INDIAN INSTITUTE OF ENGINEERING SCIENCE AND TECHNOLOGY(IIEST), SHIBPUR

Department of Earth Sciences

Syllabus of BS-MS Course in Applied Geology

(As per NEP, 2020)
Approved by BOAC, 21st January, 2026
2025

Course Structure

First Semester

Sl. No.	Type	Course Name	Course code	Class Load/Week			Credit	Class load/ week	Marks
				L	T	P			
1	PC	Introduction to Earth System Science	ES1101N	4	0	0	4	4	100
2	PC	Geological mapping: techniques and tools	ES1171N	0	0	3	2	3	50
3	PM	Mathematics 1					4	4	100
4	VAC	Environmental Science (CE)					3		100
5	MDC	Physical and Chemical processes of the Earths interior	ES1161N				3	3	100
6	SEC	Theory (Departmental) / Practical (Departmental) / Introduction to Computing (CST)					3		50
7	AEC	English Language (HSS)					3		100
	Total						**22**		**600**

Second Semester

Sl. No	Type	Course Name	Course code	Class Load/Week			Credit	Class load/ Week	Marks
				L	T	P			
1	PC	Mineralogy and Geochemistry	ES1201N	4	0	0	4	4	100
2	PC	Hand specimen study of rocks and minerals	ES1271N	0	0	3	2	3	50
3	PM	Mathematics II		4	0	0	4	4	100
4	VAC	Well-beings and happiness (HSS)					3		100
5	MDC	Introduction to Optical and Microscopic properties of Minerals and rocks	**ES1261N**	3	0	0	3	3	100
6	SEC	Fieldwork	ES1272N				3		100
7	AEC	Language Course (HSS)					3		100
	Total						**22**		**650**

Third Semester

Sl. No	Type	Course Name	Course	Class Load			Credit	Class load	Marks
				L	T	P			
1	PC	Igneous Petrology	ES2101N	4	0	0	4	4	100
2	PC	Structural Geology I	ES2102N	4	0	0	4	4	100
3	PC	Optical Mineralogy and Microscopic study of Igneous rocks	ES2171N	0	0	3	2	3	50
4	PM	Mathematics III					4	4	100
5	MDC	Natural hazards and disaster mitigation	ES2161N	3	0	0	3	4	100
6	SEC	Mathematical geology and Geostatistics*	ES2172N	3	0	0	3	3	100
7	AEC	Structural Geology Practical I*	ES2173N	0	0	4	3	4	50
	Total						**23**		**600**

Fourth Semester

Sl. No	Type	Course Name	Course	Class Load/Week			Credit	Class load/ week	Marks
			Code	L	T	P			
1	PC	Metamorphic and Sedimentary Petrology	ES2201N	4	0	0	4	4	100
2	PC	Printiples of Stratigraphy and Engineering Geology	ES2202N	3	0	0	3	3	100
3	PC	Introduction to Hydrogeology and sustainable development	ES2203N	3	0	0	3	3	100
4	PC	Sedimentology and metamorphic Petrology Practical	ES2271N	0	0	3	2	3	50
5	PC	Fieldwork	ES2272N				2		50
6	PM	Mathematics IV		0	0	4	4	4	100
	Total						**18**		**500**

Fifth Semester

Sl. No	Type	Course Name	Course Code	Class Load/Week L	T	P	Credit	Class load/ week	Marks
1	PC	Principles of Palaeontology and Paleobiology	ES3101N	4	0	0	4	4	100
2	PC	Petroleum Geology, Coal Geology and Nuclear Fuels	ES3102N	4	0	0	4	4	100
3	PC	Tectonics and Physical Geology	ES3103N	4	0	0	4	4	100
4	PC	Structural Geology practical (II) and Palaeontology Practical	ES3171N	0	0	3	2	3	100
5	PM	Physics - I / Chemistry - I					4		100
6	PM	Physics - II / Chemistry - II					4		100
	Total						**22**	**15**	**600**

Sixth Semester

Sl. No	Type	Course Name	Course Code	Class Load/Week L	T	P	Credit	Class load/ week	Marks
1	PC	Ore Geology Metal and non-metal	ES3201N	4	0	0	4	4	100
2	PC	Indian Stratigraphy and boundary problems	ES3202N	4	0	0	4	4	100
3	PC	Solid Earth Geophysics	ES3203N	4	0	0	4	3	100
4	PC	Ore Geology practical and Fieldwork	ES3271N	0	0	3+field	2	3+field	100
5	PM	Physics - III / Chemistry - III		3	0	0	4	3	100
6	PM	Physics - IV / Chemistry - IV		3	0	0	4	3	100
7	I	Internship	ES3291N				2		50
	Total						**24**		**700**

Seventh Semester

Sl. No	Type	Course Name	Course Code	Class Load/Week L	T	P	Credit	Class load/ week	Marks
1	PC	Remote sensing, GIS, AI-Ml applications in Geosciences	ES4101N	4	0	0	4	4	100
2	PC	Environmental Geology and Marine Geology	ES4102N	4	0	0	4	4	100
3	PC	Coal and Mineral Beneficiation (from Mining)		3	0	0	3	3	100
4	PC	Coal and Mineral Beneficiation Practical (from Mining)		0	0	3	2	3	50
5	P	Term Paper /Literature Review	ES4191N				2		50**
6	P	Thesis Progress Report/Thesis Progress Report	ES4192N				2		50**
7	O	Seminar/Viva-voce	ES4193N				2		50**
Total (For Four Years UG Honours with Research)							**19**		**500**
8	PC	NPTL		3	0	0	3	3	100*
9	PC	NPTL		3	0	0	3	3	100*
Total (Total Credit for Four years UG Honours)							**21**		**450***

**For Four Years UG Honours with Research

*Only for Four years UG Honours

Eighth Semester

Sl. No	Type	Course Name	Course Code	Class Load/Week			Credit	Class load/ week	Marks
				L	T	P			
1	PC	Principles of Geophysical exlporations	ES4201N	4	0	0	4	4	100
2	PC	Hydrogeology II and Climatology	ES4202N	4	0	0	4	4	100
3	PC	Introduction to Exploration and Extraction of Critical minerals	ES4203N	4	0	0	4	4	100
5	P	Thesis Final Report/Thesis Progress Report	ES4291N				6		100**
6	O	Seminar/Viva-voce	ES4292N				2		50**
Total (For Four Years UG Honours with Research)							**20**		**450**
7	PC	NPTL		3	0	0	3	3	100*
8	PC	NPTL		3	0	0	3	3	100*
Total (Total Credit forFour years UG Honours)							**18**		**500**

**For Four Years UG Honours with Research

*Only for Four years UG Honours

Ninth Semester

Sl. No	Type	Course Name	Course Code	Class Load/Week			Credit	Class load/ week	Marks
				L	T	P			
1	PC	Structural Geology II and Basin Tectonics	ES5104N	4	0	0	4	4	100
2	PC	Sedimentary Facies Analysis and Sequence stratigraphy	ES5105N	4	0	0	4	4	100
3	PC	Application of Modern techniques in Petrology	ES5106N	4	0	0	4	4	100
4	P	Thesis Progress Report	ES5191N				4		100
5	O	Project Seminar	ES5192N				2		50
6	O	Viva-voce	ES5193N				2		50
7	P	Research Methodology					2		50
	Total						**22**		**550**

Tenth Semester

Sl. No	Type	Course Name	Course	Class Load/Week			Credit	Class load/ week	Marks
			Code	L	T	P			
1	PC	Mettalogeny and Hydrogeology (Part-III)	ES5204N	4	0	0	4	4	100
2	PC	Palaeontology, Palaeoclimatology and Isotope Geochemistry	ES5205N	4	0	0	4	4	100
3	P	Project Final Report	ES5293N				6		150
4	P	Project Final Seminar	ES5294N				4		100
5	O	Viva Voce	ES5295N				2		50
	Total						**20**		**500**
(i) One Year PG Degree for Four Years UG Degree Holders							**42**		**1050**
(ii) Two years PG degree for Three Years UG Degree Holders							**81**		**2000**

Type of Course

Program Core (PC)
Program Minor (PM)
Value Added Course (VAC)
Multidisciplinary Course (MDC)
Skill Enhance Course (SEC)
Ability Enhance Course (AEC)
Project (P)
Internship (I)
Other (O) such as seminar, viva voce, etc.

Detailed Course Content

FIRST SEMESTER

Course Code	ES1101N	Course Name	PC -I Introduction to Earth System Science	Course Category	PC	L	T	P
						4	0	0

Module	Syllabus	Duration (class-hour)
1	**Concept of Systems and Components. Introduction to various branches of Earth System Sciences.**	04
2	**Theories on origin and evolution of the Universe, the Solar system and its planets and satellites. Theories of origin of the Earth.**	06
3	**Meteorites and asteroids**	02
4	**Cosmic abundance of elements and distribution of elements in solar system and in Earth. Introduction to Isotopic age-dating of the Earth.**	10
5	**Earthquake, Seismic Waves and Earth's Interior.**	10
6	**Heat budget of the Earth, concept of Plate Tectonics**.	08
7	**Origin of atmosphere, ocean, and life**	06
8	**Introduction to the dynamic Earth**	04
Total		**52**

Learning Resources	
	• Grotzinger, J., Jordan, T.H., Press, F., Siever, R. (2007): Understanding Earth. W.H. Freeman & Co., New York, 5 th Ed. • Emiliani, C. (1992): Planet Earth: Cosmology, Geology, and the Evolution of Life and Environment. Cambridge University Press. Published in USA. • Skinner, B.J., Porter, S.C., Botkin, D.B. (1999): The Blue Planet – An Introduction to Earth System Science. John Wiley & Sons, Inc. New York. P.552. • Mathez, E.A. and Webster, J.D. (2004): The Earth machine – The Science of a Dynamic Planet. Columbia University Press, New York. P.335. • Duff, P. M. D., & Duff, D. (Eds.). (1993). Holmes' principles of physical geology. Taylor & Francis. • Gross, M. G. (1977). Oceanography: A view of the earth.

Course Code	ES1171N	Course Name	**PC -II** Geological mapping: techniques and tools	Course Category	PC	L	T	P
						0	0	3

Module	Syllabus	Duration (class-hour)
1	Introduction to Geological Mapping	4
2	Essential Field Tools & Equipment (Use of a geologic compass for measuring strike, dip, and trend. Utilize GPS devices and smartphone applications for accurate location and navigation in the field. Employ hand lenses, hardness kits, rock hammers, and field notebooks effectively).	6
3	Pre-Field Preparation & Introduction to Remote Sensing approach. (Interpret topographic maps, aerial photographs, and satellite imagery for terrain analysis. Create a base map and a fieldwork plan. Identify potential field areas, access routes, and safety considerations).	6
4	Field Observation & Data Collection (Accurately describe and classify lithological units in the field using standard terminology. Measure and record structural data. Collect representative rock samples and create precise field sketches and photographs).	8
5	Introduction to use of Symbols Notation & Plotting Field Data (Apply standard geological map symbols and notation. Plot structural measurements and lithological contacts accurately on a topographic base. Draft a preliminary field map with clear boundaries and a legend).	6
6	Introduction to Digital Mapping Tools (Operate a tablet or smartphone with mapping software for digital data capture. Integrate GPS data directly into a digital field map. Manage and organize digital field data efficiently).	8
7	Mapping in Different Terrains & Contexts (Adapt mapping techniques to challenges posed by specific terrains and surface cover. Design a mapping strategy suited to a specific geological question or industry need. Recognize and map superficial deposits and their relationship to bedrock).	6
8	Map Compilation, Interpretation & Report Writing (Compile and clean field data to produce a finalized geological map using illustration software (e.g., Adobe Illustrator, Inkscape and Coreldraw). Construct geological cross-sections that reflect subsurface interpretation.Write a professional field report that integrates observations, maps, sections, and a coherent geological history narrative).	8
Total		**52**

Learning Resources	• Coe, A. 2010. Geological Field Techniques. Wiley-Blackwell. • Ragan, D.2009. Structural Geology: An Introduction to Geometrical Techniques, Cambridge University Press.

