Course Structure for Two-Year M. Sc. Program in Applied Geology
(From 2019 Onward)
Department of Earth Sciences, IIEST, Shibpur,

First Semester

Sl. No.	Subject Code	Subject Name	Class Load/Week			Total load/ Week	Credit	Marks
			L	T	P			
1	ES5101	Paper-I (Core) **Igneous Petrology & Phase Equilibria**	4	0	0	4	4	100
2	ES5102	Paper-II (Core) **Mineralogy & Geochemistry**	4	0	0	4	4	100
3	ES5103	Paper-III (Core) **Structural Geology & Tectonics**	4	0	0	4	4	100
4	ES5121 ES5122	Paper-IV **Departmental Elective: I** **1. Environmental Geology** **2. Engineering Geology**	3	0	0	3	3	100
5	ES5161 ES5162	Paper-V **Open Elective I**	3	0	0	3	3	100
6	ES5171	Laboratory-I **Structural Geology Practical and Field- work**	0	0	3	3	2	50
7	ES5172	Laboratory-II **Igneous Petrology and Mineralogy**	0	0	3	3	2	50
Total			**18**	**0**	**06**	**24**	**22**	**600**

Second Semester

Sl. No.	Subject Code	Subject Name	Class Load/Week			Total load/ Week	Credit	Marks
			L	**T**	**P**			
1	ES5201	Paper-VI (Core) **Sedimentology & Basin Analysis**	4	0	0	4	4	100
2	ES5202	Paper-VII (Core) **Metamorphic Petrology &Thermodynamics**	4	0	0	4	4	100
3	ES5203	Paper-VIII (Core) **Principles of Stratigraphy & Indian Stratigraphy**	4	0	0	4	4	100
4	ES5221 ES5222	Paper-IX **Departmental elective: II** **3. Mathematical Geology** **4. Marine Geology**	3	0	0	3	3	100
5	ES5261 ES5262	Paper-X **Open Elective II**	3	0	0	3	3	100
6	ES5271	Laboratory-III **Metamorphic Petrology and Sedimentology Practical**	0	0	3	3	2	50
7	ES5291	**Term Paper**	0	0	8	8	4	100
8	ES5292	**Term paper Viva**					2	50
Total			**18**	**0**	**11**	**29**	**26**	**700**

Third Semester

Sl. No.	Subject Code	Subject Name	Class Load/Week			Total load/ Week	Credit	Marks
			L	**T**	**P**			
1	ES6101	Paper-XI (Core) **GIS & Remote Sensing**	3	1	0	4	3	100
2	ES6102	Paper-XII (Core) **Hydrogeology & Exploration Geophysics**	4	0	0	4	3	100
3	ES6103	Paper-XIII (Core) **Ore Geology & Fuel Geology**	4	0	0	4	3	100
4	ES6171	Laboratory-IV **Ore Geology practical & Underground Geological Mapping**	0	0	3	3	2	100
5	ES6191	**MSc thesis progress report**	0	0	16	16	8	100
6	ES6192	**Thesis progress report seminar & viva**	0	0	0	0	2	100
Total			**11**	**1**	**19**	**31**	**21**	**600**

Fourth Semester

Sl. No.	Subject Code	Subject Name	Class Load/Week			Total load/ Week	Credit	Marks
			L	**T**	**P**			
1	ES6201	Paper-XIV (Core) **Palaeontology & Mass Extinction**	4	0	0	4	4	100
2	ES6221 ES6222	Paper-XV **Departmental Elective: III** **5. Geodynamics** **6. Geomorphology**	3	0	0	3	3	100
3	ES6271	Laboratory-V **Palaeontology practical & Borehole Geology**	0	0	3	3`	2	100
4	ES6291	**M.Sc. Thesis Final report**	0	0	16	16	8	200
5	ES6292	**Thesis Seminar & Viva voce**	0	0	0	0	4	100
Total			**7**	**0**	**19**	**26**	**21**	**600**

Total Credits = [22+26+21+21] = 90; **Total Marks = 600 + 700 + 600 + 600 = 2500.**

Open elective courses offered:

1. 1st Semester: Introduction to Earth materials (ES5161) / Earth Surface Processes and Structures (ES5162)

2. 2nd Semester: Life through Ages (ES5261) / Natural Resources and Energy (ES5262)

Syllabus of M. Sc. In Applied Geology
(2019 onwards)

Semester I

Core Subject: ES5101 **Credits 4** **Full marks 100**

Course name: Igneous Petrology and Phase Equilibria

Course objective: The objective focuses on ideas about various aspects of igneous rocks which are controlled by chemical and physical properties of magmas and their surroundings. This course will help in the understanding of melt generation and crystallization mechanisms, diverse rock types and their relation with the tectonic settings.

Course content:

- Differentiation of the Earth, major structural units of the Earth, magmatism in relation to plate setting. Composition of the upper mantle, energy and mantle heat engine, gravity, pressure and geobaric gradient, viscosity of melts chemical diffusion, heat diffusion, nucleation and crystal growth, vesiculation and fragmentation of magma, igneous rock series. **(08 lectures)**
- Classification of magmatic rocks - based on fabric, field relations, mineralogical and modal, and whole rock compositions, IUGS classification of plutonic, hypabyssal and volcanic rocks. **(04 lectures)**
- Gibbs Phase Rule and Cryoscopic Equation: application to magmatic crystallization. Magmatic phase equilibria: binary, ternary and quarternary systems involving congruent and incongruent melting, continuous and discontinuous solid solutions, polymorphism, liquid immiscibility, equilibrium crystallization and fractional crystallization, equilibrium partial melting and fractional partial melting. **(08 lectures)**
- Cooling behaviour, convection, crystal settling and floating, diffusion, Soret effect, flow and diapirism. Simple numerical problems. Trace element fractionation in magmas: equilibrium crystallization and Rayleigh fractionation, REE patterns of common basalts. **(04 lectures)**
- Low-pressure fractional crystallization of basaltic magmas: thermal barrier between tholeiitic and alkaline trends, generation of common crustal-level igneous rocks. Melt composition, mantle material, partial melting of the peridotite mantle and magma generation, alkaline magma generation, magma generation in continental crust, differentiation (open and closed systems) and assimilation, hybrid magmas, magma storage, ascent and emplacement, field relations of intrusions. **(08 lectures)**
- Layered mafic complexes: Structural, petrographic and chemical characters, origin of cumulates and layering. **(04 lectures)**

- Magmatic evolution in different plate tectonic settings: Mid-oceanic ridge basalts, ocean floor basalts, ophiolites, intra-plate oceanic island basalts, andesites and calc-alkaline volcanic rocks in plate convergences, continental flood basalts. **(06 lectures)**
- Granites and granitic rocks: Review of the structural-tectonic and petrographic –chemical varieties. Primary magmatic, anatectic and metasomatic processes in different settings. Isotopic-geochemical and geochronological signatures of granites. Simple numerical problems. Alkaline rocks, carbonatites and kimberlites: brief review of the mode of occurrence, petrography, chemistry and genetic processes. **(06 lectures)**
- Precambrian magmatism: petrology of komatiites and massif-type anorthosites—brief introduction to problems of heat flow, plate movements and place-time constrains in the Precambrian. **(06 lectures)**
- Ultramafic rocks: Structure, petrography and chemistry in relation to tectonic settings. Upper mantle petrology and phase equilibria: geophysical and geochemical constraints partial melting, origin of primary basaltic magmas. **(06 lectures)**

Recommended Books:

1. Igneous Petrology by Anthony Hall. .
2. Introduction to Igneous and Metamorphic Petrology by John D. Winter.
3. Igneous and Metamorphic Petrology by Myron G. Best.
4. Principles of Igneous and Metamorphic Petrology by Anthony R. Philpotts and Ague
5. Using Geochemical Data: Evaluation, Presentation, Interpretation, Hugh Rollinson.
6. Igneous and Metamorphic Rocks under the Microscope: Classification, textures, microstructures and mineral preferred orientation by D. Shelley.

