): Field Geology - II	MTB-2 (09)	MTB-5 (09)
ES202 (09): Physical Hydrology	ES206 (11): Igneous & Metamorphic Petrology	ES303 (09): Structural Geology	MTB-1 (9)	MTB-3 (09)	MTB-6 (09)
ES203 (06): Geomorphology	ES207 (04): Field Geology - I	OE - 1 (09)	OE-2 (09)		OE-3 (09)
55-57	56-58	53	48	45	49

For BSM, 54 credits of courses should be completed from the management Track Basket (MTB)
^ES208(9) is compulsory EME course from Y24 and onward batch students only.

Template for five-year dual-degree program in Earth Sciences

Template for 9th and 10th semester of dual-degree program in Earth Sciences (Category A)	
Semester 9	Semester 10
DEPG - 1 (09/11)	MS Project (36) (S/X)
DEPG - 2 (09/11)	
DEPG - 3 (09)	
DEPG - 4 (09)	
DEPG - 5 (09)	
MS Project (09) (S/X)	
54-58	36

- The Department of Earth Sciences will offer BS-MS (5-year Dual Degree Program) under Category A, only.

The Department of Earth Sciences does not to offer dual-major or minors

DEPARTMENT OF ES			
Courses ID	**Course Title**	**Credits L-T-P-D-[C]**	**Content**
ESO213	Fundamentals Of Earth Sciences	3-0-0-0 [9]	The universe and its characteristics Solar System and Earth The primitive Earth Geological Time scale Origin of the life and major geological events Numerical Dating. Rocks, minerals and soils; Plate Tectonics and Mountain building, Deformation and Geodynamics Earthquakes; Volcanoes.Earth, Ocean, Land, Rivers, Atmosphere, Biosphere, Cryosphere and Climate; Energy budget; Carbon Cycle; Hydrological Cycle; Weathering and erosion. coupled processoes in Earth System; climate change, Geological resourses (minerals, hydrocarbons and water); Sustainability and Anthropocene activities **Course Reference**: 1. D.R. Prothero and R.H. Dott, Jr. Evolution of the Earth. 2010 (8th Ed.), McGraw Hill, 576p; 2. E.J. Tarbuck, F.K. Lutgens and D.G. Tasa. Earth: An introduction to Physical Geology, 2013 (11th Ed.). Prentice Hall. 912 p; 3. J. Grotzinger and T. Jordan, Understanding Earth, 2010 (6th Ed.). Freeman, 210p.
DC - ES201	Crystallography And Mineralogy	3-0-2-0-11	Chemical and physical properties and identification of rock-forming minerals; crystallography, Unit cells, Symmetry, 32 Crystal Classes, Systems, Plane and Bravais Lattices, Axial Ratios, Parameters, Miller Indices, Point Groups, Crystal Form, Zones, Crystal Habit, Stereographic Projection of Crystal Faces, Polymorphs and Pseudomorphs, Twinning; optical mineralogy, uniaxial, biaxial minerals; introductions to x-ray crystallography; crystal structures, chemistry, and origin and significance of the rock-forming minerals, Mineralogy of the Earth's crust, upper mantle, lower mantle, and its Core. Independent project includes use of electron microprobe (EPMA) and x-ray facilities. **Course Reference**: 1. Nasse, W. 2011. Introduction to Mineralogy (2 nd Ed.) Oxford University Press. 496 p; 2. Klein, C. & Dutrow, B. 2007. Manual of Mineral Science. Wiley. 716 p; 3. Putnis, A. 1992. An Introduction to Mineral Sciences Cambridge University Press. 480 p; 4. Sands, Donald (2012). Introduction to crystallography Courier Corporation; 5. Hammond, C. (2001). The basics of crystallography and diffractions, Oxford Science Publications; 6. Lovett, David (1999) Tensor properties of crystals, CRC Press. 11-MAR-2016
DC – ES202	Physical Hydrology	3-0-0-0-9	Hydrology is the scientific study of water underneath and on the Earth's surface, including those in the atmosphere. Water has unique properties that make it vital to life on Earth and its physical environment. Alongside the core concepts of hydrometeorology and physical hydrology, this course we will explore the components of the hydrologic cycle, including processes of precipitation, evaporation, transpiration, groundwater flow, surface runoff and streamflow. In this course we will also learn about the basic methods of measuring and estimating the rates of hydrologic processes.
DC - ES203	Geomorphology	3-0-0-0-9	Earth as a system; Earth's energy balance, global heat transfer; Guiding Principles of Earth's surface processes: Conservation, transport rules, event size and frequency; rates of processes and ages of landscapes. Fundamental concepts of geomorphic system; Exogenic

			and endogenic processes; Weathering and soil system: physical and chemical weathering; formation of soils, soil erosion; Hydrological cycle and water budget. The Surface water system: Drainage basins and river systems; river morphology and hydrology; hydraulic geometry and governing principles of open channel flow; river processes and landforms, river dynamics. The Groundwater system: Groundwater in hydrological cycle, groundwater flow and storage; chemistry of groundwater. The Atmospheric System: Atmospheric composition and mixing, atmospheric circulation, greenhouse effect. The Ocean and Coastal system: Coastal environment, waves, tides and currents; coastal processes and landforms. Cryosphere – growth and decay of ice sheets, controlling factors, Himalayan glaciers; Wind activity and geomorphic work, desertification and controlling factors. Global geomorphology and tectonics: Earth's physiography and landscape evolution; Tectonic uplift and denudation – rates and controlling factors, Sea level change – evidence, mechanism and effects; coupled tectonic-surface process models. Global geomorphology and tectonics: Earth's physiography and landscape evolution; Landforms and tectonics of plate margins and plate interiors; Tectonic uplifts and denudation – rates and controlling factors, Sea level change – evidence, mechanism and effects; coupled tectonic-surface process models. **Course Reference**: 1. Summerfield, S.A. (1991) Global Geomorphology, Longman; 2. Ernst, W.G. (2002) Earth Systems: Processes and Issues, Cambridge University Press; 3. Richards, K.S. (1982) Rivers: forms and processes in alluvial channels, Metheun; 4. Kale, V. and Gupta, Introduction to Geomorphology, Orient Longman; 5. Merrits, D, Dewet, A. and Menking, K. (1998) Environmental Geology; An earth system science approach. W.H. Freeman. 11-MAR-2016
DC - ES204	Fundamentals Of Geophysics	3-0-0-0-9	Introduction to geophysics, Earth as a planet and member of the solar system, origin and evolution of the Earth, Internal structure of the Earth; Concept of plate tectonics, plate motions and triple junctions; Gravitation, gravity anomalies and its variations, geoid, isostasy, rheology; Geomagnetic field, its origin and variations, paleomagnetism, and geomagnetic reversals; Introduction to seismology, seismic waves P, S and surface waves, seismograph, travel time curves and radial Earth structures, general properties of surface waves and normal modes, earthquake source theory, intensity and magnitude scales of earthquakes, PREM model, elastic rebound theory, global seismecity and tectonics, focal mechanisms, seismic anistropy; Heat within the Earth, thermal structure of continental and oceanic lithospheres at subduction zones and spreading centres, mantle convection. **Course Reference**: 1. Lowrie, W; Fundamentals of Geophysics, Cambridge University Press; 2. Fowler, C.M.R., 2004, The Solid Earth: An Introduction to Global Geophysics; Cambridge University Press; 3. Robert J. Lillie, 1999; Whole Earth Geophysics: An Introductory Textbook for Geologists and Geophysicists, Prentice Hall. 11-MAR-2016.
DC - ES205	Sedimentology	3-0-0-0-9	Basinal Sedimentary Systems: Sedimentary basisn and production of sediments; Transport of sediment grains; depositional processes and forms; Post depositional changes lithification and diagenesis. Sediment grain, Bedforms and Sedimentary Structures: Mechanics of sediment