						L	T	P
Course Code	ES1161N	**Course Name**	**MDC-I** Physical and Chemical processes of the Earth's interior	**Course Category**	PC	3	0	0

Module	Syllabus	Duration (class-hour)
1	**Earth's Internal Structure and Observational Foundations** Seismological probes: travel-time curves, velocity-depth profiles, seismic discontinuities (Moho, 410, 660, D" layer), and their mineralogical interpretations. Earth's density structure and moment of inertia: constraints on core composition. Gravity field, isostasy, and geoid anomalies as indicators of deep mantle density heterogeneity. Geomagnetism: generation of the main field, secular variation, and paleomagnetism as probes of core dynamics.	08
2	**Thermodynamics and Phase Equilibria of Deep Earth Materials** Review of thermodynamic potentials (G, H, S) relevant to high P-T. Phase rule and construction of phase diagrams for silicate and metallic systems. High-pressure mineralogy of the mantle: olivine-wadsleyite-ringwoodite, pyroxene-garnet transitions, perovskite and post-perovskite. Iron alloy phase relations in the outer and inner core. Melting relations in the mantle: solidus, liquidus, partial melting, and melt migration.	10
3	**Rheology and Deformation Mechanisms of the Mantle and Lithosphere** Concepts of stress, strain, and strain rate. Brittle vs. ductile deformation. Flow laws for diffusion creep, dislocation creep, and Peierls creep. The role of water, melt, and pressure on rheology. Lithospheric strength profiles and the concept of the elastic lithosphere vs. viscous asthenosphere. Seismic anisotropy as a marker of lattice-preferred orientation and mantle flow.	08
4	**Heat Transfer, Mantle Convection, and Geodynamics** Heat sources in Earth (radiogenic, primordial, latent heat). Conduction, convection, and advection. Fundamentals of fluid dynamics: Rayleigh number, Nusselt number. Styles of mantle convection (layered vs. whole mantle, plumes). Geodynamic models: driving forces of plate tectonics (ridge push, slab pull, mantle drag). Thermal evolution of the Earth. Physics of mantle plumes and hotspots.	10
5	**Chemical Differentiation and Geochemical Reservoirs** Bulk composition of the Earth (chondrite models). Isotope geochemistry (Rb-Sr, Sm-Nd, U-Pb, Hf-W systems) as tracers of differentiation and reservoir ages. Formation and evolution of the core, mantle, and crust. Concept of geochemical reservoirs: depleted mantle, continental crust, primordial	08

	reservoirs. Mantle geochemistry: MORB vs. OIB sources, evidence for mantle heterogeneity. Core-mantle interaction and geochemical plumes.	
Total		**52**

Learning Resources	• Turcotte, D.L. and Schubert, G. (2014). *Geodynamics*. 3rd Edition, Cambridge University Press. • Anderson, D.L. (2007). *New Theory of the Earth*. 2nd Edition, Cambridge University Press. • Poirier, J.P. (2000). *Introduction to the Physics of the Earth's Interior*. 2nd Edition, Cambridge University Press. • Fowler, C.M.R. (2005). *The Solid Earth: An Introduction to Global Geophysics*. 2nd Edition, Cambridge University Press. • Albarede, F. (2009). *Geochemistry: An Introduction*. 2nd Edition, Cambridge University Press. • Philpotts, A. and Ague, J. (2022). *Principles of Igneous and Metamorphic Petrology*. 3rd Edition, Cambridge University Press.

SECOND SEMESTER

Course Code	ES1201N	**Course Name**	**PC-III** Mineralogy and Geochemistry	**Course Category**	PC	L	T	P
						4	0	0

Module	**Syllabus**	**Duration (class-hour)**
1	**Crystallography:** Crystal--Concept of crystalline matter; Interfacial angle and external morphology in relation to internal structures; Crystal parameters and indices; form and zone. Stereographic projection of crystal faces. Crystal symmetry, classification of crystals into systems and point groups. International symbol of point groups	10
2	**Mineral structure:** Atomic arrangements: Unit cell, CCP, FCC and HCP; Ionic radius and coordination, Pauling's rules. Solid Solution, Polymorphism, Pseudomorphism; Twining. Crystal Field Theory and its application	5
3	**Rock forming minerals:** Minerals - definition and classification, physical and chemical properties; Chemical classification of minerals; Internal structure, classification and Composition of common rock-forming minerals (silicates); Derivation of structural formulae based on composition	10
4	**Basic Concepts of Geochemistry**: Introduction to properties of elements: Meteorite-classification and significance; Chemical	3
5	**Layered Structure of Earth and Geochemistry:** Composition of the bulk silicate Earth; Composition of core; Composition of mantle: depleted mantle and enriched mantle; Composition of crust: Continental and Oceanic	6

6	**Element transport:** Advection and diffusion; Aqueous geochemistry- basic concepts and application in geological processes like Weathering, diagenesis & hydrothermal system; Eh, pH relation; Elements of marine chemistry; Geochemical behaviour of elements.	8
7	**Geochemistry of solid Earth:** Geochemical behaviour of elements during magmatic crystallization, partial melting; Concept of partition coefficient (Kd), compatible and incompatible elements; REE-essential characters, behaviour and importance	8
8	**Introduction to isotope geology:** use of stable and radiogenic isotopes in Earth science.	2
Total		**52**

Learning Resources	• Klein, C., Dutrow, B., Dwight, J., & Klein, C. (2007). The 23rd Edition of the Manual of Mineral Science (after James D. Dana). J. Wiley & Sons. • Deer, W. A., Howie, R. A., & Zussman, J. (1992). An introduction to the rock-forming minerals (Vol. 696). London: Longman. • Putnis, A. (1992): Introduction to Mineral Sciences. Cambridge University Press. • Nesse, W.D., 2000, Introduction to Mineralogy, Oxford University Press, New York, 442 p. • Mason, B. (1986). Principles of Geochemistry. 3rd Edition, Wiley, New York. • Rollinson, H. (2007). Using geochemical data – evaluation, presentation and interpretation. 2nd Edition. Publisher Longman Scientific and Technical. · Walther, J. V. (2009). Essentials of geochemistry. Jones and Bartlett Publishers. · • Albarède, F. (2003). Geochemistry: an introduction. Cambridge University Press. · • Faure, Gunter and Teresa M. Mensing (2004). Isotopes Principles and Applications. Wiley India Pvt. Ltd • Killops S.D., Killops V.J. 2005. An introduction to organic geochemistry. 2nd ed. Blackwell Publishing, Malaysia

						L	T	P
Course Code	ES1271N	**Course Name**	**PC-IV** Hand specimen study of rocks and minerals	**Course Category**	PC	0	0	3

Module	**Syllabus**	**Duration (class-hour)**	**Module outcome**
1	Study of the symmetry of crystals. Stereographic projection of crystals.	15	Students will gain hands on experience on the crystallography
2	Study of physical properties of common rock-forming minerals: silicates, Sulphides, Sulphates, carbonates, oxides etc	24	Students will learn to identify various minerals
Total		**39**	

Learning Resources	• Deer, W. A., Howie, R. A., & Zussman, J. (1992). An introduction to the rock-forming minerals (Vol. 696). London: Longman • Perkins, D., 1998. Mineralogy. Begin, 17, pp.17-38. • Dana, J.D., 2022. Manual of mineralogy. BoD–Books on Demand. • Cornelis Klein and Barbara Dutrow, The manual of Mineral Science, Wiley Publication 2007

						L	T	P
Course Code	ES1261N	**Course Name**	**MDC-II** Introduction to Optical and Microscopic properties of Minerals and rocks	**Course Category**	PC	3	0	0

Module	**Syllabus**	**Duration (class-hour)**
1	Description of petrological microscope and the working principle	3
2	Introduction to mineral crystallography	5
3	Study of optical properties of common rock-forming minerals: quartz, Feldspar,pyroxene, hornblende, staurolite, garnet, muscovite, biotite, calcite, tourmaline.	31
Total		39

Learning Resources	• Nesse, W. D. (2011). Introduction to Optical Mineralogy (Fourth Edition). Oxford University Press. • Verma, P. K. (2010). Optical Mineralogy (Four Colour). Ane Books Pvt Ltd. • Whalstrom, E.E. (1969): Optical Crystallography. John Wiley & Sons

Course Code	ES1272N	Course Name	SEC-II Feildwork	Course Category	PC	L	T	P
						4	0	0

Module	Syllabus	Duration (class-hour)
	Mandatory Field work for one week duration at any suitable place in India	1 week
Total		**52**

Learning Resources	• Coe, A. 2010. Geological Field Techniques. Wiley-Blackwell. • Ragan, D.2009. Structural Geology: An Introduction to Geometrical Techniques, Cambridge University Press.

THIRD SEMESTER

Course Code	ES2101N	Course Name	PC – V Igneous Petrology	Course Category	PC	L	T	P
						4	0	0

Module	Syllabus	Duration (class-hour)
1	**Introduction to Igneous Petrology:** Magma generation in the crust and upper mantle. Physical properties of magma - temperature, viscosity, density and volatile content. Modes of emplacement of igneous rocks: volcanic, hypabyssal, plutonic	5
2	**Forms, Igneous rock bodies**: Texture and Structures of igneous rocks. Forms of Igneous rock bodies. Mode of occurrence of igneous rocks.	4
3	**Classification and Petrographical analysis of Igneous Rocks:** Bases of classification of igneous rocks: mineralogical, textural, chemical, chemico-mineralogical and associational. Norm and mode. Standard classification. Composition and texture of important igneous rocks.	6
4	**Phase Diagrams:** Gibbs Phase Rule and Cryoscopic Equation: application to magmatic crystallization to eutectic, peritectic and solid solution system. Phase equilibria in the following binary and ternary systems under high dry and wet pressure with respect to their nature under low pressure (1 atmosphere), and their petrogenetic significance: diopside – anorthite, forsterite – silica, albite – anorthite, albite – orthoclase, diopside – albite – anorthite, forsterite – diopside – silica and nepheline - kalsilite – silica	15
5	**Diversification of igneous rock and Mantle Petrology:** Bowen's reaction Series and its application, Magmatic differentiation- fractional crystallization, partial melting, assimilation and their role in magmatic differentiation. Bi-variate and tri-variate chemical variation diagram.	4

6	**Petrogenesis of Igneous Rocks:** Petrogenesis felsic and mafic igneous rocks: granitoids (I-, S-, M-, and A-type), basalt, gabbros, anorthosite, alkaline rocks, kimberlites	8
7	**Magmatism in the following plate tectonic settings-** **i)**Mid Oceanic Ridge setting ii)Subduction Zone setting iii)Continental and oceanic rift zone	2
8	**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.	8
Total		**52**

Learning Resources	• Frost, B. R. and Frost, C. D., (2013) Essentials of Igneous and Metamorphic Petrology Cambridge University Press. • Philpotts, A., & Ague, J. (2009). Principles of igneous and metamorphic petrology. Cambridge University Press. • Winter, J. D. (2014). Principles of igneous and metamorphic petrology. Pearson. • Rollinson, H. R. (2014). Using geochemical data: evaluation, presentation, interpretation. Routledge. • Sen, G. (2014) Petrology Principles and Practice, Springer-Verlag Berlin Heidelberg • Bose M.K. (1997). Igneous Petrology. • Wilson, M. (1989) Igneous Petrogenesis, Springer-Verlag Berlin Heidelberg.