Semester I

Core Subject: ES5102 **Credits 4** **Full marks 100**

Course name: Mineralogy and Geochemistry

Course objective: The course aims to provide knowledge on the characteristics of major rock forming mineral groups, their crystal symmetry, crystallography and atomic structure. A detailed study on their formation environments and associations of rock-forming minerals will be provided along with techniques of mineral characterization. The course will further give an insight on how chemical principles are used to explain the mechanisms that control the large geological systems such as the Earth´s mantle, crust, ocean and atmosphere and the formation of the solar system.

Course content:

Mineralogy

- Rock Forming Minerals: their distribution; importance; some important crystals. Chemical features in silicate minerals, coordination, substitution, omission Solid Solution, order-disorder etc. **(04 lectures)**
- Crystal Field Theory: its application in distribution of transition elements in minerals and rocks; bonding in minerals. **(02 lectures)**
- Calculation of atomic ratios from analysis. **(02 lectures)**
- Alkali feldspar: classification; optic relation; perthite solvus; structure of feldspar; aluminium silicon ratio; order in feldspar; ordering paths; estimate of the degree of order. Polymorphism of $NaAlSi_3O_8$, structural states of plagioclase. **(04 lectures)**
- Structure of Nepheline, constitution of Nepheline and its significance. **(02 lectures)**
- Pyroxene group: classification: atomic structure; optical properties; pyroxene inversion; experimental observations; exsolution; Fe-Mg order. **(02 lectures)**
- Olivine group: classification; structure; optical properties; paragenesis; Olivine-Spinel transition and its significance. **(02 lectures)**
- Amphibole group: classification; structure; comparison with pyroxene. **(02 lectures)**
- X-ray crystallography: Bragg's law; single crystal and powder methods; principle and application in determination of crystal structure. Defects in minerals, phase relations in major groups of minerals. **(04 lectures)**
- Ore mineralogy: mineralogy of important ores of the following elements; iron, manganese, titanium, chromium, tin, tungsten, copper, lead, zinc, nickel, uranium, thorium. Texture of the ore minerals and their interpretations. **(04 lectures)**
- Concept of symmetry, point group, lattice and space group, principles of crystal chemistry, principles of optical and x-ray mineralogy. **(02 lectures)**

Geochemistry

- Origin and abundance of elements in the solar system and Earth; Chemical composition and properties of atmosphere, hydrosphere and lithosphere; Geochemical cycles; Atomic structures and properties of elements in the periodic table with special reference to major, minor and trace elements (transition, LILE, HFSE) including rare earth elements; Geochemical classification of elements. **(06 lectures)**
- Laws of Thermodynamics; Concepts of Free Energy, Activity, Fugacity and Equilibrium Constant, Thermodynamics of Ideal, Non-Ideal and Dilute Solutions. Element Partitioning In Minerals/Rock Formation and Concept of Distribution of Coefficients. **(08 lectures)**
- Radioactive Isotope: Radioactive decay schemes. Growth of Daughter Isotopes and Radiometric Dating. Geochronology—Methods. **(06 lectures)**
- Stable isotopes: Nature, Abundance, Fractionation, Evolution and Fluid interactions. **(06 lectures)**
- Concepts of P-T-X, Eh-Ph Diagrams and Mineral Stability; Geochemical processes involved in rock weathering and soil formation; Metamorphism as a geochemical phenomenon. Mineral/Mineral Assemblages as 'Sensors' Of Ambient Environments.

(04 lectures)

Recommended Books:

1. Rock-Forming minerals, Deer, W.A., Howie, R.A. & Zusaman.
2. Introduction to Mineralogy by William D. Nesse.
3. Manual of Mineralogy by James D. Dana, Cornelius S. Hurlbut, and Cornelis Klein.
4. Using Geochemical Data: Evaluation, Presentation and Interpretation by Hugh Rollinson.
5. Principles of Geochemistry, 4th edition by B Mason & C. B Moore.
6. Geochemistry: An Introduction by Albrecht W. Hofmann and Francis Albarède.
7. Principles and Applications of Geochemistry by Gunter Faure.

Semester I

Core Subject: ES5103 **Credits 4** **Full marks 100**

Course name: Structural Geology and Tectonics

Course Objective: Tectonic activity of the Earth's surface is the external manifestation of internal dynamism of the Earth. Enormous tectonic forces are developed due to this tectonic activity. These trigger deformation of rocks which subsequently lead to the development of different complex structures. The present course will help the students to understand the deformation-mechanisms of rocks through geometric, kinematic, dynamic analysis of rock structures and their relation to different tectonic environments.

Course content:

Structural Geology

- Stress: Definition, Stress at a point, component of stress matrix, principal axes of stress, stress ellipsoid, stress on planes inclined to principal axes of stress, Mohr circle diagram of stress. **(03 lectures)**
- Strain: Types and measurement of strain, strain ellipse and ellipsoid, principal axes of strain, rotational and irrotational deformation, flattening, constriction and plane strain, pure shear and simple shear, concept of zones of shortening and extension in pure and simple shear. **(04 lectures)**
- Progressive Deformation: Concept of infinitesimal and finite strain, co-axial and non-coaxial deformation, particle paths for pure and simple shear and combined pure and simple shears. Rotation of rigid spherical and ellipsoid inclusions. **(03 lectures)**
- Behavior of Rocks under Stress: Brittle, ductile and plastic deformation with stress-strain relation, creep deformation. *Rheology*. Classification of Rheology. How extrinsic parameters (Pressure, Temperature etc.) influence Rheology. Rheology in Earth Science, Constitutive equation of Rheology, Rheological models, complex rheology. **(04 lectures)**
- Superposed Folds: Fold interference in a single deformation, types of superposed fold, Ramsay's classification of fold interference [pattern, superposed folding depending on

the mechanism of late fold and early and late folds, methods of geometrical analysis of superposed folds in mesoscopic and macroscopic scales. **(05 lectures)**

- Lineation: Types of lineation, use of lineation in structural geology, reorientation of early lineation in superposed deformation. **(03 lectures)**
- Cleavage: Nomenclature, geometrical relation with folds, use of axial plane cleavage in geometrical/structural analysis, origin of axial plane cleavage, problem concerning the origin of cleavage. **(03 lectures)**
- Boudinage: Significance of boudin shapes, geometrical relation with fold, origin of boudinage. **(03 lectures)**
- Shear zone: Brittle and ductile shear zones, structures in ductile shear zone, Mylonites-classification and textural features, shear sense indicator. **(04 lectures)**
- Mechanism of faulting: Anderson's theory of faulting, Halfner's analysis of faulting. Rejuvenation of earlier fault/weak zone by imposed later stress. **(06 lectures)**

Tectonics

- Mobile Belts and Craton. **(04 lectures)**
- Concept of vertical and horizontal tectonics and its limitations. **(03 lectures)**
- Concepts of plates, plate boundaries, pole of rotation, Euler's theorem, plate tectonics on sphere, plate tectonics and mountain building processes, plate tectonics at subduction zones, transform and divergent boundaries, evolution of plateau and rift valleys, study of plate tectonics and interior of the earth through seismology, Driving forces of plate tectonics, origin of mantle plumes/hot spot and its role on plate tectonics of the Indian plate, Drifting of the Indian sub-continent through time. **(15 lectures)**

Recommended Books:

1. Structural Geology—Fundamentals and Modern developments by S.K. Ghosh.
2. Folding and Fracturing of Rocks by J.G. Ramsay.
3. Structural Geology by H Fossen
4. An outline of Structural Geology by B.E. Hobbs, W.D. Means and P.F. Williams.
5. Structural analysis of Metamorphic tectonites by J.G. Turner and L. E. Weiss.
6. Use of stereographic projection in Structural Geology by F. C. Phillips.
7. Elasticity, Fracture and flow by J.C. Jaeger.
8. Structural Geology by Twiss and Moores
9. Rheology of the Earth by G. Ranalli, Allen and Unwin
10. Plate tectonics and crustal evolution, 3rd ed. Ed by K.C. Condie.
11. The Dynamic Earth by P.J. Willie
12. The Evolving Continents by B.F. Windley
13. Elementary Seismology by C.F. Richter
14. Plate Tectonics by X. LePichon, J. Francheteau and J. Bonnin.

