Savitribai Phule Pune University

Pune, Maharashtra India

Structure, and Syllabus of Two Years Masters in Geology (M Sc) Degree Program with Exit Option

TWO YEAR MASTERS PROGRAMME IN SCIENCE

Subject: **Geology**

Under the Faculty of
Science and Technology

Effective from Academic year 2023 – 2024
(As per NEP-2020)

Preamble

The new M.Sc. Geology program offered by the Savitribai Phule Pune University has been prepared as per the Credit Framework guidelines of National Education Policy (NEP) 2020 and vide the university circular 122/2023/ dated 21/06/2023, and revised and updated with subsequent circulars and revision workshops. The program for two academic years consists four semesters with the provision for exit at the end of first year as per the NEP 2020. Candidates will be examined and evaluated under grade system at the end of each semester separately for theory and practical papers as per the credits offered by each course.

The M.Sc. Geology program consists of Major Core Courses, Major Electives Courses, Research Methodology, Research Project and the On Job Training. This two-year program is of total 88 credits, with 22 credits each semester. Students can choose the Elective Courses per semester from the list of Elective Courses provided. Students are also encouraged to select the Elective courses from National Educational Platforms such as MOOCS/NPTL/SWAYAM.

In addition to class-room teaching and laboratory practices, the M.Sc. Geology program offers geological fieldwork. After completion of the field training, students need to submit a field report. Intensive On Job Training (OJT) /Internships in national/state institutes and relevant industry is essential. The semester breaks can be utilized for the geological field/internships/research projects.

Students will be assessed through Continuous Assessment (CA) and End Semester Assessment (ESA). The Research Project/Dissertation work is based on either new data generated for the proposed scientific problem *OR* based on available large global data sets using innovative and original ideas in consultation with the respective Teacher/Supervisor. The thesis should be based on sound methodology and well-defined objectives. Based on the research needs of the department, the Departmental Committee will develop the framework for research projects/dissertations and will be applicable to the course.

The M Sc Geology programme will develop deep level understanding and the skills of disciplinary knowledge (domain area) and the ability to apply/practice it in multidisciplinary or multi-professional context. They will be able to acquire, analyze and interpret data generated from the laboratory or field, and can decipher the results to the scientific community in the form of report. The graduates shall be capable of expanding their knowledge boundary through research and training; and take lead in cross-disciplinary studies. The graduates will be competent to adopt careers in geoscience, in research, teaching, government, industry and non-governmental organizations within local as well as global competitiveness.

This document provides the structural framework, teaching scheme, evaluation schemes and the detailed contents of the syllabus.

M Sc Geology Syllabus Structural Framework (NEP 2.0, 2024 onwards)

Sem.	Course Type	Course Code	Course Code: Course Name	Cre-dits	Sub Total
I	**Major Core**	GL-501-CT	Mineralogy	2	**14**
		GL-502-CT	Principles of Stratigraphy and Palaeontology	2	
		GL-503-CT	Planetary Geology	2	
		GL-504-CT	Geochemistry	2	
		GL-505-CT	Sedimentology	2	
		GL-506-CP	Practicals Related to the above courses	4	
	Major elective	GL-510-E	Geochronology and Isotope Geology	2	4
		GL-511-E	Gemmology and Gem Testing	2	
		GL-512-E	Micropalaeontology	2	
		GL-513-E	Natural Resource Management	2	
		GL-514-E	Climate Change and Sustainable development	2	
		GL-515-E	GPS Geodesy	2	
		GL-516-E	Nuclear Geology	2	
	Res Method.	GL-541-RMT	Theory of Research	2	4
		GL-542-RMP	Research Tools and Methods	2	
Total				**22**	**22**
II	**Major Core**	GL-551-CT	Igneous Petrology	2	14
		GL-552-CT	Metamorphic Petrology	2	
		GL-553-CT	Structural Geology	2	
		GL-554-CT	Geodynamics	2	
		GL-555-CT	Geomorphology	2	
		GL-556-CP	Practical's Related to the above courses	4	
	Major elective	GL-560-E	Tectonic Geomorphology	2	4
		GL-561-E	Disaster Management	2	
		GL-562-E	Quaternary Geology	2	
		GL-563-E	Palaeomagnetism	2	
	O.J.T.	GL-581-OJT	On Job Training	4	4
Total				**22**	**22**
III	**Major Core**	GL-601-CT	Stratigraphy of India	2	14
		GL-602-CT	Economic Geology	2	
		GL-603-CT	Environmental Geology	2	
		GL-604-CT	Geophysical Exploration	2	
		GL-605-CT	Remote Sensing Applications	2	
		GL-606-CP	Practicals related to the above	4	
	Major elective	GL-610-E	Geoinformatics	2	4
		GL-611-E	Urban Geology	2	
		GL-612-E	Computer Applications in Geology	2	
		GL-613-E	Sequence Stratigraphy	2	
		GL-614-E	Industrial Mineralogy	2	

		GL-615-E	Advanced Structural Geology	2	
		GL-616-E	MOOC Courses to be approved by the Departmental Committee	2	
	Res. Project	**GL-631-RP**	Geological Field Studies	4	4
Total				**22**	**22**
IV	**Major Core**	GL-651-CT	Mining Geology	2	12
		GL-652-CT	Petroleum Geology	2	
		GL-653-CT	Engineering Geology	2	
		GL-654-CT	Hydrogeology	2	
		GL-655-CP	Practicals related to the above subjects	4	
	Major elective	GL-660-E	Marine Geology	2	4
		GL-661-E	Aqueous Geochemistry	2	
		GL-662-E	Oil Field Services	2	
		GL-663-E	Watershed Development & Management	2	
		GL-664-E	Groundwater Survey and Modelling	2	
		GL-665-E	Geothermal Energy Resources	2	
		GL-666-E	Medical Geology	2	
		GL-667-E	Geotechnical Studies	2	
	Res. Project	GL-681-D	Dissertation Project	6	6
Total…….				**88**	**88**

Note: Minimum 5 Students are required to run any course out of the above electives.

Evaluation Criteria:

a) **In-semester Assessment**: Internal assessment for each course would be continuous, and dates for each tutorials/practical tests will be pre-notified in the time table for teaching or placed separately as a part of time table. Departmental Internal Assessment Committee will coordinate this activity.

i) Theory Courses: There will be a minimum one test of 10 marks for each credit in a theory course and will compose multiple choice type, and or short answer type questions or assignments. Of the total period of 15 weeks of teaching, the internal assessment tests will commence after 3 weeks and 2 to 4 tests will be conducted per week

ii) Practical Courses: Practical courses will be evaluated on the basis of each practical. For 2 credit practical course 14 practicals will be conducted, there will be two practical tests of 10 marks each and 5 marks will be given for attendance and journal completion. Practicals can be of varied types including outdoor surveys, assignments and small projects to encourage the individualistic skills

iii) On Job Training (OJT):

iv) Research Project:

GL-631 RP: Research Project

Course	Paper Title	Credits	Total Marks

GL-631 RP	Geological Field Studies	**4**	**100**

Introduction

NEP 2020 has emphasized including research projects to develop a goal-oriented, independent, innovative practice in the student. Geology is a field-oriented subject, and geological acumen is created by assessing geological conditions. The skills for geologists include the identification of geological structures by assessment of juxtaposition of rocks as outcrops, their morphology and weathering status, soil-water interaction, groundwater assessment, etc., for various objectives- including economic geology and geotechnical evaluations, land use and land survey, groundwater availability, and contamination, disaster mitigation, etc. Geological field studies are, therefore, pivotal in all these demands of geologists in various organizations, industries, and entrepreneurship. Geology comprises multiple general and specialized topics covered in the syllabus and represented by the faculty. This credit, therefore, introduces the field practices in different subjects, and after the common fieldwork, individual students develop the topic of a research project of his/her interest. The Departmental Committee evaluates the topics, and the mentoring faculties are assigned to supervise the issues. Such research projects will enhance research productivity and collaboration at national and international levels amongst various industries, government, and community-based organizations and agencies. It will help the student to develop an experience of independence, teamwork, collaboration, management, and decision-making in his career.

Objectives

1. To enable the students to undertake research projects that are relevant, significant, and futuristic.
2. To apply pre-learned concepts to design a research problem with the help of a literature survey.
3. Enable students to do sufficient groundwork in preparing the outline of a research plan, including grants, infrastructural requirements, and resource procurement.
4. Students must follow the guidelines for writing the research proposal to allow them to develop a thorough proposal.
5. To encourage research culture, which includes exploring collaborative project ideas.
6. To allow students to present their proposal before funding agencies and, if possible, procure funding for the project

Outcome

I. Students will do the groundwork for research by identifying a relevant research topic (relevance will be decided based on the subject), identifying the queries, and conducting a literature review.

II. Define well-formulated specific objectives that help develop the overall research methodology,

III. By the end of the semester, the student is expected to compile and communicate the research proposal in the proper format, along with funding components and their justification.

Evaluation

I. In GL 631 RP, the total credits for the research project are 4.

II. The student will be evaluated by Presentation, Submission of project and by other activities during the work.

Parameters for assessment

(Based on overall performance and oral presentation/ viva voce for the project)

SR. NO.	POINTS / Evaluation Parameters	Marks (Internal)	Marks (External)
1	Idea/Topic and Originality of the Research Problem Identified		
2	Significance of the Work and Literature Review		
3	Review A statement of Aims and Objectives		
4	Plan of Research Project		
5	The thoroughness of the proposal regarding methodology, apparatus/equipment required, and timeline (PERT chart).		
6	Regularity of work carried		
7	Bibliography		

*PERT stands for Program Evaluation and Review Technique

b) **Term End Examination**: - The term end examination per course would be held about two weeks after the completion of teaching for the semester. Paper setting and assessment for a particular course would be the responsibility of the course In-charge, course coordinator and these activities would be co-ordinated by under the Department Examination Committee. The Department Examination committee would be responsible for the results.

GPA Rules:

1. The formula for GPA will be based on Weighted Average. The final GPA will not be printed unless a student passes courses equivalent to minimum 88 credit hours decided by the departmental and exam committees (Science). Total credits hours means the sum of credit hours of the courses which a student has passed.
2. A seven-point grade system [guided by the Government of Maharashtra Resolution No. NGO – 1298 / [4619] / UNI 4 dt. December 11, 1999 and University regulations] will be followed. The corresponding grade table is attached herewith.
3. If the GPA is higher than the indicated upper limit in the third decimal digit then the student be awarded higher final grade (e.g. a student getting GPA of 4.492 may be awarded 'A')
   For Semester I, II, III examinations, only the grade points will be awarded for each subjects. Final GPA along with final grade will be awarded only at the end of IVth semester. There is also a provision for verification and revaluation. In case of verification, the existing rules will be applicable. The revaluation result will be adopted if there is a change of at least 10% marks and in the grade of the course.
4. After the declaration of result, for the improvement of Grade, the student can reappear for the examination of 30 credit worth theory courses.

Explanation of Grade & Grade Point Average:

Marks Obtained	Grade	Grade Points
100 – 80	**'O'** Outstanding	10
79 - 70	**'A+'** Excellent	9
69 - 60	**'A'** Very Good	8
59 - 55	**'B+'** Good	7
54 - 50	**'B'** Above average	6
49 - 45	**'C'** Average	5
44 - 40	**'P'** Pass	4
39 -0	**'F'** Fail	0
0	**Ab**	Absent

Final Grade Points:

Grade Points	Final Grade
9 - 10	O
8.99 - 8.5	A+
8.49 - 7.5	A
7.49 - 6.5	B+
1.49 - 5.5	B
5.49 - 4.25	C
4.24 - 4	P
3.99 - 0	F

Common Formula for GPA:

$$\text{GPA (Grade Point Average)} = \frac{\text{Total of (Grade Points earned x Credit hours for each course)}}{\text{(Total Credit hours)}}$$

B Grade is equivalent to at least 55% of the marks.

Note: The Departmental Examination Committee in consultation with Departmental Committee will have the full rights to make changes in the evaluation system but within the norms of the SPPU Board of Examination and Evaluation.

