University of Delhi

MASTER OF GEOLOGY

(1-year PG Programme under NEP 2020)

(Effective from Academic Year 2026-27)

Programme Brochure

Syllabus as approved by the Committee of Courses of Department of Geology held on 16/10/2025 and revised on 19/03/2026

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I. About the Department

Academic Program in Geology at the University of Delhi was conceived by Prof. A. G. Jhingran. He established the department in the year 1966 after his retirement as Director General of Geological Survey of India. Prof. Jhingran is credited as one of the most accomplished geologist, educationist and administrator of his time.

In his visionary leadership, Department of Geology was established to expand and disseminate geoscience through teaching, research and collaboration to produce highly skilled professional and academics in the field of geology in particular and science in general.

Over the last 50 years, with a modest beginning now our department is functioning from three small buildings adjacent to CSL with office, class rooms, laboratories, thin-section workshops, and museum. Addition of new faculties over the years with diverse field of expertise in geoscience has helped us to achieve new highs in teaching and research. At present the department is rated as one of the best institutions of the country imparting education and research.

The Geology Department of the University of Delhi is committed to provide the highest levels of education through continuous revisions and expansion of our educational, research, and interactive programs in order to produce well-trained, competent, academic and professional geologists capable of scaling new heights in frontiers of geoscience.

II. 1 year M.Sc. in Geology programme details

Scope

The overall objective of the program is to foster high-quality post-graduate teaching to students who have four-year undergraduate degree (including research) in geological sciences under NEP, 2020. With three different modules (Coursework, Coursework + Research, Research), the aim of the programme is to develop specialised Earth Science professionals and academicians who can contribute in the economic development of the country.

Programme Objectives (POs):

The proposed programme (1 year M.Sc. Geology) will be offered by the Department of Geology, University of Delhi, Delhi -110007. The programme will offer advance level theory and practical teaching as well as research training to train students of 21st century with Viksit-Bharat dream. The objectives are:

- To educate and train a new generation of young minds in Earth Science
- To create a passion for research with scientific temperament and knowledge
- Intellectual grooming of each student to be a potential leader in the field of Geology
- To teach beyond textbook and inculcate the spirit of science

Programme Specific Outcome

To achieve the objectives, the Department of Geology has structured the course with a fine mix of coursework and research component. With the choice of electives, students will be able to foster their research interest. Attempt has been made to design the contents of the course to expose students to the state-of-the-art knowledge and research questions in the field of Earth Sciences.

Programme Structure:

As per the NEP-2020 guideline, the 1-year M.Sc.. in Geology programme is launched for students who have completed four-year undergraduate degree in NEP-2020 framework. The programme will be divided into two semesters and in three different modules 1. M.Sc. with only Coursework, 2. M.Sc. with coursework + Research, and 3. M.Sc. with Research.

The programme will have a total of 44 credits with 22 credits in each semester.

Eligibility for Admission:

4-year Bachelor's degree in Geology under NEP-2020 scheme

Structure 1 (Level 6.5) PG Curricular Structure with only course work

Semester	DSC	DSE	**2 Credit course** Skill-based course/ workshop/ Specialised laboratory/ Hands on Learning	Dissertation/ Academic Project/ Entrepreneurship	Total Credits
Semester- I	**DSC – 7** Deformation, Rheology and Tectonics **DSC – 8** Groundwater Science	**DSE - 5** Metallogeny through time and space/ Paleoclimate **DSE – 6** Remote sensing and GIS/ Phase equilibria and magmatic rocks **DSE – 7** Surface and Shallow Subsurface processes / Applied Stratigraphy/ Applied Geophysics OR **DSE – 3** Geological Application of Remote Sensing and GIS/ Numerical	**SBC – 1** Thin section preparation techniques for petrological studies (Hands on training)	Nil	22

	(08 credits)	**Methods and Modelling in Earth Sciences** **DSE – 4** **Vertebrate and Invertebrate Paleontology/Geochemistry/ Advanced River Science** **&** **GE-3** **(offered by Department of Geology: To be included in the central pool)** **Geological heritage and Geoconservation** **(12 credits)**			
Semester-II	**DSC-9** **Paleoenvironment and Basin analysis** **DSC -10** **Rock mechanics and Rock engineering**	**DSE – 7** **Surface and Shallow Subsurface processes /Applied Stratigraphy/Applied Geophysics** **DSE – 8** **Thermobarometry of Igneous and metamorphic rocks / Applied Paleontology and Oceanography** **DSE – 9** **Applied hydrogeology/Fossil fuels and sustainable energy resources**	**SBC– 2** **Geological Mapping and Lithotectonic Characterization (Hands on training)**	Nil	**22**

	(8 credits)	OR **DSE-5** **Metallogeny through time and space/ Paleoclimate** **DSE 6** **Remote sensing and GIS/ Phase equilibria and magmatic rocks** **&** **GE-4** **(Offered by Department of Geology. To be included in the central pool)** **Natural Hazards and Disaster Mitigation** **(12 credits)**			

Structure 2 (Level 6.5): PG Curricular Structure with Course work + Research

Semester	DSC	DSE	2 Credit course	Dissertation/ Academic Project/ Entrepreneurship	Total Credits
Semester- I	**DSC-7** **Deformation, Rheology and Tectonics** **DSC – 8** **Groundwater Science**	**DSE - 5** **Metallogeny through time and space/ Paleoclimate** **DSE – 6** **Remote sensing and GIS/ Phase equilibria and magmatic rocks** OR **DSE – 3** **Geological Application of Remote Sensing and GIS/ Numerical Methods and Modelling in Earth Sciences** **GE-3** **Student can opt any GE that may help in writing their Dissertation or study only DSE** **(08 credits)**	Nil	**See detail outcomes** **(6 credits)**	**22**

	(8 credits)				
Semester- II	**DSC-9** **Paleoenvironment and Basin analysis** **DSC -10** **Rock mechanics and Rock engineering** **(8 credits)**	**DSE – 7** **Surface and Shallow Subsurface processes/ Applied Stratigraphy/ Applied Geophysics** **DSE- 8** **Thermobarometry of Igneous and metamorphic rocks / Applied Paleontology and Oceanography** OR **DSE-4** **Vertebrate and Invertebrate Paleontology/Geochemistry/ Advanced River Science** **&** **GE-4** **Student can opt any GE that may help in writing their Dissertation or study only DSE**	Nil	**See detail outcomes** **(6 credits)**	**22**

		(8 credits)			

Structure 3 (Level 6.5): PG Curricular Structure (Research)

Semester	DSC	DSE (related to identified research field)	Research Methods/ Tools/ Writing (2 courses)	One intensive problem-based research	Total Credits
Semester- I	**DSC 11** Frontiers in Geoscience Research	**1 DSE (Any one from DSE-3 to DSE-9)** **(Course related to or allied to the area identified for research)**	SBC-3 **Advanced Research Methodology** + SBC-4 **Tools for Research** **(2x2 = 4 credits)**	**Outcomes are listed** **(10 credits)**	**22**

	(4 credits)	(4 credits)			
Semester- II	-	1 DSE DSE of an allied subject related to the area of research (4 credits)	SBC-5 Techniques of research writing (2 credits)	Research (16 credits)	22

Course code	Name	Theory (Credit/Hours)	Tutorial (Credit/Hours)	Practical (Credit/Hours)	Total (Credit/Hours)
	Discipline Specific Core (DSC) Course				
DSC – 7	Deformation, Rheology and Tectonics	3/45	0	1/30	4/75
DSC – 8	Groundwater Science	3/45	0	1/30	4/75
DSC-9	Paleoenvironment and Basin analysis	3/45	0	1/30	4/75
DSC-10	Rock mechanics and Rock engineering	3/45	0	1/30	4/75
DSC-11	Frontiers in Geoscience Research	3/45	0	1/30	4/75
Discipline Specific Elective (DSE) Course					
DSE – 3	Geological Application of Remote Sensing and GIS/ Numerical Methods and Modelling in Earth Sciences	3/45	0	1/30	4/75

DSE – 4	Vertebrate and Invertebrate Paleontology/Geochemistry/ Advanced River Science	3/45	0	1/30	4/75
DSE - 5	Metallogeny through time and space/ Paleoclimate	3/45	0	1/30	4/75
DSE – 6	Remote sensing and GIS/ Phase equilibria and magmatic rocks	3/45	0	1/30	4/75
DSE – 7	Surface and Shallow Subsurface processes / Applied Stratigraphy/ Applied Geophysics	3/45	0 (1/30-only for Applied Geophysics)	1/30 (0- for Applied Geophysics)	4/75
DSE – 8	Thermobarometry of Igneous and metamorphic rocks / Applied Paleontology and Oceanography	3/45	0	1/30	4/75
DSE – 9	Applied hydrogeology/Fossil	3/45	0	1/30	4/75

	fuels and sustainable energy resources				
General Elective (GE) Course					
GE-3	Geological heritage and Geoconservation	3/45	1/30	0	4/75
GE-4	Natural Hazards and Disaster Mitigation	3/45	0	1/30	4/75
Skill Based Course (SBC)					
SBC – 1	Thin section preparation techniques for petrological studies	1/15	0	1/30	2/45
SBC– 2	Geological Mapping and Lithotectonic Characterization	1/15	0	1/30	2/45
Structure-3 (Research Methods/Tools/Writing)					
SBC-3	Advanced Research Methodology	1/15	1/30	0	2/45
SBC-4	Tools for Research	1/15	0	1/30	2/45
SBC-5	Techniques of research writing	1/15	1/30	0	2/45

SEMESTER -I

DSC 7 DEFORMATION, RHEOLOGY AND TECTONICS

Duration: 45 Hours (Lecture)+ 30 Hours (Practical)

Course Title and Code	Total Credit	Credit distribution in course		
Deformation, Rheology, and Tectonics (DSC- 7)	4	Lecture	Tutorial	Practical
		03	0	01

LEARNING OBJECTIVES:

- This course aims to provide a comprehensive understanding of the mechanical principles governing rock deformation under natural stress conditions.
- It introduces the concepts of stress, strain, and deformation behaviour of rocks, emphasizing the mechanics of folding, faulting, and shear zones.
- Students will learn to analyze crustal deformation processes and plate boundary structures using theoretical, analytical, and practical approaches, including map interpretation, strain analysis, and stereographic techniques.

LEARNING OUTCOMES:

- Students will be able to analyze the state of stress and strain in rocks and interpret their deformation behaviour under varying geological conditions.
- Students will also be able to explain the mechanics and kinematics of geological structures such as folds, faults, joints, and shear zones, and their role in crustal evolution.
- Students will apply practical techniques like strain measurement, stereographic projection, and geological map interpretation to understand regional structural frameworks.
- Students will be able to relate the knowledge with crustal-scale processes and global tectonic framework.

Lecture **3 Credit (45 Hrs)**

Unit- I: Introduction to rock mechanics **(14 Hours)**

Stress at a point in a solid body: 3-D Stress Tensor; Homogeneous and heterogeneous stress: stress functions. Concept of deformation: distortion, rotation, dilatation etc; Deformation Tensor; Analysis of homogeneous deformation: strain ellipses of different types and their geological significance; concept of stress-strain compatibility. Mohr diagrams for stress and strain and their use. Behaviour of rocks under stress: elastic, plastic, viscous and viscoelastic responses and their geological significance. Concept of continuous and discontinuous media. Mechanics of rock fracturing: fracture initiation and propagation; Coulomb's criterion and Griffith's theory; Crack linkage and their Importance. Effect of strength anisotropy on fracturing; Role of fluids in rock fracturing.

Unit- II: Folds, Faults and Joints **(12 Hours)**

Fold interference and superposed folds. Strain distribution in a folded layer and its significance.

Evolution of axial planar and transected cleavages with folds. Fold-related lineations. Mechanics of faulting: Anderson's theory and its limitations. Complex geometry of normal, strike slip and thrust faults with natural examples. Paleostress analysis using fault-slip data. Geometric analyses of joints - mesofracture analyses.

Unit- III: Ductile Shear Zones **(11 Hours)**

Shear zones: their significance in continental crustal evolution. Shear/fault zone rocks: mylonite, cataclasite and pseudotachylyte. Kinematics of flow in a shear zone: flow eigenvectors and their significance; 2-D flow vorticity analyses. Grain-scale deformation mechanism in mylonite: dislocation and diffusion creep, strain hardening and softening mechanisms lattice. Shape- and lattice-preferred orientation, superplasticity.

Unit- IV: Crustal Deformation & Structural analysis of plate boundary fault zones **(8 Hours)**

Deformation behaviour of quartzo-feldspathic rocks. Brittle-plastic transition and seismic behaviour of the upper crust. Plate convergence and continental deformation: Indian and overseas examples. Oblique convergence of plates: Transpression and Transtension. Transform and Transcurrent faults: different types and classical examples. Normal faults in Mid-oceanic ridges: implication for magmatism and heat flow. Megathrusts in subduction and collision zones: their seismogenic implications, with natural examples.

Practical **1 Credit (30 Hrs)**

1. Problems related to practical strain measurement (Rf -φ method, Fry method etc.)
2. Analysis and interpretation of geological maps of various complexities.
3. Stereographic techniques: contour diagrams and orientation analyses of foliation and lineation data for regional structural geometry.

ESSENTIAL READINGS:

1. Bayly, B., 1992. Mechanics in Structural Geology, Springer.
2. Davis, G.H. and Reynolds, SJ., 1996. Structural Geology of rocks and regions John Wiley. and Sons.
3. Ghosh: S.K., 1993. Structural Geology: Fundamentals and modern developments, Pergamon Press.'
4. Leyson, P.R. and Lisle, RJ., 1996. Stereographic projection techniques in structural Geology, Cambridge University Press.
5. Passhier, C. and Trouw, RAJ, 2005. Microtectonics. Springer, Berlin.
6. Pollard, O.O and Fletcher, R.C., 2005. Fundamentals of structural geology, Cambridge University Press.

SUGGESTED READINGS:

1. Rams ay, J.G. and Huber, M. l., 1983. Techniques of Modern Structural Geology: Vol. I & Il. AcadeJnic Press

2. Ramsay, J. G., 1967. Folding and Fracturing of Rocks, McGraw-Hill Book Company, New York
3. Rowland, S.M., Duebendorier, E. and Schiefelbei I.M., 2007 Structural analysis and synthesis a laboratory course in structural geology, Balckwell Pub.
4. Suppe, J., The Principles of Structural Geology prentice Hall Inc., Jersey, 1985
5. Twiss, R.J. and Moores EM 2007 Structural Geology Freeman
6. Van der Pluijm, B.A. and Marshak, S 2004. Earth structure:an introduction to structural geology Tectonic.W.W. Norton and
Company Ltd.

DSC 8: GROUNDWATER SCIENCE

Duration: 45 Hours (Lecture) + 30 Hours (Practical)

Course Title and Code	Total Credit	Credit distribution in course		
		Lecture	Tutorial	Practical
Groundwater Science	4	03	0	01

LEARNING OBJECTIVES:

- The course is aimed at imparting advanced-level conceptual clarity and understanding of groundwater science.
- It will share knowledge about the occurrence and movement of groundwater, water-bearing properties of formations, aquifer types, aquifer parameters, drilling methods, well construction, and completion.
- It also enables students to acquire knowledge about the physical and chemical attributes and the exploration of the groundwater resources.

LEARNING OUTCOMES:

- The students will learn about occurrence of groundwater, water bearing properties of formations, aquifer types and aquifer parameters.
- The course imparts knowledge about construction, design and development of water wells, aquifer parameter estimation and the science of groundwater flow under different conditions.
- Develop a concise understanding of groundwater quality, its analytical representation, contamination and variability in India
- The students will learn about the concepts of groundwater exploration and the different methods of groundwater exploration.