			transport and transport laws; Grain size parameters and distribution, grain shape and form; primary grain fabric; Bedforms & inorganic primary sedimentary structures. Sedimentary Facies analysis: Concept of sedimentary facies; facies relationships; controlling factors; facies association and models; Fluvial environments and facies; Lacustrine facies, Deltaic environments and facies models. Clay Sedimentology: Origin of clay minerals, clay minerals in fluvial, aeolian and lacustrine environments, paleoenvironmental interpretations. Techniques in elastic sedimentology: Grain size determination; Xray diffraction; Heavy mineral analysis; cathodoluminescence microscopy. **Course Reference**: 1. Allen P.A. and Allen J.R., Basin Analysis: Principles and Application, Blackwell publishing; 2. Leeder M., Sedimentology and Sedimentary Basin: from Turbulence to Tectonics; Wiley Blackwell; 3. Selley R.C., Applied Sedimentology; Academic Press; 4. Reading H.G., 2009, Sedimentary Environments: processes, facies and stratigraphy, Blackwell. 11-MAR-2016
DC - ES206	Igneous & Metamorphic Petrology	3-0-2-0-11	Classification, Nomenclature of Igneous Rocks, Igneous textures and petrogenetic interpretations; Thermodynamic evaluation of phase diagrams; Phase Rule and One Component System; Phase Diagrams for Binary Systems (Solid solution, Eutectic, and Peritectic systems), Ternary eutectic and peritectic systems; Bowen's Reaction Series, Effect of pressure, temperature & fluids on Melting, Olivine Geothermometer; Chemical Petrology: compositional variations, analyses and NORMS, Interpretations of Variation Diagrams; graphical and mathematical models of magma evolution; Fractionation of trace elements during melting and crystallization; Rare Earth Element (REE) patterns and modeling source magma composition; Generation and diversification of magmas; MORB Volcanism; Mantle Plumes and Ocean Island Basalts; Arc Magmas; Origin and composition of Continental Crust; Types of metamorphism, Contact and Regional Metamorphism; Classification of metamorphic rocks; metamorphic textures; Metamorphic mineral assemblagesand chemographic (ACF, AKF, and AFM) diagrams; Metamorphic Facies; Metamorphic Reactions; Thermodynamics of Metamorphic Reactions; Radiometric Age Dating of Igneous & Metamorphic Rocks
DC - ES207	Field Geology-I	0-0-3-0-3	Observation and identification, interpretations and descriptions of igneous, sedimentary and metamorphic rocks and their mineral contents; Reading topographic and geological maps in the field; Elementary geological field mapping of rock formations using geological compass. **Course Reference**: 1. Robert R. Compton, Geology in the Field. July, 1985; 2. Angela L. Coe, Geological Filed Techniques. October 25, 2010; 3. Richard J. Lisle, Peter Brabham, John W. Barnes, Basic Geological Mapping, 5th Edition August 2011. 11-MAR-2016
DC - ES301	Fundamentals Of Stratigraphy	2-0-0-0-6	Earth's history in rock record, geological time scale; Basic concepts in stratigraphy and stratigraphic principles; Gaps and hiatus in stratigraphic record - conformable and unconformable sequences; Architecture of sedimentary basins: rift basins, foreland basins, fore-arc/back-arc basins, strike slip basins; Lithostratigraphy, cyclostratigraphy, chronostratigraphy, event stratigraphy; Stratigraphic correlation: concepts and applications; Depositional models, accommodation space; External Controls on stratigraphic development: Climate, Tectonics and Sea Level; Subsidence and thermal history; Concepts in seismic and sequence stratigraphy; Magnetostratigraphy,

			Application of paleomagnetism to the solution of problems in stratigraphic correlation and to the construction of a high-precision geological timescale; Application to petroleum play assessment: the petroleum system and play concept, reservoirs, traps and regional top seal; application of stratigraphy in hydrogeology – aquifer stratigraphy and modeling; Stratigraphy of India.
DC - ES302	Ore Geology	3-0-0-0-9	Introduction: Terms and scope of ore deposit geology, Plate tectonics and Ore forming processes, Classification of ore deposits, Ore deposits and environments; Metallic ore deposits: Orthomagmatic deposits, Pegmatitic deposits, Hydrothermal deposits, VMS SedEx and MVT ore deposits, Supergene and residual ore deposits, Sedimentary ore formations, Metamorphic and metamorphosed ore deposits, Ore remobilization; Non-metallic ore deposits: Various non-metallic minerals and rocks, Salt deposits; Hydrocarbon resources: Coal types, chemical composition and formation, Coalification process, Post depositional changes, Petroleum and natural gas, Oil shale- Formation and Exploration; Methods in mineral exploration: Geological exploration, Remote sensing, Geological mapping, Delineation of ores, geochemical and geophysical exploration, Ore textures and paragenesis, Fluid inclusions. Laboratory classes on understanding and identifications of ore-minerals/rocks using transmission and reflection microscopy.
DC - ES303	Structural Geology	2-0-3-0-9	Concepts of deformation and structures in Earth and planetary systems; Concepts of Continuum, Solid, Fluid, Tensor, Force, Stress and Strain; Basics of rheology and deformation mechanisms; Structures associated with extensional, compressional, sliding tectonics and erosion; Fold morphology, kinematics and mechanism; Normal, reverse, oblique and strikeslip faults; Fold and thrust belts; Measurement and presentation of 1, 2 and 3D structural elements; Ductile shear zones; Polyphase (superposed) deformation and overpriting relationships; Application of Structural Geology. **Lab-work:** Measurement of structural features; Stereographic projection and interpretation; Construction and interpretation of structural map, profile and balanced cross section; measurement of finite strain; studying structures under optical microscope.**Course Reference**: 1. Ramsay, J.G., & Huber, M.I., 1983. The Techniques of Modern Structure Geology: V.1: Strain analysis. NY, Academic Press, 307 p; 2. Ramsay, J.G., and Huber, M.I., 1987. The Techniques of Modern Structural Geology, V.2: Folds and Fractures, NY, Academic Press, 392 p; 3. Ramsay, J.G., and Lisle, R.J., The Techniques of Modern Structural Geology, V.3: Applications of Continuum Mechanics in Structural Geology. Academic Press, 361 p. 11-MAR-2016.
DC - ES304	Fundamentals Of Remote Sensing And Gis	3-0-0-0-9	Remote sensing has become an integral part of Earth observation systems and contributes significantly towards the enhancement of the understanding of Earth system processes. Since its integration with Geographic Information Systems (GIS), remote sensing has evolved from an observation platform to a crucial decision-making support system. Course contents will cover the principles, components and techniques of remote sensing and GIS. **Course Reference**: 1. Gupta, R.P. (1991), Remote Sensing Geology, Springer verlag; 2. Lio, J.G. an Mason, P. (2009). Essential image processing and GIS for remote sensing. Wiley Blackwell; 3. Lillesand, T.M. & Kiefer, R.W. (1994), Remote sensing and image interpretation, John Wiley & Sons; 4. Langley, P.A., Goodchild, M.F., Maguire, D.J. & Rhind. D.W. (1999), Geographical Information Systems, Vol. 1 & 2,