Detailed Semester-wise contents of the M Sc. Geology Syllabus with the scope of exit after First Year

Semester I

Course Type: Major Core

GL 501 CT: Mineralogy	**02 Credits**
GL 502 CT: Principles of Stratigraphy and Palaeontology	**02 Credits**
GL 503 CT: Planetary Geology	**02 Credits**
GL 504 CT: Geochemistry	**02 Credits**
GL 505 CT: Sedimentology	**02 Credits**
GL 506 CP: Practicals Related to the above courses	**04 Credits**

Course Code: GL 501 CT; Credits: 02;
Course Title: Mineralogy
Type: Core and Skill based

Course Learning Outcomes (CLO):

Upon successful completion of this course, the student will be able to:

CLO1	Learn the Concepts of crystal structure, morphology and mineral optics.
CLO2	Describe various types of minerals based on their physical, chemical and optical properties
CLO3	Illustrate common rock-forming minerals on the basis of their crystal structure, physical properties and mineral chemistry
CLO4	Distinguish the functioning of various analytical techniques
CLO5	Interpret the origin and association of various minerals.
CLO6	Generate a Database of analytical results and their evaluation

Unit/ Hour	Course Contents	Mapping with CLO
I/10	Definition of Crystal, Study and Classification of crystals into Crystal systems. Unit cell - Proper and improper symmetry operations Point Groups - Classification of crystals into 32 Point Groups Space lattice - Derivation of 14 Bravais lattices – HCP Concept of Space Group - Derivation of 230 space groups, Symmorphic and Asymomorphic Space Groups Twinning in crystals. Twin laws, causes, effects and genetic types of twinning. solid solutions,	1,3,6

	Imperfection in solids – types of imperfections – point, line area defects	
II/10	**Mineral Optics:** Plane polarized and cross polarized light, Isotropic and Anisotropic minerals, Behavior of minerals in cross polarized light Birefringence - Uniaxial and Biaxial minerals - Uniaxial and Biaxial Indicatrises - Orientation of indicatrises as per the section, Interference of light waves - Passage of light through doubly refracting minerals, Generation of interference colours Conoscopic or convergent polarized light, Generation of Uniaxial and Biaxial interference figures, Forms of interference figures related to sections, Optical accessories like mica, gypsum and quartz plates. Determination of Optic sign of uniaxial and biaxial minerals. Dispersion of light - its effect on interference figures. Absorption of light by minerals - Scheme of pleochroism.	1,2,4,6
III/10	**Descriptive Mineralogy – I:** Structure, relation of Chemical composition with optical, physical properties, alteration products and paragenesis of following group of minerals : Olivine, Pyroxenes, Amphiboles, Garnet, Mica, Alumino silicate, Epidote, Feldspar, Fledspathoid, Zeolite. The six major groups of nonsilicate minerals Carbonates, Halides, Native elements, Oxides, Sulfates, and Sulfides.	CLO4 CLO5 CLO6

Reference Books:

Rutley **Mineralogy (2022)**
Götze and Göbbels (2023) Introduction to Applied Mineralogy (Springer)
Schmidt (2023) Transmitted Light Microscopy of Rock-Forming Minerals: An Introduction to Optical Mineralogy (Springer)
Okrusch and Frimmel (2020) Mineralogy: An Introduction to Minerals, Rocks, and Mineral Deposits (Springer)
Ndimofor (2018) The Fundamentals of Crystallography and Mineralogy (Spears)
Haldar (2020) Introduction to Mineralogy and Petrology (Elsevier)
Dana and Ford (2006) A textbook of Mineralogy (John Wiely and Sons).
Flint (1975) Essential of crystallography, Mir Publishers.
Phillips (1963) An introduction to crystallography. Wiley, New York.
Berry, Mason and Dietrich (1982) Mineralogy. CBS Publ.
Read (1968) Rutley's Element of Mineralogy (Rev. Ed.). Thomas Murby and Co.
Kerr (1995) Optical Mineralogy 5th Ed. McGraw Hill, New York.
Wahlstrom (1971) Optical crystallography, John Wiley and sons.
Sharma and Sharma, (2013) Crystallography and Mineralogy -Concepts and Methods. Text Book Series, Geological Society of India, Bangalore
Hota (2012) Practical approach to Mineralogy and Crystallography, CBS
Deer, Howie and Zussman 1966, An Introduction to Rock forming minerals, Longman
Dexter Perkins,2011, Mineralogy, Prentice Hall,3rd edition Indian editon
Winchell: Elements of Optical Mineralogy
Cracknell: Crystals and their structure
Frye Keith: Modern Mineralogy

List of Journals:

1.The American Mineralogist
2. The Indian Mineralogist
3. Mineralogical Record
4. International Journal of Mineralogy
5. Mineralogical Magazine

Course Code: GL 501C**P; 1 Credit**

Course Title: Crystallography and Mineralogy (Practical)

Course Learning Outcomes (CLO):

CLO 1	Identification of crystal characters, parameters, symmetry and systems.
CLO 2	Describe and identify different minerals in hand specimens to recognize certain common minerals based on their diagnostic physical properties,
CLO 3	Use transmitted and reflected light microscopes for study of optical properties of common rock-forming minerals.
CLO 4	Distinguish different minerals with the help of X-ray diffractograms,Operate polarizing microscope to determine 2V and 2E
CLO5	Evaluate physical and optical properties of common rock forming minerals.
CLO6	Construction of Stereograms and Gnomonograms

Unit/ Hour	**Contents**	**Mapping with CLO**
I/15	Classification of different crystal models based on various crystallographic parameters	**CLO1**
	Study of rock forming minerals in hand specimens	**CLO2**
	Study of rock forming minerals in thin sections	**CLO3**
	measurement of interfacial angle with contact goniometer - determination of 2V and 2E, study of X-ray diffractograms	**CLO4**
	Study of interference figures - determination of optical sign of minerals, , determination of birefringence of minerals	**CLO5**
	Construction of Stereograms and Gnomonograms	**CLO6**

Reference Books:

MacKenzie and Guilford: Atlas of Rock Forming Minerals in Thin Section

Course Name: Principles of Stratigraphy and Palaeontology

GL 502CT: Principles of stratigraphy and Palaeontology, 2 Credit
Type: Core and Skill based

Course Learning Outcomes (CLO):

CLO1	Understand the History and development of Stratigraphy. Familiarize with the basic principles of stratigraphy, Different types of stratigraphic units and their nomenclature
CLO2	Understand the Stratigraphic procedures used in Surface and Subsurface stratigraphic studies.Development and importance of Concept of Lithofacies & Biofacies for stratigraphic sections and in correlation
CLO3	Standard stratigraphic codes including Lithostratigraphic, Bio-stratigraphic and Chronostratigraphic nomenclature and hierarchy..Study of various Stratigraphic Correlation procedures used in Litho-, Bio- and Chronostratigraphic studies.
CLO 4	Understand the Concepts of Magnetostratigraphy, Chemostratigraphy, Event stratigraphy, and Sequence stratigraphy.
CLO5	Various Palaeontological perspectives used in study of stratigraphy
CLO 6	Interpretation, writing, compilation and presentation of a detailed report based on the knowledge of Stratigraphy and Palaeontology.

Unit/Hour	**Course Contents**	**Mapping with CLO**
I/04	Introduction to the principles of stratigraphy. Contributions of cardinal principles given by various researchers. The study of lithology sections. Principles and stratigraphic practices for outcrop and subsurface strata. The concept of Lithofacies & Biofacies, Walther's Law used in understanding the facies successions, Process/ Response Model used and terms like Lithotopes and biotopes, lithologic aspect and biologic aspect and lithofacies and biofacies and their interrelationships.	CLO1 CLO2 CLO3 CLO4 CLO6
II/05	History and development of Geological Time Scale. International Code of Stratigraphic Nomenclature. A brief study of the stratotypes. Global Boundary Stratotype Sections & Points (GSSP) with following systems: Cambrian, Carboniferous, Cretaceous, Tertiary and Quaternary.Lithostratigraphic, Biostratigraphic and Chronostratigraphic studies with standard principles and procedures. Hierarchical terms used in lithostratigraphy, various zones in biostratigraphy and major systems in Chronostratigraphy and their correlation. Stratigraphic Correlation (Litho-, Bio- and Chronostratigraphic Correlation.	CLO5 CLO6
III/04	Understand in detail the Concepts of Magnetostratigraphy, Chemostratigraphy, Event stratigraphy, and Sequence stratigraphy with case studies.	CLO3 CLO5 CLO6
IV/05	Origin and evolution of life through various geological ages. Phases in evolution and extinction. Different Techniques used in collection of mega fossils,	CLO4 CLO5 CLO6
V/05	Invertebrate Palaeontological study, emphasis on their morphological features, standard classification, prominent phases of evolutionary trends and Distribution of Molluscs i.e. Bivalves and Gastropods, Echinoids, Corals & Brachiopods in geological timescale.	CLO4 CLO5 CLO6
VI/05	Vertebrate Palaeontology, study the evolution of mammals especially horse and elephant.	CLO3 CLO4 CLO5

		CLO6
VII/02	Generate (interpretation, writing, compilation and presentation) a detailed report based on the above knowledge.	CLO6

Suggested Readings:

Brookfield M. E. Principles of Stratigraphy. 2008
Dunbar C. O. & Rogers J. Principles of Stratigraphy
Gignoux M. Stratigraphic Geology. Freeman.
Eicher L. D. Geologic Time.
Weller J. M. Stratigraphic principles & Practice.
Krumbein N. C. & Sloss L. D. Stratigraphy and sedimentation.
Brenner and Mc Hargue : Integrative stratigraphy
Boardman R.S., Cheetham A.H., Rowell A.J. : Fossil invertebrates
Clarkson E.N.K. : Invertebrate Palaeontology & Evolution
John R.Haynes, Hohn Wiley & Sons : Foraminifera
M.D.Brasier : Microfossils Swinnerton : Outline of Palaeontology Moore
Lalicker & Figher : Invertebrate Palaeontology Remer : Vertebrate Palaeontology
Shrock and Twenhofel : Principles of invertebrate Palaeontology
Arnold : Introduction to Palaeobotany
Bignot G : Elements of Micropalaeontology. The microfossils, their Geological and Palaeobiological applications
Clobert E.H. : Evolution of the Vertebrates

Course Code: 502CP

Course Title: Principles of stratigraphy and Palaeontology (Practical)
Total Hours: 15

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to:

CLO 1	Construct rank charts for lithostratigraphy, biostratigraphy & Chronostratigraphic nomenclature
CLO 2	Construct graphical logs from given data in text descriptions
CLO 3	Exercises in litho-correlation from given data or logs
CLO 4	Construct range charts
CLO 5	Study of Palaeontological technique related to megafossils.
CLO 6	Study of morphology of Bivalves, Gastropods Echinoids, Brachiopods

Unit/ Hour	Contents	Mapping with CLO
I/15	Understanding the updated International stratigraphic chart and know about rank charts for lithostratigraphy, biostratigraphy & Chronostratigraphic nomenclature.	**CLO1**
	Construction of graphical sections from given data using standard symbols of lithology, sedimentary structures and fossils.	**CLO2**
	Graphical correlation of surface and subsurface lithological data with proper scale and symbols.	**CLO3**
	Available data of fossiliferous strata used in construction of range charts	**CLO4**
	Megafossils studied including nomenclature and detail morphology of Bivalves, Gastropods Echinoids, Brachiopods	**CLO5 CLO6**

References:

1. Embry (2009). Practical sequence stratigraphy. *Canadian Society of Petroleum Geologists*, *81*, 79.
2. Catuneanu (2022). *Principles of sequence stratigraphy*. Newnes.
3. Thomason (Ed.). (1997). *Functional morphology in vertebrate paleontology*. Cambridge University Press.

Course Code: GL 503CT; 2 Credit

Course Title: Planetary Geology

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to:

CLO 1	Knowledge about the evolution of the Solar system and cosmology in context to the evolution of planetary system
CLO 2	Student will learn in detail about the fundamental physical and chemical properties of the earth and its variation with the interior.
CLO 3	Student will know the applications of the physical and chemical properties in understanding the evolution of the earth.
CLO 4	To apply geochemical principles to solve many types of geological problems

Unit/ Hour	**Contents**	**Mapping with CLO**
I/5	Introduction to Planetary Geology; Laws of Universe; Galaxies & their classification; Stars and star formation processes; Theories of origin of solar system; Orbital dynamics of the earth-moon system; Planetary Habitability.	**CLO1**
II/5	The Earth as a planet; Physical properties of the Earth's interior; Seismology and the internal structure of the Earth; Martian analogues.	**CLO2**
III/5	Gravity, the figure of the Earth and geodynamics; Geomagnetism and paleomagnetism; Early earth and the evolution of the Earth's crust.	**CLO3**

Practicals

Unit/ Hour	**Contents**	**Mapping with CLO**
I/8	Plotting of various parameters with interior of the earth and understanding phase changes	**CLO1**
II/7	Problems related to seismic, geomagnetic, and gravity parameters	**CLO1**

Suggested Books:

New Theory of the Earth; by Don L. Anderson; Publisher: Cambridge University Press 2007
Lowrie, W., 1997. Fundamental of Geophysics, Cambridge Univ. Press. London.
Fowler, 2005.The Solid Earth: An Introduction to Global Geophysics, Cambridge University Press.
Peter Shearer, 1999.Introduction to Seismology, Cambridge University Press, Cambridge.
Alan E. Mussett, M. Aftab Khan, 2000.Looking in to the Earth: An Introduction to Geological Geophysics, Cambridge University Press.
Lillie, R.J., 1998. Whole Earth Geophysics: An Introductory Book for Geologists and Geophysicists,Pearson Education.
Parasnis, D. S., 1986. Principles of Applied Geophysics, Chapman and Hall.