LECTURE **3 Credit (45 Hrs)**

Unit I: General concepts: **(14 hours)**

Water on earth. Types of water: meteoric, juvenile, magmatic and sea waters. Hydrologic cycle. Vertical distribution of water: zone of aeration and zone of saturation. Concept of depth to water level and water table contour maps. Concepts of drainage basin and groundwater basin. Classification of rocks and formations according to their water-bearing properties. Aquifers and their types. Water table and piezometric surface. Water bearing properties of rocks and aquifer parameters: porosity, permeability, specific yield, specific retention, hydraulic conductivity, transmissivity, intrinsic permeability, storage coefficient, storativity, specific storage. Fluctuations of water table and piezometric surface; Barometric and tidal efficiencies. Geologic and geomorphic controls on groundwater. Hydrostratigraphic units. Springs. Introduction to hydrogeology of India and the groundwater provinces of India.

Unit II: Water wells and well hydraulics: (13 hours)

Types of wells, drilling methods, construction, design, development, maintenance and revitalization of wells. Specific capacity and its determination. Darcy's Law and its applications. Theory of groundwater flow, numerical solutions for steady state linear groundwater flow in confined and unconfined aquifers and Dupuit's assumption for unconfined flow. Numerical solutions for steady state radial flow to a well in confined (Thiem's equation) and unconfined aquifers (Dupuit's equation). Numerical solutions for unsteady state groundwater water flow condition. Methods of permeability estimation in laboratory and field. Evaluation of aquifer parameters of confined aquifer using Theis and Jacob methods.

Unit III: Groundwater chemistry: (10 hours)

Groundwater quality - physical and chemical properties of water, quality criteria for different uses. Groundwater contamination and pollution from natural (geogenic) and anthropogenic sources. Graphical presentation of water quality data. Saline water intrusion in aquifers and its prevention. Groundwater quality in different provinces of India.

Unit IV: Groundwater exploration: (8 hours)

Geological, lithological, structural and hydrogeomorphic mapping, fracture trace analysis, lineament mapping. Remote sensing as a tool in groundwater exploration. Surface-based geophysical methods - seismic, gravity, electrical resistivity and magnetic. Subsurface geophysical methods.

PRACTICAL 1 credit (30 Hours)

1. Depth to water level and water table contour map-based exercise.
2. Numerical problems related to steady state radial flow to wells in confined and unconfined aquifer.
3. Numerical problems related to estimation of permeability in laboratory and field.
4. Practical exercise based on Theis and Jacob's equation and methods of aquifer parameter estimation.
5. Practical exercises based on Hydrochemical facies and Trilinear (Hill-Piper) diagram.
6. Numerical problems related to sea water intrusion in the coastal aquifers.

ESSENTIAL READINGS:

1. Davies, S.N. and De-West, R.J.N., 1966. *Hydrogeology*, John Wiley & Sons, New York.
2. Driscoll, F.G., 1988. *Ground Water and Wells*, UOP, Johnson, Div. St. Paul. Min. USA.
3. Fetter, C.W., and D. Kreamer. 2022. *Applied Hydrogeology*, 5th ed. Long Grove, IL: Waveland Press
4. Fitts, C.R., 2023. *Groundwater Science* (3rd ed.), Academic Press.
5. Freeze, R.A. and Cherry, J.A., 1979. *Groundwater*, Englewood Cliffs, New Jersey: Prentice-Hall.

6. Karanth K.R., 1987. *Groundwater: Assessment, Development and Management*, Tata McGraw-Hill Pub. Co. Ltd.

SUGGESTED READINGS:

1. Raghunath, H.M., 1987. *Ground Water*, Wiley Eastern Ltd., Calcutta.
2. Schwartz, F. W., & Zhang, H. 2024. *Fundamentals of groundwater* (2nd ed.). Wiley.
3. Todd, D. and Mays, L. 2005 *Groundwater Hydrology*. (3rd ed.), John Wiley and Sons, Inc., Hoboken, N.J.
4. EPG Pathsala lecture modules at web link: http://epgp.inflibnet.ac.in/ahl.php?csrno=448
5. Uliana, M. M. 2025. *Basic hydrogeology: An introduction to the fundamentals of groundwater science*. The Groundwater Project. https://doi.org/10.62592/CBIQ7579.
6. Younger, P. L., 2009. *Groundwater in the environment: an introduction*. John Wiley & Sons.

DSE 5: METALLOGENY THROUGH TIME AND SPACE

Duration: 45 Hours (Lecture) + 30 Hours (Practical)

Course Title and Code	Total Credit	Credit distribution in course		
		Lecture	**Tutorial**	**Practical**
Metallogeny through time and space	**4**	**03**	**0**	**01**

LEARNING OBJECTIVES:

- To introduce the understanding of ore deposits and how they form
- Ores in the context within the framework of tectonics and metallogeny.
- The student will be introduced to several ore deposit styles.
- A suite of important ore minerals (oxides and sulphides) will be examined in reflected light.

LEARNING OUTCOMES:

- Students will be able to identify a number of important ore minerals in reflected light, thereby aiding in the exploration and characterization of ore deposits
- Students will recognize the key factors controlling several ore deposits so that deposits may be characterized and linked to existing ore deposit models
- Students will have knowledge on metallogenic provinces and their evolution in time domain
- Students will also be able to apply their knowledge to link these ore deposits within a metallogenic framework and thereby enhance exploration strategies

LECTURE **3 Credit (45 Hrs)**

Unit-I: Concept of metallogeny and metallogenic provinces **(12 Hours)**

Introduction and objectives; Metallogeny principles and practice; Metallogenic terms and definitions; Metallogenic classification of ore and mineral deposits; The concept of metallogenic provinces and epochs

Unit-II: Tectonics and Metallogeny **(14 Hours)**

Global Tectonics and Supercontinent Cycles, Introduction to crustal evolution and metallogeny; Metallogeny, geodynamics, and deep time: Metallogeny and non-uniformitarian models of ancient earth geodynamics, Metallogeny and plate tectonics: within-plate settings and incipient divergent plate boundaries, divergent plate boundaries, and convergent plate boundaries

Unit-III: Controls on ore mineralization (11 Hours)

Hydrothermal alteration Ore deposits within the context of their characterization, tectonic setting, structural control, alteration, and ore mineralogy: Porphyry Cu and Mo; Carlin gold; Epithermal; SEDEX and VMS; MVT; Sedimentary Ore deposits: Iron and Manganese; Magmatic – Bushveld Igneous Complex

Unit-IV: Metallogeny models (8 Hours)

Metallogenic models: source of elements, supercritical hydrous melts and fluids, architecture and timing of flow path activation, controls on sites and physico-chemical conditions; Features of Metallogenic Provinces: Regional tectonic types of ore-bearing provinces, Evolution of ore-bearing provinces in time, composition of ores characterizing the ore-bearing provinces, form of ore deposits, and the ore-bearing provinces.

PRACTICAL 1 credit (30 Hours)

1. Learning diagnostic physical properties and identification of metallic and non-metallic ore minerals in hand specimens.
2. Training on the microscopic identification of sulphide, oxide and carbonate ore minerals
3. Learning approaches to understand the textural relationships and mineral paragenesis in the assemblage of gangue and ore minerals.

ESSENTIAL READINGS:

1. Richard, H. Sillitoe (2024). Metallogeny and Mineral Exploration – Some Personal Reminiscences. Geochemical Perspectives.
2. Moon, C.J., Whateley, M.K.G. and Evans, A.M. (2006). Introduction to mineral exploration.
3. Robb, L.J. (2005). Introduction to ore-forming processes
4. Ridley, J. (2013) Ore Deposit Geology

DSE 5: PALEOCLIMATE

Duration: 45 Hours (Lecture) + 30 Hours (Practical)

<table>
<tr><td>Course Title and Code</td><td>Total Credit</td><td colspan="3">Credit Distribution in Course</td></tr>
<tr><td rowspan="2">Paleoclimate</td><td rowspan="2">4</td><td>Lecture</td><td>Tutorial</td><td>Practical</td></tr>
<tr><td>3</td><td>0</td><td>1</td></tr>
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LEARNING OBJECTIVES:

- Understand Earth's climate system, energy balance, and feedback mechanisms.
- Apply sampling, dating, and analytical techniques to paleoclimate archives.
- Reconstruct past climates using multiproxy data and Earth system processes.
- Evaluate anthropogenic impacts and mitigation strategies in a changing climate.

LEARNING OUTCOMES

- Explain climate system dynamics, energy balance, and radiative forcing.
- Apply sampling, dating, and proxy analysis for paleoclimate reconstruction.
- Reconstruct past climates and relate them to orbital, oceanic, and tectonic controls.
- Evaluate anthropogenic impacts, risks, and mitigation/adaptation strategies.

LECTURE **3 Credit (45 Hrs)**

Unit I: Introduction to Weather and Climate **(12 Hours)**

Concepts of **weather** and **climate** and their classification systems, **Greenhouse gases**: sources, changing concentrations, and their role in climate change, Components of the **climate system** and their interactions, **Climate forcing**, system responses, response rates, and feedback mechanisms, **Incoming solar radiation**: short-term and long-term variability (insolation), Receipt, storage, and transformation of heat; **Earth's heat budget**, Radiative forcing, albedo, and anthropogenic influences on energy balance

Unit II: Sampling Earth Materials to Understand Climate Change **(14 Hours)**

Sampling methods for retrieving **climate and oceanographic archives** (deep-sea cores, ice cores, lake sediments, speleothems), **Dating techniques**: radiometric, radiocarbon, and others; advantages, limitations, and uncertainties, **Elemental and isotopic analysis** for paleoclimate reconstruction, Instruments used in paleoclimate studies: mass spectrometers, gas chromatographs, stable isotope analysers, Climate modelling approaches and **IPCC climate change projections**; multiproxy integration for climate reconstructions

Unit III: Paleoclimate Reconstruction **(11 Hours)**

Reconstruction from **deep-sea cores, ice cores, pollen and spores, biogeochemical proxies, corals, and speleothems,** Astronomical controls: **Milankovitch cycles** and solar variability, Glacial–interglacial cycles; **Last Glacial Maximum (LGM)** and **Younger Dryas,** Monsoon variability over geological timescales and the role of the **Intertropical Convergence Zone (ITCZ),** Atmospheric layering, circulation, and **heat transfer in the atmosphere and oceans, Global Ocean Conveyor Belt** and its control on climate, Plate tectonics and long-term climate regulation, Teleconnections, ocean–atmosphere feedbacks, and paleoclimate modelling

Unit IV: Anthropogenic Effects, Climate Impacts, and Mitigation **(8 Hours)**

Natural vs **anthropogenic drivers** of climate change, **Regional climate records**, with emphasis on the Indian subcontinent, Biosphere responses to climate variability, Human impacts on climate and consequences for society, ecosystems, and economy, Climate change hazards, disasters, and risk assessment, Mitigation strategies, adaptation measures, and policy frameworks

PRACTICAL **1 credit (30 Hours)**

1. Interpreting Paleoclimatic data
   (a) Quantitative Faunal data
   (b) Distribution of Fossils on Paleogeographic Maps
   (c) Interpreting Stable Isotope Data obtained from Archives
2. Exercises on Ocean Circulation and resultant Climate Change
3. Exercises on Closing and Opening of Ocean gateways and resultant Continental Glaciations
4. Interpreting Past sea level curves and their climatic Causes.

ESSENTIAL READINGS:

1. Ruddiman, W.F., 2001. Earth's climate: past and future. Edition 2, Freeman Publisher.
2. Rohli, R.V., and Vega, A.J., 2007. Climatology. Jones and Barlatt
3. Lutgens, F., Tarbuck, E., and Tasa, D., 2009. The Atmosphere: An Introduction to Meteorology. Pearson Publisher**.**
4. Aguado, E., and Burt, J., 2009. Understanding weather and climate. Prentice Hall.
5. Bradley, R.S., *Paleoclimatology: Reconstructing Climates of the Quaternary*, Academic Press.
6. Braiser, M.D., 1980. *Microfossils*, George Allen, and Unwin.

SUGGESTED READINGS:

1. Cronin, T.M., 1999.*Principles of Paleoclimatology*, Columbia University Press.
2. Fischer, G. and Wefer, G., 1999.*Use of Proxies in Paleoceanography: Examples from the South Atlantic*, Springer.
3. Kennett, J.P., 1982.*Marine Geology*, Prentice-Hall Inc.
4. North, G.R. and Crowley, T.J., 1995. *Paleoclimatology*, Oxford University Press

DSE 6: REMOTE SENSING AND GIS

Duration: 45 Hours (Lecture) + 30 Hours (Practical)

Course Title and Code	Total Credit	Credit distribution in course		
		Lecture	**Tutorial**	**Practical**
Remote Sensing and GIS (DSE 6)	**4**	**03**	**0**	**01**

LEARNING OBJECTIVES:

- The primary aim of this course is to equip students with a thorough understanding of the principles and applications of modern geospatial technologies.
- The course will cover the fundamental theories of remote sensing and GIS before advancing to hands-on techniques for data processing, and analysis.
- The course will focus on applying the integrated methodologies to address the critical role in geological investigation and analysis.

LEARNING OUTCOMES:

- The students learn about the fundamental principles of remote sensing, photogrammetry, Geographic Information Systems (GIS), and the Global Positioning System (GPS)
- The course will impart proficiency in using specialized software (QGIS and programming language) to process and analyse geospatial data, including satellite images and geographic datasets.
- The students will also learn application of remote sensing and GIS methodologies to evaluate real environmental problems.
- Students will be acquainted with GPS accuracy and error sources and integration of GPS data with GIS

LECTURE **3 Credit (45 Hrs)**

Unit I: Foundation of Remote Sensing **(12 Hours)**

History of Remote Sensing; Concepts in Remote sensing; Electromagnetic (EM) waves in free space; EM radiation interaction with matter and atmosphere; Photogeology; Photogrammetry; Platform, sensors and scanners; Earth resources satellites; Data acquisition; Data formats; Introduction to Microwave Remote Sensing

Unit II: Geospatial Programming and Image Analysis **(14 Hours)**

Introduction to R Software; Measure or Central Tendency; Correlation; Covariance and Multivariate Statistics; Regression; Least Square Analysis and Probability Distributions. Digital Image Processing Image rectification and restoration; Image enhancement, contrast stretching, PCA, FCC, Image ratioing; Image classification and accuracy assessment - supervised & unsupervised classification, error estimation; Data merging and GIS integration

Unit III: Spatial Modelling and Geographic Information System **(11 Hours)**

Introduction, Coordinate systems and datum Projection systems; Spatial data models and data structures; Attribute data management; Digital terrain analysis using DEM data; Introduction to GIS models and modelling including surface analysis, multicriteria analysis and spatio-temporal analysis.

Unit IV: Global Navigation Satellite System **(8 Hours)**

Introduction to GNSS; Introduction to GPS; GPS receivers; GPS positioning mode- point positioning & relative positioning (DGPS & RTK GPS); GPS accuracy and error sources, Integrating GPS data with GIS; Applications in earth system sciences.