Course Code	ES2102N	**Course Name**	**PC-VI** Structural Geology I	**Course Category**	PC	L	T	P
						4	0	0

Module	**Syllabus**	**Duration (class-hour)**
1	**Fundamentals of Structural Geology & Orientation Analysis** Scope of structural geology vs. tectonics; Linear & planar structures; Measurement and representation of orientation (strike, dip, pitch, plunge); Introduction to diastrophic vs. non-diastrophic structures; Primary structures and unconformities; Principles of structural analysis at different scales.	6
2	**Stress: The Driver of Deformation** Concept of stress; Normal stress, shear stress, and the stress tensor; Stress at a point (stress ellipse); Principal stresses and axes; Differential, isotropic, and deviatoric stress; Mohr's circle for stress.	6
3	**Strain: The Result of Deformation** Deformation components (translation, rotation, strain); Longitudinal, shear, and volumetric strain; The strain ellipsoid and its axes; Homogeneous vs. inhomogeneous, rotational vs. irrotational strain; Finite vs. infinitesimal strain;	6

	Strain ellipsoid types (Flimn & Ramsay diagrams); Coaxial vs. non-coaxial deformation.	
4	**Rock Rheology & Deformation Mechanisms** Brittle and ductile deformation; Rheological models (elastic, viscous, plastic); Factors controlling rock behavior: confining pressure, temperature, strain rate, fluid presence, and composition.	6
5	**Folds: Anatomy, Geometry, and Genesis** Morphology and elements of a fold; Geometric, morphological, and genetic classifications; Ramsay's fold classification; Outcrop patterns of folds; Relationship between minor and major folds; Mechanisms of folding (buckling, bending, flexural slip/flow).	6
6	**Foliation, Lineation, and Fabric Analysis** Penetrative vs. non-penetrative structures; Rock cleavage and its types; Morphological classification of foliation (cleavage, schistosity, gneissosity); Types of lineation; Relationship of foliation and lineation to folds.	6
7	**Fractures, Faults, and Andersonian Theory** Fracture types: joints, shear fractures, and faults; Fault zone terminology and rocks; Geometric and kinematic classification of faults; Criteria for fault recognition; Anderson's theory of faulting; Characteristics of normal, thrust/reverse, and strike-slip fault systems.	6
8	**Shear Zones & Kinematic Analysis** Basic concepts of shear zones; Contrast with brittle faults; Classification of shear zones; Shear zone rocks (mylonites); Introduction to kinematic indicators (e.g., S-C fabric, rotated porphyroclasts, mica fish).	10
Total		**52**

Learning Resources	• Davis, H.G, Reynolds, S.J, Kluth, C. F. (2011), Structural Geology of Rocks and Region, John Wiley • Ragan, D. M. (2009) Structural Geology: an introduction to geometrical techniques (4th. Ed.) Cambridge University Press (For Practical) • Twiss, R. J. and Moores, E. M (2007) Structural Geology, Second Edition. W. H. Freeman and Company. • Fossen, H (2010), Structural Geology, Cambridge University Press. • Marshak, S and Mitra G. (1988) Basic Methods in Structural Geology, Prentice Hall. • Ben A. van der Pluijm and Stephen Marshak (2004) Earth Structure: An Introduction to Structural Geology and Tectonics (Second Edition) 2nd Edition • Ghosh, S.K., 1993. Structural Geology: Fundamentals, and modern developments, Pergamon Press. • Passhier, C. and Trouw, RAJ, 2005. Microtectonics. Springer, Berlin. • Ramsay, J.G and Huber, M.I., 1983. Techniques of Modern Structural Geology: Vol.I & 11. Academic Press • Ramsay, J. G, 1967. Folding and Fracturing of Rocks, McGraw-Hill Book Company, New York.

						L	T	P
Course Code	ES2171N	**Course Name**	**PC VII (P)** Optical Mineralogy and Microscopic study of Igneous rocks	**Course Category**	PC	0	0	3

Module	**Syllabus**	**Duration (class-hour)**
1	Description of petrological microscope and the working principle	3
2	Study of optical properties of common rock-forming minerals: quartz, Feldspar,pyroxene, hornblende, staurolite, garnet, muscovite, biotite, calcite, tourmaline.	15
3	Study of important igneous rocks thin sections under microscope- granite, granodiorite, diorite, gabbro, anorthosites, ultramafic rocks, basalts, andesites, trachyte, rhyolite.	15
2	Classification of Igneous Rocks. Plotting and interpretation of variation diagrams. NORM calculation	6
Total		**39**

Learning Resources	
	• Nesse, W. D. (2011). Introduction to Optical Mineralogy (Fourth Edition). Oxford University Press. • Verma, P. K. (2010). Optical Mineralogy (Four Colour). Ane Books Pvt Ltd. • Whalstrom, E.E. (1969): Optical Crystallography. John Wiley & Sons Deer, W.A., 1978. Rock-forming minerals. Geological Society of London. • Perkins, D., 1998. Mineralogy. Begin, 17, pp.17-38. • Dyar, M.D., Gunter, M.E. and Tasa, D., 2008. Mineralogy and optical mineralogy (p. 708). Chantilly, VA: Mineralogical Society of America. • Dana, J.D., 2022. Manual of mineralogy. BoD–Books on Demand. • RAITH, M.M. and RAASE, P., THIN SECTION MICROSCOPY. • Shelley, D., 1985. Optical mineralogy.

Course Code	ES2161N	Course Name	**MDC III** Natural Hazard and Disaster mitigation	Course Category	PC	L	T	P
						3	0	0

Module	Syllabus	Duration (class-hour)
1	**Natural Hazard :** Introduction to natural hazard, Effects of hazards: Primary, secondary and tertiary	5
2	**Mass movement with special emphasis on landslides and causes of hillslope instability.** Identification of landslide prone areas; Flood hazard: Management. Zoning and risk assessment: Hazard Zonation maps.	8
3	**Seismic hazards**: Earthquake and seismicity, Causes and prediction; Seismic zones of India. Aseismic design of buildings. Influence of geological condition on foundation and design of buildings.	8
4	**Water crisis in global and Indian perspective**. Drought. Introduction to drought prone areas.	8
5	**Floods**: Causes, types of floods, Impact, monitoring and mitigation of flood, Flood hazard: Management. Flood hazard Zoning and risk assessment	8
7	**Understanding the Disasters Mitigation**: Hazards, Disasters, Vulnerability, Resilience, Disaster Management and Cycle, Prevention, Risk, Mitigation, Relief and Response, Recovery and Rehabilitation.	7
8	**Disaster management in India and world**. Role of i) social sciences, ii) natural sciences in disaster management. Disaster as multidisciplinary subject	8
Total		**52**

Learning Resources	
	• Edward A Keller and Robert H Blodgett. 2008. Natural hazards. Pearson Prentice Hall, 488p. • Donald Hyndman and David Hyndman. 2009. Natural hazards and disasters. Brooks/Cole. 555p. • Bankoff, G., Frerks, G. and Hilhorst, D. 2004. (eds.) Mapping Vulnerability: Disasters, Development, and People, Earthscan, London. • Birkmann, J. 2007. "Risk and vulnerability Indicators at Different Scales: Applicability, Usefulness and Policy Implications", Environmental Hazards, 7 (1): 20-31.

Course Code	ES2172N	Course Name	SEC III Mathematical geology and Geostatistics	Course Category	PC	L	T	P
						3	0	0

Module	Syllabus	Duration (class-hour)
1	**Core Mathematical Tools for Geology** Review of trigonometry: applications in map calculations, dip and strike problems, and three-dimensional geometry. Fundamentals of differential calculus: concept of the derivative, rules of differentiation, application to rates of change in geological processes (e.g., cooling rates, sedimentation rates). Fundamentals of integral calculus: the definite integral as a tool for calculating area, volume, and total accumulation from rate functions.	10
2	**Probability Theory for Earth Sciences** Basic probability concepts relevant to geology: Binomial, Poisson, Normal (Gaussian), and Log-Normal distributions. Applications in hazard assessment, resource estimation, and data interpretation.	06
3	**Descriptive Statistics & Data Visualization in Geology** Types of geological data. Measures of central tendency, dispersion, skewness, and kurtosis. Graphical representation of data: histograms, frequency curves, scatter plots, and ternary diagrams.	10
4	**Inferential Statistics & Hypothesis Testing** Sampling theory and the Central Limit Theorem. Confidence intervals. Formulation of null and alternative hypotheses. Parametric tests: t-tests (one-sample, two-sample) and introduction to Analysis of Variance (ANOVA). Non-parametric tests: Chi-square test and Mann-Whitney U test.	14
5	**Correlation, Regression, and Multivariate Concepts** Covariance and correlation coefficients (Pearson's r). Simple linear regression: model fitting, goodness-of-fit (R^2), residual analysis. Introduction to the concepts of multiple regression and multivariate data analysis in geology.	06
6	**Introduction to Geostatistics** The regionalized variable theory; limitations of classical statistics for spatial data. Spatial autocorrelation and the variogram: calculation, interpretation, and model fitting (spherical, exponential). Basic principles of kriging as a spatial interpolation technique.	06
Total		**52**

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

Course Code	ES2173N	Course Name	**AEC III** Structural Geology Practical I	Course Category	PC	L	T	P
						0	0	3

Module	Syllabus	Duration (class-hour)
1	The Stereographic Projection: A 3D Toolkit Principles of the stereonet (equal-area/equal-angle). Plotting planar data (poles, great circles) and linear data. Performing rotations about horizontal and inclined axes. Determining angles between lines and planes. Solving for the intersection of two planes and the plane containing two lines.	10
2	Solving Structural Problems: 3-Point and Fold-Fault Analysis 3-Point Problem**:** Determining the strike and dip of a plane from three points of known location and elevation using both graphical (orthographic) and stereographic methods. Fold-Fault Problems: Graphical and stereographic techniques to determine fault displacement, reconstruct folded layers, and calculate missing stratigraphic section across faults.	10
3	Advanced Applications: Borehole Data and Rotational Analysis Determining the true orientation of planar structures (bedding, fractures) intersected by inclined boreholes. Rotational Problems**:** Analyzing complex rotations of fault blocks or folded layers. Synthesizing multiple data sets (borehole, surface) to construct a consistent cross-section and validate structural interpretations.	10
4	Foundation: Topographic Maps and Basic Geometry Introduction to topographic maps: contour interpretation, scale, relief. Calculating gradients. Understanding the relationship between topography and geological outcrop patterns. Introduction to basic structural geometry: true dip, apparent dip, and thickness.	10
Total		**40**

Learning Resources	
	• Davis, H.G, Reynolds, S.J, Kluth, C. F. (2011), Structural Geology of Rocks and Region, John Wiley • Ragan, D. M. (2009) Structural Geology: an introduction to geometrical techniques (4th. Ed.) Cambridge University Press (For Practical) • Twiss, R. J. and Moores, E. M (2007) Structural Geology, Second Edition. W. H. Freeman and Company. • Fossen, H (2010), Structural Geology, Cambridge University Press. • Marshak, S and Mitra G. (1988) Basic Methods in Structural Geology, Prentice Hall. • Ben A. van der Pluijm and Stephen Marshak (2004) Earth Structure: An Introduction to Structural Geology and Tectonics (Second Edition) 2nd Edition