			John Wiley & Sons; 5. Carbonneau, P. and Piegay, H. (2012). Fluvial remote sensing for science and management. Wiley Blackwell. 11-MAR-2016
DC - ES305	Geochemistry	2-0-0-0-6	Fundamental chemical principles, Elements, Atoms, and Chemical Bonds, electronic structure, chemical bonding, and chemical properties of elements. Fundamental Thermodynamic Concepts: Fundamental Thermodynamic Variables, Equations of State, Temperature, Absolute Zero, and The Zeroth Law Of Thermodynamics, Energy and The First Law of Thermodynamics, exact differentials and state functions, The Second Law and Entropy, Statistical Mechanics: A Microscopic Perspective of Entropy, Enthaply and heat capacity, The Third Law and Absolute Entropy, Gibbs Free Energy, Criteria for Equilibrium and Spontaneity, Temperature and Pressure Dependence of the Gibbs Free Energy, The Maxwell Relations, Solutions and Thermodynamics of Multicomponent Systems, Phase Equilibria, Raoult's law and Henry's Law, Chemical Potential, Thermodynamics and Phase Diagrams. Chemical kinetics and Diffusion rate Law, Ionic (Radii) Substitutions, Geochemical Classification of Elements, Trace Elements in Igneous Processes, Modeling Trace Element partition during magma genesis, Primary silicates and chemical weathering, Aqueous Geochemistry, Acids and Bases, Dissolution and Precipitation Reactions, Mineral Stability Diagrams, Oxidation-Reduction Reactions, Eh-pH diagrams, brief introduction to radiogenic and stable isotope geochemistry. **Course Reference**: 1. Principles and applications for Geochemistry (1998). Faure, G., Prentice Hall ISBN 10:0023364505; 2. Geochemistry: Pathways and Processes (2004). McSween, H.Y., Richardson, S.M., Uhle, M., Columbia University Press ISBN 10:0231124406; 3. Geochemistry (2013). White, W., Wiley Blackwell ISBN 10:047656686. 11-MAR-2016
DC - ES306	Field Geology Ii	0-0-6-0-6	General overview of geological structures in the field; Concept of orientation and scale in the field; Identification, measurement and presentation of different structural elements (lineation, cleavage, foliation, schistocity etc.) and their mutual relationships. Morphology and elements of fold, fractures, faults, shear zones and macrostructures; Strain analysis from deformed objects; Technique and ethics of geological samples collection; Large and small scale lithostructural mapping (on toposheet and white paper), crosssections, and their interpretation for regional tectonics. **Course Reference**: 1. Davis, G.H., & Reynolds, S.J., 1996. Structural Geology of rocks and Regions (2nd Ed): NY, John Wiley & sons, 776 p; 2. Lisle, R.J., 1995. Geological Structures & Maps, a Practical Guide. 2nd Ed., Butterworth / Heinmann, Woburn, 104 p; 3. Bennison, G.M., and K.A., Moseley, 1998. Geologic Structures & Maps; 6th edition. Arnold, London, 129 p. 11-MAR-2016
DC - ES401	Exploration Geophysics	3-0-0-0-9	Introduction to geophysical methods of exploration and their applications, physical properties of rocks, minerals and ores, types and scales of survey. Principles of gravity and magnetic methods, Working principle of gravimeters, fluxgate and proton precession magnetometers, gravity and magnetic surveys, data reduction, anomalies, geological interpretation and modeling for simple

			geometrical shapes. Fundamentals of electrical and electromagnetic methods of prospecting, origin of self potential and induced polarization, surveys, instruments, application and interpretation. Theory and geometry of seismic wave propagation, Reflection and refraction methods, CMP technique, seismic sources and arrays, Data processing sequence, velocity analysis, stacking and migration, Seismic interpretation. Introduction to well logging, formation evaluation, principles of electrical, nuclear, density and sonic logging with applications.
DC - ES402	Field Geology Iii	0-0-4-0-4	Introduction to geophysical methods; resistivity surveys – Vertical Electrical Sounding (VES) and resistivity profiling; Shallow seismic surveys; GPR surveys and data interpretation; Well-logging and data interpretation; seismic data interpretation Course Reference: 1. Compton, R. (1985) Geology in the field, Wiley; 2. Lahee, F.H. (2002). Field geology, CBS publishers; 3. John Milson and Asger Eriksen, 2011, Field Geophysics (4th Edition): Wiley Blackwell; 4. Reynolds, J.M. (2011), An Introduction to Applied and Environmental Geophysics, Second Edition: Wiley; 5. Everett, M.E., 2013, Near surface applied geophysics: Cambridge University Press. 11-MAR-2016
DE - ES450	Economic Geology	3-0-0-0-9	Classification of ore deposits. Orthomagmatic, pegmatitic and pneumatolitic deposits. Hydrothermal processes, deposit forms and classification. Weathering, supergene enrichment and residual deposits. Sedimentary, metamorphic and metamorphosed ore deposits. Important examples. Geological mapping, guides for ore search, delineation of ores, drilling, core-sampling, reserve estimation. Introduction to underground and surface mining methods. Underground exploration and sampling of ore deposits. Methods of computation of developed ore reserves. Introduction to geostatistical ore reserve estimation. Mineral resources and their classification.
DE - ES451	Environmental Geology	3-0-0-0-9	Earth as a system. Fundamental concepts in environmental geology. Geological cycles. Soil and environment. Natural hazards and environmental degradation. Surface and ground water system & management. Water pollution and treatment. Waste management. Atmospheric processes and related hazards. Geochemical cycles- C, N, & P. Earth's energy balance, greenhouse effect, and global warming. Human role in environmental changes
DE - ES452	Engineering Geology	3-0-0-0 [9] or 2-0-3-0 [9]	Study of rocks for their mineralogical, textural, weathering and discontinuity aspects. Engineering properties of rocks, soils, clays, and construction aggregates. Maps and numerical exercises. Instrumentation in engineering geology and hydrogeology. Geophysical Surveys resistivity, gravity and magnetic methods. Runoff estimation, borehole data analysis, groundwater exploration, pump test and estimation of aquifer hydraulics.
DE - ES453	Microstructures In Earth Sciences	2-0-3-0-9	Basics of optics, image formation and acquisition in optical microscope. Principles of geological thin/polished section and their preparation. Introduction to one open source image processing and analysis software. Understanding and identification of grain, grain shape, grain boundaries, cracks, cleavages etc. Measuring size, volume and distributions. Microscopic classification of cleavages. Microscopic shear sense indicators and rotational structures. Characteristics microstructures of different deformation mechanisms (cataclastic, intracrystalline and diffusion). Deformation and metamorphism at crystal