PRACTICAL **1 Credi (30 Hours)**

1. Data procurement from major satellite data portals and Visualization of the electromagnetic spectrum and analysis of the spectral signature different land cover types.
2. Understanding the concepts of resolutions by comparing different satellite images through Multi-source data integration and Georeferencing
3. Visual Interpretation of Aerial & Satellite Imagery
4. Introduction to R for Geospatial Data, Basics of Statistics - Measure or Central Tendency; Correlation
5. Image Enhancement and Band Ratios
6. Multivariate Image Analysis

7. Unsupervised Image Classification, Supervised Image Classification & Accuracy Assessment
8. Data Merging, GIS Integration and Spatial interpolation methods in QGIS
9. Generation of DEM Derivatives and watershed analysis

ESSENTIAL READINGS:

1. Bhatta, B., Remote Sensing and GIS, Oxford Publication
2. Gupta, R. P., 2003. Remote Sensing Geology Springer
3. Lillesand, T. M & Kiefer R W 2007 Interpretation of Remote Sensing and Image
4. Richards, JA., 1999. Remote Sensing Digital Image Analysis, An Introduction
5. Sabin, F. F., 2007 Remote Sensing: Principles, Interpretation, and Applications.

SUGGESTED READINGS:

1. Jensen, J.R., 1997 Introductory Digital Image Processing: A Remote sensing perspective, Springer. Verlag.
2. Demers: M.N., 1997. Fundamentals of Geographic Information system, John Willey & sons. Inc.
3. Verbyla, D.L., 2002. Practical GIS Analysis, Taylor & Francis.
4. Hofmann-Wellenhof, B., Lichtenberger, H. and Collins J 2001. GPS. Theory & Practice, Springer Wien New York.

DSE 6: PHASE EQUILIBRIA AND MAGMATIC ROCKS

Duration: 45 Hours (Lecture) + 30 Hours (Practical)

Course Title and Code	**Total Credit**	**Credit distribution in the course**		
Phase equilibria and magmatic rocks (DSE- 6)	**4**	**Lecture**	**Tutorial**	**Practical**
		03	**0**	**01**

LEARNING OBJECTIVES

- The course aims to introduce the principles of phase equilibria and their application to natural silicate systems.
- It will explain the petrology and geochemistry of the Earth's mantle, focusing on its composition, structure, and dynamics. Students will develop an understanding of magma generation, evolution, and the processes of mantle melting.
- Ultimately, this study will provide insights into melt generation and crystallization mechanisms, as well as the diverse types of rock and their connections to tectonic settings.

LEARNING OUTCOMES

- Students will be able to apply the phase rule to igneous rock systems.
- Students will understand the melting and crystallisation behaviour of silicate systems.

- Students will also be able to describe the mantle mineralogy and geochemistry.
- Students will understand the melting processes, mantle heterogeneity and isotopic reservoirs.

LECTURE **3 Credit (45 Hrs)**

Unit- I: Thermodynamics & Principles of Phase Equilibria (12 Hours)

Laws of thermodynamics, Gibbs free energy, Enthalpy, entropy, Clapeyron equation Concepts of system, phase, component, and degree of freedom, Gibbs Phase rule and Lever rule, Types of systems: open, closed, isolated, Phase diagrams: definition, uses, and interpretation

Unit- II: Silicate Systems and Phase Diagrams (12 Hours)

Crystallization behaviour of natural magmas, Fractional crystallization and equilibrium crystallization, Binary silicate systems: eutectic, peritectic, and solid-solution, Ternary silicate systems: Diopside-Anorthite-Forsterite and Forsterite-Anorthite-Silica system, Effects of Pressure and Fluid on Eutectic and Melting Temperatures.

Unit- III: Geochemistry (12 Hours)

Trace element partitioning between minerals and melts, Geochemical modelling of mantle processes, Rare earth elements and their application, Application of major and trace elements in petrogenesis, Stable and radiogenic isotopes, isochron technique, Rb-Sr, Sm-Nd and U-Pb-Th systems

Unit- IV: Mantle Petrology (9 Hours)

Structure and composition of the Earth's mantle, Process of Mantle Melting and the generation of basaltic melt, Petrogenesis of MORB, OIB, and arc magmas, Mantle metasomatism and heterogeneity, Mantle reservoirs

PRACTICAL **1 credit (30 Hrs)**

1. Study of igneous rocks under the petrological microscope.
2. CIPW Norm calculations.
3. Identifying the minerals using mineral chemistry.
4. Calculation on batch and fractional melting models.
5. Numerical on bulk partition coefficient, equilibrium crystallization, fractional crystallization

ESSENTIAL READINGS:

1. Winter, J. D. (2014). Principles of igneous and metamorphic petrology. Pearson.
2. Wilson, M. (1989) Igneous Petrogenesis, Springer-Verlag Berlin Heidelberg.
3. Frost, B. R. and Frost, C. D., (2013) Essentials of Igneous and Metamorphic Petrology. Cambridge University Press.
4. Philpotts, A., & Ague, J. (2009). Principles of igneous and metamorphic petrology. Cambridge University Press.
5. Rollinson, H. R. (2014). Using geochemical data: evaluation, presentation, interpretation. Routledge.

DSE 7: SURFACE AND SHALLOW SUBSURFACE PROCESSES

Duration: 45 Hours (Lecture) + 30 Hours (Practical)

Course Title and Code	Total Credit	Credit distribution in the course		
Surface and Shallow Subsurface Processes (DSE- 7)	4	Lecture	Tutorial	Practical
		03	0	01

LEARNING OBJECTIVES:

- Teach the fundamental physical, chemical, and biological processes that shape Earth's surface and near subsurface.
- Analyze how tectonics, climate, and human activities influence geomorphic systems.
- Apply quantitative tools and models to study surface process rates and patterns.
- Explore subsurface data (geophysical, borehole, and sedimentological) to infer shallow Earth processes.
- Develop skills in field mapping, remote sensing, and laboratory analysis for surface–subsurface process investigation.

LEARNING OUTCOMES:

- Students will be able to explain key mechanisms of erosion, sediment transport, and deposition in various environments.
- Students will assess interactions between geomorphic, hydrologic, and pedologic systems.
- Students will analyze surface and subsurface datasets to reconstruct process history and landscape evolution.
- They will use modelling tools to interpret geomorphic and subsurface features.

LECTURE **3 Credit (45 Hrs)**

Unit I: Earth's Surface and Subsurface Systems **(12 Hours)**

Earth's surface as an open system — energy and material fluxes, Interactions among tectonics, climate, and surface processes, Near-surface materials: regolith, soil, sediments, and weathered bedrock., Introduction to process domains — hillslopes, fluvial, aeolian, coastal, and glacial systems, Overview of surface–subsurface coupling and feedback mechanisms.

Unit II: Weathering, Soils, and Hillslope Dynamics **(12 Hours)**

Physical, chemical, and biological weathering mechanisms, Soil formation, classification, and critical zone processes, Methods of measuring weathering rates and denudation, Slope evolution theories — diffusion, threshold, and mass movement models, Hillslope processes: creep, landslides, and debris flows.

Unit III: Fluvial, Coastal, Aeolian, and Glacial Systems (12 Hours)

Mechanics of sediment transport: entrainment, transport, and deposition, River dynamics, channel morphology, and floodplain processes, Coastal morphology and sediment transport, Aeolian erosion, transport, and deposition processes, Glacial and periglacial landforms; subsurface effects (permafrost, meltwater channels), Quantitative approaches: sediment budgets, stream power, and incision models.

Unit IV: Subsurface Processes, Coupling, and Modelling (9 Hours)

Near-surface hydrology: infiltration, percolation, and flow in the vadose zone, Groundwater–surface water interactions, Subsurface weathering profiles and saprolite development, Shallow geophysical methods: resistivity, GPR, and seismic refraction, Process coupling: tectonics–climate–erosion feedbacks, Landscape Evolution Models (LEMs) and integrated geomorphic modelling, Integrating geophysical, geochemical, and geomorphic datasets, Human impacts and landscape resilience.

PRACTICAL 1 Credit (30 Hours)

1. Soil profile description, pH and texture analysis, mass balance calculation.
2. Stream power computation
3. Slope stability analysis using DEMs,
4. Sediment grain-size statistics.
5. Interpretation of coastal and aeolian features using satellite imagery and DEMs.
6. Introductory exercises using Topographic Analysis Kit (TAK).

ESSENTIAL READINGS:

1. Anderson, R.S. and Anderson, S.P. (2010). Geomorphology: The Mechanics and Chemistry of Landscapes. Cambridge University Press.
2. Allen, P.A. (1997). Earth Surface Processes. Wiley Publications
3. Bridge, J. and Demicco, R. (2012). Earth Surface Processes, Landforms and Sediment Deposits. Cambridge University Press
4. Summerfield, M.A. (1991). Global Geomorphology. Longman.
5. Ritter, D.F., Kochel, R.C. & Miller, J.R. (2011). Process Geomorphology. Waveland Press.
6. Nichols, G. (2009). Sedimentology and Stratigraphy. Wiley-Blackwell.

DSE 7 : APPLIED STRATIGRAPHY

Duration: 45 Hours (Lecture) + 30 Hours (Practical)

Course Title and Code	**Total Credit**	**Credit distribution in the course**		
Applied Stratigraphy (DSE 7)	**4**	**Lecture**	**Tutorial**	**Practical**
		03	**0**	**01**

LEARNING OBJECTIVES:

- The course aims to introduce the principles of applied branches of stratigraphy.
- The course will explain how depositional record vary in basins of different tectonic settings, how eustacy, sediment supply and tectonics play role in the depositional history of basins.
- Also, an attempt will be made to discuss different depositional models in space-time framework. In addition, the course will also delve into Magneto-stratigraphy and isotope stratigraphy and discuss how different branches of stratigraphy converge in explaining the depositional records of a basin.
- Application of this knowledge in hydrocarbon industry will also be discussed.

LEARNING OUTCOMES:

- Students will be able to apply the understanding of sequence stratigraphy in basin analysis
- Students will able to decode depositional history of a basin in space-time framework
- They will be able to describe how different branches of stratigraphy converge in basin analysis.
- Students will be able to apply the knowledge in Oil/Gas industry to search for new reserves

LECTURE **3 Credit (45 Hrs)**

Unit I: Sequence Stratigraphy **(12 Hours)**

Historical developments. Definitions and key concepts. Base level changes, Transgressions and regressions, T-R cycles, Stratigraphic surfaces: Stratal terminations, sequence stratigraphic surfaces, Unconformity and correlative conformity, Ravinement surface, Initial and maximum flooding surface.

Unit II: Systems Tracts and Sequence Models **(14 Hours)**

Systems Tracts: Lowstand, Transgressive, Highstand, Falling stage, Sequence Models: Depositional sequence (Type I, II, III), Genetic stratigraphic sequence, Transgressive-Regressive sequence, Hierarchy of sequences and bounding surfaces.
Application of sequence stratigraphy in hydrocarbon exploration

Unit III: Magnetic Stratigraphy **(8 Hours)**

Principles, Earth Magnetism, The magnetization process, Inclination, Declination, Paleomagnetism, Magnetic epochs, magnetic properties of marine sediment, Fundamentals of reversal magnetostratigraphy, The Plio-Pliestocene reversal record, Magnetic stratigraphy of cenozoics

Unit IV: Isotope stratigraphy **(11 Hours)**

Geochemistry of stable isotope (C, O, S). Application of stable isotopes: Oxygen and hydrogen in Paleothermometry, and Paleoclimatology. Carbon in modern biosphere, sedimentary rocks of Precambrian age, and marine and nonmarine sediments. Nitrogen: Geochemistry and isotope fractionation. Nitrogen in fossil fuels. Biogenic fractionation of sulphur. Sulphur in recent sediments, fossil fuels (petroleum and coal), and sulfide ore deposits.

PRACTICAL **1 credit (30 Hrs)**

1) Exercises on paleo-environments and their shifts through time with both surface and sub-surface data

2) Exercises on Key surface tracing and their designation
3) Exercises on sequence modelling
4) Exercises involving Magnetostratigraphy and biostratigraphy.

ESSENTIAL READINGS:

1. Sequence Stratigraphy: D. Emery, K. Mayers and G.T.Bertram (1996)
2. Principles of Sequence Stratigraphy: Octavian cateneauau (2006) Elsevier
3. Basin Analysis: Principles and Applications: P.A. Allen and J.R.Allen (1990) Blackwell Publishing
4. The geology of stratigraphic sequences: A.D. Miall (1997)
5. Isotope chronostratigraphy: Theory and Methods by D.F.Williams, I. Lerche and W.E.Full

DSE 7: APPLIED GEOPHYSICS

Duration: 45 Hours (Lecture) + 15 Hours (Tutorial)

Course Title and Code	Total Credit	Credit distribution in the course		
Applied Geophysics (DSE- 7)	4	Lecture	Tutorial	Practical
		03	01	0

LEARNING OBJECTIVES:

- This course introduces students to the physical properties of Earth and the principles of geophysical investigation.
- It will cover the basics of gravity, magnetic, seismic, and electrical exploration methods used to study Earth's resources.
- Students will gain essential knowledge about the relationship between geology and geophysics, which is important for understanding the Earth's geodynamic behaviour and interior.
- The course will focus on fundamental concepts, exploration methods, and geophysical anomalies to enhance our understanding of Earth's geodynamics and resources.

LEARNING OUTCOMES

- Students will be able to gain a fundamental understanding of geophysical methods and their applications in exploring and understanding the Earth and its interior.
- Students will learn about gravity, magnetism, palaeomagnetism, electrical, and seismic.
- They will acquire essential skills in identifying geophysical anomalies and their relationship to geological processes.
- Students will learn the methodologies for geophysical data acquisition, as well as the correction and reduction procedures.

LECTURE **3 Credit (45 Hrs)**

Unit- I: Introduction to Geophysical prospecting **(10 Hours)**

Introduction to Geophysical Prospecting. Branches of geophysics: solid earth geophysics and exploration geophysics. Overview of various geophysical methods, measured parameters and their respective physical properties. Signal and Noise. Data acquisition and processing. Concept of geophysical modelling: Forward and Inverse modelling. Importance of geophysical methods in mineral exploration.

Unit- II: Gravity and Magnetic (12 Hours)

Gravity fields of the Earth: Gravity potential, Earth's figure, International Reference Ellipsoid, Normal-gravity, Geoid, and gravity anomalies. Principles of gravimeters, stable and unstable types. Gravity corrections and reduction: Free-air, Bouguer, and terrain. Gravity anomalies and concept of isostatic compensation. Interpretation of anomalies for simple geometric bodies, e.g. sphere, horizontal cylinder, dyke and fault. Origin of Earth's magnetic field and changes in the geomagnetic field. Magnetic properties of rocks and minerals. Measurement and reduction of magnetic data. Magnetometer and magnetic anomalies. Application of gravity and magnetic survey in mineral exploration. Palaeomagnetism, Paleopole, Apparent Polar wandering curves and Continental drift.

Unit- III: Electrical and Electromagnetic (12 Hours)

Electrical resistivity of rocks and minerals. Apparent resistivity and special electrode configurations. Vertical Electrical Sounding (VES) and Profiling techniques. Application of resistivity data for groundwater and mineral exploration. Induced Polarisation and Self-potential methods. Theory of electromagnetic induction, skin depth. Transient electro-magnetic methods (TEM), Very low frequency methods (VLF), Magnetotelluric (MT) methods, Ground Penetrating radar (GPR) methods.

Unit- IV: Seismic and Well Logging (11 Hours)

Nature and types of seismic waves (P, S, and surface waves). Seismic ray paths, reflection, and refraction principles. Subcritical and supercritical reflections, and critical refraction. Seismic Refraction in 2-layered, 3-layered earth models. Seismic Reflection survey, Normal move out (NMO). Elements of earthquake seismology; Focal mechanism and Fault plane solutions. Seismic evidence for Earth's layering. Concept of well logging and borehole environment. Difference between geological, geophysical, and petrophysical logs. Well-logging techniques: Resistivity log, Induction log, Spontaneous Potential Log, Caliper log, Gamma Ray log, Density log.