FOURTH SEMESTER

Course Code	ES22O1N	Course Name	PC VIII Metamorphic and Sedimentary Petrology	Course Category	PC	L	T	P
						4	0	0

Module	Syllabus	Duration (class-hour)
1	**Metamorphism: controls and types** Definition of metamorphism Factors controlling metamorphism Types of metamorphism: contact, regional, fault zone metamorphism, impact metamorphism	2
2	**Metamorphic Facies and Grades** Index minerals, metamorphic zones and isograds. Concept of metamorphic facies and grade Composition-paragenesis diagrams. ACF, AKF and AFM diagrams	4
3	**Metamorphism and deformation** Structure and textures of metamorphic rocks. Relationship between metamorphism and deformation.	4
4	**Metamorphic reactions** Types of metamorphic reactions Kinetics of metamorphic reactions Metamorphic fluid and metasomatism Progressive metamorphism of pelitic, basic and carbonate rocks	12
5	**Quantification of metamorphic processes** Geothermobarometry PTt path Ultrahigh temperature (UHT) and ultrahigh pressure (UHP) metamorphism Anatexis and migmatites Partial melting of crustal rocks	4
6	**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.	4
7	**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.	4

8	**Carbonate Sedimentary Environments. Paleoenvironment analysis:** Application of radioactive and stable isotopes in reconstruction of paleoenvironments.	12
9	**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.	6
Total		**52**

Learning Resources	• Shelly, D., 1993. Igneous and metamorphic rocks under microscope Chapman and Hall. • Fry, N., 2013. The field description of metamorphic rocks. John Wiley & Sons. • Miyashiro, A., 1994. Metamorphic petrology. Crc Press. • Winter, J.D., 2014. Principles of igneous and metamorphic petrology (Vol. 2). Harlow, UK: Pearson education. • Vernon, R.H. and Clarke, G.L., 2008. Principles of metamorphic petrology. Cambridge University Press. • Philpotts, A.R. and Ague, J.J., 2009. Principles of igneous and metamorphic petrology. Cambridge University Press. • Frost, B.R. and Frost, C.D., 2019. Essentials of igneous and metamorphic petrology. Cambridge University Press. • Best, M.G., 2002. Igneous and metamorphic petrology. John Wiley & Sons. • Spear, F.S., Pattison, D.R. and Cheney, J.T., 2017. The metamorphosis of metamorphic petrology. • Mason, R. and Mason, R., 1990. Petrology of the metamorphic rocks (p. 230). London: Unwin Hyman. • Tyrrell, G.W., 2012. The principles of petrology: an introduction to the science of rocks. Springer Science & Business Media. • Kornprobst, J., 2002. Metamorphic rocks and their geodynamic significance: a petrological handbook. Springer Science & Business Media. • Sedimentary Environments: Processes, Facies and Stratigraphy H. G. Reading. • Sedimentary Petrology by M. E. Tucker. • Approaches to Interpretation of Sedimentary Environments by Douglas J. Cant and F. J. Hein. • Applied Sedimentology by Richard C. Selley. • Principles of Sedimentology and Stratigraphy by Sam Boggs Jr. • The Evolution Of Clastic Sedimentology by Hakuyu Okada and Alec Kenyon-Smith • Basin Analysis: Principles and Applications by P.A. Allen and J. R. Allen. • Principles of sedimentary basin analysis by A.D. Miall.

Course Code	ES2202N	Course Name	PC IX Principle of Stratigraphy and Engineering Geology	Course Category	PC	L	T	P
						4	0	0

Module	Syllabus	Duration (class-hour)
1	**Introduction to Stratigraphy and the Geological Time Scale** Definition, scope, and historical development of stratigraphy. Principles of stratigraphy: Original horizontality, Superposition, Lateral continuity, Cross-cutting relationships, Faunal succession. The Geological Time Scale: Eons, eras, periods, epochs; absolute vs. relative dating.	4
2	**Lithostratigraphy and Facies Analysis** Lithostratigraphic classification: Formation, Member, Group, Supergroup. Concepts of facies and sedimentary environments. Walther's Law.	6
3	**Biostratigraphy and Chronostratigraphy** Principles of biostratigraphy: Index fossils, zones (biozones). Introduction to chronostratigraphy: Global Standard Stratigraphic Age (GSSA) and Global Boundary Stratotype Section and Point (GSSP). Overview of geophysical correlation methods (seismic, well-log).	6
4	**Unconformities, Sequence Stratigraphy, and Applied Stratigraphy** Types and significance of unconformities. Basic concepts of sequence stratigraphy: systems tracts, sequence boundaries. Introduction to applied stratigraphy in hydrocarbon and groundwater exploration.	8
5	**Introduction to Engineering Geology and Site Investigation** Scope and importance of engineering geology. Stages of site investigation: desk study, reconnaissance, subsurface exploration (boreholes, geophysics).	6
6	**Engineering Properties of Earth Materials** Physical and mechanical properties of rocks and soils: density, porosity, permeability, strength, deformability. Rock mass classification systems (RMR, Q-system). Soil classification (USCS).	8
7	**Groundwater, Subsidence, and Foundation Geology** Groundwater flow, aquifer properties, and engineering impacts (seepage, uplift). Causes and mitigation of land subsidence. Geological considerations for foundation design: bearing capacity, settlement, and selection of foundation type.	6
8	**Geohazards and Slope Stability** Types of geohazards: landslides, earthquakes, sinkholes. Slope stability analysis: factors of safety, causes of failure, and basic stabilization methods. Seismic hazards and liquefaction.	8
Total		**52**

Learning Resources	
	• Principles of Sedimentology and Stratigraphy by Sam Boggs Jr. • Gary Nicols, Sedimentology and Stratigraphy, ISBN: 978-1-119-41727-9 • Stratigraphy: A Modern Synthesis — *Andrew D. Miall* • Engineering Geology — *D. V. Reddy*

	• Engineering Geology — *Subinoy Gangopadhyay* • Engineering Geology — *Dieter D. Genske* (Springer Textbooks)

						L	T	P
Course Code	ES2203N	**Course Name**	**PC X** Introduction to Hydrogeology and Sustainable Development	**Course Category**	PC	4	0	0

Module	**Syllabus**	**Duration (class-hour)**
1	**Water on Earth & The Hydrologic Cycle:** Global water distribution; Components and processes of the hydrologic cycle; Groundwater as a key reservoir; Water balance equation.	10
2	**Geology of Groundwater & Aquifer Properties:** Subsurface distribution of water; Aquifer types (unconfined, confined); Porosity, Specific Yield, Specific Retention; Permeability and Hydraulic Conductivity.	09
3	**Principles of Groundwater Flow:** Darcy's Law: derivation, assumptions, and applications; Hydraulic head and gradient; Transmissivity and Storativity; Introduction to groundwater flow direction analysis.	09
4	**Groundwater & Sustainable Development:** UN Sustainable Development Goals; Concepts of water security and Integrated Water Resources Management; Introduction to watershed management, rainwater harvesting, and artificial recharge.	10
5	**Groundwater Resources of India:** Overview of major groundwater provinces of India; Focus on the hydrogeology of West Bengal; Current challenges and management issues.	14
Total		**52**

Learning Resources	• Todd, D.K. and Mays, L.W. (2005). *Groundwater Hydrology*. 3rd Edition, John Wiley & Sons. • Fetter, C.W. (2018). *Applied Hydrogeology*. 4th Edition, Waveland Press. • Raghunath, H.M. (2007). *Ground Water*. 3rd Edition, New Age International Publishers. • Gleick, P.H. et al. (2014). *The World's Water Vol. 8: The Biennial Report on Freshwater Resources*. Island Press.

Course Code	ES2271N	Course Name	PC XI (P) Sedimentology and Metamorphic Petrology Practical	Course Category	PC	L	T	P
						0	0	3

Module	Syllabus	Duration (class-hour)
1	**Metamorphic Petrology** Studies of petrography of common metamorphic 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.	19
2	**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	20
Total		39

Learning Resources	
	o Shelly, D., 1993. Igneous and metamorphic rocks under microscope Chapman and Hall. o Fry, N., 2013. The field description of metamorphic rocks. John Wiley & Sons. o Miyashiro, A., 1994. Metamorphic petrology. Crc Press. o Winter, J.D., 2014. Principles of igneous and metamorphic petrology (Vol. 2). Harlow, UK: Pearson education. o Vernon, R.H. and Clarke, G.L., 2008. Principles of metamorphic petrology. Cambridge University Press. o Adams, A.E., MacKenzie, W.S. and Guilford, C., 2017. Atlas of sedimentary rocks under the microscope. Routledge. o Boggs Jr, S., 2009. Petrology of sedimentary rocks. Cambridge university press. o Korte, D., Kaukler, D., Fanetti, M., Cabrera, H., Daubront, E. and Franko, M., 2017. Determination of petrophysical properties of sedimentary rocks by optical methods. Sedimentary Geology, 350, pp.72-79. o Tucker, M.E., 2011. Sedimentary rocks in the field: a practical guide. John o Wiley & Sons.

Course Code	ES2272N	Course Name	PC XII (P) Field Work	Course Category	PC	L	T	P
						0	0	3

Module	Syllabus	Duration (class-hour)
	Field Orientation & Preliminary Data Collection Introduction to the topographic map (toposheet) of the field area: understanding contours, scale, landmarks, and coordinate systems. Using compass and GPS for location plotting and navigation. In-field identification of major rock types (igneous, sedimentary, metamorphic) and their preliminary classification. Techniques for systematic field observation, note-taking, and sketching of outcrops. Measurement of basic planar features (bedding) using a clinometer compass.	1 week
	Geological Map Construction & Plane Paper Mapping Principles of geological mapping: tracing contacts, identifying markers, understanding outcrop patterns. Techniques for plotting geological data directly onto a base map in the field. Introduction to plane paper mapping Plotting lithological boundaries and structural symbols on a plane paper map. Drafting a clean field map and creating a legend**.**	
	Structural Data Analysis & Synthesis Detailed measurement and recording of structural data: joints, faults, cleavage, and fold axes. Techniques for analyzing structural relationships in the field (overprinting, cross-cutting). Preparation of a structural data summary: rose diagrams for joints, stereographic projections (beta/gamma diagrams) for folds and faults. Integration of lithological and structural data to draft a final geological map and a representative cross-section. Writing a concise geological summary report interpreting the history of the area.	
Total		**1 week**

Learning Resources	• Geological Field Techniques by Angela L. Coe et al. • Basic Geological Mapping by John W. Barnes and Richard J. Lisle. • Maps and guidebooks of the specific field area.