			scale. Strain analysis using deformed grains
DE - ES454	Geology Of Fuels	3-0-0-0-9	Origin of petroleum, source rock and maturation of kerogen, palaeothermometers; primary and secondary migration; reservoirs – porosity, permeability and capillary pressure, porosity types in clastic and carbonate reservoirs, reservoir heterogeneity, drive mechanisms; traps and seals – classification of traps; compositin of petroleum, physical and chemical properties of oil; brief idea about the hydrocarbon resources of India, the classification and stratigraphy of petroliferous basins of India. Origin of coal, classification of coal, morphology, composition of peat, lignite, anthracite. Coal series, terminology, structure and petrography of coals; physical and chemical properties of coal; coal reserve in India; brief idea about the world coal resources; exploration of coal; utilization of coal- combustion and gasification of coal; coal and environment.
DE - ES455	Analytical Methods In Earth Sciences	2-0-3-0-9	Hands-on training (project mode) in several analytical techniques including sample preparation, measurement procedures, compilation and processing of data, interpret results: Atomic Absorption Spectrometry, Inductively Coupled Plasma: Emission and Mass Spectrometry, Interferences in Inductively Coupled Plasma Mass Spectrometry, Introduction to Electron Microprobe Analysis, scanning electron imaging with back-scattered electron (BSE), secondary electron (SE), X-ray using WDS or EDS (elemental mapping), and cathodoluminescence (CL), Stable isotope ratio mass Spectrometry analyses.
DE - ES417	Geology Of India	2-0-0-0-6	Present day tectonic and geological configuration of the India with and overview of timescale and evolution; Cratons of India (Dharwar, Bastar, Singbhum, Bundelkhand and Aravalli); Mobile Belts of India (Eastern Ghats, Pandyan, Satpura and Himalaya); Sedimentary Basins of India (Chhatisgarh, Cuddapah, Marwar, Pranhita-Godavari, Vindhyan and Gondwana); Overall palaeo-tectonics of India (Rifting, drifting, palaeomagnetic interpretation and the evolution of India's continental margins). **Course Reference**: 1. Ramakrishnan, M. and Vaidyanadhan, R., 2008. Geology of India: Vol: I and II, Geological Society of India Publication; 2. Wadia, D.N. 1919. Geology of India for students, McMillan and Co., Ltd. 466 p; 3. Valdiya, K.S., 2015. The Making of India Geodynamics Evolution, 2nd Edition (Society of Earth Scientist Series), Springer, 942 p. 11-MAR-2016
ES599	MS Project	-	MS thesis
ES640	Earth System Processes	3-0-0-0 [9]	Principles: Earth System processes, geomorphic systems, Threshold and equilibrium; scale in geomorphology, key concepts in geomorphology, hydrologic cycle. Processes and Products: Exogenetic and endogenetic processes, climatic vs. geomorphic processes, soil and weathering system. The Surface water system: Drainage basins and river systems, river morphology and hydrology, fluvial erosion, transport and sedimentation, fluvial depositional landforms, geomorphometric concepts and drainage basin morphometry. The Groundwater system: Groundwater in hydrological cycle, water table, groundwater flow and storage; porosity and permeability, aquifers, chemistry of groundwater. The Atmospheric System: Atmospheric composition and mixing, atmospheric circulation, greenhouse effect. The Ocean and Coastal system: Coastal environment, waves, tides and

			currents, description and classification of coasts, shoreline development, coastal erosion and resulting topographic features, coastal deposition and landforms. Global geomorphology and tectonics: Earth's physiography and landscape evolution; Landforms and tectonics of plate margins and plate interiors; Tectonic uplifts and denudation rates and controlling factors, Sea level change evidence, mechanism and effects; coupled tectonic surface process models. **Course Reference**: 1. Summerfield, S.A. (1991) Global Geomorphology, Longman; 2.Ernst, W.G. (2000) Earth Systems: Processes and Issues, Cambridge University Press; 3.Richards, K.S. (1982) Rivers forms and processes in alluvial channels, Metheun; 4.Kale, V. and Gupta, A. (2001) Introduction to Geomorphology, Orient Longman; 5. Thronbury, W.D. (1969) Principles of geomorphology, John Wiley & Sons; 6.Williams, M.J. (1998) Quaternary Environments, Arnold Publishers; 7.Reading, H.G. (1996) Sedimentary Environments. Blackwell; 8. Merrits, D, Dewet, A. and Menking, K. (1998) Environmental Geology: An earth system science approach. W.H. Freeman.
ES641	Environmental Geology	3-0-0-0 [9]	Earth-environment interaction; Fundamental concepts of environmental geology, Natural hazards, Environment of soil formation, erosion and soil contamination, Water resources & contamination, waste management, Energy resources & Environmental impact of resource exploration and use, Geological considerations of toxic and radioactive waste disposal; Environment vs. development. **Textbook:** Required: Introduction to Environmental Geology, 5th edition by Edward Keller (Prentice Hall), ISBN- 10: 0-321-72751-7 Recommended: Environmental Geology: 7th edition by Carla Montgomery (McGraw Hill), ISBN-0-07-304082-7
ES642	Geochemistry	3-0-0-0 [9]	Chemical differentiation of the Earth; Basic principles of atomic physics and Electronic structure of atoms; Chemical bonds, Ionic radii, Ionic substitution in crystals; Geochemical classification of elements; Fundamental Thermodynamic concepts: First Law, Enthalpy, Heats of reactions, Heat capacity, Second law and Entropy, Gibbs free energy, Partition function, Fugacity and Activity; Kinetics: reaction mechanisms, reaction rates, enthalpy and activation energy, Transition state theory, Diffusion and Fick's law; Trace Element partition during magma genesis; Aqueous geochemistry, Solubility and mineral stability diagrams; Oxidation-Reduction Reactions; Isotope geochronometers; Stable Isotopes and Theory of Isotope Fractionation; application of geochemistry to the solutions of geological problems.
ES643	Aqueous Geochemistry	3-0-0-0 [9]	The course will primarily cover (1) the quantification of key geological processes controlling the chemical composition of water, precipitation and dissolution of certain minerals, and fluid–mineral interaction; (2) Chemical principles of weathering and its effects on water chemistry; (3) application of stable and radioisotopes to understand the source, pathways, and age of water; (4) contaminant geochemistry of some elements. Detailed topics to be discussed are: chemical thermodynamics and kinetics, aqueous complexation, acids and bases, redox geochemistry and Eh-pH-pE diagrams, carbonate geochemistry, chemical weathering, adsorption-desorption reactions, tracing of water cycle, controls on water chemistry, groundwater dating, and contaminant geochemistry.

ES644	Remote Sensing And Gis For Geo-Resource Evaluation	2-0-3-0 [9]	Remote sensing platforms satellite-based and airborne sensors; Basic principles of image interpretation; Spectra of Earth's surface material; Interpretation of regional geological and geomorphological features; Lithological and structural mapping, mapping of landforms and interpretation; Basic principles of geographic Information System (GIS) and its application; Analytical Hierarchy Process (AHP) technique and its integration into GIS. River erosion studies; Identification of groundwater potential zones; criteria for identification and integration of controlling factors into GIS; Lake and wetland studies using remote sensing; Water quality mapping; water quality parameters, indices of water quality monitoring; Vegetation Mapping and forestry applications; Application in glaciology and snow hydrology; Coastal zone mapping and other related applications; Natural hazards floods, landslides, earthquakes; causative factors, choice of data and use of remote sensing technique for mapping and prediction; Mineral resources evaluation with particular reference to digital remote sensing; Application of thermal infrared data for mapping surface moisture and rock types and environmental studies.
ES645	River Science	3-0-0-0 [9]	Integrated Multi-Disciplinary Approach in river science; River Science in Indian Context; Geomorphic Analysis of River Systems - Key Concepts in River Geomorphology, Catchment Scale Controls on River Morphology, Catchment Hydrology, Sediment Movement and Deposition in River System, Channel Geometry, Floodplain Forms and Processes, River Diversity and River Evolution, Human Impacts on River Systems; River Ecosystem Synthesis - Introduction to hydrogeomorphic patches, functional process zones, hierarchical patch dynamics and biocomplexity, river as a continuum, longitudinal, lateral, temporal, vertical dimensions; Hierarchical patch dynamics in riverine landscapes; the hydrogeomorphic character of a riverine ecosystem.; Ecological Implications of RES Biocomplexity Concepts; River Health and River Futures – Human impacts on river systems including climate change impacts; river hazards and their causes, Environmental Flow (e-flow) – definition, data requirement, different approaches for e-flow estimation; Integrated approach to river management, River health and river futures.
ES647	Geology And Geochemistry Of Petroleum	3-0-0-0 [9]	History of petroleum and gas exploration in India; Carbon cycle, origin and preservation of organic matter-the source material of petroleum; Oil and gas bearing rocks, reservoir rocks, trap and seal rocks- the petroleum system key components; Petroleum generation, migration, and accumulation- the petroleum system processes; Composition of crude oil and oilfield water – upstream and downstream linkages; Multiple controls on petroleum biodegradation and impact on oil quality; Classification of oil and gas accumulations; Geochemical screening of source rocks and petroleum - total organic carbon, petrographic analysis of macerals, vitrinite reflectance, elemental analysis of kerogen, rock eval pyrolysis, thermal alteration index, organic biomarkers, trace metals, carbon isotopes, and radiogenic isotopes; Application of geochemical tracers in petroleum exploration. Age of oil deposits, oil-oil correlation and oil-source correlation techniques, reservoir compartmentalization issues, identification of oil-bearing horizons and reservoir rocks from geochemical logs, and reservoir filling history; Unconventional oil and gas resources. Oil shales, tar sands, and gas hydrates; Petroliferous