TUTORIAL 1 credit (15 Hrs)

1. Problems on free air and Bouguer anomalies.
2. Numerical problems on isostasy and density contrasts.
3. Calculating paleolatitude and paleopole,
4. Resistivity curve plotting and interpretation
5. Problems on seismic survey.

ESSENTIAL READINGS:

1. Lowrie, W. (2007). Fundamentals of geophysics. Cambridge University Press.
2. Kearey, P., Brooks, M. and Hill, I., (2002). An Introduction to Geophysical Exploration. Third Edition. Blackwell Publishing.
3. Mussett, A.E. and Khan, M.A., (2000). Looking into the Earth: An Introduction to Geological Geophysics. Cambridge University Press.

4. Telford, W.M., Geldart, L.P., and Sheriff, R.E. (1990). Applied Geophysics. Cambridge University Press.
5. Fowler, C.M.R. (2005). The Solid Earth: An Introduction to Global Geophysics. Cambridge University Press.

DSE 3: GEOLOGICAL APPLICATION OF REMOTE SENSING AND GIS

Duration: 45 Hours (Lecture) + 30 Hours (Practical)

Course Title and Code	Total Credit	Credit Distribution in Course		
		Lecture	Tutorial	Practical
Geological Application of Remote Sensing and GIS	4	03	0	01

LEARNING OBJECTIVES

- The objective of this course is to train the students with the geological applications of remote sensing and Geographic Information System (GIS).
- This course provides opportunity to students to gain knowledge on various remote sensing datasets and algorithms of data analysis and apply this in the field of geosciences.

LEARNING OUTCOMES

The students will be able to:

- Understand the advanced concepts of remote sensing and GIS in the field of Geosciences.
- Gain expertise in utilizing the Remote Sensing datasets for various geological applications using diverse techniques.
- Work with different datasets including Microwave and Hyperspectral and not limited to Optical datasets.

LECTURE **3 Credit (45 Hrs)**

Unit I: **10 Hrs**

Introduction to remote sensing: Electromagnetic radiation principles, Sensors, Data formats, Concepts of GIS, Concepts of GPS (Global Positioning System).

Unit II: **10 Hrs**

Digital image processing: Image resolutions, Image errors and corrections, Image classification (unsupervised and supervised), Image enhancement methods, Spatial and Temporal interpolation.

Unit III: **10 Hrs**

Geological mapping: Mapping of geological features and landforms through aerial photographs, optical remote sensing and band transformations (band ratioing/ band indices/ PCA).

Unit IV: 15 Hrs

Applications in Natural Resource Management and Natural Hazard Mitigation: Groundwater potential zone mapping, Watershed delineation and application, Morphometric analysis, Total water storage analysis (GRACE), Hyperspectral remote sensing in Mineral mapping. Susceptibility Mapping, Applications of SAR data (flood mapping/ landslide detection/ deformation analysis).

PRACTICAL (30 Hrs)

1. Introduction to software (QGIS/R), data procurement.
2. Image classification (unsupervised and supervised).
3. Image enhancement and Interpolation methods.
4. Feature extraction and mapping (optical remote sensing/aerial photographs).
5. Susceptibility mapping/groundwater potential zones.
6. Watershed delineation and analysis.
7. Morphometric analysis and interpretation.
8. SAR data analysis (Flood mapping/landslide detection).
9. SAR data for deformation analysis.
10. Mineral mapping using hyperspectral data.

SUGGESTED READINGS:

1. Demers: M.N., 1997. Fundamentals of Geographic Information system, John Willey & sons. Inc.
2. Gupta, R. P., 2003. Remote Sensing Geology Springer
3. Hofmann-Wellenhof, B., Lichtenberger, H. and Collins J 2001. GPS. Theory & Practice, Springer Wien New York.
4. Jensen, J.R., 1997 Introductory Digital Image Processing: A Remote sensing perspective, Springer. Verlag.
5. Lillesand, T. M & Kiefer R W 2007 Interpretation of Remote Sensing and Image
6. Richards, JA., 1999. Remote Sensing Digital Image Analysis, An Introduction
7. Sabin, F. F., 2007 Remote Sensing: Principles, Interpretation, and Applications
8. Verbyla, D.L., 2002. Practical GIS Analysis, Taylor & Francis.

DSE 3: NUMERICAL METHODS AND MODELLING IN EARTH SCIENCES

Duration: 45 Hours (Lecture) + 30 Hours (Practical)

Course Title and Code	Total Credit	Credit distribution in course		
Numerical Methods and Modelling in Earth Sciences	4	Lecture	Tutorial	Practical
		03	0	01

LEARNING OBJECTIVES:

- To provide a general introduction to numerical methods relevant to Earth Sciences.
- To refresh foundational mathematical skills for modelling Earth system processes.
- To introduce the basics of geostatistics and spatial data handling.
- To build confidence among students in applying quantitative reasoning to geological problems.

LEARNING OUTCOMES:

By the end of the course, students will be able to:

1. Use basic numerical techniques to solve geological problems.
2. Apply simple mathematical models to Earth science processes.
3. Understand and perform basic geostatistical analyses.
4. Use Excel or basic Python scripts for data visualization and numerical computation.
5. Interpret numerical and spatial outputs in the context of Earth systems.

LECTURE **3 Credit (45 Hrs)**

Unit I: Refresher in Basic Mathematics **(10 Hours)**

Fundamental concepts such as arithmetic operations, algebraic expressions, percentages, and logarithms. Introduction to functions, graphs, and equations, including linear and polynomial forms. Key mathematical concepts like slope, area under a curve, and rate of change. These concepts will be applied to real-world geoscientific examples, such as calculating stream gradients, analysing hypsometric curves, and estimating sediment accumulation, thereby linking computation to geomorphological processes.

Unit II: Numerical Methods **(12 Hours)**

Root-finding techniques such as the Bisection method for determining solutions of nonlinear equations, along with interpolation methods including linear and polynomial approaches for estimating intermediate values from discrete datasets. The unit also addresses numerical differentiation and integration using tabulated data and tools like Excel. Application of these methods to simple environmental modelling scenarios, such as estimating erosion rates, analysing water balance components, and simulating decay processes.

Unit III: Introduction to Modelling Earth Systems **(11 Hours)**

Fundamental concept of a model, distinguishing between conceptual and numerical models. Importance of understanding model sensitivity and conducting uncertainty analysis to evaluate the reliability and robustness of model outputs. The unit incorporates practical examples such as heat flow in rocks, sediment transport dynamics, and groundwater recharge processes. Additionally, focus is on the use of mathematical equations to simulate basic Earth processes.

Unit IV: Geostatistics **(12 Hours)**

Focus on the analysis and interpretation of spatial data with distinguishing between point data and gridded datasets, followed by the application of descriptive statistical measures such as mean, median, and standard deviation to summarize spatial variables. Fundamental probability concepts, including basic probability theory, conditional probability, and probability distributions. Understanding of spatial patterns through correlation analysis, trend surface modelling, and regression techniques. Introduction to the basics of variogram analysis and spatial interpolation methods, including inverse distance weighting and kriging.

PRACTICAL **(30 hours)**

1. Basic operations, formulas, graphing geological data (e.g., rainfall, temperature, sediment yield).
2. Solving simple problems using spreadsheets: root finding, slope analysis, interpolation.
3. Create simple models for stream discharge, radioactive decay, or slope erosion using Excel.
4. Introduction to modelling softwares (TopoToolbox, LSD TopoTools, MODFLOW).
5. Calculate mean, variance, and construct simple variograms manually.

SUGGESTED READINGS:

1. Martin H Trauth (2022) *Python recipes for Earth Sciences.* Springer
2. Jon D Pelletier (2008) *Quantitative Modelling of Earth Surface Processes.* Cambridge University Press
3. Turcotte, D.L., & Schubert, G. (2014). *Geodynamics*. Cambridge University Press
4. Gersten, J., & Smith, J. (2006). *Introduction to Numerical Methods for Earth Scientists*. Oxford University Press
5. Burrough, P.A., & McDonnell, R.A. (1998). *Principles of Geographical Information Systems*. Oxford University Press
6. John C. Davis (2002). Statistics and Data Analysis in Geology, 2nd ed. Wiley

DSE 4 : VERTEBRATE AND INVERTEBRATE PALEONTOLOGY

Duration: 45 Hours (Lecture) + 30 Hours (Practical)

Course Title and Code	Total Credit	Credit distribution in the course		
DSE-4		Lecture	Tutorial	Practical
Vertebrate and Invertebrate Paleontology	4	03	0	01

LEARNING OBJECTIVES

- Understand the diversity, evolution, and dynamics of life forms in the geological past.
- Explain evolutionary transitions and functional adaptations in major invertebrate and vertebrate groups.
- Apply fossil evidence in relative dating of rocks and reconstruction of past ecosystems.
- Recognize major bio-events, mass extinctions, and basic methods for processing and studying paleontological specimens.

LEARNING OUTCOMES

- Identify and interpret different modes of fossil preservation and evaluate the nature of the fossil record.
- Classify fossils within a taxonomic framework using basic paleontological principles.
- Analyze major invertebrate, vertebrate, and plant fossil groups to understand their paleobiology and evolutionary significance.
- Utilize fossil evidence to perform relative dating of rocks and reconstruct past climates, environments, and paleogeographic settings.

LECTURE **3 Credit (45 Hrs)**

Unit -I **10 Hrs**

Introduction of Paleontology: Taphonomic processes and modes of preservation; nature and importance of fossil record. Taxonomic hierarchy; Speciation, species concept in palaeontology; Evolution and the fossil record; Modes of evolution, applications of biostratigraphy.

Unit-II **13 Hrs**

Invertebrate Paleontology: Brief introduction to important invertebrate groups (Bivalvia, Gastropoda, Brachiopoda, Graptolites, Trilobites) and their biostratigraphic significance. Significance of ammonites in Mesozoic biostratigraphy and their palaeobiogeographic implications. Functional adaptation in trilobites and ammonoids.

Unit -III **12 Hrs**

Vertebrate Paleontology: Origin of vertebrates and major steps in vertebrate evolution; Vertebrate evolution in the Palaeozoic Era; Mesozoic reptiles with special reference to origin diversity and extinction of dinosaurs, evolution in Proboscidea, Equidae and Hominidae.

Unit-IV **10 Hrs**

Paleobotany: Introduction to palaeobotany; fossil record of plants through time, fossil spores and pollen, Gondwana flora.

Ichnology: Introduction to ichnology; application of trace fossils in stratigraphy, fossils and paleobiogeography; fossils as a window to the evolution of ecosystems.

PRACTICAL **(30 Hours)**

1. Study of fossils showing various modes of fossilization.
2. Study of diagnostic morphological characters, systematic position, stratigraphic position and age of various invertebrate, vertebrate and plant fossils.

SUGGESTED READINGS

1. Clarkson, E.N.K.1998. Invertebrate Palaeontology and Evolution, George Allen & Unwin.
2. Raup, D.M. and Stanley, S. M. 1971. Principles of Palaeontology, W.H. Freeman and Company.
3. Benton, M. 1997. Basic Palaeontology: An introductory text, D.Harker, Addision Wisely Longman.
4. Prothero, D.R. 1998. Bringing fossils to life – An introduction to Palaeobiology, McGraw Hill.
5. Benton, M.J. 2005. Vertebrate palaeontology (3rd edition). Blackwell Scientific, Oxford.
6. Willis, K.J. & McElwain, J.C. 2002. The evolution of plants, Oxford University Press.
7. Brenchley, P. J., and Harper, D. A. T. 1998. Palaeoecology: Ecosystems, Environments and Evolution by Chapman and Hall.
8. Foote, M. & Miller, A. I. (2006). Principles of Paleontology, third edition.
9. Shukla, A. C. & Mishra, S.P. (1982). Essentials of Palaeobotany.
10. Jones, R.W. (2011). Applications of Palaeontology - Techniques and Case Studies

DSE 4 : GEOCHEMISTRY

Duration: 45 Hours (Lecture) + 30 Hours (Practical)

Course Title and Code	Total Credit	Credit distribution in course		
Geochemistry	4	**Lecture**	**Tutorial**	**Practical**
		03	0	01

LEARNING OBJECTIVES:

- Understand the origin, composition, and geochemical differentiation of the Earth and its relation to the solar system.
- Explain the geochemical behaviour of major and trace elements in magmatic systems and their role in rock petrogenesis.

- Apply radiogenic and stable isotope techniques for geological dating and interpretation of geochronological data.
- Interpret geochemical processes controlling mineral stability, weathering, and the chemistry of natural waters and sedimentary rocks.

LEARNING OUTCOMES:

- Understand the evolution of the early Earth from proto-planetary material and its differentiation into the present-day structure.
- Describe the composition and characteristics of the Earth's major geochemical reservoirs.
- Explain element fractionation and its role in interpreting geochemical processes.
- Apply radiogenic and stable isotope techniques to trace sources of rocks/minerals, date geological events, and understand weathering effects on sediments, soils, and natural waters.

LECTURE **3 Credit (45 Hrs)**

Unit- I **10 Hrs**

Earth in relation to Solar system and Universe, Nucleosynthesis, Meteorites, cosmic abundance of elements, Geochemical differentiation of primordial earth, chemical composition and properties of Earth's layers, Geochemical cycles.

Unit- II **15 Hrs**

Geochemical classification of elements, mineral partitioning coefficient; Behaviour of major and trace elements in magmatic systems, handling and plotting of major and trace element data from igneous rocks, spider and REE diagrams, trace element modelling, discrimination diagrams, their use in understanding petrogenesis of rocks, Introduction to important analytical techniques used in geochemistry.

Unit- III **10 Hrs**

Radioactive decay schemes, principles and methods of radioactive dating, isochron calculation, model ages, interpretation of geochronological data, K-Ar, Ar-Ar, Rb-Sr, Sm-Nd, U-Th-Pb systems, isotopic reservoirs, Cosmogenic radionuclides, Fission Track and Radiocarbon methods of dating. Stable isotopes and their fractionation; principles of oxygen, carbon and sulphur isotope geochemistry and their application in Geology.

Unit- IV **10 Hrs**

Mineral stability in Eh-Ph diagrams; redox reactions, Mineral/mineral assemblages as sensors of ambient environments, a brief introduction to geochemistry of natural waters and sedimentary rocks; geochemical processes involved in weathering of minerals and rocks.

PRACTICAL **(30 Hrs)**

1. Calculation of Partition Coefficients (D-values): Perform calculations of mineral-melt partition coefficients using provided compositional data. Interpret the geochemical behaviour of major and trace elements during partial melting and fractional crystallization.
2. Major and Trace Element Data Processing and Interpretation: Utilize spreadsheet software or specialized geochemical programs to process, normalize, and graphically represent major and trace element data. Construct multi-element (spider) and rare earth element (REE) diagrams to interpret magmatic processes and petrogenetic trends.
3. Tectonic Discrimination Diagram Analysis: Generate AFM, TAS, and tectonic discrimination diagrams using geochemical data. Apply software tools (e.g., IgPet, GCDkit) to classify igneous rocks and interpret their tectonomagmatic settings.
4. Isochron Diagram Construction and Interpretation: Construct Rb-Sr or Sm-Nd isochron diagrams from isotopic data sets. Calculate the age and initial isotopic composition of geological samples to understand geochronological evolution.
5. Radiometric Dating and Decay Equation Applications: Solve numerical problems using decay equations for various radiometric systems (e.g., K-Ar, U-Pb, Rb-Sr). Understand the principles of radioactive decay and their application in absolute age determination.
6. Stable Isotope Fractionation and Environmental Interpretation: Plot $\delta^{18}O$ and $\delta^{13}C$ values for rock or water samples. Interpret isotopic variations in the context of geological processes such as diagenesis, hydrothermal alteration, and paleoclimatic changes.