Semester I

Departmental elective: ES5121 **Credits 3** **Full marks 100**

Course name: Environmental Geology

***Course objective*:** The objective of the course is to decipher the interaction of humans with the geological environment, familiarize students about the recent challenges of environmental issues. To the students of geology, knowledge of genesis, preparedness, mitigation of natural hazards with respect to geological agents is important.

Course content:

- Introduction to different types of Natural hazards. **(01 lectures)**
- Earthquake and coastal hazards with special emphasis on tsunami—genesis, prediction and mitigation. **(02 lectures)**
- Earth processes related to landslide and flood- genesis, prediction and mitigation. **(03 lectures)**
- Cyclones-types of cyclones, genesis, mitigation. **(04 lectures)**
- Global water crisis. General ideas on distribution of water resources. Scarcity and pollution of water resources. **(04 lectures)**
- Change of global climatic condition. Soil degradation, deforestation, and biodiversity crisis. **(04 lectures)**
- Progress of civilization and environment. **(01 lectures)**
- Structure and composition of atmosphere insolation and terrestrial radiation **(04 lectures)**
- Factors controlling temperature distribution **(04 lectures)**
- Heat budget **(02 lectures)**
- Humidity and condensation **(01 lectures)**
- Clouds. Classification of clouds **(02 lectures)**
- Precipitation. Precipitation mechanism. Different types and forms of precipitation **(02 lectures)**
- Pressure belts. Atmospheric circulation **(03 lectures)**
- Winds-Planetary Winds, Seasonal and local Winds, Cyclones Tropical and Temperate cyclone **(03 lectures)**
- Formation of cyclone, characteristics and impact, Jet streams **(03 lectures)**
- Various atmospheric phenomenon **(02 lectures)**

Recommended Books:

1. Geology for Engineers and Environmental Scientists by Alan E. Kehew.
2. Environmental Geology: Edward A Keller.
3. Environmental Geology: Lawrence Lundgren
4. Earth's climate: past and future by W.F. Ruddiman.
5. Climatology by R.V. Rohli, and A. J. Vega.

Semester I

Departmental elective: ES5122 **Credits 3** **Full marks 100**

Course name: Engineering Geology

***Course objective*:** Engineering geology is the application of the knowledge of geological sciences to engineering projects. The course will teach operational applications of geological knowledge, methods of response and management of geological risks. A student will be equipped with the knowledge of identifying potential geological hazards along with various structures and ways of preventing and dealing with them.

Course content:

- Mechanical properties of rocks, rock discontinuities, building stones, metals and Concrete aggregates. **(06 lectures)**
- Applications of Engineering Geology in civil constructions e.g. geological considerations (types, methods, problems related to geological point of views) of river valley projects—Dam, reservoirs, tunnels, bridges etc. **(06 lectures)**
- Applications of Engineering Geology in construction and mining industry. **(06 lectures)**
- Mass movements with special emphasis on Landslides. Introduction, classification, causes, predictions, preventions of landslide. **(06 lectures)**
- Siesmicity—Seismic zonation of India. Earthquake resistant building structures. **(06 lectures)**
- Concept of ground water engineering related problems. **(07 lectures)**
- Geotechnical case studies in Indian context. **(08 lectures)**

Recommended Books:

1. Engineering Geology: Principals and Practice by David George Price and M.H. de Freitas.
2. Geology for Engineers and Environmental Scientists by Alan E. Kehew.
3. Geology For Civil Engineers by Adam C. McLean and C. D. Gribble
4. Principles of engineering geology by Robert Britten Johnson

Semester I

Laboratory I: ES5171 **Credits 2** **Full marks 50**

Course name: Structural Geology Practical and Field-work

Course objective: Objective of the present study is to introduce various problems of structural geology and equip students to enable identification of various structures in field, processing structural data and making an integrated structural map.

Course content:

- Solution of structural problems of stereographic projection (in combination with other graphical methods when necessary) in the laboratory.
- Structural interpretation of geological maps of superposed fold and complex structure related to fault and fold in the laboratory.
- Mapping of lithological boundaries, identification of structural features and interpretation with respect to the regional deformational history of the different litho-units in the field.

  The field duration will be of at least two weeks duration.

Semester I

Laboratory II: ES5172 **Credits 2** **Full marks 50**

Course name: Igneous Petrology and Mineralogy Practical

***Course objective*:** Identification of minerals and igneous rocks is one of the main objectives of this course. With a revision of each common specimens of minerals and rocks this course is designed to give and teach students advanced techniques of deduction of paragenesis of mineral evolution or crystallization. Thorough textural, compositional (presence of zoning) study of rocks and minerals under microscope will be taught with an aim to decipher the palaeotectonic model of magma generation and the formation of that particular mineral/ rock.

Course content:

Igneous Petrology

- Studies of petrography of common igneous rocks under microscope.
- Study of rock texture under microscope and their interpretation.
- Calculation of CIPW norms and preparation of variation diagrams.

Mineralogy

- Study of common rock forming minerals in light of their optical properties under microscope.
- Training in preparation of microscopic thin sections of rocks, etching and staining of rock samples.

Semester II

Core Subject: ES5201 **Credits 4** **Full marks 100**

Course name: Sedimentology and Basin Analysis

***Course objective*:** Sedimentology is the study of sediments, particularly focusing on how it is produced, transported, and deposited. Sedimentary rocks illuminate many of the details of the Earth's history-- effects of sea level change, global climate, tectonic processes, and geochemical cycles. This course will cover basics of fluid flow and sediment transport, sedimentary textures and structures. It will provide an overview of facies analyses, modern and

ancient depositional sedimentary environments, and the relationship of tectonics and sedimentation.

Course content:

- Physical Sedimentology: sedimentary rocks & their types; clastic, volcaniclastic and chemical. Transportation and flow mechanisms. Dynamics of sediment transportation and deposition. Different types of flows, flow regimes. Sedimentary textures and structures and their genetic relation to the different parameters controlling the transportation and deposition.

  (15 lectures)

- Sedimentary Environments:

  Application of Walther's law, concept of facies, facies associations, facies sequence and transgression and regression

  Fluvial Systems: Alluvial Fan, Braided fluvial system and Meandering fluvial system, Architectural Elements

  Aeolian Environment: Aeolian facies attributes and associations--evaporites, ephemeral facies, draas, erg and their migration

  Shallow-marine (Coastal Environments—Tidal flats, Deltas, Lagoons, Barrier Bars)

  Deep-Marine (Slope facies, Olitostromes, Turbidites and Contourites. **(20 lectures)**
- Carbonate Sedimentary Environments. **(05 lectures)**
- Paleoenvironment analysis: Application of radioactive and stable isotopes in reconstruction of paleoenvironments. **(05 lectures)**
- Sedimentation and Tectonics: a) Cratonic Sedimentation. b) Plate tectonics and sedimentary basins. c) Tectonics and sandstone petrology d) Depositional styles of sandstones, mudstones, carbonates, evaporites and iron-rich rocks through the vast span of geological time.