			basins of India. Case studies on specific oil producing Indian basins; Petroleum and environment; future of hydrocarbon resources.
ES648	Instrumentation In Earth Sceinces	2-0-3-0 [9]	Near subsurface mapping using Ground Penetrating Radar (GPR) – mapping of buried structures, depth determination of underground bodies and lithounits; Generation of Digital Elevation Models (DEM); Landform mapping using Total Station, Integrated TS-GPS system and by Real Time Kinematic (RTK) survey; Field training including geological mapping; X-Ray Diffraction – sample preparation and interpretation of XRD charts for qualitative and semi-quantitative analysis of crystalline materials; Principles and theory of Scanning Electron Microscopy (SEM); Sample preparation, coating, imaging and analysis; X-Ray Fluorescence – sample preparation and semi quantitative and quantitative chemical analysis of geological samples; sample-acid digestion and chemical analysis by Inductively Coupled Plasma Mass Spectrometry (ICP-MS).
ES649	Isotope Geochemistry And Applications	3-0-0-0 [9]	Nucleosynthetic processes and the isotopic abundances of elements, Decay mechanisms of radioactive atoms, Equations of Radioactive Decay and Radiogenic Growth, Geochronology using radioactive decay schemes of Rb-Sr, Sm-Nd, U-Th-Pb, K-Ar, U-series disequilibrium method of dating, 14C dating, Fission track Dating, Analytical methods in Thermal Ionization Mass Spectrometry, Isotope Geochemistry of the Earth's Mantle and crust, Isotopic evidence regarding the formation of the Earth, Stable Isotope Theory, Kinetic and equilibrium isotope fractionation, Analytical methods in Stable isotope ratio mass spectrometry, Specific applications of stable isotopes in hydrology, climate and environment, archaeology and paleontology, Carbon cycle and climate.
ES651	Mathematics For Earth Sciences	3-0-0-0 [9]	Introduction to importance of mathematics in Earth sciences, Basics of MATLAB; Vector analysis, Grad, Div, Curl, application of Gauss's Theorem to potential methods and seismology; Matrix analysis, Matrix inversion for the solution of simultaneous equations; Coordinate systems: Curvilinear coordinates, Cartesian, Cylindrical, and Spherical coordinates, Applications of coordinate systems to Plate motion, (non) seismic; Complex analysis in geosciences; Tensor analysis and its application to (non) seismic and geodynamics; Ordinary and partial differential equations, separation of variable, numerical solution to Heat diffusion equation; different data types in Earth sciences, methods of data analysis: Univariate Statistics, Empirical distributions, theoretical distributions, statistical tests ($\chi 2$, Kolmogorov-Smirnov and Kuiper tests), Bivariate and multivariate Statistics, Correlation coefficient, linear regression analysis, bootstrap estimates, Data modeling, best fit, fitness evaluation; Multiple correlation coefficients; basics of geophysical signal processing.
ES653	Sedimentology And Basin Analysis	3-0-0-0 [9]	Introduction to applied sedimentology, Siliciclastic, Carbonate, Phosphates, Iron-rich and Evaporite sediments and their economic significance; Physical properties of sediments – density, porosity and permeability, field and laboratory methods of their determination (rock physics properties); Sedimentary Basins- Basin-forming mechanisms; Basins due to lithospheric stretching, flexure and strike-slip; classification and evolution of sedimentary basins; Metallogeny, and Petroleum system in sedimentary basins; Major external controls on sedimentation; Continental sedimentary environments; Marine sedimentary environment; Basin fills and stratigraphy; Subsidence and

			Thermal history; Sediment to rock - the Subsurface Environment.
ES654	Advanced Structural Geology	3-0-0-0 [9]	Introduction and methods of quantitative Structural Geology; Force and stress fields in Earth; Displacement and strain; Stress and Strain tensors; Mohr Circles; Geological analysis of field data (stereographic analysis and cross-section construction); Strain analysis from deformed rocks; Stress-Strain-Time relationship under different conditions; Failure Mechanism; Deformation mechanisms and Rheology of cataclasis, crystal-plasticity and dissuasive mass transfer; Role of fluids and Fluid flow; Deformation in Brittle, Ductile and Brittle-Ductile transition; Structural anatomy and strength profile of tectonic boundaries; Applications.
ES655	Solid Earth Geophysics	3-1-0-0 [11]	This course will introduce the laws of physics in understanding the Earth Structures and geological processes associated with the Earth. It will focus on the application of basic mathematics and physical concepts to better understand the structure and composition of the Earth's interior and interaction among crust, mantle, and core. It will provide qualitative as well as quantitative knowledge on Earth structures and plate tectonics using Earth's gravity-magnetic fields, seismic reflection and refraction, seismology and thermal processes.
ES656	Geophysical Methods	2-0-3-0 [9]	Introduction to different geophysical methods; Concepts of gravity and magnetism, working principles of measuring instruments, field operations, micro-gravity survey, gravity and magnetic gradiometry, data reductions, regional-residual separation, direct and indirect interpretation and applications; Elementary theories of DC resistivity, resistivity surveying equipment's and different arrays, interpretation of electrical sounding and profiling data, IP measurements in time and frequency domains, applications of SP methods; EM induction theory, time and frequency domain EM, EM systems for ground, marine and airborne surveys, working principles of VLF, MT and GPR and their applications; Theory of elasticity and wave propagation, concept of rays, ray paths in layered media, principles of marine and land seismic sources and receivers, land and marine seismic data acquisition techniques, data pre-processing - static corrections, multiple attenuation techniques, filtering and processing steps – NMO, velocity analysis, stacking, migration, interpretation of migrated sections, basics of Tomography and AVO; Principles of well logging, Archie's law, different petro-physical parameters, different logging techniques and interpretation of field log data.
ES657	Experimental Rock Mechanics & Rock Physics	2-0-3-0 [9]	Introduction and historical development; Principles and terminologies; Sensors, transducers and their calibrations; Design of deformation apparatus, safety features; Selection, preparation and dimension of samples; Uniaxial, biaxial, triaxial and torsion test set-up; Rock mechanics at room and high pressure-temperature; Rate dependent rheology; Role of porosity, pore-fluid, grain size and mechanical anisotropy; Collection and processing of experimental data; Understanding stress-strain and related curves; Calculation of flow-laws, effective-viscosity and frictional properties; Mechanics of crystalline and porous rocks; Recovery and post-processing of deformed samples for further physical and chemical analysis; Measurement of electrical; thermal and hydraulic (liquid and gas) conductivity of rocks; Techniques of ultrasonic pulse transmission (Vp-