SUGGESTED READINGS:

1. Hugh R. Rollinson (1993) Using Geochemical Data: Evaluation, Presentation and Interpretation, Pearson Prentice Hall.
2. Alan P. Dickins (2005) Radiogenic Isotope Geology,. Cambridge University Press.
3. Kula C Misra (2012) Introduction to Geochemistry: Principles and Applications, Wiley-Blackwell.
4. Gunter Faure, 1998. Principles and applications of Geochemistry, Prentice Hall.
5. Claude Allegre, 2008. Isotope Geology, Cambridge University Press
6. Mason, B. and Moore, C.B., 1991. Introduction to Geochemistry, Wiley Eastern.
7. John V. Walther, 2010. Essentials of Geochemistry, Jones and 35 Bartlett Publication.

DSE 4: ADVANCED RIVER SCIENCE

Duration: 45 Hours (Lectures) + 30 Hours (Practical)

Course Title and Code	Total Credit	Credit distribution in course		
Advanced River Science	4	**Lecture**	**Tutorial**	**Practical**
		03	0	01

LEARNING OBJECTIVES:

- This course aims to provide an in-depth understanding of river system dynamics through interdisciplinary perspectives combining geomorphology, hydrology, sedimentology, and ecology.
- It will train students to analyse fluvial processes using modern quantitative tools, field data, and remote sensing–GIS techniques to interpret river behaviour
- The course will aim at addressing changes in river systems and design sustainable river management strategies.

LEARNING OUTCOMES:

- Students will be able to understand and appreciate river basins as systems with internal and external dynamics
- Students will be able to explain river morphology, discharge behaviour, including hydrographs and flood, and sediment transport processes
- Students will understand theoretical and quantitative techniques to study bedrock rivers and landscape evolution.
- They will be able to assess human impacts on rivers and explore approaches for sustainable management and restoration. Also, they will apply advanced technologies, including AI and GIS, for river monitoring and analysis.

LECTURE **3 Credit (45 Hrs)**

Unit I: Fundamentals of River System Dynamics **(12 Hours)**

Catchment hydrology, runoff, hillslope processes, channel initiation; River as a system: system approaches in fluvial geomorphology, Driving and resisting forces in river systems; Key concepts in river geomorphology: spatial and temporal scale, disturbance events, river sensitivity, resilience, threshold, (dis)connectivity, hierarchy and complexity

Unit II: Fluvial forms, processes and evolution **(14 Hours)**

River diversity: Channel pattern, Channel geometry, Channel morphology, Floodplains, instream features; River flow, discharge, and discharge measurement; Sediment load, entrainment, transport, deposition and measurement; Weathering and river chemistry: geochemical proxies and tracers to study fluvial dynamics; Hydrographs, hydrograph separation, baseflow; Groundwater-river interaction; Hyporheic zone; Flood hydrology, Flood frequency analysis; River evolution - River response to climate, tectonics and human disturbance; Impact of increased cryospheric dynamism on rivers

Unit III: Bedrock rivers **(8 Hours)**

Bedrock channel processes, Longitudinal profile analysis, Stream power incision model, Geomorphometrics, Evolution of fluvial landscapes.

Unit IV: Rivers in the Anthropocene, River Management and Emerging Themes (11 Hours)

Anthropogenic impacts on rivers: dams, diversions, river sand mining, land-use change, and pollution, Emerging contaminants in rivers; River management and River future: Riverine Ecology and Habitat, River Health, e-flow, Application of the River Styles Framework in River Management, River rehabilitation and repair; River rights and governance; Transboundary rivers; Modern methods and tools of data acquisition and data analysis for river science; Applications of Artificial Intelligence and Cloud based GIS in river science.

PRACTICAL **1 credit (30 Hours)**

1. Exercises on Hydrographs
2. Exercises on Flood frequency analysis
3. Extraction and analysis of geomorphometrics using MATLAB Topotoolbox
4. Fluvial morphological mapping and analysis using cloud and desktop GIS
5. Analysis of sediment load data

ESSENTIAL READINGS:

1. Fryirs, K. A., & Brierley, G. J. (2013). *Geomorphic analysis of river systems*. Wiley-Blackwell.
2. Wohl, E. (2010). *Mountain rivers revisited*. American Geophysical Union.
3. Bierman, P., & Montgomery, D. (2014). *Key concepts in geomorphology* (2nd ed.). W. H. Freeman.
4. Kondolf, G. M., & Piégay, H. (2003). *Tools in fluvial geomorphology*. Wiley.
5. Charlton, R. (2008). *Fundamentals of fluvial geomorphology* (2nd ed.). Routledge.

SUGGESTED READINGS:

1. Kelly, J. M., Scarpino, P. V., Berry, H., Syvitski, J., & Meybeck, M. (Eds.). (2018). *Rivers of the Anthropocene*. Springer.
2. Robert, A. (2011). *River processes: An introduction to fluvial dynamics* (2nd ed.). Routledge.
3. Brierley, G. J., & Fryirs, K. A. (Eds.). (2008). *River futures: An integrative scientific approach to river repair*. Island Press.

GE 3: GEOLOGICAL HERITAGE AND GEOCONSERVATION

Duration: 45 Hours (Lectures) + 30 Hours (Tutorial)

Course Title and Code	Total Credit	Credit distribution in course		
Geological Heritage and Geoconservation	4	**Lecture**	**Tutorial**	**Practical**
		03	1	0

LEARNING OBJECTIVES

- To understand the concepts of geodiversity, geoheritage, geoconservation, and geotourism, and their interrelationships in the context of sustainable development.
- To develop knowledge and skills for identifying, documenting, and curating geoheritage inventories and geosites for geotouristic and geoeducational purposes.
- To familiarize students with geotourism potential, geoparks, and geoheritage sites, including their scientific, educational, and economic significance.
- To enable students to analyze and promote geological features and landscapes for responsible geotourism and public geoscience awareness.

LEARNING OUTCOMES

On successful completion of the course, students will be able to:

- Identify and evaluate potential geological sites of tourist interest, including geomorphic landforms, fossil sites, and important stratigraphic boundaries.
- Distinguish and interpret different types of geoheritage sites and their significance in geotourism and geoconservation.
- Assess the geotourism potential of geological sites and relate them to other tourism destinations within a thematic framework.
- Apply knowledge of geoheritage and geotourism to understand their role in education, sustainable development, and economic growth.

LECTURE **3 Credit (45 Hrs)**

UNIT – I **(9 Hours)**

Geodiversity, Geoheritage, Geoconservation and their relationship to geotourism. Concept of geoheritage in relation to other historical heritages, Tourism and its different forms and their interrelations, Geotourism: definition, characteristics and international/national perspectives, Eco-tourism and Geo-tourism, Defining the geoheritage sites and the concept of Geoheritage parks (UNESCO guidelines). Geographical context and contemporary geoheritage challenges, Geoheritage inventory of India and its curation context, legal framework of geoheritage, Relevance of geoheritage to Sustainable Development Goals (SDG).

UNIT – II **(9 hours)**

Education as a key tenet of geotourism and Earth Science Education & Geotourism Geoheritage and public geoliteracy: opportunities for effective geoscience education within geosites Earth Science Museums and their role in promotion of Geotourism Examples of Geotourist sites from India - e.g. Glacier features, Ox-bow lakes, Deltas etc.

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UNIT – III **(10 Hours)**

Geotourism, Society and Sustainability: Public–private partnership framework for sustainable geopark development. Geotourism—a focus on the urban environment including historical Geotourism. Geotourism and cultural heritage. Potential of Geotourism in Economic development of any region. Role of Tourism sector in terms of world economy/ Indian economy. Role of Geotourism in Tourism industry with special reference to Indian scenario Entrepreneurship and start-up.

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UNIT – IV **(17 Hours)**

Geotourism and geoparks: UNESCO Global Geoparks and Geoconservation.

Geo site developed by Geological Survey of India. The application of geographical information systems in geotourism. Geotourism potential of the Indian geoheritage sites societal and economic context including case studies. Geoheritage in Indian Context: Study of Geological Map of India. Plotting the established geosites, geoparks and geo monuments of India on map. Plotting geosites, geoparks and geo monuments on map of World. Detailed study of geosites of India-Locality, Approach, Geological importance and foot fall. Five Case studies from. India where geosites can be developed.

TUTORIAL **1 Credit (30 hours)**

1. Identification and description of geosites.
2. Case study and detailed analysis of famous geotourism sites.
3. Sustainable geotourism.
4. Designing a geotourism plan.

ESSENTIAL READINGS:

1. T.A. Hose (Ed.) (2016). Appreciating Physical Landscapes: Three Hundred Years of
2. Geotourism, Geological Society Special Publication No. 417, London.
3. Thomas A. Hose (Ed.)(2016).Geoheritage and Geotourism- a European Perspective, Boydell
4. Press Woodbridge, UK
5. Ross Dowling & David Newsome (Eds) (2018). Handbook on Geotourism, Edward Elgar
6. Publishing.
7. A monograph on National Geoheritage Monuments of India. Indian National Trust for Art
8. and Cultural Heritage(INTACH) Natural Heritage Division, New Delhi (2016).
9. National Geological Monuments. Geological Survey of India, Kolkata, Special Publication
10. No.6 1(2001)
11. Kale, V.S. (ed.) (2014). Landscapes and Landforms of India, Springer, Dordrecht.
12. C. V. Burek and C.D. Prosser (Eds.) (2008) History of Geoconservation Special Publication
13. 300, Geological Society of London

SUGGESTED READINGS:

1. Young C.Y. Ng. &Yunting Lu (2015). The Principles of Geotourism, Anze Chen, (Springer).
2. Dowling, R. & Newsome, D. (Eds) (2018). Handbook on Geotourism, Edward Elgar
3. Publishing.
4. National Geological Monuments. (2001) Geological Survey of India, Kolkata, Special
5. Publication No.61
6. Burek, C.V. & Prosser, C.D. (Eds.) (2008). History of Geoconservation Special Publication
7. 300, Geological Society of London.
8. Santangelo, N. and Valente, E. (Eds.) (2020). Geoheritage and Geotourism Resources.

Skill-Based Course (SBC 1): THIN SECTION PREPARATION TECHNIQUES FOR PETROLOGICAL STUDIES

Duration: 15 Hours (Lecture) + 30 Hours (Practical)

Course Title and Code	Total Credit	Credit distribution in the course		
Thin section preparation techniques for petrological studies (SBC- I)	**2**	**Lecture**	**Tutorial**	**Practical**
		01	**0**	**01**

LEARNING OBJECTIVES:

- This course aims to train students in the preparation of thin and polished rock sections
- Students will develop proficiency in using both optical and reflected light microscopes.
- They will learn to identify and interpret minerals and textures observed under the microscope. Additionally, the course will cover laboratory safety, maintenance, and quality control in petrographic work.

LEARNING OUTCOMES:

- Students will learn the process of preparing standard-quality thin and polished sections.
- Students will identify minerals under plane-polarized and cross-polarized light.
- The will get to know the use petrographic and ore microscopes effectively for mineral and textural analysis.
- They will be able to appreciate maintenance of laboratory instruments and follow standard safety procedures. Also, they will be able to document and report petrographic observations systematically.

LECTURE **1 Credit (15 hours)**

Unit- I: Introduction to Microscopy and Laboratory Tools **(10 Hours)**

Importance of microscopy in geology. Parts and functioning of a petrographic microscope. Principles of transmitted and reflected light microscopy. Preparation tools and materials: saws, grinders, polishing wheels, resins, and adhesives.

Optical Properties and Mineral Identification: Optical principles: isotropic and anisotropic minerals, Relief, colour, pleochroism, interference colours, Extinction, twinning, cleavage, and refractive index, Identification of common rock-forming minerals (silicate and ore minerals) in thin section, Diagnostic features of major rock types.

Unit- II: Preparation of Thin and Polished Sections **(5 Hours)**

Selection and orientation of rock samples. Cutting, mounting, grinding, and thinning procedures. Standard thin section thickness (≈30 μm). Polishing techniques for opaque

PRACTICAL **1 credit (30 Hrs)**

1. Demonstration of rock cutting, mounting, and grinding.
2. Preparation of thin and polished sections.
3. Identification of minerals in thin sections under PPL and XPL.
4. Study of textures and microstructures in igneous, sedimentary, and metamorphic rocks.
5. Observation of opaque minerals under reflected light.
6. Maintenance of the microscope.

ESSENTIAL READINGS:

1. Barker, A. J., 2014. A Key for Identification of Rock-Forming Minerals in Thin Section-CRC Press
2. MacKenzie, W.S. & Guilford, C. 1980. Atlas of Rock-Forming Minerals in Thin Section. Longman.
3. Nesse, W.D. (2012). Introduction to Optical Mineralogy. Oxford University Press.

Semester II

DSC 9: PALEOENVIRONMENT AND BASIN ANALYSIS

Duration: 45 Hours (Lectures) + 30 Hours (Practical)

Course Title and Code	Total Credit	Credit distribution in course		
		Lecture	Tutorial	Practical
Paleoenvironment and Basin Analysis (DSC- 9)	4	03	0	01

LEARNING OBJECTIVES:

- This course aims to provide an in-depth understanding on sedimentary basins, different depositional agents operative in sedimentary basins, their interpretational technique from the rock record
- The course will address combination of depositional agents operative in different environmental settings sub-aerial or sub-aqueous.
- Additionally, this course will expose to students how to decode the subsidence history of basin; roles of tectonic/volcano-tectonics as well as paleobathymentry, water and sediment load, compaction etc will be discussed. Attempt will be made to expose the students to the source- to sink relationship and sedimentary budget in different environmental set-up.

LEARNING OUTCOMES:

- Students will be able to explain the fundamental concepts of paleoenvironment, relationship between different environmental settings, operative depositional agents in different environmental et-ups.
- Students will be able to analyze environmental set-ups in spatio-temporal manner.
- Students will be able to explore 'Backstripping' and 'Geohistory analysis' techniques for understanding evolution of a basin in space-time frame
- They will be able to apply geological and basin analysis model in exploration purpose of oil, gas and other hydrocarbon resources.

LECTURE **3 Credit (45 Hrs)**

UNIT I **(14 Hours)**

Siliciclastic sedimentary Environment: Concepts of sedimentary environment, Interpretation techniques of environmental settings from the rock record, Facies Analysis, sedimentary processes and Sediment characteristics. Continental (Terrestrial) Environments: Glacial systems, Alluvial systems (Alluvial fan, Fluvial), Eolian desertic systems, Lacustrine Systems. Marginal Marine Environments: Deltaic, Beach-Barrier bar, Estuary, Lagoon and Tidal Flat systems. Marine Environments: Shelf, Continental slope and Oceanic deep-water environments

UNIT II **(12 Hours)**

Carbonate and Evaporite Environments: Carbonate shelf environments, Examples of modern carbonate platforms, Examples of ancient carbonate shelf successions. Slope/ Basin carbonate, Organic Reef Environments, Ancient reefs. Mixed carbonate-silciclastic systems, Modern Evaporite Environment

UNIT III **(11 Hours)**

Basin subsidence: Mechanisms controlling subsidence, Thermal uplift and subsidence, Subsidence without thermal effects, Flexural response for the crust to loading. Methods of determining subsidence of sedimentary basins; Sediment decompaction, Isostatic adjustment, Effects of paleo-bathymetry and sea level changes. Backstripping and Geohistory analysis.