  (10 lectures)
- Basin Analysis: Sedimentary basins and their evolution. **(05 lectures)**

Recommended books:

1. Sedimentary Environments: Processes, Facies and Stratigraphy H. G. Reading.
2. Sedimentary Petrology by M. E. Tucker.
3. Approaches to Interpretation of Sedimentary Environments by Douglas J. Cant and F. J. Hein.
4. Applied Sedimentology by Richard C. Selley.
5. Principles of Sedimentology and Stratigraphy by Sam Boggs Jr.
6. The Evolution Of Clastic Sedimentology by Hakuyu Okada and Alec Kenyon-Smith
7. Basin Analysis: Principles and Applications by P.A. Allen and J. R. Allen.
8. Principles of sedimentary basin analysis by A.D. Miall.

Semester II

Core Subject: ES5202 **Credits 4** **Full marks 100**

Course name: Metamorphic Petrology and Thermodynamics

Course objective: The objective of the course will enable students to critically identify the geodynamic processes and orogenic event which the rock suffered, through mathematical, textural and theoretical study. Identification of mineral assemblage and their interpretation of the process involved in the evolution will be aimed. Quantitative and qualitative plots of each assemblage and the reaction texture will be aimed to interpret the evolutionary history.

Course content:

- Introduction: Factors controlling transformations (T, P and fluids, Heat flow), minerals as pure and impure phases. Types of metamorphism: Regional, contact, dynamic, hydrothermal, impact, retrograde and ocean floor metamorphism; Protolith types and characteristic metamorphic minerals; metamorphic textures. Textures of contact and regional metamorphism, Tectonic context of metamorphic transformations Metamorphism: controls and types. Factors controlling metamorphism. **(10 lectures)**
- Metamorphic phase equilibria: nature of metamorphic transformations; textural and mineralogical evidence of equilibrium in metamorphic rocks; fluid-free, dehydration and decarbonation type metamorphic reactions; calculation of metamorphic reaction curves using standard state thermodynamic parameters (Gibbs free energy, enthalpy, entropy and volume) of mineral end members and fluid phase fugacities; activity-composition relations and solution models for important metamorphic minerals, variance of metamorphic assemblages, metamorphic geothermometry and geobarometry, solution of numerical problems.

  (14 lectures)
- Metamorphic grade and metamorphic facies: historical review; geological set-ups of low- and high-grade regional, thermal and burial type metamorphism; prograde and retrograde metamorphism. Concept of Geothermobarometry and calculations. **(12 lectures)**
- Graphical analysis of metamorphic rocks: construction and use of ACF, AKF and AFM diagrams; Schreinemakers analysis of metamorphic equilibria. **(08 lectures)**
- Progressive regional metamorphism- of pelitic, quartzofeldspathic, basic and calcareous rocks: brief outlines of the classic type-areas; progressive metamorphism in relation to progressive deformation: pre-, syn- and post-deformation metamorphic textures. **(08 lectures)**
- Metamorphism and global tectonics: regional metamorphism in relation to plate movements, orogeny and plutonism; origin of granulites and regional high-grade belts; pressure-temperature-time paths of metamorphism. **(08 lectures)**

Recommended books:

1. Field Description of Metamorphic Rocks by Norman Fry.
2. Igneous and Metamorphic Petrology by Francis John Turner and J. Verhoogen.
3. An Introduction to Metamorphic Petrology by B.W.D. Yardley.

4. Introduction to Igneous and Metamorphic Petrology, John D. Winter.
5. Igneous and Metamorphic Petrology, Myron G. Best.
6. Igneous and Metamorphic Rocks under the Microscope: Classification, textures, microstructures and mineral preferred orientation by D. Shelley.

Semester II

Core Subject: ES5203 **Credits 4** **Full marks 100**

Course name: Principles of Stratigraphy and Indian Stratigraphy

Course objective: The objective of learning Stratigraphy is to acquire knowledge of synthesis of the stratal record, emphasizing the analysis of layered sequences, principally sedimentary, that cover about 3/4th of the Earth's surface. Archaean cratonic nucleii of Peninsular India (Dharwar, Singhbhum, and Aravalli cratons); Proterozoic mobile belts (Central Indian Tectonic Zone, Aravalli-Delhi and Eastern Ghats); Purana sedimentary basins (Cuddapah and Vindhyan); Phanerozoic stratigraphy of India- Spiti, Kashmir, Assam-Arakan, Damodar valley, Kutch, Trichinopoly, Siwaliks and Indo-Gangetic alluvium.

Course content:

Principles of Stratigraphy

- Law of superposition. Stratigraphic nomenclature- lithostratigraphy, biostratigraphy and chronostratigraphy **(08 lectures)**
- Sequence Stratigraphy-- Early Development of Sequence Stratigraphy Era—Eustatic vs. Tectonic Controls on Sedimentation; Sequence Models, Sea-level changes; Definitions of eustasy; relative sea-level and water depth, Accommodation and Shoreline Shifts, Shoreline trajectories--Transgression; Forced Regressions; Normal Regressions, Stratigraphic Surfaces, Concept of system tracts **(12 lectures)**
- Event stratigraphy **(04 lectures)**
- Boundary problems **(06 lectures)**

Indian Stratigraphy

- Scope of stratigraphy:Broad distinction between Precambrian and Phanerozoic Stratigraphy **(02 lectures)**
- Precambrian stratigraphy

  Precambrian and its subdivisions, Archean Provinces, Archean Nucleii, Cratons, Shields, Platforms and Mobile belts. Plate tectonics during the Precambrian **(08 lectures)**

  Stratigraphy of Cuddapah and Vindhyan basins; Tectonostratigraphic framework of Dharwar craton, an overview of Bastar, Singhbhum, Bundelkhand and Aravalli cratons, Eastern Ghat mobile belt, Central Indian Tectonic Zone; Proterozoic sedimentary basins of India. Precambrian biota and its stratigraphic significance. **(08 lectures)**
- Phanerozoic stratigraphy

Major plate movements during Phanerozoic. Subdivisions of Phanerozoic up to Stage level. **(02 lectures)**

Stratigraphic framework of Marine Palaeozoic rocks of Himalaya with special reference to Kashmir, Spiti, Kumaon and their correlatives in Salt Range and peninsular India.

(02 lectures)

Criteria for recognising major stratigraphic boundaries of Phanerozoic and their GSSPS.

(01 lecture)

Permian-Triassic boundary sections of India Marine Mesozoic Rocks of the Himalaya Gondwana Supergroup of rocks, its fauna and flora, depositional history, economic importance and climate; Jurassic sedimentary basins of Kachchh and Jaisalmer; Cretaceous stratigraphy of the Cauvery Basin and Narmada Valley; Deccan Volcanic Province **(04 lectures)**

Cretaceous-Palaeogene boundary sections of India. Palaeogene stratigraphy of Kachchh. Stratigraphy of the Himalayan foreland basin (Subathu, Murree/Dagshai-Kasauli, Siwalik) and recent advances. Indus Basin sediments of the Indus Tsangpo Suture Zone. Quaternary deposits of Andaman Islands. **(03 lectures)**

Recommended books:

1. Principles of Sequence Stratigraphy by Octavian Cateneauau
2. Geology of India and Burma, M.S. Krishnan
3. Manual of Geology of India and Burma, E.H. Pascoe.
4. Fundamentals of Historical Geology and Stratigraphy of India by Ravindra Kumar.
5. Applied Stratigraphy by Eduardo A.M. Koutsoukos.
6. Geology of India, Vol-I, Vol-II, M. Ramakrishnan and R. Vaidyanadhan, Geological Society of India, Bangalore

Semester II

Departmental Elective: ES5221 **Credits 3** **Full marks 100**

Course name: Mathematical Geology

Course objective: Geology is an applied science and in different branches of geology mathematics is used as a tool. Mathematical tools are required Mathematics has a wide application in Geology to understand geological processes too. Knowledge of mathematics is essential to conduct analog and numerical experiments in geology in order to match field observations. The course claims to help students to understand and develop an idea on the nature of geological and deformational processes precisely.