			Vs) and acoustic emission; Applications and limitations.
ES658	Natural Hazards	3-0-0-0 [9]	Natural Hazards and Disasters, Human Impact on Natural Disaster, Predicting Catastrophe (01), Mitigating Hazards; Plate Tectonics and related Hazards; Earthquakes and their causes, Ground Motion and Failures; Tsunami: Giant Tsunamis, Generation and movement, Tsunami Hazard Assessment; Volcanic Eruption and Hazard: Eruption-Type of Volcanoes and Tectonic environment; Landslide and other downslope movements: Causes of Landslides, Type of downslope movement, associated hazard; Land Subsidence and associated hazard; Floods and Human Interaction, Flood Frequency and Recurrence Interval; Human intervention and mitigation; Storms: Tropical Cyclone, Hurricane, Tornado, Storm damage and safety; Wildfires: Fire Process and Secondary effects.
ES659	Active Tectonics And Paleoseismology	3-0-0-0 [9]	Crustal deformation and earthquakes (02); significance of seismicity (01); Identification of Prehistoric Earthquakes based on Primary and Secondary signatures preserved in landforms and sediment succession (03); Interpretation and Identification of Active Fault and associated Tectonic Landforms Photogeologic Mapping, onfault and offfault landforms, indentification and mapping of active faults and associated landforms in field, structural analysis of active faults & its implication to regional scale tectonics (04); Field Techniques in Paleoseismology, quantification of active fault scarp by precise mapping, identification of old (prehistoric) earthquake by trenching, mapping of deformed sedimentary succession by faulting, estimation of net displacement during single event, slip rate, magnitude of historic earthquake, recurrene interval, and prediction of future earthquake if possible (05); Identification and mapping of secondary effects due to strong seismic shaking identification of paleoliquefaction features (02); Dating techniques (01); Correlation of paleoseismic data with existing geodetic and geophysical data (01); Delineation of seismogenic faults (01).Paleotsunami geology Identification of Paleotsunami and Megasubduction zone earthquakes signatures in the coastal region along subduction zones (05); Understanding landlevel change caused by major earthquakes (02); decoupling the role of climate and tectonics (01); Understanding the effect of nearfield and farfield earthquakes from stratigraphic records (01); effects of near field and farfield tsunami (01). **Course Reference**: 1. McCalpin, J.P., (1996), Paleoseismology, Academic Press, New York, p. 588; 2. Yeats, R.S., Sieh, K., Allen, C.R., (19997), Geology of Earthquakes, Oxford Univ. Press, 568; 3. Shiki, T., Tsuji, Y., Yamasaki, T., Minoura, K. Tsunamiites, Elsevier, Amsterdam; 4. Burbank, D. W. and Anderson, R.S. Tectonic Geomorphology, Blakwell Sciences, 287; 5. Bull, W. B. Tectonic Geomorphology of Mountains; A new Approach of Paleoseismology, Blackwell Sciences, 326.
ES600	Introduction To Profession & Communication Skills In Earth Sciences	1-0-0-0 [3]	This course will fulfil the requirement of communicating more effectively at work and achieving your goals. Improving communication skills and becoming aware of the future pathways are essential to developing the most successful strategies and using them to advance career goals. You'll also learn how to present your work (written and oral) and, most importantly, what to do and what not to do.
ES661	Planetary Remote Sensing	3-0-0-0 [9]	This course is aimed at developing perspectives on geological processes on planetary bodies (apart from the Earth) and how remote sensing is used for deciphering planetary composition, structure and

			evolutionary history. The course would explore diverse geological processes, some of which do not occur on the Earth (e.g. space weathering) and others that occur in a very different form (e.g. convection in ice). The major objectives of this course are: i) Develop a sound understanding of the diverse geological processes on planetary bodies. ii) Become well-versed with remote sensing applications in planetary science. iii) Utilize this knowledge to view Earth and its geological processes with a fresh perspective and ask interesting new questions. The course would involve introductory lectures, research-paper-based discussions and in-class exploration of remote sensing data from recent missions (e.g. Chandrayaan-1, ISRO; Kaguya, JAXA; Lunar Reconnaissance Orbiter; NASA, Cassini, NASA). The class would identify some special topics for detailed discussion. The course would also include a project component which would either be a critical evaluation of a scientific problem (based on available literature) or data-Manalysis based project after consultation with the instructor.
ES662	Advance Metamorphic Peterology	3-0-0-0 [9]	Basics of petrology; Rock classifications; Structures and textures of rocks; Metamorphic Facies; Magmatism and metamorphism at various tectonic settings with associated rock-types and mineral assemblages. Electron microprobe, EPMA data processing, Ideal mixing activity, Mineral formula and Endmember calculations. Metamorphic stable mineral assemblages; Projections; Gibbs free energy; Phase rule, Metamorphic reactions; Mineral equilibrium; Influence of compositional variations. Geothermobarometry; Schreinemakers method; Petrogenetic grid; Phase diagrams; P-T-t paths, Thermochronology. Metamafics and Metaultramafics: Assemblages, Facies series; Metamorphism of felsic rocks; Metapelites: Barrovian sequence; Metacarbonates and metacalcareous rocks; Fluid inclusions; Metasomatism; Tectonic significance. High-pressure (HP) and High-temperature (HT), Ultra high-pressure (UHP), Ultra high-temperature (UHT) metamorphism: P-T ranges, textures, Mineral assemblages, Mineral chemistry and Tectonic setting. Metamorphism in plate boundaries; Collisional tectonics. Using petrological datasets; linking petrology with field information, structure, geochemistry and geochronology; Petrogenesis and tectonics interpretations. Case studies and examples on metamorphic evolution, P-T history; petrogenesis and tectonic setting of some global and Indian metamorphic terranes.
ES663	Non-Traditional Stable Isotope Geochemistry	3-0-0-0 [9]	Notation for stable isotope systems, reference standards, equilibrium and kinetic fractionations of non-traditional stable isotopes, history of non-traditional stable isotope-based research, method of sample preparation (e.g., ion exchange chromatography), measurement techniques (in-situ and non-in-situ) by mass spectrometry, data correction (e.g., sample-standard bracketing, internal normalisation, double spike etc.) and representation, applications of stable Ca, Mg, Li, K and Zn isotope systems in low and high T systems including isotopic fractionation during continental weathering, surface runoff, nutrient transfer from root to leaf of vegetation etc.; coupling of continental and oceanic processes, inter-mineral isotopic fractionation and bond-lengths, bulk-silicate Earth compositions, diffusion in silicate melts, isotopic compositions igneous rocks formed at different tectonic settings, isotopic compositions of Lunar and Martian rocks, isotopic fractionation during nucleosynthesis and early volatile depletion