Web Resources:

Databased Sites of IRIS; NGDC; USGS; NOAA

Course Code: GL 504CT; 2 Credit

Course Title: Chemistry of the Earth

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to:

CLO 1	Understand the geochemical behavior of elements and their distribution in Earth's spheres.
CLO 2	Apply geochemical principles to study Earth's processes and materials.
CLO 3	Use analytical techniques to collect and interpret geochemical data.
CLO 4	Address geological and environmental problems using geochemical tools.

Unit/ Hour	Contents	Mapping with CLO
I/10	Origin of elements: Nucleosynthesis processes (Big Bang, stellar, and supernova). Abundance of elements in the Earth, solar system, and universe. Periodic table, geochemical classification and distribution of elements in the Earth Chemical bonding and coordination in minerals.	CLO1
II/10	Basic concepts of thermodynamics: Enthalpy, entropy, Gibbs free energy. Phase rule and phase diagrams. Kinetics of geochemical reactions. Applications to metamorphism, weathering, and magmatic processes. Chemical properties of the Earth's interior, Evolution of Mantle, Trace elements and rare earth elements: Partitioning and fractionation.	CLO2 CLO3 CLO4
III/10	Law of Radioactivity, Principles of radiometric dating, Decay schemes, Common geochronological methods Rb-Sr, Sm-Nd, U-Pb and Ar-Ar.	CLO2 CLO3 CLO4

Transactional Modes: Lecture, Demonstration, Lecture cum demonstration, Project and assignment Mode, Seminar, Group discussion, Field visit, E- tutoring.

Suggested Readings

"Principles of Geochemistry" by Brian Mason and C.B. Moore.
"Geochemistry: Pathways and Processes" by Harry Y. McSween, Steven M. Richardson, and Maria E. Uhle.
"Introduction to Geochemistry" by K.B. Krauskopf and Dennis K. Bird.
"Stable Isotope Geochemistry" by Jochen Hoefs.
Research articles and case studies as recommended by the instructor.

Course Code: GL506CP; 1 Credit

Course Title: Chemistry of the Earth

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to:

CLO 1	Use analytical techniques to collect and interpret geochemical data.
CLO 2	Address geological and environmental problems using geochemical tools.

Unit/ Hour	Contents	Mapping with CLO
I/15	Overview of analytical techniques: XRF, ICP-MS, AAS, and SEM-EDS. Sample preparation and contamination issues. Geochemical data interpretation and visualization.	CLO1 CLO 2

Course Code: GL 506CP

Course Title: Chemistry of the Earth

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to:

CLO 1	Students will know about the general methods and tools of determining various chemical parameters about the universe, the planetary system and the earth's interior.

Unit/ Hour	Contents	Mapping with CLO
I/8	Deterministic methods for rock and mineral analysis; Introduction to the use of routine instrumental techniques of analyses of rocks; soils & water, plotting chemical data on variation diagrams.	**CLO1**
II/7	Plotting various parameters with interior of the earth and understanding phase changes. Use of isotopic methods.	**CLO1**

Suggested Books:

New Theory of the Earth; by Don L. Anderson; Publisher: Cambridge University Press 2007
Lowrie, W., 1997. *Fundamental of Geophysics*, Cambridge Univ. Press. London.
Mussett, M. Khan, 2000.*Looking in to the Earth: An Introduction to Geological Geophysics*, Cambridge University Press.

Course Code: GL 505 CT
Course Title: Sedimentology
Type: Core and Skill based; Total Hours: 30 hrs

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to:

CLO1	Understand the process of formation of siliciclastic and carbonate sediments and sedimentary rocks, their texture and structures, and reconstruction of paleo-environments. .
CLO2	Explore modern and ancient sedimentary environments and knowledge and skills necessary to describe, and interpret sediments, sedimentary rocks and environments through time.
CLO 3	Identify the main types of sedimentary rocks, textures, ichnofacies and sedimentary structures, to reflect on the implications of their formation
CLO 4	Describe the most important characteristics of continental and marine sedimentary environments
CLO 5	Interpret depositional processes, facies and stratigraphical subdivision in relation to depositional environment, sedimentary basin and the climate
CLO 6	Explain different sedimentary environments and identify their processes and products.

Unit/ Hour	**Course Contents**	**Mapping with CLO**
I/7	Clastic transport and fluid flow (fluid flow in theory and in nature, Reynold's Numbers, Froude Number, Sediment lift, transport, deposition, sedimentary gravity flow); Sedimentary structures (Physical structures, Biogenic sedimentary structures, Diagenetic structures). Sedimentary textures: Fundamentals of sediment textures, grade scale, Methods, presentation and geological significance of size analysis (granulometric analysis); Shape of sediment; Form Indices /Sphericity, Form, Roundness; Fabrics, Porosity and Permeability; Surface textures. Heavy mineral analysis & Insoluble residue analysis.	CLO1 CLO2 CLO3 CLO5 CLO6
II/7	Petrography of rocks of clastic, chemical and biochemical origin; Major and minor mineralogy components, textural aspect, fabric, and nature and composition of matrix and Classifications of; Conglomerates and Breccias, Sandstone, Mudstone, Limestone & Dolostone; Carbonate minerals, Diagenetic Environments/ Dolomitization, texture, structure, origin of dolomite.	CLO1 CLO2 CLO3 CLO5 CLO6
III/10	Concept of Sedimentary facies association models (Marine, Nonmarine, and Mixed Depositional Environment); Glacial, Aeolian, Lacustrine, Fluvial, Deltaic and,Marine Environments.	CLO4 CLO6
IV/6	Sedimentation and Tectonics; Sedimentation in extensional and convergent sedimentary basins; Paleocurrents Analysis	CLO5 CLO6 CLO6

Course Code: GL506CP
Course Title: Sedimentology Practical

CLO 1	Understand, interpret and characterize the sediments and sedimentary rocks
CLO 2	Understanding, relating and characterization of the sedimentary process
CLO 3	Sediment composition and its relation to the provenances
CLO 4	Understand the processes of generation of sedimentary structures and lithofacies analysis in reconstruction of depositional environment
CLO5	Recognize and characterize different sedimentary rocks from their petrographic composition, texture and other characters.
CLO6	Understand the origin, classification and distribution of non-clastic sediments.

Unit/ Hour	**Contents**	**Mapping with CLO**
I/30	Sieve Analysis and its interpretation.	**CLO1** **CLO2** **CLO3**
	Size Analysis (Procedures, Cumulative curve, Histogram, Visher's curve and Statistical calculation-Mean, Median, Standard deviation, Skewness, Kurtosis, Modality Index and Interpretation).	**CLO6**
	Shape Analysis-Sphericity and Roundness and its interpretation.	**CLO3**
	Identification of Heavy Minerals.	**CLO1**
	Megascopic and studies of Conglomerate and Breccias.	**CLO2**
	Megascopic and Microscopic study of Sandstone.	**CLO5** **CLO4, CLO6**
	Megascopic and Microscopic study of Limestone.	**CLO2**
	Observation and interpretation of primary and secondary sedimentary structures.	**CLO5**
	Paleocurrent Analysis and its interpretation.	**CLO 4**

Suggested Readings:

Applied Sedimentology" by Selly R C
Depositional Sedimentary Environments" by Reineck H E and Singh I B

Sedimentary Environments and Facies" by Reading H G
Sedimentary Structures" by Collins J D and Thompson D B
Introduction to Sedimentology" by S M Sengupta
Sedimentology and Stratigraphy" by Nichols G
Sedimentology: Process and Product" by M R Leeder
Sedimentology" by Herve Chamley and Thomas Reimer
Environmental Sedimentology" by Perry C T and Taylor K G
Principles of Sedimentology and Stratigraphy: Sam Boggs, Jr.,
Flugel, E.V., (2002) Microfacies analysis of limestones. Elsevier.
Lindholm, R., (1988) A practical approach to Sedimentology. Blackwell publication.
Nicholls, G. (1999) Sedimentology and Stratigraphy. Wiley-Blackwell,.
Pettijohn F.J. (1975) Sedimentary rocks. Harper and Row Publ., New Delhi.
Sengupta.S.M, (2007), Introduction to Sedimentology, CBS Publishers & Distributors, New Delhi.
Mc Lane, M. 1995, Sedimentology, Oxford University press ,USA (April 27, 1995), 448 pages, ISBN-10: 0195078683.
Blatt, H., Middleton, G.V. and Murray, R.C. (1980): Origin of Sedimentary Rocks, Prentice-Hall Inc, New Jersey, 782pages, ISBN 0-13-642710.
Collinson, J.D., and Thompson, D.B., 1982: Sedimentary Structures, George Allen and Unwin, London.194p. Lindholm, R.C. , 1987 A Practical Approach to Sedimentology, Allen and Unwin, London, 276p.
Miall, A.D. (2000): Principles of Sedimentary Basin Analysis, Sjpringer-Verlag, 628 pages, ISBN-10: 3540657908
Pettijohn;, F.J. (1975): Sedimentary Rocks (3rd Ed.), Harper and Row Publ., New Delhi, 628 pages Reading, H.G. (1997): Sedimentary Environments and facies, Blackwell Scientific Publication, ISBN 0-632-03627-3.
Selley, R. C. (2000) Applied Sedimentology, Academic Press, 523 pages, ISBN 012 636375
Tucker, M.E. (1981): Sedimentary Petrology: An Introduction, Wiley and Sons, New York 272 pages ,ISBN 0-632-05735-1.
Pettijohn : Sedimentary Rocks
Blatt, Middleton and Murray : Origin of sedimentary rocks
Reineck and Singh : Sedimentary Depositional Environments
Carozzi : Petrography of Sedimentary Rocks
Carver : Procedures in Sedimentary petrology
Potter and Pettijohn : Paleocurrents and Basin analysis

List of Journals:

Sedimentary Geology Print ISSN: 0037-0738 Online ISSN: 1879-0968
The ***Journal*** of the Indian Association of ***Sedimentologists*** (IAS)
Sedimentology Journals.
Journal of Sedimentary Environments Electronic ISSN 2447-9462
Journal of Sedimentary Research
Journal of Sedimentology and Basin Analysis
Latin American Journal of Sedimentology and Basin Analysis
Journal of Stratigraphy and Sedimentology Researches J
ournal of the Sedimentological Society of Egypt

Semester I

GLRM 541 RMT and GL 542 RMP

Course title: GL 541 RMT: Research Methodology (theory); 2 Credit

CLO1	Choose and propose appropriate research methods according to aims and objectives
CLO2	Review, test and find limitations of particular research methods
CLO3	Selection of various instruments and sample preparation techniques for addressing specific research problem

Unit/ Hour	**Contents**	**Mapping with CLO**
I/15	Concept and definition of Research; Types of research; Tools of Research; Hypothesis, Research proposal and concepts. Developing research proposals in the field of geosciences; research approach, methodology and identifying the gap areas from literature review; Origin of problem and Statement of research objective, Research outcomes, parameters to monitor the progress of research.	CLO1 CLO2
II/15	Literature survey and review, use of digital library, and online resource; database analysis. Concepts on plagiarism, ISSN and ISBN numbers, impact factors and citation index of research articles and assessing the quality of research articles.	CLO3

GL 542 RMP: Research Methodology (Practical)