Course content:

- Solving equations graphically and analytically. **(07 lectures)**
- Numerical differentiation and integration. **(10 lectures)**
- The concept of probability. **(03 lectures)**

- Normal statistics, Universe, population, sample, random variable, Normal distribution, mean, mode, median, skewness, kurtosis, log-normal distribution, Multivariate distribution, 't'test, 'F'test, fiducian levels correlation, covariance, regression, linear and non-linear relationship. **(10 lectures)**
- Fundamentals of geostatistics, spatial and numerical variability of samples, variogram, estimation variance, geostatistical modeling, krigging. **(10 lectures)**
- Some geosciences applications of trigonometry. **(05 lectures)**

Recommended books:

1. Statistics and data analysis in Geology by J.C. Davis.
2. Statistical methods in geology by R.F. Cheeney.
3. Essential maths for Geoscientists: An Introduction by Paul I. Palmer.
4. Principles of mathematical geology by Andreĭ Borisovich Vistelius
5. Handbook of Mathematical Geosciences edited by Daya Sagar, B.S., Cheng, Qiuming, Agterberg

Semester II

Departmental Elective: ES5222 **Credits 3** **Full marks 100**

Course name: Marine Geology

***Course objective*:** The study of Marine Geology is interdisciplinary. It is concerned with all aspects of the oceans and seas, including their physical and chemical properties, origin, geology and life forms. The objective is to study all aspects of the ocean. It covers a wide range of topics, from marine life and ecosystems, to currents and waves, to the movement of sediments, to seafloor geology.

Course content:

- Morphologic and tectonic domains of the ocean floor. Structure, composition and mechanism of the formation of oceanic crust. Hydrothermal vents. **(05 lectures)**
- Ocean margins and their significance. Ocean Circulation, Coriolis effect and Ekman spiral, convergence, divergence and upwelling, El Nino. Indian Ocean Dipole Thermohaline circulation and oceanic conveyor belt. Formation of Bottom waters; major water masses of the world's oceans. **(05 lectures)**
- Oceanic sediments: Factors controlling the deposition and distribution of oceanic sediments; geochronology of oceanic sediments, diagenetic changes in oxic and anoxic environments. **(06 lectures)**
- Tectonic evolution of the ocean basins. **(04 lectures)**
- Mineral resources. **(05 lectures)**
- Paleoceanography– Approaches to paleoceanographic reconstructions; various proxy indicators for paleoceanographic interpretation. **(10 lectures)**
- Reconstruction of monsoon variability by using marine proxy records **(05 lectures)**
- Opening and closing of ocean gateways and their effect on circulation and climate during the Cenozoic. Sea level processes and Sea level changes. **(05 lectures)**

Recommended books:

1. Marine Geology by J Kennett
2. The Sea floor Spreading- An introduction to Marine Geology by Seibold, Eugen Berger and Wolfgang
3. An Introduction to Marine Geology by M. J. Keen.
4. Essentials of oceanography by Harold V. Thurman
5. Descriptive Physical Oceanography: An Introduction by George L Pickard

Semester II

Laboratory III: ES5271 **Credits 2** **Full marks 50**

Course name: Metamorphic Petrology and Sedimentology Practical

Course objective: The main objective of the petrological study of metamorphic rock is to familiarize student with different variety of metamorphic rocks in hand specimens for field identification and also under thin section in laboratory work. The textural study will teach them the process to identify the reaction texture, processes involved and finally deduction of the evolutionary history of the rocks. The practical lessons in sedimentology will enable the students to identify sedimentary rocks in hand specimens and thin sections. Detailed study of textures, grain-size analyses, diagenetic structures will be dealt in detail to formulate an idea on the depositional condition and provenance.

Course content:

Metamorphic Petrology

- Studies of petrography of common igneous rocks under microscope.
- Microscopic study of metamorphic facies, deformation and recrystallisation history from set of thin sections of metamorphic rocks.
- Construction of ACF, AKF, and AFM diagrams.
- P-T estimation using important models of geothemobarometry.
- Interpretation of reaction textures.

Sedimentology

- Study of sedimentary rocks from hand specimens.
- Detailed petrographic studies of various clastics, non-clastics and volcaniclastics--descriptive studies and grain-size analysis
- Paleocurrent Analysis.

Semester III

Core Subject: ES6101 **Credits 3** **Full marks 100**

Course name: GIS and Remote Sensing

Course objective: At the onset of a geological work in an area or site, it is important to know the geological, geographical and geomorphological information of that area and ultimately to

prepare a map. GIS and Remote Sensing offer such study by which one can access any area remotely and make maps bearing series of information. Study based on GIS and Remote Sensing is evolving at a rapid rate. GIS and Remote Sensing have potential to be used as essential tools in various aspect of Geology.

Course content:

- Basic Principles of Remote Sensing. **(02 lectures)**
- Definition of Remote Sensing. Energy sources and radiation principles, Atmospheric absorption, interaction of energy with various features of the earth's surface, Spectral reflectance curves, Airborne Remote Sensing, spaceborne Remote Sensing, Optical Remote Sensing, Infrared Remote Sensing, Microwave Remote Sensing, Platforms, Sensors, Resolutions-spatial-spectral-radiometric-temporal. **(10 lectures)**
- Digital processing of satellite images. **(08 lectures)**
- Geometric rectification, spatial and radiometric enhancement, edge detection, band ratio, false colour composites (FCC), Principal component analysis, Spectral domain enhancement, Supervised and unsupervised classification for thematic map generation. **(07 lectures)**
- Geographic Information System (GIS). **(08 lectures)**
- Basic concepts, Hardware and software module of GIS, Data representation, Raster and Vector mode operation, Advantages and Disadvantages of Raster and Vector data, Topology-Topology of raster and vector data, Case study(2). **(10 lectures)**

Recommended books:

1. Remote Sensing and Image Interpretation, 4th Edition by Thomas M. Lillesand and Ralph W. Kiefer.
2. Geographic Information Systems and Science by Paul A. Longley, Michael F. Godchild, David J. Maguire, and David W. Rhind
3. Image Interpretation in Geology by S.A. Drury,
4. Remote Sensing Geology by R.P. Gupta.
5. Remote Sensing and Image Interpretation by T.M. Lillesand and R.W Kieffer.
6. Photogeology by V.C. Miller.
7. Aerial Photography and Image Interpretation for Resource Management. D.P. Paine.
8. Principles and Applications of Photogeology by S.N. Pandey.
9. Remote Sensing Principles and Applications. Freeman. F.F. Sabbins,

Semester III

Core Subject: ES6102 **Credits 3** **Full marks 100**

Course name: Hydrogeology and Exploration Geophysics

***Course objective*:** Water crisis is a burning topic globally. The present day society is affected by a few challenges regarding water crisis, ground water contamination, inferior quality of water, saline water intrusion etc. Students of geology should have therefore the ideas about

occurrence, physical and chemical attributes of water along with the exploration of groundwater resources. In the course content main emphasis has been given on these important aspects of groundwater. Exploration geophysics deals several indirect techniques to understand the subsurface geology as well as the subsurface structures which is necessary for any kind of exploration work. Students will be acquainted with geophysical techniques, extensively to be used in exploration sector.