FIFTH SEMESTER

Course Code	ES3101N	Course Name	PC XIII Principles of Palaeontology and Palaeobiology	Course Category	PC	L	T	P
						4	0	0

Module	Syllabus	Duration (class-hour)
1.	Definition and significance of fossils, Historical development of palaeontology, Nature of fossil record, Fossilization process- its types and condition	5
2.	Principles of paleontology vis-à-vis paleobiology; Species concept and speciation. Species problem in paleontology, bio, chrono, and morphospecies, Concepts of Linnean, Numerical and Cladistic Taxonomy, Outline of molluscan coiling, growth rate.	7
3.	Adaptation and functional morphology; Mechanism of evolution; Major Mass Extinction Events of Earth's history. Palaeobiogeography, Taphonomy, Major Mass Extinction Events of Earth's history.	7
4.	Identifying morphology and Functional morphology and evolutionary history of Brachiopoda, Mollusks and Echinoids. Variations in pedicle opening in brachiopods, variation in occulogenital system and ambulacralplates in echinoids. Evolution and ecology of corals.	7
5.	Brief morphology, classification, evolution of foraminifera, Ostracoda, Radiolaria, Conodonts and their significance; dinoflaggellates and their significance, Morphology, classification of diatom and calcareous nannofossil.	7
6.	Morphology of plant fossil, use of plant fossil, Evolution of land floras, Gondwana flora, Palynology including spore/pollen morphology and their application.	7
7.	Vertebrate body plan, major evolutionary events of vertebrates; evolution of Horses, Elephant, Hominid.	7
8.	Trace fossils: kinds, classification and their significance in palaeoenvironmental analysis.	5
Total		**52**

Learning Resources	
	• Alfred R. Loeblich, Jr. and Helen Tappan(1998):Foraminiferal Genera and their classification: Van Nostrand Reinhold Company, New York • Arnold (2002): Quaternary Environmental Micropaleontology (Ed. Simon K. Haslett), Oxford niversity Press, New York. • B.K.Sengupta: Modern Foraminifera • Benton, M.J. (1990): Vertebrate Paleontology. Unwin Hyman, Lindon. • Bignot, G., Grahm and Trottman (1985): Elements of Micropaleontology, London • Boardman, R.S., Cheethan, A.M. and Rowell, A.J. (1988): Fossil Invertebrates, Blackwell • Clarksons, E.N.K. (1998): Invertebrate Paleontology and Evolution, Allen and Unwin, London. • Colbert, E.H. (1984): Evolution of Vertebrates. Willey Eeastern Ltd.

	• Glaessner. N.(1944) :Principles of Micropaleontology,Melbourne • Haynes,J.R; 1981: Foraminifera, John Wiley • Jones, D..J. Introduction to Microfossils:,Cambrigde University press • M. Brasier: Micropaleontology, Blackwell • Raup, D.M. and Stanley, S.M (2008): Earth System History, Blackwell Publ.

						L	T	P
Course Code	ES3102N	**Course Name**	**PC XIV** Petroleum Geology, Coal Geology and Nuclear Fuels	**Course Category**	PC	4	0	0

Module	Syllabus	Duration (class-hour)
1	**Fundamentals of Petroleum Systems: From Organics to Hydrocarbons** Introduction to Fuel Geology. Physico-chemical properties and composition of crude oil & natural gas. Source Rocks: types, organic facies, and geochemical indicators (TOC, Rock-Eval pyrolysis). Diagenesis and thermal maturation of organic matter: formation of kerogen types, catagenesis, and thermal cracking. Concepts of the oil window and gas window. Introduction to basin modeling for hydrocarbon generation.	8
2	**Reservoir Geology, Traps, and Hydrocarbon Entrapment** Reservoir rock characteristics: porosity (primary, secondary) and permeability, pore geometry, capillary pressure. Reservoir fluids: oil, gas, and water properties (API gravity, GOR, formation water salinity). Fluid contacts and pressure regimes (overpressure). Migration: primary and secondary mechanisms. Traps: detailed classification of structural (anticlines, faults), stratigraphic (unconformities, pinch-outs), and combination traps. Seal rocks and their effectiveness.	10
3	**Petroleum Exploration, Drilling, and Production** Surface and subsurface indications of hydrocarbons. Exploration methods: geological mapping, seismic acquisition/interpretation, gravity-magnetic surveys. Drilling technology: well types, rig components, drilling fluids. Well logging: principles and interpretation of electric, sonic, nuclear, and imaging logs for formation evaluation. Formation tests. Introduction to reservoir development and enhanced oil recovery (EOR). Overview of unconventional resources (shale gas, tight oil).	10
4	**Coal Geology: Formation, Petrology, and Utilization** Definition and basic types of coal. Peat formation and depositional environments (mires). Coalification: biochemical and geochemical stages, rank advancement (lignite to anthracite). Coal petrology: macerals (inertinite, liptinite, vitrinite), microlithotypes, and reflectance as a rank indicator. Industrial classification of coal. Coal characterization for beneficiation and end-use (coking, power generation). Environmental aspects of coal use. Coalbed Methane (CBM): origin, reservoir characteristics, and extraction methods.	12
5	**Nuclear Fuel Geology** Radioactive minerals: Uranium (Uraninite, Pitchblende) and Thorium (Monazite) mineralogy and geochemistry. Mode of occurrence: magmatic, hydrothermal, sedimentary (sandstone-type, unconformity-related), and placer deposits. Principles of radioactivity detection and measurement	6

	(geiger counters, scintillometers, gamma-ray spectrometry). Radiometric surveying and logging.	
6	**Indian Context and Global Perspectives** Global and Indian petroleum basins: tectonic classification and productivity. Detailed geology of major Indian petroliferous basins (e.g., Bombay Offshore, Assam Shelf, Krishna-Godavari). Coal deposits of India: stratigraphic and geographic distribution; geology of important coalfields (Jharia, Raniganj). Distribution of radioactive minerals in India. Current production, reserves, future prospects, and economic and policy challenges for all three fuel sectors in India.	6
Total		**52**

Learning Resources	• Selley, R.C. and Sonnenberg, S.A. (2014). *Elements of Petroleum Geology*. 3rd Edition, Academic Press. • Gluyas, J. and Swarbrick, R. (2004). *Petroleum Geoscience*. Blackwell Publishing. • Thomas, L. (2013). *Coal Geology*. 2nd Edition, John Wiley & Sons. • Taylor, G.H., Teichmüller, M., et al. (1998). *Organic Petrology*. Gebrüder Borntraeger. • Dahlkamp, F.J. (2009). *Uranium Deposits of the World*. Springer. • Directory of Geological Survey of India Publications and Reports of the Ministry of Petroleum & Natural Gas and Ministry of Coal, Government of India.

Course Code	ES3103N	**Course Name**	**PC XV** Tectonics and Physical Geology	**Course Category**	PC	L	T	P
						4	0	0

Module	**Syllabus**	**Duration (class-hour)**
1	**Historical background** Continental drift theory, sea floor spreading and the development of plate tectonics, Geosynclinal theory	4
2	**Interior of the Earth:** Earthquake seismology, Earth's internal structure, composition Rheology of lithosphere and asthenosphere; Lithosphere as a thermal boundary layer. Characteristics of Continental and oceanic crust; Concept of hot spot and mantle plume. Ophiolites and its significance.	6
3	**Isostasy Mobile Belts and Craton.** Orogeny and Epirogeny, Concept of vertical and horizontal tectonics and its limitations.	6
4	**Framework of plate tectonics** Plates and plate margins, Earthquake and earthquake belts; Volcanoes-types, products and their distribution.	8

5	**Plate Tectonics- Past and Present:** Plate tectonics model and its evidences. Reconstruction of plates. Supercontinent, their break up and assembly. Assembly and break up of Pangaea. Wilson cycle. Driving Mechanisms of plates, Plate tectonics and mantle convection. Drifting of the Indian sub-continent through time.	6
6	**Physical geology** **Earth's Dynamic Systems and Materials** The Scientific Method in Geology; Earth as a System,	8
7	**The Rock Cycle and Earth's Internal Engine** The Rock Cycle in detail; **Igneous Rocks & Processes:** magma vs. lava, intrusive vs. extrusive, classification by texture and composition;	6
8	**Sculpting the Landscape: Surface Processes** Mass Wasting: types of landslides, triggers, and mitigation; Running Water: the hydrologic cycle, stream erosion/deposition, floodplains, and drainage patterns; Groundwater: aquifers, wells, karst topography, and contamination; Glaciers: glacial erosion and depositional landforms; Deserts & Wind Processes: erosion and deposition; Coasts: wave erosion, longshore drift, and coastal features.	8
Total		**52**

Learning Resources	• Press, F., Siever, R. (2007): Understanding Earth. W.H. Freeman & Co., New York, 5 th Ed. • Emiliani, C. (1992): Planet Earth: Cosmology, Geology, and the Evolution of Life and Environment. Cambridge University Press. Published in USA. • Skinner, B.J., Porter, S.C., Botkin, D.B. (1999): The Blue Planet – An Introduction to Earth System Science. John Wiley & Sons, Inc. New York. P.552. • Mathez, E.A. and Webster, J.D. (2004): The Earth machine – The Science of a Dynamic Planet. Columbia University Press, New York. P.335.

Course Code	ES3171N	Course Name	PC XVI (P) Structural Geology Practical II and Palaeontology Practical	Course Category	PC	L	T	P
						0	0	3

Module	Syllabus	Duration (class-hour)
1	Advanced Geological Map Interpretation & 3D Visualization Analysis of maps with polyphase deformation (multiple folding/faulting events). Interpretation of unconformities and their structural implications. Use of borehole and subsurface data to constrain interpretations. Introduction to map patterns of plunging folds, domes, and basins. Outcrop ompletion: Predicting geology between data points using structural rules.	6
2	Cross-Section Construction, Balancing, and Retrodeformation Advanced cross-section techniques: Principles of line-length and area balancing. Restoration of cross-sections to pre-deformation states.	6
3	Quantitative Strain Measurement and Analysis Review of strain concepts. Practical strain measurement techniques: Rf/φ method for deformed clasts/objects, Fry method for centroids. Calculation of strain ratios (Rs) and kinematic vorticity (simple vs. pure shear). Graphical representation of strain data.	4
4	Analogue Modeling of Structural Processes Scaling principles and model materials (sand, silicone putty, clay). Designing an experiment to test a hypothesis Model construction, monitoring, and documentation. Sectioning and analyzing the final model. Critical comparison of model results with natural case studies.	4
5	Systematic Identification of Fossils: Practical study and identification of representative invertebrate, vertebrate, plant fossils, and microfossils using hand specimens, thin sections, and microscope slides, with emphasis on diagnostic morphological characters and taxonomic classification.	10
6	Morphological Analysis and Documentation**:** Detailed observation, measurement, and description of external and internal morphological features of fossils; preparation of sketches, photomicrographs, and descriptions to understand growth patterns, functional morphology, and evolutionary trends.	10
Total		**40**

Learning Resources	
	• Coe, A. 2010. Geological Field Techniques. Wiley-Blackwell. • Ragan, D.2009. Structural Geology: An Introduction to Geometrical Techniques, Cambridge University Press. • M. Brasier: Micropaleontology, Blackwell • Raup, D.M. and Stanley, S.M (2008): Earth System History, Blackwell Publ

SIXTH SEMESTER

Course Code	ES3201N	Course Name	PC XVII Ore Geology: metal and non-metal	Course Category	PC	L	T	P
						4	0	0

Module	Syllabus	Duration (class-hour)
1	**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.	8
2	**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.	10
3	**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.	12
4	**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 paleo-placer) 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.	12
5.	**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. Classification of Precious metal deposits with special reference to Platinum Group metals and Gold. Genetic processes and Indian context.	10
Total		**52**

Learning Resources	• The Geology of Ore Deposits — Guilbert & Park • Ore Deposit Geology — John Ridley • Ore Geology and Industrial Minerals — Anthony M. Evans • Ore Geology, Economic Minerals and Mineral Economics — S. K. Tiwari • Economic Mineral Deposits — Allan M. Bateman & others

						L	T	P
Course Code	ES3202N	**Course Name**	**PC XVIII** Indian Stratigraphy and Boundary Problems	**Course Category**	PC	4	0	0