Course title: Research Methodology (Practical); 2 Credit; 30 Hours

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to:
CLO1: Understand the practical methods of doing research with their research aims and objectives
CLO2: Develop the criticality and be aware of the limitations of particular research methods to search for better ones.
CLO3: Justify knowledge of the selection of various instruments and sample preparation techniques for addressing research problem
CLO4: Develop skills in qualitative and quantitative data analysis and presentation
CLO5: Design advanced critical thinking skills and enhanced writing skills

I/15	Concepts of using Advanced methods in Fieldwork, Pre-field preparations, Field mapping and documentation; Philosophy and Procedures of sampling, Introduction to field mapping and section measurements, Recent advancement on analytical techniques, field gears, data sciences and AI in the field of Earth Sciences.	CLO1 CLO2 CLO3

II/15	Types of data: primary and secondary data, Source and authenticity of secondary data. Introduction to analytical data treatment and modelling. Application of softwares in Earth science with hands-on experience on few available softwares; Introduction on the techniques of data representation, documentation and representation tools, basic presentation structures, writing a scientific paper, abstract and summary writing and organizing thesis, project reports; Integrative approach in geology. Applications of EPMA and SEM in understanding the mineral chemistry and thus to deduce the terrain evolution and the fertility in the aspects of ore deposit formation. Borehole; planning and Resource estimation methods of complex and stratiform deposits.	CLO3 CLO4 CLO5

Suggested readings:

1. John, W. C., 2011.*Research Design: Qualitative, Quantitative and Mixed Methods Approaches*, Sage Publications, Thousand Oaks.
2. Blaxter, L.; Hughes, C. and Tight, M. (1996): How to Research. Open University Press, Buckingham.
3. Paltridge, B., Starfield, S. (2019). *Thesis and Dissertation Writing In a Second Language,* Routledge Publisher.
4. Hofmann, A. H. (2019). *Scientific Writing and Communication: Papers, Proposals, and Presentations,* Oxford Univ Pr; 4th edition, USA.
5. Kothari, C. R., Garg, G. (2019). *Research Methodology: Methods And Techniques,* New Age International Publishers; Fourth edition, India.
6. Prathapan, K. (2019). *Research Methodology for Scientific Research*, Dreamtech Press, India
7. Kothari, C. R. (2008). *Research methodology(s)*. New Age International, New Delhi.
8. Lester, James, D. and Lester Jr. J. D., 2007. *Principles of Writing Research Papers*, Longman, New York.
9. Reed, S. J. B., 1990. *Recent developments in geochemical microanalysis: Chemical Geology*, Volume.83, PP. 1-9.
10. Frank A. Settle, 1997. *Handbook of Instrumental Techniques for Analytical Chemistry*, Prentice Hall, Upper Saddle River, NJ.

M Sc Geology: Semester I Elective Courses

Baskets for Major Electives (each 2 Credit T/P):

Note: Minimum 5 Students are required to be opted to run any course out of the above electives.

GL 510E: Geochronology and Isotope Geology

Course Code: GL 510E
GEOCHRONOLOGY & ISOTOPE GEOLOGY
Course Title: Type: Subject Elective, 30 hrs

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to:

CLO1	Concepts of radioactivity and radioactive decay
CLO2	Difference between Radiogenic and Stable isotopes
CLO 3	Whole rock vs. mineral ages, Datable minerals and their closure temperature
CLO 4/ CLO 5	Methods of dating
CLO 6	Applications of Stable Isotopes
CLO 7	Generate isotopic data and their geological interpretations. Besides, evaluating, writing, compilation and presentation of reports/research papers based on the above knowledge.

Unit/ Hour	Course Contents	Mapping with CLO
I/07	**Fundamentals of Geochronology and Isotope Geochemistry** ● Introduction to radioactivity, Decay mechanisms of radioactive atoms, Derivation of age equation, Age of the Earth. ● Introduction to Stable and Radiogenic isotopes ● Whole rock vs. mineral ages ● Datable minerals, mineral separation techniques, closure temperature of datable minerals. ● Zirconology **Learning Activities:** Learning Concepts through presentations, black board teaching. Student Seminars, Assignments.	CLO1 CLO2 CLO3
II/08	**Methods of dating:** ● Radioisotopes in geochronology ● Concept of Isochron, errorchron and geochron. ● Rb-Sr dating method ● Sm-Nd dating method ● K-Ar and 40Ar-39Ar dating ● U-Th-Pb systematics, governing equations ● The Wetherill Concordia and Tera-Wasserberg diagram and dating. **Learning Activities:** Plotting and interpretation of diagrams, Hands on exercise, reading case studies.	CLO4 CLO5
III/08	**Stable isotopes and their applications**	CLO6

	● Fractionation of stable isotopes in lithosphere, hydrosphere and atmosphere ● Stable isotopes of oxygen and hydrogen, ● Stable isotopes of carbon and sulphur ● Use of stable isotopes in dating. **Learning Activities:** Lectures, assignment, student Seminar, group discussions	
IV/07	**Applications of Isotopes** ● Stable isotope geothermometry ● Isotopes in deciphering sedimentary environments, paleoclimate, environmental geology, mineral exploration, etc. ● Other dating methods e.g. Thermoluminiscence, OSL, ESR dating, Fission track dating. ● Cosmogenic isotopes and applications **Learning Activities:** Student seminar, group discussion on Metamorphism related to Plate Tectonics, Case study paper reading.	CLO7

Suggested Readings:

1.Faure, G., Principles of Isotope Geology, 2nd Edn. John Wiley & Sons, 1986.
2.Faure, G. and Mensing, T. M., Isotopes: Principles and Applications, 3rd Edn. John Wiley & Sons, 2005.
3.Dickin, A. P., Radiogenic Isotope Geology. Cambridge University Press, 1995.
4.Hoefs, J., Stable Isotope Geochemistry, 3rd Edn. Springer-Verlag, 1987.
5.Geyh, M. A. and Schleicher, H., Absolute age determination. Springer, 1990.
6.Rollingson Hugh, Using Geochemical data: evaluation, presentation, interpretation, Prentice Hall, 1993.

GL 511 E: Gemmology and Gem Testing

CourseCode: GL 511E; Major Elective; 2 Credits
CourseTitle: Gemology and Gem Testing
Type: Core and Skill based

Outcomes (CLO):

CLO1	Understand the fundamentals of various precious and semiprecious gemstones.
CLO2	Know their formation, classifications, basic qualities of gemstones, and description of their various physical properties and inclusions
CLO3	Geological association of gemstones.
CLO4	Treatments involved to enhance the natural and synthetic gemstones.
CLO5	Discuss and use different gem testing methods and instruments in the identification of the gemstones
CLO6	Differentiate between natural and synthetic gems

Unit/ Hour	Course Contents	Mapping with CLO
I/15	**Introduction to Gemology** Basic properties of gems, Geological activities, Origin and occurrence of gemstones, Formation - Geology related to gem minerals; Inorganic and Organic, Crystalline state and crystalline Materials; Crystal lattice; Amorphous and metamict minerals, Internal growth (twinning), Crystal surface markings, Crystalline features in important gemstones; Physical properties, Optical properties, Introduction to special optical properties like Sheen; Opalescence; Adularescence; Iridescence; Asterism; Chatoyancy, labradorescence, 4 C's of Gemstones **Colour in gemstones:** Colouring elements, Causes of colour in gemstones: **Inclusions:** Inclusions and their causes, Special optical effects due to inclusion, Identification of various inclusions in gemstones by occurrences, Different Types of Synthetics & Its Identification, Distinction between natural and synthetic stones **Different types of treatments on gemstones**: Heat treatment, glass filling, diffusion etc.; Identification of treated gemstones, Enhancements and its types, and Imitations. Processes of Synthesis. **Differentiating natural gemstones from their synthetics and simulants; Description of gem materials of organic origin**	1,2,3
II/15	**Gem species and their varieties** (colour-wise), Chemical composition, Crystal system, Physical and optical properties, Characteristic inclusions and Geographical Occurrences; Corundum, Beryl, Garnet, Feldspar, Silica, Tourmaline, Topaz, Spinel and Chrysoberyl, Diamonds, Opaque gem varieties; Rare Gemstones (Peridot, kyanite, iolite, sphene, zircon, apatite etc) **Gem testing instruments and their use and working in gemstone identification**	4,5,6

	Use of Gem Testing Instruments: hand lens (10x), Detection of double refraction, with the Dichroscope, Identification of gemstones based on pleochroic colours; Detection of double refraction, interference figures and internal strain with the Polariscope, the study of the fluorescent colours exhibited by various gemstones under Ultraviolet (longwave and shortwave) light, Measurement of refractive indices and birefringence tests using a gem-testing Refractometer.	

Books Recommended:

1. Karanth R.V (2000) Gems and Gem Industry in India, Geological society of India
2. Read, P. G.(1991) Gemmology, Butterworth-Heinemann Ltd.
3. Webster, R. and edited by Anderson, B.W. (1983) Gems: Their Sources, Descriptions and Identification, Butterworth-Heinemann Ltd
4. Sinkankas, J. (1969) Mineralogy: A First Course, Van Nostrand Reinhold Company.
5. Karanth R.V (2008) Gemstones Enchanting Gifts of Nature, Geological society of India
6.Anderson B.W (2011) Gem Testing, Read books Ltd.
7. Turner and Groat (2022) Geology and Mineralogy of Gemstones (AGU Advanced Textbooks, Wiely)

List of Journals:

1.Gems and Gemology, a quarterly Journal of GIA
2.Journal of Gems

GL 512 E:

CourseCode: GL 511 E; Major Elective; 2 Credits; 30 hrs; 50 Marks
CourseTitle: Micropalaeontology
Type: Core and Skill based

Course Learning Outcomes (CLO):

CLO1	Know about the origin and evolution of microfossils through geologic time.
CLO2	Understand the Techniques used in Micro Palaeontology. Collection of microfossils, nannofossils and ichnofossils their reformation & illustration with binomial nomenclature.
CLO 3	Use of Micropaleontology for various applications

	Content	CLO
Unit 1/15	Micropaleontology: Definition and scope, Surface and subsurface sampling methods, Laboratory techniques and equipment for micropaleontological studies. Geological Time Scale. Techniques of separation of microfossils from matrix and preparation of slides. Foraminifera: morphology, biostratigraphic significance, application and paleobathymetry reconstructions. Calcareous algae: Classification, morphology and biostratigraphic significance; applications and paleobathymetry interpretation. Ostracoda: classification, morphology and biostratigraphic significance, applications and paleoclimatic studies.	CLO 1 CLO 2
Unit 2/15	Organic walled Microfossils: Pollens and Spores: Morphology, Classification and Applications; Palynomorphs Introduction to Acritarch, Dinoflagellates and Phytoliths; morphology and significance (In brief) Siliceous Microfossils: Diatoms: morphology and classification, and Application. Introduction to Silicoflagellates and Radiolaria, their morphology and significance (In brief) Phosphatic Microfossils: Conodonts: morphology; stratigraphic significance (In brief). Industrial and Environmental Applications	CLO2 CLO3

Reference Books:

Haq and Boersma, Introduction to Marine Micropaleontology, 1978, Elsevier.

Jones RW, Micropaleontology in Petroleum exploration, 1996, Clarendon Press Oxford

Kathal, P.K., Applied Geological Micropaleontology, 2011, Scientific Publishers, Jodhpur.

Kennett and Srinivasan, Neogene Planktonic Foraminifera: A phylogenetic Atlas, by, Hutchinson Ross, USA. 1983.
Kundal, P. and Humane, S.K. (Eds.) Applied Micropaleontology, 2010, Gondwana Geological Society,V. 24 (1).
Prothero, D.R., Bringing Fossil to Life – An Introduction to Paleontology (2nd Ed.), 2004, McGraw Hill. Seaward, A.C., Plant fossils, Today's and Tomorrow, 1991, New Delhi.
Wray, J.L., Calcareous Algae, 1977, Elsevier

GL 513E: Natural Resource Management

Course Code: GL 513 E
Course Title: Natural Resource Management
Type: Core and Skill based: 30 hrs

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to:

CLO1	Learn about the Natural Resources, their divisions, conditions to classify different resources.
CLO2	Have a detailed idea on development and management of Natural Resources. Government Policies and regulations.
CLO 3	Adopt a Case study for a particular Natural Resource.
CLO 4	Compare and distinguish the various Natural resources by means for different analysis.
CLO5	Make a review on the specific topics, present on a specific topic for evaluation.
CLO6	Generate (interpretation, writing, compilation and presentation) of a detailed report based on the above knowledge.