Course content:

Hydrogeology

- Hydrologic cycle and occurrence of ground water, Porosity and permeability, Aquifer properties, Darcy's Law and groundwater movement, Specific yield, Specific retention, transmissivity, storage co-efficient or storativity, Hydraulic conductivity, Cone of Depression, Hydrologic data interpretation, and flow-net analysis. **(05 lectures)**
- Well Hydraulics: Steady and non-steady radial flow in confined and unconfined aquifers. **(02 lectures)**
- Geophysical methods in groundwater exploration: Electrical, Seismic and Well Logging etc. **(03 lectures)**
- Groundwater quality and pollution with more emphasis on trace element, toxic and non-toxic elements, problems of saline water intrusion in coastal areas. **(05 lectures)**
- Groundwater development and management, concept of watershed management and in-situ groundwater development, artificial recharge, Rainwater harvesting. **(04 lectures)**
- Groundwater provinces of West Bengal and India. **(02 lectures)**
- Solution of Problems related to Hydrogeology. **(02 lectures)**

Exploration Geophysics

- Seismology and the interior of the earth: elementary principles of elastic wave propagation through the earth; travel-time curves and location of earthquakes; earthquake intensity and scales; whole earth seismic velocity-depth models and crust-mantle-outer core-inner core zonations; seismic tomography. **(05 lectures)**
- Earth's gravity field and gravitational acceleration; gravity anomalies and isostasy; simple isostatic compensation calculations for the Airy and Pratt models. **(05 lectures)**
- Earth's magnetism, basic concepts of magnetic field, field components and intensity, magnetic susceptibility, magnetic anomalies; magnetization and remanent magnetization, paleomagnetism; paleomagnetic poles and polar wandering: tectonic implications; earth's magnetic field reversals, reversal time scale. **(05 lectures)**
- Plates and plate configuration of the earth; plate motion: geometry, time scales and forces, physical basis of plate tectonics. **(03 lectures)**
- Heat and thermal structure of the earth; oceanic and continental heat flow; the geotherm and the adiabat: implications for melting in the mantle and primary magma generation. **(04 lectures)**

Recommended books:

1. Groundwater in Geologic Processes by Steven E. Ingebritsen, Ward E. Sanford, and Christopher E. Neuzil.
2. Field Hydrogeology: A Guide for Site Investigations and Report Preparation by John E. Moore.
3. Ground Water Hydrology, 2nd Edition by David Keith Todd
4. Geohydrology by R.J.M.De Wiest
5. Groundwater Hydrology by David Keith Todd and Larry W. Mays
6. The Solid Earth: An Introduction to Global Geophysics by C. M. R. Fowler
7. The Blue Planet: An Introduction to Earth System Science by Brian J. Skinner, Stephen C. Porter, and Daniel B. Botkin.
8. Earth Structure: An Introduction to Structural Geology and Tectonics by Ben A. Van Der Pluijm and Stephen Marshak.
9. **Basic Exploration Geophysics** by Edwin S. Robinson and Cahit Coruh**.**

Semester III

Core Subject: ES6103 **Credits 3** **Full marks 100**

Course name: Ore Geology and Fuel Geology

Course objective: The main objective of the course is to familiarize with common ore minerals, their identifying criteria at various scales of study, to understand the genetic controls exerted by physical and chemical processes on ore formation in various geologic settings. Understanding on the origin of different variety of fuels and their process of preservation and thus finally track down natural reserves.

Course content:

Ore Geology

- Introduction to ore and ore deposits: Primary differentiation of the earth into shell structure and elemental zonation. Mineralization through ages and geological events. Classification of ore deposits with special emphasis on tectonics, mineralization in mobile belts and in stable areas in relation to plate theory.

  (03 lectures)
- Magmatic Ore Deposits: Petrological and geochemical background to ore formation; general characteristics and genesis of magmatic ore deposits: chromite deposits, base-metal Ni-Cu sulfide deposits, PGE sulfide deposits, rare-metal pegmatites and diamond deposits associated with kimberlites and lamproites. **(04 lectures)**
- Hydrothermal Ore Deposits: Basic concepts related to hydrothermal ore formation - Role of physical and chemical environment on metal complexing, transport and deposition; chemical nature of hydrothermal ore fluid in magmatic, metamorphic and sedimentary basinal environments; fluid. General characteristics and genesis of hydrothermal ore deposits: Porphyry deposits; greisens and related ore deposits; skarn and carbonate-replacement deposits; epithermal deposits; volcanic-hosted massive sulfide deposits;

orogenic gold deposits; iron oxide-copper-gold (IOCG) deposits; SEDEX Pb-Zn-Ag deposits. **(05 lectures)**

- Ore deposits Formed by Chemical and Clastic Sedimentary Processes: Ore deposits formed by chemical precipitation from surface waters (hydrogene deposits) and clastic sedimentation - Iron ores in ironstones; sedimentary-rock-hosted Mn and P deposits; coastal heavy mineral sand deposits; and fluvial placer (and paleoplacer) deposits. Ore deposits formed by supergene processes. In-situ supergene ores and formation of lateritic bauxite and Ni-Co deposits; overprinting of hypogene ores and formation of supergene gold (in lateritic weathering) and copper (in arid and semi-arid climates) ores. **(04 lectures)**
- Indian Mineral deposits: India's geological frame and Precambrian mineralization and Archean Greenstone belts and metallogenic pattern. Metallogenic provinces and epoch in Indian subcontinent; distribution of various types of ore deposits and industrial minerals in India. Major ferrous and non-ferrous metal deposits in India and their genesis. **(05 lectures)**
- Classification of Precious metal deposits with special reference to Platinum Group metals and Gold. Genetic processes and Indian context. **(02 lectures)**

Fuel Geology

- Physico-chemical properties of natural hydrocarbon. Its composition and different fractions. Source rock, maturation studies. Origin, nature and migration (primary and secondary) of oil and gas. Transformation of organic matter into kerogen, organic maturation, thermal cracking of kerogen. **(02 lectures)**
- Characteristics of Reservoir rocks and traps: structural, stratigraphic and combination), Reservoir geometry, porosity, permeability, overpressure, entrapment: classification of traps. Oilfield fluid: water, oil and gas occurrence. Movement of oil and gas in a pool. **(02 lectures)**
- Surface indications and direct detention of hydrocarbon: mode of occurrence-surface and subsurface occurrences. **(02 lectures)**
- Migration and accumulation of petroleum and its geological framework. **(02 lectures)**
- Prospecting for oil and gas, drilling and logging procedures. **(01 lectures)**
- Oil bearing basins of India and the world. Geology of productive oilfields of India. Position of oil and natural gas in India, future prospects and economic scenario. **(01 lectures)**
- Definition of Coal, Types of Coal, stages of coal formation **(02 lectures)**
- Peatification, **(02 lectures)**
- Coalification and its stages

  Geological features of peatlands and coal seams. Coal petrography: macerals, their origin and microlithotypes. Application of coal petrology. Coal characterization. Beneficiation, utilization and industrial classification. Processing and end-use sector quality control, environmental aspects of coal-based industries.

  Geological and geographical distribution of coal deposits in India. Detailed geology for some important coalfields of India.

Methods of coal prospecting and estimation of coal reserves. Coal production and problems of coal industry in India.

Coalbed Methane----mode of occurence, method/s of extraction. **(04 lectures)**

- Minerology, Geochemistry and mode of occurrence of radioactive minerals. **(02 lectures)**
- Techniques of detection and measurements of radioactivity, Distribution of radioactive minerals in India. **(02 lectures)**

Recommended books:

1. Elements of Petroleum Geology by Richard C. Selley.
2. Coal: Classification, Coalification, Mineralogy, Trace-Element Chemistry, and Oil and Gas Potential, Edited by P.C. Lyons B. Alpern.
3. Coal and Lignite Resources of India: An overview, Geological Society of India, Banglore by S.K. Acharyya.
4. Stach E. Mackowsky M.T.H., Teichmuller M., Taylor G.H. Chandra D., Teichmuller R., 1982, Coal petrology, Gebruder Borntraeger, Stuttgart
5. Textbook of Coal (Indian Context) by D. Chandra, R.M. Singh and M.P Singh.
6. Petroleum Geology by F.K North.
7. Principles of Nuclear Geology by U. Aswathanarayana.
8. Radioactivity in Geology. Principles and applications by Ellis Hoorwool Durrance E.M.