Module	Syllabus	Duration (class-hour)
1	**Proterozoic Stratigraphy of Indian Cratons: Basins and Correlations** Archean-Proterozoic transition in India. Stratigraphy of the Aravalli-Delhi and Satpura Mobile Belts. Proterozoic basin analysis: Cuddapah, Bhima, Kaladgi, and the great Purana Basins (Vindhyan, Chhattisgarh, Indravati). Lithostratigraphy, sedimentology, and paleocurrent analysis. Absolute age constraints and controversies. The "Vindhyan Enigma": age of the Upper Vindhyans and fossil controversies.	10
2	**Phanerozoic Stratigraphy of Peninsular India: Gondwana and Beyond** Late Paleozoic-Mesozoic stratigraphy: Gondwana Supergroup (Talchir to Kota); rift tectonics, glacial to fluvial cycles, and the Permian-Triassic boundary. Jurassic-Cretaceous successions of Kachchh, Narmada, and Godavari grabens. The Deccan Volcanic Province: stratigraphy, volcanology, and age. Cretaceous-Paleogene (K-Pg) boundary in India: marine and terrestrial (Deccan intertrappean) records.	10
3	**Stratigraphy of the Himalayan Orogen: A Tectono-Stratigraphic Approach** Tethyan Himalayan Zone: Cambrian to Eocene passive margin succession. Lesser Himalayan Zone: Proterozoic to Paleozoic meta-sedimentary sequences and thrust-bound stratigraphy. Sub-Himalayan Zone: Neogene Siwalik Group molasse sedimentation, magnetostratigraphy, and vertebrate biostratigraphy. Stratigraphic constraints on timing of Himalayan orogeny and thrust propagation.	
4	**Quaternary Stratigraphy and Coastal Basin Evolution** Stratigraphy of the Indo-Gangetic Plains: alluvial architecture and subsurface configuration. Quaternary stratigraphy of India: glacial, fluvial, and aeolian records. Evolution of East and West Coast basins: Tertiary to Recent stratigraphy, sea-level change records, and deltaic evolution (Ganges-Brahmaputra, Krishna-Godavari).	6

5	**Methods in Stratigraphy and Boundary Problem Analysis** Application of modern techniques: biostratigraphy (microfossils, palynology), chemostratigraphy (C, Sr, Os isotopes), magnetostratigraphy, and sequence stratigraphy. Definition and recognition of GSSPs (Global Boundary Stratotype Sections and Points). Methodology for studying boundary problems: integrating litho-, bio-, chemo-, and magneto-stratigraphic data.	8
5	**Major Boundary Problems and Synthesis of Indian Stratigraphy** In-depth case studies of key boundaries: 1. Proterozoic-Phanerozoic (Ediacaran-Cambrian) in the Lesser Himalaya. 2. Permian-Triassic in terrestrial (Gondwana) and marine (Himalayan) sections. 3. Cretaceous-Paleogene in marine and Deccan intertrappean sections. Synthesis: Paleogeographic reconstructions of the Indian plate from Neoproterozoic to Recent. Stratigraphic controls on the distribution of major economic resources (coal, hydrocarbons, bauxite).	8
Total		**52**

Learning Resources	• Krishnan, M.S. (1982). *Geology of India and Burma*. 6th Edition, CBS Publishers. • Valdiya, K.S. (2010). *The Making of India: Geodynamic Evolution*. Macmillan. • Ravindra Kumar (2012). *Fundamentals of Historical Geology and Stratigraphy of India*. New Age International. • Sastri, V.V., Bhandari, L.L., et al. (1981). *Basins of India: Their Stratigraphy and Petroleum Potential*. ONGC Bulletin. • Gradstein, F.M., Ogg, J.G., et al. (2020). *The Geologic Time Scale 2020*. Elsevier. • Benton, M.J. and Harper, D.A.T. (2020). *Introduction to Paleobiology and the Fossil Record*. Wiley-Blackwell.

Course Code	ES3203N	**Course Name**	**PC XIX** Solid Earth Geophysics	**Course Category**	PC	L	T	P
						4	0	0

Module	**Syllabus**	**Duration (class-hour)**
1	**Hypothesis for Origin of Solar System:** Kepler's Law of Planetary Motion, Planets and Satellites in Solar System and their Characteristics	9
2	**Shape and Size of Earth, Various Motions of Earth:** Rotation, Revolution, Precession and Polar Wandering	3
3	**International Gravity Formulae, Internal constitution of the Earth :** Characteristics of Lithosphere and Asthenosphere, Introduction to Geoid	10

	and Spheroid, Derivation and explanation of Geoid and Spheroid at different locations of earth's surface. Its significance to dynamics of the Earth	
4	**Geodynamic Models:** Continental drift, ocean floor spreading, plate tectonics and plate margin process, geomagnetic time scale, Benioff zones, ocean ridges, evolution of triple junction	10
5	**Airy, Heiskanan and Pratt-Hayford Hypotheses:** Elastic waves and elastic parameters, wave equations and velocities,	10
6	**Introduction to earthquake seismology:** Intensity and magnitude scales, elastic rebound theory, Global seismicity and tectonics, seismic phases and ray paths, internal structure as derived seismology, Heat flow, conduction, convection, radiation, geothermal modelling and geotherms.	10
Total		**52**

Learning Resources	W.E. Telford, L.P. Geldart, R.E. Sheriff, 2nd Edition, Cambridge University Press, 2004. C.M.R. Fowler, 2nd Edition, The Solid Earth, Cambridge University Press, 2005. William Lowrie, Second Edition, Fundamentals of Geophysics, Cambridge University Press, 2007. D.L. Turcotte and G. Schubert, Geodynamics, Cambridge University Press, 2014.

						L	T	P
Course Code	ES3271N	**Course Name**	**PC XX** Ore Geology Practical and Field Work	**Course Category**	PC	0	0	3

Module	**Syllabus**	**Duration (class-hour)**
1	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.	39
Total		**39**

Learning Resources	• Pracejus, B., 2015. The ore minerals under the microscope: an optical guide (Vol. 3). Elsevier. • Craig, J.R., Vaughan, D.J. and Hagni, R.D., 1994. Ore microscopy and ore petrography (Vol. 406). New York, NY: John Wiley & Sons. • Deer, W.A., 1978. Rock-forming minerals. Geological Society of London.

	• Uytenbogaardt, W. and Burke, E.A.J., 1985. Tables for microscopic identification of ore minerals. Courier Corporation. • Castroviejo, R., 2023. Introduction to Ore Microscopy. In A Practical Guide to Ore Microscopy—Volume 1: Mineral Identification (pp. 3-25). Cham: Springer International Publishing. • Lindsley, D.H. ed., 2018. Oxide minerals: petrologic and magnetic significance (Vol. 25). Walter de Gruyter GmbH & Co KG.

Course Code	ES3291N	**Course Name**	**Internship**	**Course Category**	PC	L	T	P
						0	0	0

Module	**Syllabus**	**Duration (class-hour)**
1	**Internship Engagement in Academic institute or in any industry**	1 months
Total		1 months

Course Outcome	Upon successful completion of the internship, students will be able to: • Demonstrate the application of disciplinary knowledge and skills to complete defined tasks or projects in a professional setting. • Exhibit professional behavior, including effective written and oral communication, time management, and collaborative work ethics. • Analyze and describe the structure, function, and culture of the host organization and its role in the broader professional landscape. • Critically evaluate their own performance, learning, and professional growth during the internship experience. • Synthesize their practical experience and academic learning to refine their career goals and professional identity.

SEVENTH SEMESTER

Course Code	ES4101N	**Course Name**	**PC XXI** Remote Sensing, GIS and AI-ML Application in Geosciences	**Course Category**	PC	L	T	P
						4	0	0

Module	**Syllabus**	**Duration (class-hour)**
1	**Basic Principles of Remote Sensing:** 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.	4

2	**Platforms, Sensors, and Data Characteristics:** Airborne and Spaceborne Remote Sensing. Optical, Infrared, and Microwave Remote Sensing. Detailed study of platforms and sensors. Resolutions: spatial, spectral, radiometric, and temporal.	6
3	**Digital Image Pre-processing & Geometric Correction:** Digital processing of satellite images. Image data formats. Causes of geometric distortion. Geometric rectification and registration techniques: image to map and image to image.	10
4	**Radiometric Enhancement and Image Transformation:** Spatial and radiometric enhancement techniques (contrast stretching, filtering). Edge detection. Spectral transformations: Band Ratios and Indices (e.g., NDVI). False Colour Composites (FCC). Principal Component Analysis (PCA).	8
5	**Image Classification and Thematic Mapping:** Spectral domain enhancement. Supervised and Unsupervised classification algorithms (e.g., Maximum Likelihood, ISO Data). Accuracy assessment. Thematic map generation for land use/land cover, lithology, etc.	6
6	**Fundamentals of Geographic Information Systems (GIS):** Basic concepts of GIS. Hardware and software modules. Data representation: Spatial vs. Attribute data. Introduction to Raster and Vector data models**.**	8
7	**GIS Data Models and Analysis:** Advantages and Disadvantages of Raster and Vector data. Topology: concepts and importance; topology in raster and vector data. Core vector operations (overlay, buffering). Case studies in geosciences (e.g., site suitability, proximity analysis).	6
8	**Introduction to AI-ML, and** AI-ML Application in geosciences**:** Transition from traditional methods to AI/ML. Basic concepts: features, labels, training, and prediction. Limitations and future trends.	8
Total		**52**

Learning Resources	• Geographic Information Systems and Science by Paul A. Longley, Michael F. Godchild, David J. Maguire, and David W. Rhind • Image Interpretation in Geology by S.A. Drury, • Remote Sensing Geology by R.P. Gupta. • Remote Sensing and Image Interpretation by T.M. Lillesand and R.W Kieffer. • Photogeology by V.C. Miller. • Aerial Photography and Image Interpretation for Resource Management. D.P. Paine. • Principles and Applications of Photogeology by S.N. Pandey. • Remote Sensing Principles and Applications. Freeman. F.F. Sabbins, • AI for everyone. S. Goswami, A. K. Das and A. Chakraborty. Pearson. • Machine Learning for absolute beginners. Oliver Theobald. Sanage publishing house.

Course Code	ES4102N	Course Name	PC XXII Environmental Geology and Marine Geology	Course Category	PC	L	T	P
						4	0	0

Module	Syllabus	Duration (class-hour)
1.	**Interaction between man and climate.** Time scale of global changes in the ecosystem and climate. Impact of atmospheric circulation and oceanic currents on climate – Southwest and Northeast monsoon in Indian subcontinent,	6
2.	**Pollution –** Types of pollution, Sources of surface and groundwater pollution, pollution of marine water, Treatment of polluted water. Air Pollution and its effects. Problems of waste disposal - solid, liquid and toxic waste. Environmental impact of mineral development exploration, extraction and processing.	7
3.	**Greenhouse effect, Global warming and Ozone depletion**. Source of Greenhouse gases and their controls on emission. Alternative energy resources – solar, wind, water, gas hydrates, bio mass and geothermal energies. Environmental Impact Assessment (EIA)	7
4.	**Morphologic and tectonic domains of the ocean floor**. Structure, composition and mechanism of the formation of oceanic crust. Hydrothermal vents.	6
5	**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	7
6	**Oceanic sediments**: Factors controlling the deposition and distribution of oceanic sediments; geochronology of oceanic sediments, diagenetic changes in different environments.	6
7	**Mineral resources**	6
8	**Paleoceanography–** Approaches to paleo-oceanographic reconstructions; various proxy indicators for palaeoceanographic interpretation.	7
Total		**52**

Learning Resources	
	• Smith, K. 1992: Environmental Hazards. Routledge, London. • Subramaniam, V. 2001: Textbook in environmental science. Narosa International. • Valdiya, K.S. 1987: Environmental Geology- Indian context. Tata Mc Graw Hill.