Unit/Hour	Course Contents	Mapping with CLO
I/15	Description of the Resources. Classification of the Natural Resources. Exhaustible resources – Minerals and Mining. Energy Resources- Oil, Coal, Natural Gas, atomic minerals. Soil as resource – types of soils. Rivers resources. Coastal resources, Coastal Processes. Renewable resources. Water resources. Land resources. Function and values of the resource. Human use and impact on the resource. Supply and demand of the resources	CLO1 CLO2 CLO4
II/15	Management tools and techniques – Natural Resources Policy Watershed Management. Methods of soil Conservation. Flood Control Measures. Coastal Zone Management. Application of Remote Sensing Techniques in resource management. Environmental Impact Analysis. Mineral Resources: Conservation and Management. Policies and legislation concerning natural resources	CLO3 CLO5 CLO6

Suggested Readings:

1. Holechek, J. L., R. A. Cole, J. T. Fisher, and R. Valdez. 2003. *Natural Resources Ecology, Economics and Policy* (2nd Edition). Prentice Hall Education.
2. Shenk, T. M., and A. M. Franklin. 2001. *Modeling in Natural Resource Management Development,mmInterpretation, and Application*. Island Press.
3. Wondolleck, J. M. and S. L. Yaffee. 2000. *Making Collaboration Work Lessons from Innovation in Natural Resource management*. Island Press
4. Paine, D. P. 1981. Aerial Photography and Image Interpretation for Resource Management. John Wiley and Sons. New York, New York. 571 p.
5. Pandey, B.W. 2005. Natural Resource Management. Mittal Publications

List of Journals:

1. Journal of Natural Resources and Environmental Management (2086-4639 (PRINT) / 2460-5824 (ONLINE))
2. Society & Natural Resources: An International Journal

Course GL 514E:

Climate Change and Sustainable development

Course Code: GL 514E, 2 Credits, 30 hrs, 50 Marks
Course Title: Climate Change and Sustainable development
Type: Core and Skill based

Course Learning Outcomes (CLO): This course is to understand the sustainable development in the context of climate change in order to reconcile the goals of economic development, environmental quality and social equity. The Climate change is one of the most important driver of Sustainable Development Goals (SDGs) and the achievement of SDGs are dependent upon the climate change conditions. The course investigates how climate change and sustainable development are linked in terms of geological factors to give better inputs to policy making, preventing disasters and promoting the sustainable developments. The main purpose is to examine the ways in which state, private sector and civil society interact on national and international levels to address climate change and sustainable development issues within sustainability frameworks. Upon successful completion of this course, the student will be able to:

CLO1	Identify the fundamental signatures of climate change that can be addressed to the governance systems.
CLO2	Critically analyze the natural processes as response to climate change and society, and to report the same to policy makers, authorities and disaster organizations.
CLO 3	Address the climate vulnerabilities documented in past records. Develop written and verbal communication skills to address the criticalities to authorities. Devise the solutions and Work effectively in a team and in tutorial/workshop situations.
CLO 4	Apply analytical, critical thinking and problem-solving skills to specific problems of sustainable development promoting the SDGs

Unit/Hour	Course Contents	Mapping with CLO
I/10	Past records of climate; Climate Change perception, Challenges, Protocols and Policy Development. Geological and geomorphological signatures of the Climate Change effects; Causes and Consequences, perspectives on the climate change disasters.	CLO1 CLO2
II/10	Climate Change and Sustainable Development: Policies and Programmes, IPCC Reports. UN Sustainable Development Goals. Climate Change and Sustainable Development: examples and case studies of developments.	CLO1 CLO2 CLO3
III/10	Sustainable Development: Scope and Emerging Trends. Climate Change and Sustainable Development: National and State Policies, Achieving Sustainable Development Goals: Role of Various Stakeholders. The SDGs and the Paris Climate Agreement. Water Deficit, inundation and its impact on the irrigation system. Sustainable living practices. Case studies from Indian region.	CLO2 CLO4

Suggested Readings

Joachim Monkelbaan. Governance for the Sustainable Development Goals, Book. Springer International Publishing, Nature Singapore Pte Ltd, 2019.

Suraj Mal, R.B. Singh, Christian Huggel, Editors. Climate Change, Extreme Events. and Disaster Risk Reduction, Towards Sustainable Development Goals. Book Springer International Publishing AG 2018.

Course: GL 515E: GPS Geodesy

Course Code: GL 515E
Course Title: GPS Geodesy
Type: Core and Skill based, Hours: 30

CLO 1	Remember and recall the basic concepts of geoid, reference ellipsoid and ground surface of the earth. Enlist the type of map projections and segments of global positioning system
CLO 2	Understand the fundamental principles and concepts of geodesy, and in-depth knowledge of coordinate systems, reference frames, and earth geodetic models.
CLO 3	Demonstrate the transformation between different coordinate systems, use of GPS data collection, DGPS surveys and implementation in various geoscience projects.
CLO 4	Analyse error sources in GPS measurements, such as atmospheric delays, satellite orbits and multipath, and identify techniques for error mitigation.
CLO 5	Compare and evaluate positioning techniques such as Differential GPS (DGPS), real-time kinematic (RTK) and Precise Point Positioning (PPP). Assess recent advancements in GPS technology.
CLO 6	Apply GPS geodesy in various geoscientific fields such as geodynamics, engineering geology, monitoring melting of glaciers and movement of tectonic plates. Design and conduct GPS-based surveys.

Unit/Hour	Course Contents	Mapping with CLO
I/10	Introduction- History of Surveying methods; GPS positioning: principles and methods; Segment of GPS: Space, control and User; Procedure of GPS Surveying. Basic operation and Global Navigation Satellite Systems (GNSS); GPS data collection and processing techniques; Differential GPS (DGPS) and real-time kinematic (RTK) positioning.	1, 2
II/05	Error sources in GPS measurements: atmospheric delays, satellite orbits, receiver noise, multipath, etc; Techniques for error mitigation and accuracy improvement. Precise Point Positioning (PPP) and network-based GNSS positioning.	2, 3
III/10	Concept of Geoid; the shape of the earth; Geodetic Datum and Coordinate Systems: Cartesian Coordinate System; Projected Coordinate System and Geodetic Reference Systems: datums and coordinate frames; Introduction to Earth models: ellipsoids, geoids, and gravity models. Transformation between different coordinate systems; GPS for geoid determination and height measurement.	2, 3, 4
IV/05	Recent advancements in GPS technology and applications; GPS Applications in Geodesy; GPS for deformation monitoring and geodynamic studies. GPS data analysis using open source software. Application of GPS in geosciences.	4, 5, 6

Reference Books:

- Ramsay, J Alfred Leick, Lev Rapoport, and Dmitry Tatarnikov 2015. GPS Satellite Surveying Publisher: JOHN WILEY (ORIGINAL); 4th edition (7 April 2015); 01149344934. ISBN-10: 978111867557

- Gopi Satheesh, R.Sathikumar And N. Madhu, 2017. Advanced Surveying: Total Station GPS GIS and Remote Sensing, Publisher: Pearson Education; Second edition (25 September 2017)
- Jan Van Sickle 2015. GPS for Land Surveyors. Publisher: CRC Press; 4th edition (14 July 2015) SBN-10: 9781466583108
- James R. Smith 1997. Introduction to Geodesy: The History and Concepts of Modern Geodesy, Wiley Series in Surveying and Boundary Control ISBN: 978-0-471-16660-3
- Guochang Xu 2007. GPS Theory, Algorithms and Applications. Springer-Verlag Berlin DOI https://doi.org/10.1007/978-3-540-72715-6
- Pratap Misra and Per 2010. Enge Global Positioning System: Signals, Measurements, and Performance, Publisher : Ganga-Jamuna Press, ISBN-10 : 0970954425
- Jayanta Kumar Ghosh 2015. A Text Book on GPS Surveying, ISBN-13:978-1522952749, Amazon US: www.amazon.com/dp/1522952748

- **List of Journals**:
  Journal of Geodesy https://www.springer.com/journal/190
  Journal of Geodetic Science https://www.degruyter.com/journal/key/jogs/html?lang=en
  Journal of Applied Geodesy: https://www.degruyter.com/journal/key/jag/html?lang=en

Course Code: **GL 516E**
Course Name: Nuclear Geology and Rare Earth-Rare Metal deposits
Course Title: Type: Subject Elective; 30 Hrs

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to:

CLO1	Introduction to Nuclear Geology
CLO2	Study Uranium and Thorium deposits in India and abroad
CLO 3	Understand what RMRE deposits are and their genesis
CLO 4	Study RMRE deposits in India and abroad
CLO5	Study the nature, mineralogy and genesis of placer deposits
CLO 6	Appraisal of Exploration, Evaluation and Exploitation for Uranium, Rare metal pegmatites and placer deposits
CLO 7	Understand Mineral Technology and beneficiation techniques
CLO 8	Identify and classify of different RMRE/ Uraniferous minerals / rocks in hand specimen.
CLO 9	Undertake mineral separation and identification of beach placer minerals in mounts.
CLO 10	Understand the process of exploration and estimation of ore reserve
CLO 11	Study various flow charts related to mineral technology and beneficiation techniques.

Unit/ Hour	**Course Contents**	**Mapping with CLO**
I/03	**Introduction to Nuclear Geology** Atomic Energy in India, Radioactive minerals-Introduction, Geochemistry of Uranium and Thorium, classification of uranium deposits, metallogenic epochs and provinces of uranium, mineralization; Uranium deposits in India and abroad; Uranium exploration and beneficiation **Learning Activities:** Learning Concepts through presentations, black board teaching. Student Seminars, Assignments.	CLO1 CLO2
II/05	**Rare Metal and Rare Earth Deposits** Mineralogy and geochemistry of RMRE minerals, RMRE deposits - the origin, genesis of carbonatite, the pegmatite systems and alkali granite types; their exploration and evaluation; and exploitation for Nb, Ta, REE, Li, Be and Y; RMRE deposits in India and abroad e.g. Kamthai REE deposit. **Learning Activities:** Learning Concepts through presentations, black board teaching. Student Seminars, Assignments.	CLO3 CLO4
III/04	**Placer Deposits** Origin, genesis of monazite, zircon, rutile, ilmenite, leucoxene and other deposits in the beach placers along the East and West Coast of India including Teri sands, their exploration, evaluation and exploitation for REE, Zr and Ti along with co- products. **Learning Activities:** Lectures, assignment, student Seminar, group discussions	CLO5
IV/02	**Mining and Exploration**	CLO6

	Exploration, Evaluation and Exploitation for Uranium, Rare metal pegmatite (Columbite-Tantalite), Xenotime, Monazite, rutile placer deposits; Mineral Technology and beneficiation techniques for RMRE **Learning Activities:** Student seminar, group discussion, Case study paper reading.	CLO7
V/15	Study of typical hand specimens of RMRE/ Uraniferous minerals	**CLO1**
	Mineral separation technique (Heavy liquid and isodynamic separation) and sample preparation for RMRE analyses. Identification of beach placer minerals in mounts.	**CLO2**
	Study of radioactive cores and estimation of ore reserve Use of Geiger-Muller counter for identifying radioactivity in hand samples/core samples; Study of flow charts for Uranium beneficiation	**CLO3**
	Study of flow charts for recovery of (a) columbite-tantalite from pegmatite soils using MS/FS jig. (b) xenotime from river sand	**CLO4**

Suggested Readings:

- Aswathanarayana, U. Principles of Nuclear Geology, Oxford Press, 1985.
- Gandhi, S.M. and Sarkar, B.C. Essentials of Mineral Exploration and Evaluation. 1st Edition, Elsevier Science Direct, 2016
- Rajamanickam, G.V., Handbook of Placer Mineral Deposits. New Academic Publishers, Delhi, 2001
- Rene, M., Nature, sources, resources and production of Thorium, 2017 IntechOpen. Doi:10.5772/intechopen/68304
- Verplanck, P.L. and Hitzman, M.W, Rare Earth and critical elements in Ore deposits. Reviews in Economic Geology, Society of Economic Geologists, v.18, 2016
- World Distribution of Uranium Deposits. 2nd Edition, International Atomic Energy Agency. 2018

Optional

- Studentship Programme (field oriented project work) of Atomic Mineral Directorate, Government of India
- Internship/Training Programme/Mini-project of Atomic Mineral Directorate, Government of India

Semester II

Course Title: Igneous Petrology GL 201

Course Code: GL 551 C**T**
Course Title: Igneous Petrology
Type: Core and Skill based; total Hours: 30

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to:

CLO1	Explain the origin, evolution, and classification of igneous rocks in relation to their physical and chemical properties.
CLO2	Evaluate the textural and structural features of igneous rocks to infer their formation and cooling histories.
CLO 3	Use geochemical, petrographic, and mineralogical data to classify igneous rocks and identify their tectonic settings.
CLO 4	Demonstrate proficiency in using geochemical and isotopic data from analytical methods to solve petrological problems.
CLO 5	Present and report geological interpretations and research findings effectively,, using appropriate scientific language and visualization tools.