Semester III

Laboratory IV: ES6171 **Credits 2** **Full marks 100**

Course name: Ore Geology Practical and Underground Geological Mapping

Course objective: For detailed idea about different physical, micro structural properties of ore minerals laboratory-demonstration is essential. To give exposure on various aspects of subsurface occurrences of ore bodies and their associated litho-units, underground and open-cast mine visits are undertaken. Ultimately these will help the students to get job in mining sectors.

Course content:

Ore Geology practical

- Megascopic study of the common ores---structures, fabric and associations.
- Microscopic study of common sulphide, oxide and non-metallic ore minerals.
- Study of the ore textures.
- Interpretation of drill core data to reconstruct subsurface structures.
- Tackling problems related to reserve estimation.

Mine visit

Visit of an opencast and an underground mine. **The visit to be completed within seven days.**

Semester IV

Core Subject: ES6201 **Credits 4** **Full marks 100**

Course name: Palaeontology and Mass Extinction

***Course objective*:** Majority of rock records from Late Archaean to Quaternary preserves evidences of life either as whole body or, parts or their activities. Appearances, persistence and disappearances of different forms of life in the rock record across time confirm the theory of evolution, extinction. Study of microfossils has a significant role in petroleum exploration.

Course content:

- Types of organisms, growth, outline of molluscan coiling, growth rate, population study, species concept, functional morphology, concept of adaptation and exaptation. **(05 lectures)**
- Theories on evolution, types, patterns and rate of evolution, paleoecology, Taphonomy, Mass extinction. Concepts of Linnean, Numerical and Cladistic Taxonomy. **(10 lectures)**
- Evolutionary patterns in different groups of mega-invertebrate and vertebrates with an outline of study of important morphological aspects. **(08 lectures)**
- Trace fossils and Precambrian fossils. **(05 lectures)**
- Morphological study of Foraminifers, Radiolaria, Ostracods, Conodonts, Diatoms, nannofossils and their importance in paleoecological analysis. **(10 lectures)**
- Synoptic overview of development of land plants. **(05 lectures)**
- Brief outline of palynology and its uses. **(02 lectures)**
- Gondwana flora—Indian and global aspects. **(04 lectures)**
- Hominid and Proboscidian evolution. **(03 lectures)**
- Definition of Extinction, background extinction, extermition and mass extinction. **(04 lectures)**
- Major and minor Mass Extinction: with special emphasis on PT and KT boundary. **(04 lectures)**

Recommended books:

1. Principles of Paleontology by David M. Raup and Steven M. Stanley.
2. Invertebrate Palaeontology and Evolution by E.N.K Clarkson.
3. Microfossils, Brasier, M.D.
4. Micropaleontology: Principles and applications by Pratul Kumar Saraswati, M.S. Srinivasan,

Semester IV

Departmental Elective: ES6221 **Credits 3** **Full marks 100**

Course name: Geodynamics

***Course objective*:** The course is formulated to develop so that the students develop an overall idea about the dynamism of the Earth and different factors controlling the dynamism.

Course content:

- Concept on dynamism of the Earth: The driving mechanism of Plates, Paleomagnetism and Motion of Plates, Wilson Cycle, Continental Collision, Accreting Plate Boundaries, Subduction, Transform Faults, Hotspots and Mantle Plumes. **(10 lectures)**
- Heat budget and heat transfer: Fourier's Law of Heat Conduction, Earth's Surface Heat Flux, Heat Generation, One-dimension Steady Heat Conduction, Continental Geotherm, Subsurface Temperature, Plate Cooling Model of the Lithosphere. **(10 lectures)**
- Introduction to fluid mechanics: One-Dimensional Channel Flows, Asthenospheric Counterflow, Pipe Flow, Flow Through Volcanic Pipes, Conservation of Fluid in Two Dimensions, Force Balance, Stream function, Post Glacial rebound, Angle of Subduction, Diapirism, Folding, Stokes law. **(10 lectures)**
- Fluid flow in porous media: Darcy's Law, Permeability Models, Flow in Confined and unconfined Aquifers, Equations of Conservation of Mass, Momentum, and Energy for Flow in Porous Media, Flow Model for Magma Migration. **(08 lectures)**
- Rheological modeling of crust and mantle: Diffusion and Dislocation Creep, Shear Flows of Fluids, Mantle rheology, Rheological Effects on Mantle Convection, Crustal rheology. **(07 lectures)**

Recommended Books:

1. **Geodynamics** by D Turcotte and G Schubert.
2. Elasticity, Fracture and flow by J.C. Jaeger
3. Rheology of the Earth by G. Ranalli, Allen and Unwin
4. The Dynamic Earth by P.J. Willie

Semester IV

Departmental Elective: ES6222 **Credits 3** **Full marks 100**

Course name: Geomorphology

***Course objective*:** A subtle difference exists between Geomorphology and Geology. Geomorphology is the study of the physical features of the Earth's crust as related to its geological features. The course provides an overview of various physical features on the surface of the earth which includes landforms, land forming processes, landscape evolution and how these depend on climate and tectonic regimes.

Course content:

- Concepts in geomorphology. Historical and process Geomorphology. **(04 lectures)**
- Landforms in relation to climate, rock type, structure and tectonics. **(10 lectures)**
- Processes– weathering, pedogenesis, mass movement, erosion, transportation and deposition. **(12 lectures)**

- Geomorphic processes and landforms – fluvial, glacial, aeolian, coastal and karst. River forms and processes – stream flow, stage discharge relationship; hydrographs and flood frequency analysis. Submarine relief. **(14 lectures)**
- Geomorphology and topographic analysis including DEM, Environmental change– causes, effects on processes and landforms. Extra-terrestrial geomorphology. **(05 lectures)**

Recommended Books:

1. Earth Surface Processes and Landforms and Sediment Deposit by John Bridge and Robert Demicco.
2. Earth Surface Processes by P. A. Allen
3. Geomorphology: A Systematic Analysis of Late Cenozoic Landforms, Pearson Education by A.L. Bloom.
4. Global Geomorphology by M.A. Summerfield.

Semester IV

Laboratory V: ES6271 **Credits 2** **Full marks 100**

Course name: Paleontology Practical and Borehole Geology

Course objective: Observing the fossils in handspecimen and under microscope will help to get the vivid ideas on functional morphology of the ancient faunas. Thorough knowledge in micropaleontology helps to get idea on petroleum exploration. To have a bird's eye view on the techniques occur in the drill site of Petroleum Exploration, each student must see and understand the operating rig to have a gross idea of the processes involved. The students are taken to drill site, mainly petroleum drill site to give an exposure of the processes of petroleum exploration. This creates the opportunity to the students to serve the petroleum industry in future.

Course content:

Paleontology practical

- Study of population in bivalves/brachiopods.
- Study of assemblage of fossils for paleo- ecological reconstruction.
- Functional morphology of bivalves.
- Study of sexual dimorphism in ammonites.
- Biometric study and simple statistical analysis there from.
- Study of larger and smaller foraminifers.
- Description of echinoid and gastropods.

Borehole Geology

A site will be chosen related to petroleum oil exploration and drilling. A short training programme by the experts on oilfield survey and drilling will be arranged for the students at

least for seven days. A report will be submitted on the visit and training aspects. Total duration of visit will be of two weeks duration. **The visit will be completed within seven days.**

Term Paper and M.Sc. Thesis

Course objective: To develop the orientation of further advanced research, Term Paper and M.Sc. thesis is compulsory for each and every student. Students are given any of the following subjects for thesis work:

1. Hydrogeology
2. Sedimentology..
3. Paleontology.
4. Structural Geology and Tectonics
5. Igneous and Metamorphic Petrology
6. Experimental Geology
7. Geochemistry

For thesis work requisite field programme may be arranged by the supervisor concerned during the semester III and IV.