	• Keller, E.A. 1978: Environmental Geology- Bell & Howell, USA. • Marine Geology by J Kennett • The Sea floor Spreading- An introduction to Marine Geology by Seibold, Eugen Berger and Wolfgang • An Introduction to Marine Geology by M. J. Keen. • Essentials of oceanography by Harold V. Thurman • Descriptive Physical Oceanography: An Introduction by George L Pickard

Course Code		**Course Name**	**PC XXIII** Coal and Mineral Beneficiation (Mining Engg. Department)	**Course Category**	PC	L	T	P
						4	0	0

Course Code		**Course Name**	**PC XXIV** Coal and Mineral Beneficiation Practical (ME Department)	**Course Category**	PC	L	T	P
						0	0	3

EIGTH SEMESTER

Course Code	ES4201N	**Course Name**	**PC XXV** Principles of Geophysical Exploration	**Course Category**	PC	L	T	P
						4	0	0

Module	**Syllabus**	**Duration (class-hour)**
1	**Introduction to Geophysics:** Densities of common rocks and minerals, Concept of Scale and Unit. Data Acquisition and Reduction, Gravity Field of the Earth, Gravitational potential, Normal Gravity Field, Shape of the Earth, Gravimeters: Principles and Types, Bouguer and Isostatic anomalies, gravity due to buried sphere, horizontal cylinder, semi-infinite horizontal sheet.	11
2	**Magnetism of the Earth:** Magnetic susceptibility of rocks and their ranges. Geomagnetic Field, Inclination and Declination; Latitudinal variation; Secular and transient variations in magnetism; Paleomagnetism, Apparent Polar wandering curves.	10
3	**Spontaneous Potential (SP) Method**: Origin of SP, Field procedure to conduct SP survey, interpretation of SP anomalies.	7

4	**Resistivity Method**: True and apparent resistivity, Resistivity of common rocks and minerals, Electrode configurations- Schlumberger and Wenner, Vertical Electrical Sounding, Interpretation of two layered VES curves.	7
5	**Well logging**: Objectives and types of well logging, Borehole Geophysics and its Applications.	7
6	**Seismic Method**: Generation and propagation of seismic waves, seismic energy sources, geometry of refraction and reflection, interpretation of travel time curves for two layered Earth	10
Total		**52**

Learning Resources	Bagchi, T.C., Sengupta, D.K., Rao S.V.L.N. Rao (1979), Elements of Prospecting and Exploration. Dobrin, M.B. and Savit, C. (1981), Introduction to Geophysical Prospecting. Nettleton, L. L. (1976): Gravity and Magnetics in Oil prospecting Parasnis, D. S. (1962): Applied Geophysics Rao, B. S. R and Murthy, I. V. R. (1978): Gravity and Magnetic Methods of Prospecting Reynolds John M., 2nd Edition, An introduction to Applied and Environmental Geophysics.

Course Code	ES4202N	**Course Name**	**PC XXVI** Hydrogeology II and Climatology	**Course Category**	PC	L	T	P
						4	0	0

Module	**Syllabus**	**Duration (class-hour)**
1	**Well Hydraulics and Pumping Test Analysis:** Steady radial flow (Thiem equation) in confined/unconfined aquifers. Transient radial flow (Theis equation); Cooper-Jacob straight-line method. Analysis of pumping test data.	8
2	**Geophysical Methods for Groundwater Exploration:** Principles and applications of Electrical Resistivity (VES, Profiling) and Seismic Refraction methods. Introduction to borehole geophysics (Well Logging).	10
3	**Groundwater Quality and Contaminant Hydrology:** Natural hydrochemical evolution; Major ion chemistry and graphical representation (Piper diagram). Sources and types of groundwater pollution; Introduction to contaminant transport.	9
4	**Coastal Hydrogeology and Saline Intrusion:** Mechanisms and indicators of seawater intrusion; Management and mitigation strategies (barrier wells, recharge).	9

5	**Climatology of Groundwater Recharge:** Precipitation patterns and measurement; Evapotranspiration processes; Methods for recharge estimation (Water Table Fluctuation, Chloride Mass Balance). Impact of climate variability on recharge.	9
6	**Climate Change and Groundwater Management:** Projected climate change impacts on groundwater resources; Concepts of aquifer vulnerability and resilience; Adaptive management and Managed Aquifer Recharge (MAR).	9
7	**Definition and concepts of climate and climate change**; Earth's climate system: atmosphere, hydrosphere, lithosphere, biosphere; Greenhouse effect and greenhouse gases; Natural and anthropogenic drivers of climate change; Evidence of climate change: temperature rise, melting glaciers, sea-level rise, extreme events	8
8	**Impacts on ecosystems and biodiversity**; Climate change and agriculture, and water resources; Impacts on human health and livelihoods; Climate change and natural disasters; Vulnerability and risk assessment	10
9	**Mitigation strategies**: renewable energy, energy efficiency, carbon sequestration; Adaptation strategies water management; Climate-resilient development; Role of technology and innovation; National and international climate policies and agreements	7
Total		**52**

Learning Resources	• Kresic, N. (2009). *Groundwater Resources: Sustainability, Management, and Restoration*. McGraw-Hill. • Fitts, C.R. (2013). *Groundwater Science*. 2nd Edition, Academic Press. • Schwartz, F.W. and Zhang, H. (2003). *Fundamentals of Ground Water*. John Wiley & Sons. • Bear, J. (1979). *Hydraulics of Groundwater*. McGraw-Hill. • Driscoll, F.G. (1986). *Groundwater and Wells*. 2nd Edition, Johnson Filtration Systems.

						L	T	P
Course Code	ES4203N	**Course Name**	**PC XXVII** Introduction to Exploration and Extraction of Critical Mineral	**Course Category**	PC	4	0	0

Module	Syllabus	Duration (class-hour)
1	**Introduction to Critical Minerals:** -Definition of Critical Elements, Critical Minerals, Strategic Elements, Energy Critical Elements. An Introduction to Physical properties of Minerals containing 30 Critical Elements: Antimony, Beryllium, Bismuth, Cobalt, Copper, Gallium, Germanium, Graphite, Hafnium, Indium, Lithium, Molybdenum, Niobium, Nickel, PGE, Phosphorous, Potash, REE, Rhenium, Silicon, Strontium,	**4**

	Tantalum, Tellurium, Tin, Titanium, Tungsten, Vanadium, Zirconium, Selenium and Cadmium.	
2	**Sources of Critical Minerals:** **Primary sources–** Magmatic, Sedimentary and Metamorphic–Metasomatic rocks, hydrothermal activity, syn-/dia-/epi-genetic affects, remobilization–recrystallization, weathering, transportation (in placers), **Secondary sources-** Waste Materials mainly e-waste	**4**
3	**Genesis of Critical Minerals:** **Magmatic mineral systems-** (1) Komatiite-hosted Ni-Cu systems; (2) Layered intrusion-hosted Cr-PGE systems; and (3) Mafic to Ultramafic Ni-Cu±PGE systems, (4) Carbonatite-hosted rare-metal (LREE±Nb±Th) systems, (5) Pegmatite-hosted Li systems **Magmatic-hydrothermal mineral systems-**Carlin-type Au systems, VMS Cu-Pb-Zn-Au systems, porphyry-skarn Cu-Au-Mo systems, Kiruna-type Fe-P systems, Iron-oxide Cu-Au-U-LREE (IOCG) systems, Intrusion-related Au (IRGD) systems	**4**
4	**Hydrothermal mineral systems**-Epithermal Au-Ag systems **Sedimentary Mineral systems-** Evaporite Li brine systems, Placer Au systems, Paleo-placer Au-U systems, Titanium-REE beach sand placer **Basinal Hydrothermal Mineral systems:** Zambian-type Cu-Co systems, Intrusion-hosted Ni-Cu±PGE, Sedimentary rock-hosted sedimentary-exhalative sulfide (SEDEX) Cu-Zn-Pb systems, Carbonatite REE, Mississippi Valley-type (MVT) Pb-Zn-Ba systems, Broken Hill-Type (BHT) Pb-Zn-Ag systems, BIF-type Fe systems, BIF-type Mn systems, Unconformity-related and Roll front-type U systems	**8**
5	**Occurrence and Use of Critical Minerals:** Global occurrence of Critical Minerals, Emphasis on Indian context. Uses of Critical Minerals	**2**
6.	**Minning of Critical Minerals** Planning and Design Development of the deposit Extraction Methods Cut-and-Fill method Placer Mining and Dredging Leaching Solution Mining Hydraulic Mining	20
7	**Extractive Metallurgy for Critical Minerals:** Hydrometallurgical Techniques - Solvent extraction, ion exchange. Pyro metallurgical Techniques - Smelting, roasting, refining. Recycling & Urban Mining - Circular economy, e-waste recovery	10
Total		**52**

Learning Resources	○ Mineral Exploration Principles and Applications (2012) S. K. Haldar ○ Mineral Resources of India: An Introduction to Economic Geology (2022). Rohini Singh ○ Rare Earth Metals and Minerals Industries (2024) Y.V Murty, Mary A. Alvin, ○ Jack. P Lifton Strategic Minerals in India: present status and future challenges. (2019). Randive, K.,

NINTH SEMESTER

						L	T	P
Course Code	ES5104N	**Course Name**	**PC XXVIII** Structural Geology II and Basin Tectonics	**Course Category**	PC	4	0	0

Module	Syllabus	Duration (class-hour)
1	**Advanced Mechanics of Rock Deformation** Advanced finite strain theory: strain ellipsoid, Flinn diagram, strain path analysis. Rheology of the lithosphere: brittle-ductile transitions, flow laws for dislocation and diffusion creep, the role of fluids. Deformation mechanisms: recrystallization, superplasticity, reaction softening. Rheological models of different materials.	4
2	**Advanced Folding and Structural Analysis** Kinematic models of folding (flexural slip/flow, passive shear). Superposed folding: interference patterns and mathematical analysis. Folds in shear zones. Application of stereographic projections for constraining fold geometry and tectonic transport direction. Axial plane foliations and cleavage-fold relationships.	6
3	**Mechanics and Evolution of Fault Systems, Thrust tectonics** Fault zone architecture and fault rock evolution (cataclasites, pseudotachylytes). Cohesive zone models and fault propagation. 3D fault geometry and linkage. Inversion tectonics: mechanisms, recognition criteria in seismic data and field studies. Reservoir implications of fault sealing/leaking. Development of thrust systems.	6
4	**Basin Tectonics:** **Geodynamics of Basin Formation** Lithospheric stretching models (McKenzie vs. depth-dependent stretching). Flexural tectonics: foreland basin evolution and lithospheric flexure. Dynamic topography and mantle-driven subsidence. Classification of basins within the plate tectonic cycle. The role of inherited structures.	8
5	**Rift Basin Architecture and Evolution** Mechanics of continental extension: pure vs. simple shear models (Wernicke model). Architecture of rift systems: border faults, horsts, grabens, and detachment faults. Syn-rift stratigraphy and facies models. Volcanic passive margins vs. non-volcanic margins. Transition to sea-floor spreading.	6

6	**Contractional Systems and Foreland Basins** Mechanics of fold-thrust belts: critical taper theory. Thin-skinned vs. thick-skinned thrusting. Structural styles in foreland fold-thrust belts. Syntectonic sedimentation: growth strata and their interpretation in seismic profiles. Piggy-back and break-forward sequences.	8
7	**Strike-Slip and Transpressional/ Transtensional Basins** Mechanics of strike-slip faulting. Basin formation in releasing and restraining bends (pull-apart and push-up structures). Flower structures in seismic data. Inversion in strike-slip settings. Complex basin geometries in oblique-slip regimes.	6
8	**Integrated Basin Analysis and Tectono-Stratigraphy** Tools for basin analysis: subsidence history curves (backstripping), thermal maturity indicators (vitrinite reflectance, fission tracks), provenance analysis (detrital zircons). Seismic stratigraphy and sequence stratigraphy in a tectonic context. Case studies of world-class basins (e.g., North Sea, Himalayan Foreland, East African Rift).	8
Total		**52**