Unit IV **(8 Hours)**

Denudation: Solute transport and flux rates of terrigenous sediment. Weathering, soils and formation of terrigenous sediment; Soils controlled by sediment aggradation or Erosion. Chemical denudation: Relationship of different factors (relief, climate, hydrology, rock type) with concentration Total suspension Solid (TSS) and Total dissolved solid (TDS); Annual runoff and Total River Load. Global effects of chemical denudation. Foreland basins: Lithosphere as an elastic beam

PRACTICAL **1 credit (30 Hrs)**

1. Exercises on spatio-temporal relation of sedimentary facies and depositional environment from surface and subsurface data
2. Exercises involving paleocurrent and depositional environment to decipher provenance and basin depocenter
3. Exercises on graphical methods of decompaction backstripping

ESSENTIAL READINGS:

1. Sam Boggs, Jr., 2011 Principles of sedimentology and Stratigraphy Fifth Edition, Pearson
2. Gerald Einsele, 2000 Sedimentary Basins: Evolution, Facies and sediment Budget, Springer
3. M E Tucker and S J Jones 2023 Sedimentary Petrology Fourth Edition, Wiley

SUGGESTED READINGS:

1. Noel P James and Brian Jones, 2016 Origin of carbonate sedimentary rocks, Wiley
2. P A Allen and J R Allen 2013 Basin Analysis Third Edition, Wiley-Blackwell

DSC 10: ROCK MECHANICS AND ROCK ENGINEERING

Duration: 45 Hours (Lectures) + 30 Hours (Practical)

Course Title and Code	Total Credit	Credit distribution in course		
		Lecture	Tutorial	Practical
Rock mechanics and Rock engineering (DSC -10)	4	03	0	01

LEARNING OBJECTIVES:

- This course aims to provide an in-depth understanding of rock mechanics and engineering geology principles
- The course will emphasize the mechanical behaviour of rocks, rock mass characterization, and slope stability analysis.
- It will focus on the geological and geotechnical investigations required for designing and evaluating engineering structures such as tunnels, dams, and foundations.

LEARNING OUTCOMES:

- Students will be able to explain the fundamental concepts of rock mechanics, stress-strain behaviour in rock, and rock mass classification systems.
- Students will be able to analyze slope stability problems and propose suitable stabilization and foundation treatment techniques.
- They will be able to apply geological and geotechnical principles, along with relevant software tools
- Students will be able to assess and design engineering structures in varied geological settings.

LECTURE **3 Credit (45 Hrs)**

Unit- I **(11 Hours)**

Development of rock mechanics and rock engineering. Rock strength; stress-strain relationships, *in-situ* stress measurements and their geological significance. Hoek's Brown criterion of rock failure. Structural discontinuities and their types; their effect on Rock Mass Strength.

Unit- II **(10 Hours)**

Engineering properties of rocks and soil. Engineering bedrock and their characteristics. Laboratory index and strength tests for rocks and soil.

Unit- III **(10 Hours)**

Rock slope failure mechanism. Mass wasting and their types. Rock slope stabilization techniques; factor of safety. Application of rock mechanics for underground openings, rock slope engineering, and foundation engineering. Landslide hazard zonation mapping.

Unit- IV **(14 Hours)**

Reservoir Induced Seismicity: their cause, effects and mitigation measures. Geological and geotechnical investigation for site selection and foundation treatment of dams, reservoirs, and tunnels. Case histories on rock engineering design and the geological, geophysical, and geotechnical aspects of megastructures, including major Indian examples such as the Tehri Dam, Chenab Bridge, and Rohtang Tunnel, along with other significant global engineering projects and their documented failures.

Comparative analysis of failure and successes of mega projects and their environmental impacts.

PRACTICAL **1 Credit (30 Hours)**

Rock Mass Classification: Rock Structure Rating; Rock Mass Rating; Q-System; Rock Quality Designation.

1) Geological mapping of engineering sites and assessment of site selection
2) Application of engineering software such as Stereonet, Rockworks, Rock-Slide etc.

ESSENTIAL READINGS:

1. Krynin, D.P. and Judd, W.R. (1957). Principles of Engineering Geology and Geotechnique, McGraw Hill (CBS Publ).
2. Gangopadhyay, S. (2013). Engineering geology. Oxford University Press.
3. Goodman, R.E. (1993). Engineering Geology: Rock in engineering constructions. Wiley& Sons, N.Y.
4. Waltham, T. (2009). Foundations of Engineering Geology (3rd Edn.) Taylor & Francis.
5. Bell, F.G. (2007). Engineering Geology, Butterworth-Heinema.

SUGGESTED READINGS:

1. Anbalagan, R. Singh, B, Chakraborthy, D. and Kohli, A. (2007) "A filed Manual for Landslide investigations". DST, Government of India, New Delhi.
2. Duncan C. Wyllie and Christopher W. Mah. (2004). Rock Slope Engineering. CRC Press. London.
3. David George Price (2009). Engineering Geology: Principles and Practice. Springer-Verlag Berlin Heidelberg.
4. Hoek, E., and Brown, E.T. (2019). The Hoek–Brown Failure Criterion – 2018 Edition. Rockscience.

DSE 8: THERMOBAROMETRY OF IGNEOUS AND METAMORPHIC ROCKS

Duration: 45 Hours (Lectures) + 30 Hours (Practical)

Course Title and Code	Total Credit	Credit distribution in the course		
Thermobarometry of Igneous and Metamorphic rocks (DSE 8)	**4**	**Lecture**	**Tutorial**	**Practical**
		03	**0**	**01**

LEARNING OBJECTIVES:

- This course aims to provide a comprehensive understanding of the methods and theoretical frameworks used to determine the pressure–temperature conditions under which igneous and metamorphic rocks form and evolve.
- The course will ignite students to explore mineral equilibria, thermodynamic modelling, and modern computational tools that link mineral chemistry with tectono-thermal histories.
- Students will learn to interpret P–T–t paths and decipher thermobaric evolution of the Earth's crust and mantle.

LEARNING OUTCOMES:

- Students will be able to explain the theoretical basis of mineral thermodynamics relevant to thermobarometry.

- Students will be able to apply various thermobarometers (e.g., garnet–biotite, two-pyroxene, amphibole–plagioclase) to determine metamorphic and magmatic conditions.
- They will be able to construct and interpret P–T diagrams and pseudosections using appropriate modelling software.
- Students will integrate thermobarometric data with petrographic and geochemical observations to reconstruct geological histories.

LECTURE **3 Credit (45 Hrs)**

Unit I: Basics of Thermo-barometry **(10 Hours)**

Concept of thermobarometry; role in petrology and tectonics. Mineral equilibria and the phase rule. Gibbs free energy, activity, and chemical potential. Equilibrium constants and activity–composition relationships. Calorimetric and experimental determination of thermodynamic data

Unit II: Thermo-barometry in Igneous Rocks **(12 Hours)**

Principles of igneous thermometry and barometry. Two-pyroxene thermometry, olivine–spinel and plagioclase–amphibole barometers etc. Calibration and application of liquid–mineral and mineral–mineral equilibria. P–T estimates in magmatic systems: volcanic vs plutonic environments

Unit III: Thermobarometry in Metamorphic Rocks **(12 Hours)**

Equilibrium thermodynamics of metamorphic reactions. Classical thermobarometers: garnet–biotite, garnet–clinopyroxene, amphibole–plagioclase etc. Metamorphic facies and inferred P–T conditions

Unit IV: Integrated P–T–t Analysis **(11 Hours)**

P–T paths and metamorphic evolution. Case studies from orogenic belts and magmatic arcs

PRACTICAL **(30 Hrs)**

1. **Mineral chemistry data handling:** Electron microprobe / EPMA data formatting and error checking
2. **Classical thermobarometric calculations:**

- Garnet–biotite thermometer
- Two-pyroxene thermometer
- Amphibole–plagioclase barometer

3. **Interpretation exercises:**

- Case studies using published datasets
- Integration of petrographic and microstructural observations

ESSENTIAL READINGS:

1. Philpotts, A.R. and Ague, J.J., 2022. Principles of igneous and metamorphic petrology. Cambridge University Press.
2. Spear, F.S., 1993. Metamorphic phase equilibria and pressure-temperature-time paths. Mineralogical Society of America Monograph, 799.
3. Ganguly, J., 2008. Thermodynamics in earth and planetary sciences (p. 501). Berlin: Springer.

DSE 8: APPLIED PALEONTOLOGY AND OCEANOGRAPHY

Duration: 45 Hours (Lectures) + 30 Hours (Practical)

Course Title and Code	Total Credit	Credit Distribution in Course		
		Lecture	Tutorial	Practical
Applied Paleontology and Oceanography (DSE 8)	4	03	0	01

LEARNING OBJECTIVES:

- The course aims to provide students with a comprehensive understanding of how fossil records, sedimentary sequences, and oceanic proxies reveal Earth's evolutionary, climatic, and environmental history.
- Students will learn to analyze macro- and microfossils for biostratigraphy, paleoecology, and paleogeographic reconstructions, while gaining insight into evolutionary principles, speciation, and major morphological trends.
- The course integrates physical, chemical, and biological oceanography with modern analytical techniques, including stable isotope geochemistry and microscopy, to interpret past oceanic and climatic changes. Additionally, students will explore the causes and consequences of mass extinction events, ocean circulation patterns, and the influence of ocean gateways on global climate, fostering a holistic understanding of Earth system science

LEARNING OUTCOMES:

- Students will understand the scope and applications of applied paleontology and oceanography in Earth sciences.
- Students will know the processes of fossilization, taphonomy, and interpret sedimentary records for biostratigraphy and paleoenvironmental reconstruction. Trace the development of evolutionary thought from classical theories to molecular evolution and modern synthesis.
- Students will be able to apply species concepts, cladistic taxonomy, and mechanisms of speciation to both macro- and microfossil records.
- They will be able to utilize fossil records, especially ammonites, trilobites, and microfossils, to subdivide geological time, correlate strata, and reconstruct paleogeography.

LECTURE **3 Credit (45 Hrs)**

Unit-I **(14 Hours)**

Applied paleontology and its significance. Fossilization processes, taphonomy, and interpretation of the sedimentary record to reconstruct past life and environments. Biostratigraphy, correlation, and diachronism in fossil assemblages. Historical and modern perspectives on evolutionary theory—from Lamarck's and Darwin–Wallace's ideas to Mendelian inheritance, molecular evolution, and the modern evolutionary synthesis integrating paleontology, genetics, ecology, and molecular data. Concepts of biological species and morphospecies, and their relevance in paleontology. Modes of speciation and cladogenesis. Types of speciation: allopatric, sympatric, parapatric, and peripatric with illustrative examples from both mega- and microfossil records; patterns of divergence and lineage formation. Classification of species into higher taxonomic categories using cladistic methods. Evolutionary trends and functional morphology of key fossil groups: Cephalopods – shell evolution, buoyancy, and ecological adaptations; Trilobites – exoskeleton morphology, ecological roles, and environmental indicators; Ammonites – shell coiling, ornamentation, and paleoceanographic significance. Environmental implications of morphological adaptations in these fossil groups.

Unit II: Fossils as Biostratigraphic Markers **(12 Hours)**

Early evolution of life: from prokaryotes to eukaryotes; Ediacaran fauna: characteristics and significance in Precambrian ecosystems; Small Shelly Fauna (SSF): origin of skeletonization and its relation to ocean chemistry and environments; Cambrian Explosion: causes, consequences, and rapid diversification of life; Early evolution and biostratigraphic significance of trilobites and graptolites for Paleozoic subdivisions; Major Paleozoic mass extinctions: End-Ordovician, Late Devonian, and End-Permian – causes, debates, and current understanding; Evolutionary trends in Ammonites and Mesozoic oceans; role of ammonites in Mesozoic stratigraphic subdivisions; Paleogeographic reconstruction and plate movements during the Mesozoic; End Triassic mass Extinction, causes and consequences. Cretaceous-Paleogene Mass Extinction and post-extinction recovery. Historical developments in Cenozoic subdivisions based on molluscan fossils as proposed by Sir Charles Lyell following Huttonian gradualism; Evolution of foraminifera in the Cenozoic and their application in Cenozoic biostratigraphy and paleoenvironmental interpretation.

Unit III: Oceanography: Exploring the Sea and Chemical Oceanography **(10 Hours)**

Techniques and methods in ocean exploration, including oceanographic surveys and sampling strategies. Overview of DSDP, ODP, IODP, and JGOFS, with emphasis on their key contributions to paleoceanography and marine geology; Laboratory methods such as mass spectrometry, SEM, and other key analytical tools in chemical oceanography. Molecular structure of water and its role in ocean processes; measurement and distribution of temperature, salinity, and density. Major and minor constituents, classification and behaviour of elements, chemical exchanges at interfaces, residence times, dissolved gases (O_2, CO_2), and carbonate chemistry with relevance to ocean buffering and paleoclimate.

Unit IV: Micropaleontology and Oceanography **(9 Hours)**

Ocean circulation, productivity, and paleoceanographic reconstruction. Topics include surface and deep circulation, the mixed layer, thermocline, pycnocline, Coriolis effect, Ekman transport, coastal upwelling, and ENSO. It examines thermohaline circulation, bottom water formation, the Great Ocean Conveyor Belt, major water masses, and the Oxygen Minimum Layer. Major ocean currents are discussed with emphasis on their climatic and ecological impacts. The section on ocean floor morphology explores oceanic crust, basins, continental margins, and sediment distribution. Paleoceanographic reconstruction focuses on past ocean conditions, Cenozoic ocean evolution, and the role of gateways in climate regulation. Sea-level and climate studies include Quaternary fluctuations, stable isotopes, and paleoclimate records from ice cores and marine sediments. Marine stratigraphy and chronology address deep-sea sedimentation, stratigraphic correlation, ocean resources, and pollution monitoring. Applications of microfossils (foraminifera, ostracods, Radiolaria, nannofossils, diatoms, dinoflagellates) in reconstructing past circulation, productivity, climate, and ocean gateway evolution, supported by stable isotope geochemistry.

PRACTICAL **(30 Hrs)**

1. Techniques of separation of microfossils from matrix
2. Types of microfossils: Calcareous, Siliceous, Phosphatic and organic-walled microfossils
3. Study of important planktic foraminifera useful in surface water paleoceanography and biostratigraphy
4. Study of larger benthic valuable foraminifera in Indian stratigraphy with special reference to Cenozoic petroliferous basins of India
5. Study of modern surface water mass assemblages of planktic foraminifera from the Indian, Atlantic and Pacific Oceans
6. Depth biotopes and estimation of paleodepth of the ocean using benthic foraminiferal assemblages
7. Identification of benthic foraminifera characteristic of various deep-sea environments
8. Identification of planktic foraminifera characteristic of Warm Mixed Layer, Thermocline and deep surface waters of the modern oceans
9. Exercises on the interpretation of the oxygen and carbon isotopic record.
11. Exercises on world ocean circulation
12. Exercises on Oceanic biostratigraphy
13. Paleogeographic reconstruction exercises for Paleozoic, Mesozoic and Cenozoic.

ESSENTIAL READINGS:

1. Bignot, G., 1985. *Elements of Micropaleontology: Microfossils, their Geological and Palaeobiological Applications*. Graham & Trotman, London, United Kingdom.
2. Braiser, M.D., 1980. *Microfossils*. George Allen and Unwin Publisher.
3. Fischer, G. and Wefer, G., 1999. *Use of Proxies in Paleoceanography: Examples from the South Atlantic*. Springer.
4. Gross, M.G., 1977. *Oceanography: A View of the Earth*. Prentice Hall.
5. Haq, B.U. and Boersma, A., 1978. *Introduction to Marine Micropaleontology*. Elsevier.