Open Electives

Semester I

Open Elective: ES5161 **Credits 3** **Full marks 100**

Course name: Introduction to Earth Materials

Course objective: The course is designed to give a brief idea of the material by which our mother Earth is made up of. The main objective is to familiarize earth material within the students of different departments. The main aim is to build a base knowledge of minerals and rocks. Fundamentals of minerals and rock properties and their use will be an important part of the course other than identification.

Course content:

- Definition of Earth materials. **(01 lectures)**

- Earth as a planet in solar system. Gross features of the Earth. Brief idea about core, mantle, crust, hydrosphere, atmosphere, biosphere and elemental abundance in each constituent. **(02 lectures)**
- Layered structure of the Earth **(02 lectures)**
- Earth's materials, minerals and rocks. Broad groups of minerals, oxides, sulphides, carbonates, sulphates and phosphates, silicates. Rocks as mineral assemblages, fabric, texture. Igneous rocks, acid, intermediate, mafic and ultramafic rocks. Sedimentary rocks, clastic and non clastic. Metamorphic rocks, foliated, nonfoliated. **(17 lectures)**
- Ore Mineralogy: Mineralogy of Important Ores of the Following Elements—Iron, Manganese, Titanium, Chromium, Tin, Tungsten, Copper, Lead, Zinc, Nickel, Uranium, Thorium. Texture of the Ore Minerals and their Interpretations. **(08 lectures)**
- Study of rock forming minerals in hand specimen: identifications of common rock forming minerals and rocks. **(05 lectures)**
- Physical Properties of minerals and rocks and their uses. **(10 lectures)**

Recommended books:

1. An introduction to the rock forming minerals by W. A. Deer, R. A. Howie and J. Zussman,
2. Optical mineralogy by P. K. Verma.
3. A Textbook of Geology by P. K. Mukherjee.
4. Fundamentals of Geology by Borges, Gwalani and Veena Rao.
5. Understanding Earth, 3rd edition, by Frank Press and Raymond Siever

Semester I

Open elective: ES5162 **Credits 3** **Full marks 100**

Course name: Earth Surface Processes and Structures

Course objective: The course provides an overview of surfacial processes responsible on for the formation of different primary and secondary landforms, land forming processes, landscape evolution and how these depend on climate and tectonic regimes.

Course content:

- Earth's energy balance, hydrological cycle, carbon cycle, heat transfer, topography and bathymetry. **(02 lectures)**
- Landforms in relation to climate, rock type, structure and tectonics. **(02 lectures)**
- Processes – weathering, pedogenesis, mass movement, erosion, transportation and deposition. **(05 lectures)**
- Geomorphic processes and landforms – fluvial, glacial, Aeolian, coastal and karst. River forms and processes – stream flow, stage discharge relationship; hydrographs and flood frequency analysis. Submarine relief. **(05 lectures)**

- Geomorphology and topographic analysis including DEM, Environmental change–causes, effects on processes and landforms. Extra-terrestrial geomorphology. **(06 lectures)**
- Types of rocks and the environment in which they occur. **(01 lectures)**
- Rock cycle. **(02 lectures)**
- Introduction to rock deformation, causes for deformation, Ductile and Brittle behaviours of rock. **(06 lectures)**
- Structures of rock: Primary and Secondary structures. **(01 lectures)**
- Penetrative and Non-penetrative structures, fold, fault, lineation, foliation, shear zone. **(06 lectures)**
- Mechanical properties of rocks and their controlling factors. **(03 lectures)**
- Structural data analysis: Solution of structural problem using graphical method Stereographic method, and π and β diagrams. **(06 lectures)**

Recommended books:

1. Earth Surface Processes and Landforms and Sediment Deposit by John Bridge and Robert Demicco.
2. Earth Surface Processes by P. A. Allen
3. Geomorphology: A Systematic Analysis of Late Cenozoic Landforms, Pearson Education by A.L. Bloom.
4. Global Geomorphology by M.A. Summerfield.
5. Structural Geology—Fundamentals and Modern developments by S.K. Ghosh.
6. Folding and Fracturing of Rocks by J.G. Ramsay.
7. An outline of Structural Geology by B.E. Hobbs, W.D. Means and P. F. Williams.
8. Engineering and general geology by Prabin Singh.

Semester II

Open Elective: ES5261 **Credits 3** **Full marks 100**

Course name: Life through ages

Course objective: Our planet Earth hosts several forms of life through the ages. The organisms including human beings are the fittest in the recent environments. Similarly, the history of the Earth also preserved the impressions of different environment friendly organisms. In the rock record we get glimpses of these organisms for different time periods. So knowledge of the appearance, ecology, and evolution of the organisms will help to decipher the geological history of different rock strata.

Course content:

- Ideas about origin of life; Geological Time Scale **(04 lectures)**
- Evidences of early life in the rock record. **(04 lectures)**
- Fossils—Different Types; Taphonomy and Preservation. **(10 lectures)**
- Classification of the organic world. **(06 lectures)**

- Cambrian Explosion **(03 lectures)**
- Appearance of Vertebrates and Invertebrates and their evolutionary diversification **(10 lectures)**
- Appearance of plants and their evolutionary diversification **(06 lectures)**
- Law of Faunal Succession **(02 lectures)**

Recommended books:

1. Principles of Paleontology by David M. Raup and Steven M. Stanley.
2. Invertebrate Palaeontology and Evolution by E.N.K Clarkson.
3. Microfossils, Brasier, M.D.
4. Micropaleontology: Principles and applications by Pratul Kumar Saraswati, M.S. Srinivasan,
5. Vertebrate Palaeontology by M Benton
6. Evolution of the Vertebrates: A History of the Backboned Animals Through Time by Edwin H. Colbert

Semester II

Open Elective: ES5262 **Credits 3** **Full marks 100**

Course name: Natural resources and Energy

Course objective: The course aims to introduce the natural energy systems coupled with unconventional energy resources emphasising particularly on geological contexts. The lectures under this course will explore the present and projected demands; genesis, resources and reserves of conventional energy (fossil fuels and nuclear energy) - their usage, application and related environmental issues. The classes will also cover a series of other alternate, unconventional and renewable energy sources including enhanced coal and shale gas energy, natural and engineered geothermal resources together with solar, biomass (conversions), wind power, and hydro-energies.

Course content:

- Introduction; historical developments; classification of energy systems. **(01 lectures)**
- Conventional Energy: origin and genesis through geological time scale; classifications; global and Indian resources; different methods of exploration and beneficiation; future demand and usage. **(12 lectures)**
- Unconventional/Alternative/Renewable Energy: Coal Bed Methane (CBM); occurrence and genesis; natural processes of recovery; Enhanced Coal Bed Methane (ECBM); processes of recovery, concepts of adsorption and desorption; application and recovery; resources and estimates for future usage; environmental risks. **(11 lectures)**
- Geothermal Energy; concepts and developments; natural and engineered Geothermal energy resources; hydro-fracking; application and recovery; resources and estimates for future usage; environmental risks. **(05 lectures)**
- Concepts, developments, usage and estimates of solar, biomass (conversions), wind power, and hydro-energies. **(04 lectures)**
- Geological CO2 sequestration **(03 lectures)**

- Present and future resources. **(03 lectures)**
- Resource and energy management **(03 lectures)**
- Energy and mineral resources in India, global scenario and demand. **(03 lectures)**

Recommended books:

1. Introducing Natural Resources by G. Park
2. Earth's Natural resources by J. V. Walther
3. Fundamentals and Applications of Renewable Energy by Mehmet Kanoglu, Yunus A. Cengel Dr., John M. Cimbala
4. Advances in Sustainable Energy by Ahmad Vasel, David S-K. Ting
5. Solar and Wind Energy by Catherine Waltz
6. Energy: Perspectives, Problems, and Prospects by Michael B. McElroy
7. Fossil Fuels by Neil Morris
8. Energy Resources by Andrew L. Simon
9. Energy for a Sustainable World: From the Oil Age to a Sun-Powered Future by Vincenzo Balzani and Nicola Armaroli