Learning Resources	○ Structural Geology—Fundamentals and Modern developments by S.K. Ghosh. ○ Folding and Fracturing of Rocks by J.G. Ramsay. ○ Structural Geology by H Fossen ○ An outline of Structural Geology by B.E. Hobbs, W.D. Means and P.F. Williams. ○ Structural analysis of Metamorphic tectonites by J.G. Turner and L. E. Weiss. ○ Use of stereographic projection in Structural Geology by F. C. Phillips. ○ Elasticity, Fracture and flow by J.C. Jaeger. ○ Structural Geology by Twiss and Moores ○ Rheology of the Earth by G. Ranalli, Allen and Unwin

						L	T	P
Course Code	ES5105N	**Course Name**	**PC XXIX** Sedimentary Facies Analysis and Sequence Stratigraphy	**Course Category**	PC	4	0	0

Module	**Syllabus**	**Duration (class-hour)**
1	**Fundamentals of Facies Analysis** Definition of facies and facies association; Facies codes and graphical logs; Physical, biogenic, and chemical sedimentary structures as environmental indicators. Walther's Law of Facies Succession. Hierarchical approach: lithofacies, lithofacies associations, depositional systems. Introduction to paleocurrent analysis and its significance.	8
2	**Siliciclastic Depositional Systems I: Continental & Coastal** **Fluvial Systems:** Braided vs. Meandering river facies models; architectural elements. **Aeolian Systems:** dune interdune facies, erg construction. **Coastal**	10

	Systems: Deltas (process-based classification: river-, wave-, tide-dominated), facies tracts. **Shallow Marine Clastic Systems:** Barrier island-lagoon-tidal flat complexes; shoreface profiles; tempestites.	
3	**Carbonate & Deep-Marine Depositional Systems** **Carbonate Systems:** Controls on carbonate production; standard microfacies; facies belts from peritidal to deep basin (ramp vs. rimmed shelf models); carbonate platform cyclicity. **Deep-Marine Systems:** Submarine fan models (Miall); lobe, channel, and overbank facies; turbidites, debrites, and contourites; basin plain deposits.	8
4	**Core Concepts and Surfaces in Sequence Stratigraphy** Historical development. Base-level and accommodation concepts. Allocyclic vs. Autocyclic controls. Definition and identification of key stratigraphic surfaces: Subaerial Unconformity (Sequence Boundary), Correlative Conformity, Transgressive Surface (TS), Maximum Flooding Surface (MFS). Parasequences and parasequence sets. Systems Tracts: Lowstand (LST), Transgressive (TST), Highstand (HST), and Falling-Stage (FSST).	10
5	**Sequence Stratigraphy in Different Data Types and Settings** **Application in Well Logs:** Gamma-ray log patterns and their sequence stratigraphic interpretation (funnel, bell, cylinder). **Application in Seismic Data:** Seismic stratigraphy principles (onlap, downlap, truncation); seismic facies analysis. **Sequence Stratigraphy in Different Settings:** Contrasting models for siliciclastic ramps, rimmed carbonate shelves, and under-filled foreland basins.	8
6	**Integrated Applications and Case Studies** Wheeler diagrams (chronostratigraphic charts) for basin visualization. Building 1D and 2D correlation panels. Integration of biostratigraphy and chemostratigraphy. Sequence stratigraphy and petroleum systems: prediction of reservoir distribution (LST sands, TST carbonates), seal integrity (MFS shales), and stratigraphic traps. Detailed case studies (e.g., Book Cliffs, Capitan Reef, or subsurface examples from Indian basins).	8
Total		**52**

Course Outcome	Upon successful completion, students will be able to: • Log, describe, and interpret sedimentary facies from outcrop and core, reconstructing their depositional processes and environments. • Predict vertical and lateral facies relationships within established facies models for siliciclastic and carbonate systems. • Apply Walther's Law and construct paleogeographic maps from facies and isopach data. • Identify and correlate key sequence stratigraphic surfaces and systems tracts in various data types (outcrop, well logs, seismic). • Interpret the relative roles of eustasy, tectonics, and sediment supply in generating the observed stratigraphic architecture.

	• Build a 1D-2D sequence stratigraphic framework and use it to predict reservoir, seal, and source rock distribution.

Learning Resources	• Walker, R.G. and James, N.P. (Eds.) (1992). *Facies Models: Response to Sea Level Change*. Geological Association of Canada. • Catuneanu, O. (2006). *Principles of Sequence Stratigraphy*. Elsevier. • Posamentier, H.W. and Walker, R.G. (2006). *Facies Models Revisited*. SEPM Special Publication 84. • Flügel, E. (2010). *Microfacies of Carbonate Rocks: Analysis, Interpretation and Application*. 2nd Ed., Springer. • Emery, D. and Myers, K.J. (Eds.) (2009). *Sequence Stratigraphy*. Wiley-Blackwell. • Miall, A.D. (2016). *Stratigraphy: A Modern Synthesis*. Springer. • Key journals: *Sedimentology*, *Journal of Sedimentary Research*, *AAPG Bulletin*, *Basin Research*, *Marine and Petroleum Geology*.

						L	T	P
Course Code	ES5106N	**Course Name**	**PC XXX** Application of Modern Techniques in Petrology	**Course Category**	PC	4	0	0

Module	**Syllabus**	**Duration (class-hour)**
1	**Advanced textural modelling in metamorphic rocks.**	8
2	**Crustal anatexis, Thermodynamic modelling** using PERPLEX, MELTS and Rcrust	12
3	**Melt generation in mantle and subduction zone:** Thermodynamic modelling through PERPLEX, MELTS and Rcrust	12
4	**Textural Geochronology in igneous and metamorphic rocks.**	12
5	**Conventional Geothermobarometry** Schreinemakers' analyses, petrogenetic grid and phase equilibria modelling through PERLEX	8
Total		**52**

Learning Resources	• Connolly, J.A., 2005. Computation of phase equilibria by linear programming: a tool for geodynamic modeling and its application to subduction zone decarbonation. *Earth and Planetary Science Letters*, *236*(1-2), pp.524-541. • Mayne, M.J., Moyen, J.F., Stevens, G. and Kaislaniemi, L., 2016. Rcrust: A tool for calculating path-dependent open system processes and application to melt loss. *Journal of Metamorphic Geology*, *34*(7), pp.663-682. • Smith, P.M. and Asimow, P.D., 2005. Adiabat_1ph: A new public front-end to the MELTS, pMELTS, and pHMELTS models. *Geochemistry, Geophysics, Geosystems*, *6*(2). • Philpotts, A.R. and Ague, J.J., 2009. Principles of igneous and metamorphic petrology. Cambridge University Press. • Winter, J.D., 2014. Principles of igneous and metamorphic petrology (Vol. 2). Harlow, UK: Pearson education. • Corfu, F., Hanchar, J.M., Hoskin, P.W. and Kinny, P., 2003. Atlas of zircon textures. *Reviews in mineralogy and geochemistry*, *53*(1), pp.469-500. • Kornprobst, J., 2002. Metamorphic rocks and their geodynamic significance: a petrological handbook. Springer Science & Business Media.

TENTH SEMESTER

Course Code	ES5204N	**Course Name**	**PC XXXI** Metallogeny and Hydrogeology (Part III)	**Course Category**	PC	L	T	P
						4	0	0

Module	**Syllabus**	**Duration (class-hour)**
1	**Hydrothermal Fluids and Ore Genesis:** Sources and chemistry of metalliferous fluids; Metal transport and depositional mechanisms (T, P, pH, Eh changes); Fluid-rock interaction.	10
2	**Exploration Hydrogeochemistry:** Pathfinder elements in groundwater; Stable isotopes (S, O, H) as fluid tracers; Concept of geochemical dispersion halos and their use as exploration vectors.	06
3	**Geogenic Trace Element Contamination:** Mobilization of arsenic, fluoride, and other trace elements; Controls of redox and pH; Case studies (e.g., Bengal Basin arsenic crisis).	10
4	**Mining Hydrogeology & Acid Mine Drainage:** Impact of mining on groundwater flow; Geochemistry of sulfide oxidation; Prediction of acid generation potential (Static and Kinetic tests).	14

5	**Contaminant Transport and Remediation:** Reactive transport of metals and acidity; Attenuation processes; Overview of remediation technologies (passive and active treatment).	06
6	**Integrated Case Studies in Metallogenic Provinces:** Synthesis of metallogeny and hydrogeology in selected provinces; Life-cycle water management in mining; Policy and closure planning.	06
Total		**52**

Learning Resources	• Barnes, H.L. (1997). *Geochemistry of Hydrothermal Ore Deposits*. 3rd Edition, John Wiley & Sons. • Plumlee, G.S. and Logsdon, M.J. (Eds.) (1999). *The Environmental Geochemistry of Mineral Deposits*. Reviews in Economic Geology, Vol. 6A & 6B, Society of Economic Geologists. • Younger, P.L., Banwart, S.A., and Hedin, R.S. (2002). *Mine Water: Hydrology, Pollution, Remediation*. Kluwer Academic Publishers. • Misra, K.C. (2000). *Understanding Mineral Deposits*. Springer. • Nordstrom, D.K. and Alpers, C.N. (1999). *Geochemistry of Acid Mine Waters*. In: Plumlee, G.S. and Logsdon, M.J. (Eds.) The Environmental Geochemistry of Mineral Deposits.

						L	T	P
Course Code	ES5205N	**Course Name**	**PC XXXII** Palaeontology, Palaeoclimatology and Stable Isotope Geochemistry	**Course Category**	PC	4	0	0

Module	**Syllabus**	**Duration (class-hour)**
1	**Biostratigraphy and its applications in geochronology**, Biozones, fundamentals, Index fossils, challenges, graphic correlation	8
2	**Quantitative palaeobiology**: Diversity indices, Linear and Geometric Morphometrics, Ordination technique (Principal Component Analysis (PCA), Non-metric Multidimensional Scaling (NMDS)), cluster analysis, multivariate analysis, Species-Area Relationships, Time-Series Analysis,	9
3	**Detail study of few important benthic and planktic foraminifera**	8
4	**Palaeoclimatology principles and proxies**: Earth's climate system through geological time, Climate proxies: isotopes, foraminifera, pollen, leaf physiognomy, biomarkers, Sedimentary and geochemical indicators of palaeoclimate; Major climatic events: PETM, Eocene–Oligocene transition, Pleistocene glaciations	9

5	**Palaeoclimate Change and Impacts:** Drivers of past climate change: orbital, tectonic, and volcanic forcing, Effects on biodiversity and extinction events, Human evolution and climate interactions, Lessons for present and future climate scenarios	9
6	**Palaeoclimate modelling**; Climate archives: ice cores, lake sediments, marine records; Current research trends in palaeontology and palaeoclimatology	9
Total		**52**

Learning Resources	• Alfred R. Loeblich, Jr. and Helen Tappan(1998):Foraminiferal Genera and their classification: Van Nostrand Reinhold Company, New York • Arnold (2002): Quaternary Environmental Micropaleontology (Ed. Simon K. Haslett), Oxford niversity Press, New York. • B.K.Sengupta: Modern Foraminifera • Glaessner. N.(1944) :Principles of Micropaleontology,Melbourne • Haynes,J.R; 1981: Foraminifera, John Wiley • Jones, D..J. Introduction to Microfossils:,Cambrigde University press • M. Brasier: Micropaleontology, Blackwell