			process, isotope transport model from food to blood, between soft tissues, bone loss or bone cancer.
ES664	Rock Magnetism	3-0-0-0 [9]	Introduction to magnetism. Magnetic fields in Solar system. Ferromagnetic minerals. Paramagnetic minerals. Diamagnetic minerals. Hysteresis, coercivity and magnetic domains. Sampling, measurement and analysis Types of anisotropies of magnetic susceptibilities-AMS. AMS parameters and ellipsoid. Primary magnetic fabrics. Secondary magnetic fabrics. Sampling, measurement and analysis. Earth's magnetic field origin, present and past. Induced and remnant magnetization. Sampling, measurement and analysis. AMS, tectonic deformation and strain. Magnetic shock barometers. Magnetic anomalies on extraterrestrial crust. Seafloor spreading and paleo geographical reconstruction. Paleomagnetism and tectonics. Lava emplacement conditions. Bio-, environmental-, archeo-magnetism. Rock magnetics in mining, petroleum and geothermal. **Course Reference**: The Magnetic Anisotropy of Rocks. Tarling, D.H. and Hrouda, F. Paleomagnetic Principles and Practice. Tauxe, L. Rock Magnetism: Fundamentals and frontiers. Dunlop, D. J. and Özdemir, Ö.
ES665	Physics Of Earthquakes	3-0-0-0 [9]	Elastic rebound theory, earthquake and its mechanism, tectonic plate motion, earthquake characteristics, earthquake source parameters, seismic moment and magnitude, seismic intensity, seismic wave types and properties, faulting in nature, types of fault setting, fault asperities, seismic cycle and a wide range of fault slip behaviors (stable creep, slow slip, regular earthquakes, supershear ruptures and more), frictional laws, concepts of static and kinetic friction, Amonton's law, Byerlee's law, stick-slip and stability of frictional sliding, velocity-jump experiments, Rate- and State-dependent friction law and parameters, elastodynamic parameters, loading conditions, velocity-weakening and velocity-strengthening properties, stability condition, earthquake cycle modeling, modeling methods, spring-slider model, finite-fault modeling, model parameters and applications, estimating static and dynamic stress drop, slip, and recurrence interval, a multi-disciplinary approach involving seismological observations, laboratory friction experiments, and numerical modeling, case studies of observations and modeling of stable creep, slow slip and tremors, bilateral and unilateral ruptures, repeating earthquakes, supershear ruptures, etc.
ES666	Applied Hydrogeology	3-0-0-0 [9]	Role of water in Earth's climate; Hydrological cycle and its components; Monitoring of hydrologic storages and fluxes; Water budget computations; Water-bearing properties of rocks - porosity, intrinsic permeability, specific yield and specific retention; Vertical distribution of sub-surface water; Classification of aquifers; quantitative assessment of aquifer properties; Aquifer parameters: transmissivity, hydraulic conductivity and storage coefficient; Determination of permeability in laboratory; Concept of heterogeneity and anisotropy; Characteristic differences between confined and unconfined aquifers; Hydrostatic pressure; Fluid potential; Energy in groundwater; Hydraulic head; Theory of groundwater flow; Darcy's law and its applications; Specific discharge; Limitations of Darcy's Law; Reynolds Number; Governing equation for flow through porous medium; Steady and non-steady state flow - Initial and boundary conditions; Solution of flow equations; Dupuit's Assumption; Boussinesq Equation; Groundwater flownet

			analysis; Groundwater flow patterns, Groundwater-Surface water interactions; Determination of flow direction. Flow through aquifers: 2-D groundwater flow equations; Flow under steady and non-steady state conditions; Evaluation of aquifer parameters of confined, semi-confined and unconfined aquifers - Thiem, Theis and Jacob methods.
ES667	Geodynamics	3-0-0-0 [9]	The course is designed to understand the dynamics, flow of mass and energy of solid Earth in a quantitative manner. It contains Kinematics of Plate Tectonics - Earth's structure, hotspots and mantle plumes, convergent, divergent and transform plate boundaries, plate motion on flat and sphere Earth; Basics of Elasticity and Flexure – body and surface forces; stresses in 2D and 3D; isostasy, linear elasticity, uniaxial stress and strain, pure and simple shear, 2D bending or flexure of plates, application to Earth's lithosphere; Heat transfer - Fourier's Law of heat conduction, Earth's surface heat flux, 1D and 2D heat conduction with advection, basics of thermochronology, frictional heating on Faults; Fluid mechanics - 1D channel flow, pipe flow, Asthenospheric Counterflow, mantle convection, diffusion of groundwater; Faulting - classification of faults, friction on faults, Anderson theory of faulting, thrust sheets and gravity sliding, earthquakes.
ES669	Data Analysis And Visualization For Earth Scientists	3-0-2-0 [11]	Data Analysis and Visualization for Earth Scientists offers the basics required to equip students to analyse data and produce high quality figures for articles, theses, dissertations, posters, and talks. This course will provide a quantitative introduction to data analysis. It will help students to visualize and create plots that represent data accurately. Finally, the students will be able to interpret and explain their plots to peers in a sophisticated and engaging way. In summary, this course will focus on data analysis, visualization, and interpretation to improve the process of demonstrating and sharing scientific information in academia.
ES702	Pg Seminar In Earth Sciences	0-0-0-0(0)	The course would have the dual purpose of: a) familiarizing the PG students with their colleagues' current themes and progress. b) In the process PG students would learn best practices in oral presentation and preparation for talks. Both these objectives need sustained exposure over many semesters, and it needs to be a weekly habit of attending such sessions.
ES671	Mineral Resource Exploration	3-0-0-0 [9]	Introduction to mineral exploration; stages of mineral exploration, crustal abundance and geochemical behaviour of the elements; geochemical anomalies; geochemical cycle: primary dispersion, secondary dispersion; pathfinder/indicator elements; geodynamic settings of mineral deposit systems; different types of ore deposits and their metallogeny, surface and subsurface mineral exploration methods, analytical techniques in mineral exploration, ore reserve estimation, national mineral policy, Indian mineral deposits, prospecting techniques for base and strategic metals.
ES680	Quaternary Geology And Tectonic Geomorphology	3-0-0-0 [9]	Quaternary time scale; Quaternary stratigraphy and geochronology – dating Quaternary records, radiometric, luminescence and other methods of dating. Climate archives and proxies, Methods of reconstructing Quaternary climate - sedimentary archives, biotic proxies, geological and geochemical proxies. Sea level changes, glacial/interglacial cycles, sea floor spreading, carbon reservoir, vegetation dynamics, migration history, response of vegetation to climatic reversals. Tectonic geomorphology and landforms: mapping

			active tectonic landforms, geomorphic markers and indices; Tectonics-climate coupling, BLAG hypothesis, Uplift-weathering hypothesis.
ES681	Potential Field Theory In Applied Geophysics	3-0-0-0 [9]	This course will provide comprehensive background about the concept of potential field theory, related mathematical tools, and its application in geophysics. It will help to develop the concepts of various data processing and interpretation approaches related to potential field methods (e.g., Gravity and magnetic methods). The major topics of this course are: Introduction to potential field theory: fields and potential, Poisson's & Laplace's equations, Helmholtz theorem, Delta & Green's functions, Green's identities. Fourier series and Fourier transform in spatial domain: power spectra analysis; Solution to Laplace's equation in cartesian & spherical co-ordinates: upward and downward continuation, spherical harmonics, Geoid & ellipsoid, and geomagnetic field representation; Gravity and magnetic methods of prospecting: instruments, data processing/enhancement, and interpretation.
ES682	Seismic Exploration & Subsurface Imaging	3-0-0-0 [9]	Acoustic and elastic wave equation, energy partitioning at interface, AVO analysis, Fourier analysis and seismic signals, signal processing, reciprocity and Green's function, land and marine seismic data acquisition techniques, wavefield sampling, wavefield, decomposition, land and marine seismic data processing (filtering, deconvolution, CMP, CDP, stack, migration), advanced migration techniques (RTM, PreSDM), seismic inversion, optimization techniques, tomography, finite difference scheme for 2D/3D seismic modeling, Ambient noise tomography, land and marine seismic interpretation.
ES683	Planetary Geomorphology : Processes And Landforms	3-0-2-0 [11]	This course will introduce the workings of various surface geological processes on planetary bodies other than Earth. The course would cover a diverse array of landscapes carved out by geological processes in substrates made up of various compositional species. The course aims at broadening the perspective on how a geological process operates, what are its various facets and how they interact with the substrate to produce a landscape. The course would therefore equip the students to infer geologic history of a region based on the study of its landscape. The course would comprise a combination of lectures and labs.
ES699	M Tech Thesis	----	M. Tech. Thesis
ES799	Ph D Thesis	----	Ph. D. Thesis
ESO213	Fundamentals Of Earth Sciences	3-0-0-0 [9]	universe and its characteristics Solar System and Earth The primitive Earth Geological Time scale Origin of the life and major geological events Numerical Dating. Rocks, minerals and soils; Plate Tectonics and Mountain building, Deformation and Geodynamics Earthquakes; Volcanoes.Earth, Ocean, Land, Rivers, Atmosphere, Biosphere, Cryosphere and Climate; Energy budget; Carbon Cycle; Hydrological Cycle; Weathering and erosion. coupled processoes in Earth System; climate change, Geological resourses (minerals, hydrocarbons and water); Sustainability and Anthropocene activities **Course Reference**: 1. D.R. Prothero and R.H. Dott, Jr. Evolution of the Earth. 2010 (8th Ed.), McGraw Hill, 576p; 2. E.J. Tarbuck, F.K. Lutgens and D.G. Tasa. Earth: An introduction to Physical Geology, 2013 (11th Ed.). Prentice Hall. 912 p; 3. J. Grotzinger and T. Jordan,