Unit/Hour	**Course Contents**	**Mapping with CLO**
I/08	Magma definition, Processes of magma generation in the mantle and crust, Physical properties of magma - geothermal gradient, heat source, Textures and structures of Igneous rocks. Classification of Igneous rocks - historic perspective and the IUGS systematic Magmatism and Plate tectonics: Magmatism at divergent and convergent plate boundaries and intraplate magmatism	CLO1 CLO2 CLO3 CLO4 CLO5
II/07	Geochemical tracers of mantle processes: Introduction, Continental and oceanic mantle lithosphere, MORB and depleted mantle, Evolution of depleted mantle, OIB and Enriched mantle, Evolution of the Enriched mantle - Metasomatic processes, Mantle reservoirs, Trace element characterization of mantle domains. Integration of petrology with geophysical and geodynamic studies.	CLO1 CLO2 CLO3 CLO4 CLO5
III/08	Magma Crystallisation and Evolution: Phase relations of silicates and silicate melts, Binary and Ternary systems, Partial melting, Magmatic differentiation - Crystal fractionation, gravitational settling, flow differentation, flow crystallisation, filter pressing, liquid immiscibility, Zone melting,	CLO1 CLO2 CLO3 CLO4

	Contamination, Mixing of magmas, Role of Volatile components, Pyroclastic rocks	CLO5
IV/07	Petrogenetic Provinces: Large Igneous Provinces: Volcanic - Flood basalts - Tholeiites (Deccan Trap, Columbia River basalts, Parna basalts), Layered gabbroic instrusions : The Bushweld Complex, Skaergaard intrusion, Stillwater complex, Plutonic: Carbonatites and alkaline rock complexes of India, Oceanic areas: Hawaiian, Kerguelen and Reunion Islands, Oceanic Rift valleys: MORB-Tholeiites-Ophiolites, Granites, andesites, kimberlites, anorthosites	CLO1 CLO2 CLO3 CLO4 CLO5

Recommended Textbooks:

"Igneous Petrogenesis" by Marjorie Wilson.

"Principles of Igneous and Metamorphic Petrology" by John D. Winter.

"The Interpretation of Igneous Rocks" by Cox, Bell, and Pankhurst.

"Using Geochemical Data: Evaluation, Presentation, Interpretation" by Hugh Rollinson.

Course Code: GL 556 C**P**	
Course Title: Igneous Petrology (Practical)	**Total Hours: 15**

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to:

CLO 1	Identify and classify different igneous rocks in hand specimen as well as under microscope.
CLO 2	Categorize the igneous rocks according to tectonic processes
CLO 3	Plot geochemical data, prepare and interpret petrogenetic diagrams
CLO 4	Perform laboratory analyses to interpret their origin and evolution.

Unit/ Hour	**Contents**	**Mapping with CLO**
I/15	Hand specimen identification and classification.	**CLO1**
	Microscopic examination of igneous rocks in thin sections.	**CLO1**
	Geochemical data interpretation and plotting	**CLO3**
	Phase diagram exercises and their applications.	**CLO3,4**

Course Title: Metamorphic Petrology
Course Code: GL 552 C**T**
Course Title: Metamorphic Petrology (Theory)
Type: Core and Skill based; total Hours: 30

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to:

CLO1	Learn the concepts of metamorphism and theory related to it. Identify metamorphic Facies
CLO2	Understand the effects of Metamorphism.
CLO 3	Illustrate different types of metamorphism & their products:
CLO 4	Analyze metamorphism in space and time:
CLO 5	Prioritise metamorphism related to Plate Tectonics. Example: Paired Metamorphic Belts.
CLO 6	Generate (interpretation, writing, compilation and presentation) of a detailed report based on the above knowledge.

Unit/Hour	**Course Contents**	**Mapping with CLO**
I/08	**Types of metamorphism and their controlling factors; Common minerals of metamorphic rocks; Prograde and retrograde metamorphism, Metasomatism; Metamorphic facies in Regional, Contact, and Burial metamorphism**	**1 3 6**
II/07	**Phase diagrams (H_2O, SiO_2, aluminosilicates, etc.); Graphic representation of mineral assemblages (ACF, AFM, AKF, etc.);**	**1 2**

	Metamorphic reactions and textures, Deformation textures; Elemental exchange and P-T conditions; Impact/Shock Metamorphism	**6**
III/08	**Regional and thermal metamorphism of pelitic rocks; Regional and thermal metamorphism of basic and ultra basic igneous rocks; Regional and thermal metamorphism of impure, silicious carbonate rocks; Metamorphism of Granitoides, Charnockites and Migmatites**	**2** **6**
IV/07	**Cataclastic metamorphism; Plate tectonics and metamorphic processes** **Paired metamorphic belts; Archaean and Proterozoic metamorphic terrains; Polymetamorphism.**	**4** **5** **6**

Suggested Readings:

1. Phillpotts : Principles of Igneous and Metamorphic Petrology
2. Harker: Metamorphism
3. Turner: Metamorphic Petrology
4. Wrinkler: Petrogenesis of Metamorphic Rocks
5. Miyashiro: Metamorphism and Metamorphic Belts
6. Yardley: An Introduction to Metamorphic Petrology
7. Spry: Metamorphic Textures
8. Best: Igneous and Metamorphic Petrology
9. Turner & Weiss: Analysis of Metamorphic Tectonites

List of Journals:

3.Journal of Metamorphic Petrology

Course Code: GL 556C**P**	
Course Title: Metamorphic Petrology (Practical)	**Total Hours: 15**

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to:

CLO 1	Identify and classify different metamorphic rocks in hand specimen.
CLO 2	Study and describe various properties of metamorphic rocks from thin sections using petrological microscope.
CLO 3	Plot geochemical analytical data into metamorphic triangular diagrams and interprete
CLO 4	Categorize the facies and grades of metamorphism from the given specimens
CLO 5	Asses themselves after acquiring practical knowledge and further take actions from the external criticism
CLO 6	Compose (interpretation, writing, compilation and interpretation) of a detailed report based on the above knowledge.

Unit/ Hour	**Contents**	**Mapping with CLO**
I/30	Study of texture, mineralogy, mineral assemblages of metamorphic rocks in hand specimens and comment their facies, grades of metamorphism. 25+samples (Regional, Burial and contact metamorphism)	**CLO1**
	Study of structure and microtextures mineralogy of metamorphic rocks in hand specimens. 15+samples (specimens with brittle/ductile deformation)	**CLO1, CLO2**
	Identification of Metamorphic rocks in thin sections and comment their facies, grades of metamorphism. 05+samples	**CLO3 CLO5**
	Plotting of geochemistry data into ACF, AKF and AFM triangular plots and interpretation.	**CLO4 CLO6**

Suggested Readings:

Phillpotts : Principles of Igneous and Metamorphic Petrology

Harker: Metamorphism

Turner: Metamorphic Petrology

Wrinkler: Petrogenesis of Metamorphic Rocks

Miyashiro: Metamorphism and Metamorphic Belts

Yardley: An Introduction to Metamorphic Petrology

Spry: Metamorphic Textures

Best: Igneous and Metamorphic Petrology

Turner & Weiss: Analysis of Metamorphic Tectonites

Structural analysis of Metamorphic Tectonites by Turner, F.J. & Weiss, L.E. 1963, McGraw Hill.

Course Title: GL 553 CT: Structural Geology

Course Code: GL 553 C**T**
Course Title: Structural Geology
Type: Core and Skill based; Hours: 30

Course Learning Outcomes (CLO):

CLO1	Identify the physical and geometric elegance of geologic structures within the Earth's crust by means of deformation regimes towards first order interpretation of the given geological structures.
CLO2	Grasp and explain the given a geological map, reconstruction of the regional tectonic set up and plan for the field based studies. To collect the field structural data and the correct sampling for microstructural and petrofabrics analysis.
CLO 3	Analyze and plot the data for assessment of the relative timing of formation of structures, identification of the kinematics of deformation and the progressive deformation histories at various tectonic regimes.
CLO 4	Develop the application of the knowledge of structural geology in mapping, exploration and mining and economic geology.
CLO5	Identify the status of landforms and the processes in local regional and global contexts and under different tectonic regimes. Identify paleo and/or active tectonic features, apply the knowledge for disaster mitigation studies (if any).
CLO 6	Generate (interpretation, writing, compilation and presentation) of a detailed report based on the above knowledge.

Unit/Hour	**Course Contents**	**Mapping with CLO**
I/7	Introduction to structural elements and their analysis. Stress and stress analysis in two and three dimension. Plane stress analysis. Concepts Mohr stress circle, and its relationship with fault kinematics and deformation mechanics. Different failure criterion and Mohr-Coulomb Envelope. Mechanical properties of rocks and their controlling factors. Theory of rock failure: brittle failure, shear and tensile failures. Strain analysis– finite and infinitesimal, homogeneous and inhomogeneous strains. Strain and deformation paths.	1 3 6
II/7	Classification of folds, fold development and distribution of strains in folds. Buckling of single layer, multilayer and anisotropic materials. Analysis and interpretation of superimposed folding. Fractures and Joints. Types and significance of Joints. Mechanics and geometric aspects of thrust, normal and strike-slip faults, and associated structural features. Planar and linear fabrics (Foliation and Lineation) in deformed rocks: description, classification, genesis and significance. Brittle and ductile shear zones, Geometry and products of shear zones, Shear sense indicators, Mylonites and Cataclasites.	1 2 5 6
III/7	Stereographic and equal area projections for representing different types of fabrics, π and β diagrams. Thin-skinned and thick-skinned deformations; Decollement. Geometrical analysis of simple and complex structures on macroscopic scale.	2 4 6

Suggested Readings:

George H. Davis and Stephen J. Reynolds. 1996. *Structural Geology of Rocks and Regions.* Jon Wiley & Sons. Second Edition.

Marl and P. Billings, 2016. *Structural Geology*, Phi Learning, 3rd edition.

Robert J. Twiss and Eldridge M. Moores, 2006.*Structural Geology*, W. H. Freeman publisher.

Haakon Fossen, 2016. *Structural Geology*, Cambridge University Press.

Donal M. Ragan, 2009. *Structural Geology: An Introduction to Geometrical Techniques*, Cambridge University Press.

Ramsay, J. G. and Huber, M. I., 1983. *Techniques of Modern Structural Geology. Vol. I. Strain Analysis*, Academic Press.

Ramsay, J.G. and Huber, M.I., 1987.*Techniques of Modern Structural Geology. Vol. II. Folds and Fractures*, Academic Press.

Ramsay, J.G., 1967. *Folding and fracturing of rocks*, McGraw Hill.

Stephen Marshak and Gautam Mitra, 1988. *Basic Methods of Structural Geology*, Prentice Hall.

Hobbs, B.E., Means, W.D. and Williams, P.F., 1976. *An outline of Structural Geology*, John Wiley and Sons. New York.

Ghosh, S. K., 2014. *Structural Geology: Fundamental and Modern Developments*, Kidlington: Elsevier Science.

Condie, K. C., 1997. *Plate Tectonics and Crustal Evolution*, Butterworth- Heinemann.

Alan E. Mussett, M. Aftab Khan, 2000. *Looking Into the Earth: An Introduction to Geological Geophysics*, Cambridge University Press.

List of Journals:

4.Journal of Structural Geology, Elsevier

5.Journal of Geodynamics, Elsevier

Course Title: GL 554 CT: Geodynamics

Course Code: GL 554 C**T**
Course Title: Geodynamics
Type: Core and Skill based; Hours: 30

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to:

CLO1	Identify the status of landforms and the processes in local regional and global contexts and under different tectonic regimes. Identify paleo and/or active tectonic features, apply the knowledge for disaster mitigation studies (if any).
CLO 2	Adopt a Case study for structural and geotectonic investigation.
CLO 3	Generate (interpretation, writing, compilation and presentation) of a detailed report based on the above knowledge.