SUGGESTED READINGS:

1. Haslett, S.K., 2002. *Quaternary Environmental Micropalaeontology*. Oxford University Press, New York.
2. Jones, R.W., 1996. *Micropaleontology in Petroleum Exploration*. Clarendon Press, Oxford.
3. Kennett, J.P. and Srinivasan, M., 1983. *Neogene Planktonic Foraminifera: A Phylogenetic Atlas*. Hutchinson Ross, USA.

4.Tolmazin, D., 1985. *Elements of Dynamic Oceanography*. Allen and Unwin.
5. Saraswati, P.K. and Srinivasan, M.S., 2016. *Micropaleontology: Principles and Applications*. Springer.
6. Benton, M.J. and Harper, D.A.T., 2009. *Introduction to Paleobiology and the Fossil Record*. Paperback Edition.
7. Raup, D.M. and Stanley, S.M., 2004. *Principles of Palaeontology*, 2nd Edition (Pb).

DSE 9: FOSSIL FUELS AND SUSTAINABLE ENERGY RESOURCES

Duration: 45 Hours (Lectures) + 30 Hours (Practical)

Course Title and Code	Total Credit	Credit Distribution in Course		
		Lecture	Tutorial	Practical
Fossil Fuels and Sustainable Energy Resources (DSE-9)	**4**	**03**	**0**	**01**

LEARNING OBJECTIVES:

- The objective of this course is to discuss with students about various kinds of energy resources their principles, exploration and exploitation techniques.
- This course will tell the students about different hypothesis related with the formation of hydrocarbon and coal. Students will learn about the generation, accumulation and migration of hydrocarbon.
- Another objective of the course is to aware students about various renewable, non-renewable, unconventional and carbon-neutral resources of energy. The knowledge on sustainable development goals while using fossil fuels and its effect on environments and policies to mitigate energy crisis, will also be discussed among students.

LEARNING OUTCOMES:

- Students will get understanding about the mechanism of hydrocarbon generation from organic matters. They will learn the relationship between temperature, pressure and other physical parameters and its effect on distribution and migration of hydrocarbons.
- Students will understand the different types of sedimentary environmental condition through the geological records and their effect on potential of hydrocarbon generation. They will comprehend fundamentals of coal and coal forming sedimentary environments, effect of tectonics and sea-level changes on coal formation and its quality.
- Students will understand analytical techniques in coal and its importance in coal classification and utilization for various industries, concept of macerals, its gross diagnostic properties under microscope and implications in climate and paleogeography.
- Students will be able to understand the principles of sustainable development, its goals and environmental challenges while using fossil fuels. They will appreciate the concept of renewable, non-renewable, unconventional and carbon-neutral resources of energy. They will understand the policies of India to engage geopolitical scenario during energy crisis and energy threats.

LECTURE **3 Credit (45 Hrs)**

Unit-I Introduction to Sustainable Development **(10 Hours)**

Introduction to sustainable development, Principles and goals of sustainable development, global challenges of sustainable development, pathway to sustainable development, sustainable development goals (SDGs) and millennium sustainable development goals (MDGs) and targets, Renewable and Non- Renewable energy resources, Economic theories of Renewable and Non- Renewable energy resources, sustainability issues related to energy resources, Resource exploitation and environmental degradation, concept of clean energy, convention and protocols of sustainable development, Climate change and natural energy resources system.

Unit-II Petroleum Geology **(14 Hours)**

Introduction to Petroleum geology, Origin of Petroleum: Inorganic and Organic theories, Organic maturation and thermal cracking of Kerogen, Types of Kerogen, Petroleum system, clastic and non-clastic reservoir rocks. Porosity and Permeability in reservoir rock, Migration of oil and gas, primary and secondary migration, Hydrocarbon traps; Anticlinal theory vs. trap theory, classification of hydrocarbon traps, Cap rocks - definition and general properties, Plate tectonics and global distribution of hydrocarbon reserves, An outline of the oil belts of the world, Petroliferous basins of India, Classification of Indian basins and petroleum geology of Assam-Arakan, Cauvery basin, Krishna-Godavari, Cambay and Bombay offshore basins.

Unit-III Coal Geology **(12 Hours)**

Definition and origin of coal, Split in coal seam, Classification of coal in terms of type, grade and rank, Composition of coal, lithotype and microlithotype classification. Proximate and ultimate analysis and its implication in coal classification and utilization, Concept of maceral and its classification: their physical chemical and optical properties, Application of macerals in coal seam correlation, climate and paleogeography, Concept of Coal Bed Methane (CBM) an unconventional source of energy, methods of reserve estimations of CBM and its production technique, Concept of underground coal gasification (UGC), clean coal technology-coal liquefaction, Geological and geographical distribution of coal and lignite in India.

Unit-IV Unconventional & Carbon-Neutral Energy Resources **(9 Hours)**

Concept of carbon capture and sequestration (CCS), techniques and research in CCS, and their environmental benefit, Nuclear fuels, major reserves of nuclear fuels and its potential in India, exploration and exploitation techniques of Shale-gas and Oil-sand, Concept of geothermal energy resources, geological factors affecting geothermal gradients and their signature on surface, and its prospect in India, Hydroelectric energy resources their benefits and threats on ecology and biodiversity, Gas hydrates - a new source of energy, challenges in their exploitations, estimated reserves of Gas-hydrates global vs. Indian context, Green hydrogen- a carbon-neutral fuel an emerging energy resource and challenges, Energy crisis and energy security policy of India.

PRACTICAL **(30 Hours)**

1. Study of hand specimens of different ranks of coal
2. Numerical problem on reserve estimation of coal
3. Section correlation and identification of petroleum system
4. Panel and Fence diagrams and interpretations of depositional environments

5. Problem on directional drilling and hydrocarbon Trap delineation
6. Facies contact map their reservoir properties through contour map
7. Geophysical map interpretation to understand subsurface geology

ESSENTIAL READINGS:

1. Thomas Larry (2002): Coal Geology. John Wiley and Sons. Ltd. England.
2. North, F.K. (1985): Petroleum Geology, Allen Unwin. Selley, R.C. (1998): Elements of petroleum geology, Academic Press.
3. Shelly R. C. (2014). Elements of Petroleum geology: Third Edition, Academic Press.
4. Chandra, D., Singh, R.M., Singh M.P., (2000): Text book of coal (Indian context), Tara Book Agency, Varanasi.
5. Scott, A.C., (1987): Coal and coal bearing strata: Recent Advances, Blackwell Scientifics Publications.
6. Barker, C. (1996): Thermal Modelling of Petroleum Generation, Elsevier Science.

SUGGESTED READINGS:

1. Jahn, F., Cook, M. and Graham, M. (1998): Hydrocarbon Exploration and Production, Eslevier Science.
2. Makhous, M. (2000): The Formation of Hydrocarbon Deposits in North African Basins, Geological and Geochemical Conditions, Springer-Verlag.
3. Bjorlykke, K. (1989). Sedimentology and petroleum geology. Springer-Verlag.
4. Tissot, B.P. and Welte, D.H. (1984): Petroleum formation and occurrence, Springer–Verlag.
5. Stach, E., Mackowsky, M-Th., Tylor, G.H., Chandra, D., Teichumullelr, L .and Teichumuller, R. (1982): Text book on coal petrology, Gebruder Borntreager Stuttgart.
6. Taylor, G.H., Teichmuller, M., Davis, A., Diessel, C.F.K., Littke, R and Robert, P. (1998): Organic Petrology. Gebruder Borntreager Stuttgart.
7. Van Krevelen., D.W., (1993): Coal: Typology-Physics-Chemistry-Constitution. Elsevier Scienc, Netherlands.

DSE – 9: APPLIED HYDROGEOLOGY

Duration: 45 Hours (Lectures) + 30 Hours (Practical)

Course Title and Code	Total Credit	Credit distribution in course		
Applied Hydrogeology	4	Lecture		Practical
		03		01

LEARNING OBJECTIVES:

- The course content aims to enrich the knowledge of the students in the field of applied hydrogeology.
- The teaching and learning process focuses on conceptual clarity of the applied aspects of the subject.
- Students will apply the knowledge they have gained in solving real-world problems as part of the learning process.

LEARNING OUTCOMES:

- The students will learn about the surface- groundwater dynamics; basics of River hydrology; River hydrographs and the flow nets.
- The course imparts knowledge about the advanced and applied aspects of well hydraulics where students will learn in detail about the pumping test data analysis of unconfined and semi-confined aquifers. The learning process will make students familiar with groundwater modelling
- The students will learn the basic concepts related to the use of isotopes in hydrogeological studies.
- The students will learn about the utility of hydrogeology in infrastructure projects; groundwater resources estimation; groundwater management and governance.

LECTURE **3 Credit (45 Hrs)**

Unit I: General concepts: **(4 hrs.)**

Surface water and groundwater interaction. Stream discharge parameters and their measurement. Stage-discharge relationship and rating curves, River Hydrographs. Flow nets.

Unit II: Well Hydraulics and Groundwater Modelling: **(22 hrs.)**

Pumping tests - methods, data analysis and diagnostic plots. Well design and well Performance Tests. Evaluation of the aquifer parameters from pumping test data of the unconfined and semi-confined aquifers (Walton's method). Evaluation of the aquifer parameters from the recovery data of the pumping tests. Basic concepts of groundwater modelling and the governing equations. Model conceptualisation; design and execution; sensitivity analysis; calibration; validation; assessment and prediction based on the model.

Unit III: Isotope hydrogeology: **(4 hrs)**

Basic concepts. Stable isotopes in the hydrogeological study. Radio isotopes in the hydrogeological study.

Unit IV: Groundwater management: **(15 hrs)**

Groundwater problems related to foundation work, mining, canals, dams, reservoirs and tunnels. Water balance and groundwater resources estimation. Problems of overexploitation and groundwater mining. Groundwater management: supply side and demand side management. Rainwater harvesting and managed aquifer recharge. Conjunctive use of surface and groundwater. Groundwater management in urban and rural areas, arid and semi-arid areas. Possible climate change impact on the groundwater resources and the mitigation measures. Concept of sustainable development of groundwater resources. Groundwater legislation. Hydrogeology of arid zones of India and the management issues. Hydrogeology of the wetlands and the management issues.

PRACTICAL **(30 Hours)**

1. Hands-on exercises using real-time groundwater level data (DWLR, etc)
2. Estimation of stream discharge, rating curves
3. River hydrographs related exercises
4. Flow net related exercises
5. Evaluation of Well Performance Tests data

6. Diagnostic plots-based aquifer assessment
7. Evaluation of the aquifer parameters from the pumping test data of unconfined aquifers
8. Evaluation of the aquifer parameters from the pumping test data of semi-confined aquifers (Walton's method)
9. Pumping test data analysis from the recovery data
10. Hands-on exercises on groundwater flow model, conceptualization, design, execution, calibration, validation and prediction
11. Interpretation of environmental isotope data of water samples

ESSENTIAL READING:

1. Fetter, C.W., and D. Kreamer. 2022. *Applied Hydrogeology*, 5th ed. Waveland Press.
2. Fitts, C.R., 2023. *Groundwater Science* (3rd ed.), Academic Press.
3. Karanth K.R., 1987. *Groundwater: Assessment, Development and Management*, Tata McGraw-Hill Pub. Co. Ltd.
4. Todd, D. and Mays, L. 2005 *Groundwater Hydrology*. (3rd ed.), John Wiley and Sons, Inc.
5. Kruesman, G.P and De Ridder N.A., 1990. *Analysis and Evaluation of Pumping Test Data,* International Institute for Land Reclamation and Improvement.
6. Clark, I.D., 2015. *Groundwater Geochemistry and Isotopes*, CRC Press.

SUGGESTED READING:

1. Anderson, M., Woessner, W., Hunt, R., 2015. *Applied Groundwater Modelling*, Elsevier.
2. Thangarajan, M., Singh V.P., 2016. *Groundwater Assessment, Modelling and Management*, CRC Press.
3. Thangarajan, M., 2007. *Groundwater: Resource Evaluation, Augmentation, Contamination, Restoration, Modelling and Management*, Springer.
4. Schwartz, F.W. and Zhang, H., 2024. *Fundamentals of groundwater* (2nd Edition). John Wiley & Sons.
5. Hiscock, K.M. and Bense, V.F., 2021. *Hydrogeology: principles and practice* (3rd Edition). John Wiley & Sons.

GE 4: NATURAL HAZARDS AND DISASTER MITIGATION

Duration: 45 Hours (Lectures) + 30 Hours (Practical)

Course Title and Code	Total Credit	Credit distribution in course		
Natural Hazards and Disaster Mitigation	4	**Lecture**	**Tutorial**	**Practical**
		03	0	01

LEARNING OBJECTIVES:

- Understand the causes and types of major natural hazards and their impacts.
- Explain the relationship between Earth processes and environmental hazards.
- Learn basic principles of disaster risk reduction and mitigation strategies.
- Develop awareness of disaster preparedness, response, and management practices.

LEARNING OUTCOMES:

After completion of the course, the students will learn:

- What is the Earth's composition and what are the various processes that make it a dynamic planet?
- How do the earth's natural processes turn into hazards and disasters?
- How do the different factors interact to create disaster risk?
- What are the existing approaches and frameworks to minimise the risk?

LECTURE **3 Credit (45 Hrs)**

Unit I: Introduction to the Earth system and natural hazards **(10 hours)**

Earth's composition: minerals and rocks, internal and atmospheric structure of Earth, Earth's energy sources. Dynamic Earth: Endogenic and exogenic processes in Earth, Balance in mass and energy flow in the Earth system, Equilibrium and perturbations in the natural equilibrium. **Disaster terminology:** Hazard, physical and social vulnerability, exposure, risk, susceptibility, coping capacity and disaster. Introduction to major natural hazards and Human-induced hazards: Geological hazards, Hydrometeorological hazards, Pandemics, and wars.

Unit II: Understanding geological hazards **(15 hours)**

Geological hazards and their causes, types, impacts, and mitigation measures: landslides, earthquakes, floods, coastal hazards, and volcanoes. Secondary impacts of natural hazards/disasters.

Unit III: Understanding hydrometeorological and other hazards **(10 hours)**

Hydrometeorological hazards, their causes and impacts: cyclones, drought, heat and cold waves. Pandemics, their causes and impacts; Human-induced hazards: wars and technology failure; climate change and its impact; Urban heat islands. Cascading and compound disaster.

Unit IV: Disaster Risk Reduction approaches **(10 hours)**

Disaster management cycle: Disaster preparedness, Hazard mitigation-structural and non-structural measures, Rescue, Relief and Rehabilitation, Response; cost-benefit analysis, Institutional and policy framework for disaster risk reduction. Sustainable development. Risk communication and technology in disaster risk reduction.

PRACTICAL **(30 Hrs)**

- Introduction to rocks and minerals;
- Introduction to maps;
- Vulnerability assessment;
- Hazard maps and hazard matrix;
- Mitigation strategies

- Seismic data and epicentre location.

SUGGESTED READINGS:

1. Allen, P. A. (1997). *Earth surface processes*. Wiley-Blackwell.
2. Highland, L. M., & Bobrowsky, P. (2008). *The landslide handbook—A guide to understanding landslides* (U.S. Geological Survey Circular 1325). U.S. Geological Survey. https://doi.org/10.3133/cir1325
3. U.S. Geological Survey. "Earthquake Magnitude, Energy Release, and Shaking Intensity." Accessed October 19, 2025. https://www.usgs.gov/programs/earthquake-hazards/earthquake-magnitude-energy-release-and-shaking-intensity.
4. Hyndman, D., & Hyndman, D. (2016). *Natural hazards and disasters* (5th ed.). Cengage Learning.
5. Keller, E. A., & Blodgett, R. H. (2021). *Natural hazards: Earth's processes as hazards, disasters, and catastrophes* (6th ed.). Pearson Education.
6. PG Diploma in Disaster Management (Textbooks). Indira Gandhi National Open University, New Delhi.
7. PreventionWeb. "Understanding Disaster Risk: Key Concepts." Accessed October 19, 2025. https://www.preventionweb.net/understanding-disaster-risk#key-concepts.