<table>
<tr><td></td><td></td><td></td><td>Understanding Earth, 2010 (6th Ed.). Freeman, 210p.</td></tr>
<tr><td>ES208</td><td>Earth And Environment</td><td>3-0-0-0 [9]</td><td>Objectives:
The objective of this course is to appraise the students with the complex interaction of the earth and the environment, with a particular reference to the interaction with humans.
The rising human population, socio-environmental shifts, and changing climate have constrained the sustainability of existing natural resources. This undergraduate-level course introduces students to the basic concepts of Earth and Environmental Science and its co-evolution with time. The course explains the components of natural ecosystems and their interconnectedness. Further, it highlights the earth's natural resources, current challenges, and its impact on various aspects of the environment and life. It also provides insights into the primary causes and possible solutions to environmental problems. Upon completing this course, the student will comprehensively understand Earth's processes and its crucial role in supporting life.

Contents:
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<tr><td>2</td><td>Environmental ecosystems</td><td>6</td></tr>
<tr><td>3</td><td>Energy Concepts in Environmental Science</td><td>5</td></tr>
<tr><td>4</td><td>Earth Materials & Management Science</td><td>4</td></tr>
<tr><td>5</td><td>Renewable & non-renewable energy resources</td><td>6</td></tr>
<tr><td>6</td><td>Interaction between atmosphere-hydrosphere-biosphere & Climate</td><td>5</td></tr>
<tr><td>7</td><td>Environmental pollution: air, water, and soil</td><td>5</td></tr>
<tr><td>8</td><td>Environmental Impact Assessment</td><td>4</td></tr>
</table>
Pre-requisites, if any: None

Recommended textbooks:

Textbooks: Class notes

Reference books:
• Cunningham, W. P., and Cunningham, M. A., 2010, Environmental Science - A Global Concern (11th Edition), McGraw Hill Publications
• Botkin, D, B., and Keller, E. A., 2010, Environmental Science - Earth as a Living Planet (7th Edition), John Wiley and Sons Inc.</td></tr>
<tr><td>ES459</td><td>Applied methods in structural geology</td><td>3-0-0-0[9]</td><td>Objectives: Introduce students with structural geological techniques having industrial applications</td></tr>
<tr><td>ES631</td><td>Quantitative Seismic Hazard and Risk Analysis</td><td>2-0-3-0 (9)</td><td>This course provides a rigorous, computational framework for quantifying the potential for future shaking (Hazard) and the consequent financial or safety losses (Risk). This course bridges the gap between Earth Science (source characterization) and Engineering (performance assessment). In this course, students will use MATLAB to code the fundamental PSHA integrals and Risk convolutions themselves, rather</td></tr>
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			than relying on pre-packaged software. The specific learning outcomes are: 1. Source & Ground Motion Characterization: Master the statistical fitting of earthquake recurrence laws (Gutenberg-Richter) and the implementation of empirical Ground Motion Models (GMMs) to predict intensity measures like PGA and Spectral Acceleration. 2. Computational DSHA and PSHA: Understand the difference between Deterministic (Scenario-based) and Probabilistic (Rate-based) approaches, and learn when to apply each (e.g., deterministic caps in design codes vs. risk-targeted design). Develop a custom MATLAB solver to perform the PSHA integration, handling Aleatory Variability (randomness in ground motion) and Epistemic Uncertainty (model uncertainty) via Logic Trees. 3. Hazard De-aggregation & Selection: Identify "controlling earthquakes" through deaggregation and implement advanced ground motion selection algorithms (e.g., Conditional Mean Spectrum) for engineering design. 4. Quantitative Risk Assessment: Move beyond hazard to Risk by deriving Fragility Functions and convolving them with hazard curves to compute actionable metrics like Average Annual Loss (AAL) and Loss Exceedance Curves.
ES632	Sequence Stratigraphy	3-0-0-0 (9)	Sequence stratigraphy emerged as a paradigm shift in the discipline of stratigraphy. This emergent branch of stratigraphy proved to be popular in industry and academia owing to its wide applicability in energy exploration and in delivering analysis with a time-space reference. In particular, contrary to the classical lithostratigraphic approach, sequence stratigraphy allows the investigation with genetically-linked, hiatus-bounded strata in a chronostratigraphic framework. Broadly, in this course, the students will learn various concepts and tools of sequence stratigraphy that will help their academic preparation and professional career. This course will focus on aspects of: terminology and methods of sequence stratigraphy, and their application to subsurface reservoirs; concepts of hierarchy of stratigraphic architecture at various scales (from parasequence to systems tracts to sequence); criteria-based interpretation and recognition of sequence stratigraphic surfaces in outcrops, subsurface core-cuttings, wireline logs, and seismic sections; comprehension on similarities and dissimilarities among several sequence stratigraphic models (depositional sequence stratigraphy, transgressive-regressive sequence stratigraphy, genetic sequence stratigraphy, etc.), on analysis of clastic vs. non-clastic (carbonate) sequence stratigraphy; use of (nearby) field locations for field training of various concepts. Overall, this course will help the students how to think and communicate like a sequence stratigrapher within the wider context of sedimentary geology.
ES633	Reservoir Characterization	3-0-0-0 (9)	Successful reservoir analysis is critically linked to optimal exploration, production and management of natural resources (oil, gas, coal, water), and associated approaches (e.g., environmental measures); it therefore influences societal and economic prosperity at national and international scales. This course will help students gain a sound understanding of various concepts and tools for reservoir

			characterization at multiple scales: from pore to basin. Teaching topics will focus on: formation mechanism of seal, reservoir and source rocks, emplacement of these rock types in various traps (e.g., stratigraphic vs. structural); Reservoir conditioning mechanisms at different settings (fluvial, eolian, shallow water, deep water) and environments (clastic; non-clastic: carbonate); Use of data types (outcrop, core, well-log, GPR, seismic) and tools (e.g., lithostratigraphy, biostratigraphy, sequence stratigraphy) for reservoir prediction; how effects of pore-scale to meso-scale to macro-scale features constrain reservoir heterogeneity and associated risks (e.g., variability in reservoir properties such as porosity and permeability); syn-depositional and post-depositional (e.g., fractures, joints) effects on reservoir compartmentalization and drainage. Students will get to know how to use multi-dimensional datasets to evaluate: reservoir attributes (e.g., thickness, area, drainage, net-to-gross); facies- to architecture- to geobody-scale reservoir complexity by analyzing (1) lithologs (2) Bioturbation Index (BI) logs, and (3) object-based and process-based models. With use of case studies, students will comprehend reservoir characterization in conventional vs. unconventional (e.g., tight gas) systems, in energy sectors (oil, gas, coal), in water management (aquifer analysis), in new energy frontiers (e.g., geothermal), and in emerging scientific thrust areas such as geologic carbon sequestration.