Unit/Hour	Course Contents	Mapping with CLO
I/4	Classical concepts in tectonics and their limitations including Continental drift, Isostasy, Orogeny and Epeirogeny, the Geosynclinal theory, the Wilson Cycle	CLO 1
II/4	Competing, Modern and advanced theories of Plate tectonics, Plume tectonics, Inversion, exhumation, Neotectonics, Seismotectonics and paleoseismicity.	CLO 1,2,3
III/5	Major tectonic features of the oceanic and continental crust. Gravity and magnetic anomalies at mid-oceanic ridges, deep sea trenches, continental shield areas and mountain chains. Seismic belts of the earth. Seismicity and plate movements.	CLO 1,2,3
IV/5	Supercontinent Reconstructions, Geodynamics and Geotectonics of the Indian plate, the Himalaya and the Indo-Bermese Range. Modern Tools and Case studies of Global tectonics and the Indian plate. **Learning Activities:** Student seminar, group discussion on global geodynamics and orogeny, Case study paper reading.	CLO 1,2,3

Suggested Readings:

Anderson, D. L. 2007. New theory of the Earth. Cambridge University Press, Cambridge. 384 p.

Condie, K. C. 1997. Plate tectonics and crustal evolution. Butterworth-Heinemann, Oxford. 282 p.

Cox, A. & Hart, R. B. 1986. Plate tectonics. How it works. Blackwell Scientific Publications,
Oxford. 392 p.

Dewey, J. F. 1977. Suture zone complexities: A review. Tectonophysics 40, 53-67.

Dewey, J. F., Pitman III, W. C., Ryan, W. B. F. & Bonin, J. 1973. Plate tectonics and the evolution of the Alpine system. Geological Society of America Bulletin 84, 3137-3180.

Kearey, P. & Vine, F. J. 1990. Global tectonics. Blackwell Scientific Publications, Oxford. 302 p.

Alan E. Mussett, M. Aftab Khan, 2000. *Looking Into the Earth: An Introduction to Geological Geophysics*, Cambridge University Press.

Course Code: GL 556C**P**

Course Title: Structural Geology and Geodynamics (Practical)
Total Hours: 15

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to:

CLO 1	Solve the stratum contours, V-rule, geometric and borehole problems related to the Structural geology.
CLO 2	Solve various stereonet problems and construct stereographic projections of the field data.
CLO 3	Interpret various maps and identify the geological structures of deformed continental regimes with microstructural analysis.
CLO 4	Fault plane solution to interpret seismic data
	Adopt a Case study for structural and geotectonic investigation.

Unit/ Hour	**Contents**	**Mapping with CLO**
I/30	Study of stratum contours and their relation with the dip of the beds	**CLO1**
	Relation between true thickness and width of outcrop of a bed using 'V' rule	**CLO1**
	Graphical solution of structural problems using geometrical methods	**CLO1**
	Bore-hole problems (Three pin problems)	**CLO1**
	Structural problems based on orthographic and stereographic projections, concerning economic deposit	**CLO2**
	Preparation and interpretation of Geological maps and sections. Balanced cross section	**CLO3**
	Recording and plotting of the structural data on base map	**CLO3**
	Fault plane solution and its seismic interpretations	**CLO 4**

Suggested Readings:

Stephen Marshak and Gautam Mitra.1988.Basic Methods of Structural Geology, Prentice Hall.

Ghosh, S.K., 1993. *Structural Geology: Fundamental and Modern Developments*, Pergamon Press.

Ramsay, J.G. and Huber, M. I., 1987. *Techniques of Modern Structural Geology. Vol. II. Folds and Fractures,* Academic Press.

Ramsay, J. G. and Huber, M. I., 1983.*Techniques of Modern Structural Geology. Vol. I. Strain Analysis*, Academic Press.

Donal M. Ragan, 2009. *Structural Geology: An Introduction to Geometrical Techniques*, Cambridge University Press.

Structural analysis of Metamorphic Tectonites by Turner, F.J. & Weiss, L.E. 1963, McGraw Hill.

Course Code: GL 555C**T; 2 Credits; 30 Hrs**

Course Title: Geomorphology
Type: Core and Skill based

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to:

CLO1	Understand the Earth processes and features
CLO2	Analyze the geomorphological process and their characteristics
CLO3	Knowledge of geomorphology of India and application of geomorphology in various studies;
CLO4	Understand Basic concepts and significance of Geomorphology, Rock weathering and soils,
CLO5	Understand Mass wasting processes, Influence of climate on processes.
CLO6	Understand the Concept of Erosion cycles.
CLO7	Understand Glacial and Aeolian landforms
CLO8	Understand Geomorphic markers and Neotectonic features

Unit/Hour	**Course Contents**	**Mapping with CLO**
I/7	Introduction: Development, Scope, Geomorphic concepts, Type and Tools; Landforms: Role of lithology, peneplanation, endogenous and exogenous forces responsible, climate and tectonic factors and rejuvenation of landforms; Denudational processes: weathering, erosion, transportation, weathering products and soils - profiles, types, duricrusts; Hillslopes: Their characteristics and development, fluvial processes on hill slopes	CLO1 CLO2 CLO3
II/8	River and Drainage basin: Drainage patterns, network characteristics, Valleys and their development. Process of river erosion, transportation and deposition. Landforms produced by geomorphic agents: Fluvial, Coastal, Glacial and Aeolian landforms; Geomorphic indicators of neotectonic movements: stream channel morphology changes, drainage modifications, fault reactivation, uplift-subsidence pattern in coastal areas. Applied Geomorphology: Application in geohydrology, engineering geology, and environmental studies	CLO4 CLO5 CLO6 CLO7 CLO8

Transactional Modes: Lecture, Demonstration, Lecture cum demonstration, Seminar, Group discussion.

Text / Reference Books

Holmes, A. 1992: Holmes Principles of Physical Geology Edited by P. McL. D. Duff. Chapman and Hall, London.

Halis, J.R. 1983: Applied Geomorphology Sharma, H.S. 1990: Indian Geomorphology. Concept Publishing Co. New Delhi.

Kale & Gupta : Introduction to Geomorphology

A.D. Howward and I Remson : Geology in Environmental Planning.

Bloom.A.L. (1992), Surface of the Earth, Prentice Hall India, New Delhi
Gass, I.G., Smith, P.S & Wilson, R.C.L., 2ndEdt., (1972), Understanding the Earth, The English Language Books Society, London.
Holmes.A, (1972), Principles of Physical Geology The English Language Book Society and Nelson
Jacob.J, Russel, R.D & Wilson, J.T, (1959), Physics and Geology, McGraw Hill, New York.
Leopold,L.S, Wolman, K & Miller, J.P, (1970), Fluvial processes in Geomorphology, Eurasia Publishing House Pvt Ltd., New Delhi.
Richard Huggett (2007) Fundamentals of Geomorphology. II Edition.
Robert, S.A. and Suzanne, P.A., (2010) Geomorphology – The mechanics and chemistry of landscapes. Cambridge University Press.
Routledge N. Y. Ritter,D.F., Kochel, R.C.,Miller, J.R.,(2002) Process Geomorphology, Waveland press,.
Eric Bird (2008) Coastal Geomorphology, Wiley
Bloom, A., (2005), Geomorphology. Pearson. New Delhi
Burbank, D. W. & Anderson, R.S., (2016), Tectonic Geomorphology. Wiley India.
Hamilton, E. I., (1965), Applied Geomorphology. Academic Press.
Sharma, H. S., (1990), Indian Geomorphology. Concept Publishing Co., New Delhi.
Small, R.J., (1978), Study of Landforms: A Textbook of Geomorphology (2nd Edition), Cambridge University Press.
Thornbury, W.D., (2002), Principles of Geomorphology, John Wiley and Sons, 2nd Edition, New York.

List of Journals:
1. Geomorphology

Geomorphology (Practical)

	Course Code : GL 556 CP	**L**	**T**	**P**	**Credits**
	Course Title: Geomorphology			**1**	**1**

Course Outcome (CO) On the successful completion of the course, the student will be able to

	Course Outcome
CLO1	Students are capable to understand geomorphological symbols
CLO2	Students are capable to understand drainage patterns
CLO3	Understand landform history and dynamics and to predict changes through a combination of field observations,
CLO4	Understand drainage basin and their significance
CLO5	To Understand drainage basin analysis
CLO6	Understand Morphometric analysis and its parameters

Unit/ Hour	**Contents**	**Mapping with CLO**
I/15	Identification of Geomorphological symbols.	CLO1
	Identify and describe different types of drainages patterns and their significance	CLO2

	Identification of landforms on toposheets, Drainage basin and network morphometry.	CLO3
	Drainage basin and network morphometry.	CLO4
	Drainage basin Analysis by Strahler's Method-Morphometric Analysis	CLO 5 CLO 6
	Drainage basin Analysis by Horton's Method-Morphometric Analysis Calculation of morphometric parameters of basin. Topographic analysis by various Landforms study and its interpretation. Study of landforms and interpretation of lithology and structure	CLO 5 CLO 6

Major Elective Semester II

Course Code: GL 560E; **2 Credits; 30 Hrs; 50 Marks**

Course Title: Tectonic Geomorphology
Type: Core and Skill based

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to:

CLO1	To Understand the Earth Surface processes and geomorphic features
CLO2	To Analyze the Geomorphic indices
CLO3	Knowledge of Holocene Deformation and Landscape Responses

Unit/Hour	**Course Contents**	**Mapping with CLO**
I/7	Active Tectonics and Models of Landscape Development Geomorphic Markers-Planar Geomorphic Markers; River terraces; Alluvial fans; Beheaded rivers; Erosional surfaces; Landslides; Glacial moraines; Beach ridges; Lake Shoreline & delta.	CLO1 CLO1
II/8	Geomorphic indices-Stream length-Gradient Index; Mountain front sinuosity; Alluvial fan tilting; Ratio of valley floor width to valley height; V-ratio Marine Terraces, Beaches, and Shorelines; Lacustrine Shorelines; River Terraces; Alluvial Fans; Linear Geomorphic Markers-Rivers and Ridge Crests	CLO2
III/8	Holocene Deformation and Landscape Responses- Base Level; Knick points. Deformation and Geomorphology at Intermediate Time Scales-	CLO3
IV/7	Calibrating Rates of Deformation Marine Terraces; Fluvial Terraces; Stream Gradients; Stream-Gradient Indices; Stream Responses to Regional Tilting	CLO3

Transactional Modes: Lecture, Demonstration, Lecture cum demonstration, Seminar, Group discussion.

Text / Reference Books

Burbank and Robert S. Anderson:Tectonic Geomorphology, Blackwell Science

Course Code: GL561E **; 2 Credits; 30 Hrs; 50 Marks**

Course Title: Disaster Management
Type: Core and Skill based

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to:

CLO1	To understand the fundamental concepts related to genesis of atmospheric
CLO2	To understand the Hazard zonation maps of different parts of the area.
CLO3	Knowledge of Remedial measures for Disaster management

Unit/Hour	Course Contents	Mapping with CLO
I/7	**Fundamentals, Types and Remedies** Concepts related to physical system and human interference; Types and genesis of atmospheric, hydrospheric, biospheric and lithospheric disasters. Remedial measures for preventing and minimizing disasters	CLO1
II/2	Hazard zonation maps: preparation and utilization	CLO2
III/6	Preparedness and Awareness Mitigation strategy: Relief measures, community health, casualty management Role of Government, Non-Governmental and media agencies, Reconstruction and Rehabilitation Awareness through print and electronic media, involving youth in field observations. **Learning activities:** Learning with the help of PPT in which efforts will be made to demonstrate identification, characterization of lithology, geological structures supported with examples of actual field characteristics. Students Seminars and assignments.	CLO3

Transactional Modes: Lecture, Demonstration, Lecture cum demonstration, Seminar, Group discussion.

Text / Reference Books

1. Geology, environment, Society K.S.Valdiya (2004) Universities Press (India) Private Limited, Hyderabad,India
2. Coping with natural hazards: Indian context K.S.Valdiya (2004) Orient Longman Private Limited, Hyderabad,India.
3. Engineering and general geology Parbin Singh (2003) S.K.Kataria and sons Delhi India
4. Genaral Geology V.Radhakrishnan (1996) V.V.P.Publishers, Tuticorin,India.
5. Lundgren (1986). Environment Geology, Rentice Hall Publishers, New Jersey.
6. Ruddiman: “Earth’s Climate, Past and Future”

GL562E: Quaternary Geology, 2 Credit, 30 Lectures, 50 Marks.