Skill-Based Course (SBC 2)

SBC 2: GEOLOGICAL MAPPING AND LITHOTECTONIC CHARACTERIZATION

Duration: 15 Hours (Lecture) + 30 Hours (Practical)

Course Title and Code	Total Credit	Credit distribution in the course		
		Lecture	Tutorial	Practical
Geological mapping and lithotectonic characterization (SBC- 2)	2	01	0	01

LEARNING OBJECTIVES

- This course will introduce students to geological mapping, focusing on rock types, their affinities, and patterns of occurrence.
- Students will develop skills in rock identification, structural measurements, and geological interpretation in the field.

LEARNING OUTCOMES:

- Students will develop basic skills to carry out geological fieldwork in different terrains.
- Students will prepare geological maps and cross-sections from field data and interpret them in terms of stratigraphy, structure, and tectonics.
- They will use geological instruments (such as the Brunton compass, GPS).

- Students will also learn to plot data on base maps or toposheets to create lithological and structural maps and prepare a report

LECTURE **(15 hours)**

Unit- I: Introduction to Geological Mapping and rock identification **(6 Hours)**

Importance and scope of geological fieldwork. Topographic sheets: scales, symbols, and interpretation. Use of Brunton compass, GPS, and other field instruments. Base map and field notebook maintenance. Field safety, ethics, and logistics. Beds in deformed and undeformed terrains – rule of V. Identification and description of igneous, sedimentary, and metamorphic rocks in the field. Methods of delineating contacts between lithological units. Textural features of different rocks through field study and microscopy. Sampling techniques and field photography.

Unit- II: Structural Features **(9 Hours)**

Identification of various structural features in the field. Identification and structural measurement of a fold in the field. Geometric classification of a fold based on field data and understanding the outcrop pattern of a fold. Overprinting nature of folds and metamorphic foliations. Distinguishing criteria of a fault in the field. Measurement and plotting of planar and linear structures (strike, dip, joints, faults, folds, foliations, lineations). Use of stereonets and structural symbols on maps. Construction of cross-sections and interpretation of structure from outcrop patterns. Preparation of geological maps. Writing a detailed geological report with an interpretation of geological history.

PRACTICAL **(30 Hrs)**

All the aforementioned techniques for measurement and identification will be demonstrated and practiced in the field. The practical classes of this course will take place through a field visit in a suitable geological terrain.

ESSENTIAL READINGS:

1. Lisle, R.J., Brabham, P., & Barnes, J.W. (2011) Basic Geological Mapping, Wiley-Blackwell.
2. Lisle, R. J. (2004). Geological structures and maps: A practical guide. Elsevier.
3. Park, R. G. (2004) Foundations of Structural Geology. Chapman & Hall.
4. Davis, G. R. (1984) Structural Geology of Rocks and Region. John Wiley.

DISSERTATION / ACADEMIC PROJECT

Duration: 90 or 150 Hours

Course Title and Code	**Total Credit**
Dissertation/ Academic Project	**6 or 10**

LEARNING OBJECTIVES

- The aim is to expose students to recent trends of Earth Science research
- To expose students state-of-art analytical techniques used for Geology research

- To enthuse students to think beyond textbook and identify the topical issues of research

LEARNING OUTCOMES:

- Students will develop critical thinking and basic skills to carry out research in different kinds of geological provinces.
- Students will come to know how research problems are identified and resolved through logical scientific outlook.
- They will use different kinds of high-end instruments to generate data. Idea is to make students equally conversant with Instrumentation.
- Students will also learn data analyses and Interpretation techniques.

SUGGESTED READINGS

Literature (Journals) related to different topics of research

Structure 3 (Level 6.5): PG Curricular Structure (Research)

DSC-11

FRONTIERS IN GEOSCIENCE RESEARCH

Course Title and Code		Total Credit	Credit distribution in course		
Frontiers in Geoscience Research		**4**	**Lecture**	**Tutorial**	**Practical**
			03	**0**	**01**

LEARNING OBJECTIVES

- To expose the students to recent trends of petrological research.
- To make students conversant with understanding of paleoceanographic evolution.
- To give students ideas about role of earth science in making the globe sustainable.
- To make the students aware about the role of geology in planning different kinds of engineering structures.

LEARNING OUTCOMES

- Students will come to know different kinds of melt systems and melt-crystal interaction.
- Students will be exposed to paleoclimatic research and ways of future climate prediction.
- Students will be aware of groundwater flow systems and real condition of the Indian energy scenario and the steps to make the globe a sustainable one.
- Students will become aware of the geotechnical properties of rocks and engineering structures for societal development.

Unit I: Emerging trends in Petrological Research (15 Hours)

Concepts of thermodynamic modelling; crust-mantle interaction through time; concepts of sedimentary basin analysis

Unit II: Current understanding of paleoceanographic evolution (10 Hours)

Evolutionary patterns in microfossils: gradualism versus punctuated equilibria; Diachronism and its implications for faunal migration and ocean circulation

Unit III: Geology for sustainable Earth (10 Hours)

Groundwater flow under different hydrogeological conditions; Sustainable energy resources, energy security-Indian scenario

Units IV: Structures, landscapes, and geological hazards (10 Hours)s

Earth processes and landscape; Geotechnical properties of rocks and soil; Natural hazards: risks, and resilience

PRACTICAL 1 Credit (30 Hours)

- Applications of PERPLEX, mELTS software.
- Exercise in oceanography; preparation of paleo-ocean circulation maps based on microfossil data
- Exercises on pumping test data analysis
- Exercises on hazard maps and matrix.

SUGGESTED READINGS:

1. Saraswati, P.K. and Srinivasan, M.S., 2015. *Micropaleontology: Principles and applications*. Springer.
2. Allen, P.A. and Allen, J.R., 2013. *Basin analysis: Principles and application to petroleum play assessment*. John Wiley & Sons.
3. Philpotts, A.R., and Ague, J.J., 2022, *Principles of Igneous and Metamorphic Petrology* (3rd edition): Cambridge, UK, Cambridge University Press, 685 p.
4. Todd, D.K. and Mays, L.W., 2004. *Groundwater hydrology*. John Wiley & Sons.
5. Gangopadhyay, S. (2013). Engineering geology. Oxford University Press.
6.
7. Keller, E. A., & Blodgett, R. H. (2021). *Natural hazards: Earth's processes as hazards, disasters, and catastrophes* (6th ed.). Pearson Education.
8. Davies, T.R., Korup, O. and Clague, J.J., 2021. *Geomorphology and natural hazards: Understanding landscape change for disaster mitigation*. John Wiley & Sons.

SBC-3 ADVANCE RESEARCH METHODOLOGY

Duration: 15 Hours (Lecture) + 30 Hours (Tutorial)

Course Title and Code	Total Credit	Credit distribution in course		
		Lecture	**Tutorial**	**Practical**
Advance Research Methodology	**2**	**01**	**01**	**0**

LEARNING OBJECTIVES:

- Develop an advanced understanding of research design, scientific investigation, and identification of research problems with the formulation of hypotheses.
- Improve the ability to review and evaluate scientific literature, identify research gaps, and select suitable methods for data collection.
- Provide knowledge of statistical tools and analytical techniques for analyzing, interpreting, and presenting research results effectively.
- Create awareness about research ethics and plagiarism, and develop skills in scientific writing and research communication.

LEARNING OUTCOMES:

- Design appropriate research strategies for scientific studies.
- Choose suitable methods for data collection and sampling and analyze and interpret data with proper techniques.
- Present findings through tables, graphs, and scholarly discussion.
- Write research papers, theses, and scientific reports following ethical standards and proper citation practices.
- Enable scholars to write and publish in peer-reviewed journals.

Lecture **(15 hours)**

Unit I: Fundamentals of Research and Research Design **(07 Hours)**

Meaning, objectives, and significance of research. Types of research. Steps in the research process. Identification and formulation of research problems. Development of research questions and hypotheses. Review of literature: sources, techniques, and critical evaluation. Research design: exploratory, descriptive, and experimental designs. Sampling techniques and methods of data collection in Earth Science.

Unit II: Data Analysis, Research Ethics and Scientific Communication **(08 Hours)**

Advanced statistical techniques in research, Multivariate data analysis and modelling, Data visualization and scientific interpretation, Big data, machine learning and computational approaches in Earth Science, Scientific data management and reproducibility, Research ethics, patent; intellectual property rights (IPR), and plagiarism, Writing high-impact research papers and review articles, Process of submitting article and scientific publishing, Preparation of research proposals, project reports, and grant applications, Oral and poster presentation of research findings.

TUTORIAL **(15 Hrs)**

1. **Field tutorials:** Stratigraphic logging and collection of rock and mineral samples.
2. **Laboratory practical:** Identification of minerals and description of rock textures. Chemical data of geological samples.
3. **Data analysis exercises:** Graphical representation of geochemical data, and use of computer tools such as spreadsheets.
4. **Research writing workshops:** Preparation of research proposals, writing of scientific reports and research papers, proper citation practices, and oral/poster presentation of research findings.

ESSENTIAL READINGS:

1. Kumar, R., 2018. Research Methodology: A step-by-step guide for beginners. SAGE Publications.
2. Creswell, J.W. and Creswell, J.D., 2017. Research design: Qualitative, quantitative, and mixed methods approaches. SAGE Publications.
3. Sarma, D.D., 2009. Geostatistics with applications in earth sciences. Dordrecht: Springer Netherlands.
4. Davis, J.C. and Sampson, R.J., 1986. Statistics and data analysis in geology (Vol. 646). New York: Wiley.
5. Ferguson, J., 1988. Mathematics in geology. London: Allen & Unwin.

SBC-4 TOOLS FOR RESEARCH

Duration: 15 Hours (Lecture) + 30 Hours (Practical)

Course Title and Code	Total Credit	Credit distribution in the course		
Tools for research	**2**	**Lecture**	**Tutorial**	**Practical**
		01	**0**	**01**

LEARNING OBJECTIVES

- To introduce tools used in academic research.
- To train students in searching research literature effectively.
- To develop skills in reference management, plagiarism checking, and document preparation.
- To familiarize students with research writing using software tools.

LEARNING OUTCOMES

- Identify and apply effective techniques for searching academic information using tools like Google Scholar, Scopus, and Web of Science.
- Use reference management tools such as Zotero and Mendeley to manage citations and generate bibliographies in standard formats (APA, MLA).
- Utilize AI-based research and writing tools including Paperguide, ChatPDF, NotebookLM, QuillBot, Grammarly, and Paperpal for research assistance and document improvement.

LECTURE 1 Credit (15 Hours)

Unit I: Research Information Search and Reference Management (7.5 Hours)

Methods to search required information effectively, Keyword searching and advanced search strategies, Use of academic databases such as Google Scholar, Scopus, and Web of Science, Pre-writing considerations in research, Identifying research problems and basics of literature review, Importance of proper citation and referencing, reference management using Zotero and Mendeley, Generating bibliography and citations (APA, IEEE, MLA styles), Core AI Research Tools like Paperguide, Chat PDF etc, Practical AI Application Tools (Writing, Editing, & Data) like NotebookLM , Quillbot, Grammarly, Paperpal etc.

Unit II: Research Document Preparation, Presentation and Ethics (7.5 Hours)

Software for paper formatting and document preparation, Introduction to Microsoft Office, Writing research papers, theses, and reports using Microsoft Office, Bibliography creation using Microsoft Office tools, Creating presentations using PowerPoint presentation, Concepts of plagiarism and research ethics, Plagiarism detection tools such as Turnitin and iThenticate

PRACTICAL 1 credit (30 Hrs)

- Searching research papers using Google Scholar
- Downloading and organizing research articles,
- Importing research papers into Zotero/Mendeley,
- Creating bibliography and citations automatically.
- Formatting reports using MS Office, Checking plagiarism reports using Turnitin/iThenticate.
- Interpreting similarity index

ESSENTIAL READINGS:

1. Ranjit Kumar, “Research Methodology: A Step by Step Guide for Beginners”, 2nd Edition, SAGE Publications Ltd.
2. G.C. Ramamurthy, “Research Methodology”, Dream Tech Press, New Delhi

SBC-5 TECHNIQUES OF RESEARCH WRITING

Course Title and Code	Total Credit	Credit distribution in the course		
Techniques Of Research Writing	2	Lecture	Tutorial	Practical
		01	01	0

LEARNING OBJECTIVES:

- To introduce students to the principles of publication, impact factor, ethics and issues such as plagiarism, authorship, and conflicts of interest in research sponsoring and publishing.
- To develop students’ knowledge of citation styles, data presentation techniques, and digital tools used in academic publishing and journal selection.

LEARNING OUTCOMES:

- Understand the purpose and structure of academic research writing.
- Develop skills in formulating research questions and thesis statements.
- Apply proper citation and referencing techniques and follow ethical standards in academic writing and publishing.
- Avoid plagiarism and maintain academic integrity.

LECTURE **1 credit (15 Hours)**

Unit- I: Fundamentals of effective research paper writing; Need and knowledge gap for writing any research paper; Types of research writing (analytical, descriptive, argumentative); Academic Language and Style-Strategies to improve the writing process and exploring disciplinary requirements: Vocabulary-Effective use of words and expansion of vocabulary, Crafting better sentences and paragraphs, Effective and varied use of punctuation marks in complex sentences, text structure: clarity, coherence, and conciseness; Organization and streamlining the writing process; Structure of manuscript: Title and abstract, Introduction and problem statement, Methodology, Results and discussion, Conclusion and recommendations; Introduction to publication misconduct: plagiarism, authorship, ghostwriting, reproducible research, conflicts of interest; Citation and Referencing Styles.

Unit-II: Introduction to data presentation, editing and proofreading; Peer Review and introduction to open access publication; Introduction to software tools to identify predatory publications and journal suggestion tools like Elsevier Journal Finder, Springer, Journal Suggester, etc.; Use of plagiarism detection software.

Tutorial **1 Credit (30 Hours)**

- Topic Selection Exercise: Choose a research topic and justify its relevance;
- Research Question Development: Formulating research questions, objectives and a thesis statement;
- Data collection basics (primary and secondary sources): Conducting literature review;
- Annotated Bibliography: Prepare summaries of at least 5 scholarly sources;
- Paragraph Writing Practice: Write structured paragraphs (introduction, body, conclusion);
- Citation Practice: Format references in APA/MLA style;
- Mini Research Paper: Write a short research paper (1000–1500 words) following proper structure.

ESSENTIAL READINGS:

1) The Craft of Research – Wayne C. Booth, Gregory G. Colomb & Joseph M. Williams
2) Writing Your Dissertation in Fifteen Minutes a Day – Joan Bolker
3) MLA Handbook – Modern Language Association
4) Mason J. (2002) Qualitative Researching. London: SAGE.
5) Weissberg R. & Buker S. (1990) Writing up Research. Englewood Cliffs, NJ: Prentice Hall.
6) Wolcott H.F. (1990) Writing Up Qualitative Research. Newbury Park, CA: SAGE.
7) Holliday A. (2007) Doing and Writing Qualitative Research. London: SAGE.
8) Silverman D. (2012) Doing Qualitative Research: a practical handbook. 4th edition. London: SAGE
9) Hopkins A. & Dudley-Evans T. (1988) A genre-based investigation of discussion sections in articles and dissertations. ESP Journal 7: 113-21.