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to:

CLO1 Know the main principles, concepts and approaches pertaining to the study of Quaternary Geology and its stratigraphic framework with emphasis on the paleoclimate.

CLO2 Identify the Quaternary landforms and processes.

CLO3 Understand the interrelation of the Quaternary records, proxies and tools with Climate change.

Unit/ Hour	Contents	Mapping with CLO
I/8	Quaternary as chronostratigraphic unit, Standard sub-divisions of the Quaternary period and their climatic significance, standard global stratotype sections, Plio-Pleistocene boundary, Glacial-Interglacial stages, Marine Oxy Isotope (MIS) stages and sea level oscillations, Archeological sub-divisions of Quaternary. **Learning Activities:** Exercises and brainstorming session and group discussion.	CLO1
II/7	The concept of modern climate, climate dynamics, factors controlling the climate change, its cyclicity and climate deteriorations with special emphasis on Asian Monsoon. Linkage of the modern climate to past climatic variations (with special emphasis on the Late Pleistocene-Holocene period). The concept of local, regional and global climatic changes, the long term and abrupt changes during Quaternary with special emphasis to tropical-Subtropical climate. **Learning Activities:** Student seminar and group discussion.	CLO2
III/8	An overview of the processes and mechanism of the Quaternary sedimentation over Indian sub-continent in relation to it's climatic and/or tectonic controls. Stratigraphic relations of the Quaternary deposits in India with special emphasis on its regional and global correlations. Fluvial, Fluvio-lacustrine, glacial and glaciao-lacustrine-fluvial and Deserts and their response to tectono-climatic changes with special emphasis on Ganga basin, Thar desert and Himalayan Quaternary sequences. **Learning Activities:** Assignments and take home exercise.	CLO3
IV/7	Mechanism and style of climatic response in the natural systems: a) Marine, b) Ice sheets/glaciers, c) Lacustrine, d) Fluvial and aeolian (including pedogenic), e) Tree rings/speleothem etc. Introduction to Quantitative methods in Quaternary Geology, Landform evolution exploratory methods.	

Transactional Modes: Lecture, Project Method, Inquiry training, Seminar, Group discussion, Blended learning, Flipped learning, Focused group discussion, Team teaching, Brain storming, Mobile teaching, Collaborative learning, Case based study.

Suggested readings:

1. Lowe, J.J., and Walker, M.J.C. (1997) Reconstructing Quaternary environments. 2nd edition, Pearson, Prentice-Hall, 446 pages.
2. Bradley, 1999, Paleoclimatology.

3. Peixoto and Oort, 1992, Physics of Climate.
4. Ruddiman: “Earth’s Climate, Past and Future”
5. Bell, M. & Walker, M.J.C. 1992. Late Quaternary Environmental Change; Physical and human perspective. Longman Scientific and Technical, New York.
6. Bradely, R.S. 1985/1999. Palaeoclimatology; reconstructing climates of the Quaternary. 2nd Edition Harcourt Academic Press: San Diego.
7. Ice Age Earth: Late Quaternary Geology and Climate (Physical Environment) by Alastair G. Dawson
8. Late Quaternary Environmental change: Physical and Human Perspectives by Martin Bell

Journals:

1. Journal of Quaternary Science
2. Boreas
3. The Holocene
4. Quaternary Science Reviews
5. Quaternary Science
6. Palaeogeography, Palaeoclimatology, Palaeoecology
7. Journal of Archaeological Science

GLE 563E: Palaeomagnetism, 2 credit, 30 hrs, 50 Marks

Course Learning Outcome

CLO 1: Appreciate the Geomagnetic field of the Earth
CLO 2: Fundamental knowledge on the earths present and past magnetic field
CLO 3: Knowledge bout applications of Palaeomagnetism and Rock Magnetism
CLO 4: Representation and meaning of the Palaeomagnetic and rock magnetic data

Course Contents

U/hrs	Content	Mapping
I/6	Introduction to Geomagnetism; Introduction to Magnetic Mineralogy; Origin and types of Natural Remanent Magnetism	CLO 1 CLO 2
II/7	Applications of Palaeomagnetism and Mineral magnetism	CLO 2 CLO3
III/10	Fieldwork and sampling methods of palaeomagnetism; Palaeomagnetic and Rock Magnetic Analyses; data treatment and statistics	CLO1 CLO2 CLO3 CLO4
IV/7	Special topics in Palaeomagnetism, Magnetostratigraphy and Rock Magnetism; Magnetic Fabrics.	CLO1 CLO2 CLO3 CLO4

Transactional Modes: Lecture, Demonstration, Lecture cum demonstration, Project and assignments. Mode, Inquiry training, Seminar, Group discussion, Blended learning, flipped learning, group discussion, Team teaching, Field visit, Brain storming, Mobile teaching, Collaborative learning, E- tutoring, Problem solving.

Suggested Readings:

E. Irving, The paleomagnetic confirmation of continental drift, Eos Trans. AGU, v. 69, 1001–1014, 1988.
R. T. Merrill and M. W. McElhinny, The Earth's Magnetic Field, Academic Press, London, 401 pp., 1983.
N. D. Opdyke, Reversals of the Earth's magnetic field and the acceptance of crustal mobility in North America: A view from the trenches, Eos Trans. AGU, v. 66, 1177–1182, 1985.
D. H. Tarling, Paleomagnetism, Chapman and Hall, London, 397 pp., 1983.

Semester III

Major Core Courses

Course Title: Geology and Stratigraphy of India

GL601CT: Stratigraphy of India; 2 Credits, 30 hrs

Type: Core and Skill based; Hours: 30

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to:

CLO1	Develop an in-depth knowledge of the geological history and stratigraphic sequences of India.
CLO2	Understand the tectonic evolution of the Indian subcontinent and its implications on stratigraphy.
CLO 3	Learn to correlate stratigraphic units across different regions of India.
CLO 4	Explore the significance of stratigraphy in natural resource exploration, including hydrocarbons and minerals.

Unit/Hour	Course Contents	Mapping with CLO
I/8	Introduction to geological framework of India (including Peninsular, Himalayan, Indo-Berman Ranges, Bengal fan and Arabian sea domains). Understanding the stratigraphic juxtapositions of various first order lithounits. Concepts of basin evolution and stratigraphy with Indian examples. Introduction to Proterozoic sedimentary basins: Cuddapah, Kurnool, Vindhyan, Chhatisgarh and Indravati Basins	CLO1 CLO2 CLO3 CLO4
II/7	Precambrian geological terrains India: Stratigraphy, sedimentation, tectonics, magmatic and metamorphic evolution of: i) Dharwar (east and west) craton; ii) Singbhum craton, iii) Bastar Craton; iii) Eastern Ghat Mobile Belt (EGMB).	CLO1 CLO2 CLO3 CLO4
III/8	Cenozoic basins of India, Stratigraphy and basin evolution of Gondwana, Jurassic of Kutch, Cretaceous of South India, Cretaceous of Narmada valley, Bengal basin. Stratigraphic evolution of the Himalayan foreland basin, Indus basin, Lahaul-Spiti basin, Kashmir basin, Zanskar basin, Garhwal-Kumaun basin.	CLO1 CLO2 CLO3 CLO4
IV/7	Introduction to Global Stratotype Sections and points. Stratigraphy of Deccan Traps and Rajmahal Volcanics, Important stratigraphic boundaries of India including their global significance and debates (e.g., K-Pg, P/T, J/K, Eparchean U/C, Pc/C, C/O, N/Q, Meghalayan stage).	CLO1 CLO2 CLO3 CLO4

Transactional Modes: Lecture, Demonstration, Lecture cum demonstration, Project and assignment Mode, Seminar, Group discussion, Field visit, E- tutoring.

Course Code: GL 606CP

Course Title: Stratigraphy of India (Practical) **Total Hours: 15**

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to:

CLO 1	Geological maps reading and interpretation
CLO 2	Decipher the geological evolution of India

CLO 3	Prepare detailed reports on the geology of given region.

Unit/ Hour	Contents	Mapping with CLO
I/15	Map Interpretation: Analysis of geological maps to understand stratigraphic relationships.	**CLO1, 2,3**
	Study of typical hand specimens of rocks from different lithological units of Indian stratigraphy	**CLO1, 2,3**
	Stratigraphic Columns: Construction and interpretation of stratigraphic columns from field data.	**CLO1,2,3**
	Geological Excursions: Visits to key stratigraphic sections in India	**CLO1,2,3**
	Field Mapping: Practical training in measuring stratigraphic sections and identifying lithological units.	**CLO1,2,3**

Transactional Modes: Demonstration, practical with real specimens, Problem solving, Group discussion, Tools used: PPT, Video, Animation,

Recommended Textbooks

"Geology of India" by M.Ramakrishnan and R. Vaidyanadhan.
"Fundamentals of Historical Geology and Stratigraphy of India" by Ravindra Kumar.
"Geology of India and Burma" by M.S. Krishnan.
"Stratigraphy of India" by V. Jayangondaperumal and S. Bhattacharya.

GL 602 CT: Economic Geology

Course Code: GL 602CT
Course Title: Economic Geology
Type: Core and Skill based, Total Hours: 30

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to:

CLO1	Understand the geological processes leading to the formation of economically valuable mineral deposits.
CLO 2	Learn modern methods for the exploration and evaluation of mineral resources.
CLO 3	Develop skills to assess the economic viability of mineral deposits.
CLO 4	Knowledge about the distribution of economic deposits, global and Indian

Unit/Hour	Course Contents	Mapping with CLO
I/15	Scope and application of economic geology; Genetic classification of ore deposits; Concept of the terms ore, gangue, grade, tenor, resources, reserves etc., Mineralisation related to Plate Tectonics, Structural controls on ore localization, Broad tectonic setting and magamatism associated with various types of ore deposits. Introduction to National Mineral Policy and Mineral Economics	CLO1 CLO2 CLO3 CLO4
II/15	Ore forming processes, and mode of occurrence, geological and geographic distribution and genesis of the related mineral deposits. Magmatic Processes: Chromite, magnetite, and platinum group element deposits. Hydrothermal Processes: Vein deposits, porphyry systems, and skarns. Sedimentary Processes: Banded iron formations, placer deposits, supergene enrichment deposits and evaporites. Coal. Metamorphic Processes: Metamorphosed ore deposits and their characteristics. Diamond deposits Indian Case Studies: Detailed study of major Indian mineral deposits such as iron and copper.	CLO1 CLO2 CLO3 CLO4

Recommended Textbooks

"Economic Geology: Principles and Practice" by Walter L. Pohl.
"Introduction to Mineral Exploration" by Charles J. Moon, Michael K.G. Whateley, and Anthony M. Evans.
"Ore Geology and Industrial Minerals: An Introduction" by Anthony M. Evans.
"Mineral Exploration and Mining Essentials" by Robert Stevens.
"Ore Deposit Geology" by John Ridley.
"Ore Geology, Economic Minerals and Mineral Economics" by S. K. Tiwari.

GL 606CP: Economic Geology

Course Code: GL 606CP
Course Title: Economic Geology Practical, 1 Credit
Type: Core and Skill based, Total Hours: 15

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to:

CLO1	Identify various economic minerals (metallic and non-metallic)
CLO 2	Understand the distribution of economic deposits in India
CLO 3	Use geochemical data for economic mineral detection and resource estimation

Unit/Hour	Course Contents	Mapping with CLO
I/15	Ore Mineral Identification: Hand specimen and microscopic examination. Geochemical Data Analysis: Interpretation of assay results and anomaly detection. Resource Estimation Exercises: Calculations using real-world data sets.	CLO1 CLO2 CLO3

Course Title: GL 603CT: Environmental Geology

GL 603: Environmental Geology, Theory, 2 Credit, 30 hrs, 50 marks
Type: Core and Skill based,

Course Learning Outcomes (CLO):

CLO1	Understand the fundamental concepts of environmental geoscience, its scope and necessity
CLO2	Familiarize with the structure, composition and general characteristics of the lithosphere, hydrosphere, atmosphere and biosphere.
CLO 3	Know more in detail about the Concept of ecology, ecosystem, its structure and functions, and types of ecosystem.
CLO 4	Acquainted with different biogeochemical cycles like carbon, nitrogen, phosphorus and sulfur.
CLO5	Study in detail major societal burning issues including Water, Soil, and Air pollution.
CLO 6	Thoroughly exposed to the concept of extreme events and catastrophic geological hazards like landslides, subsidence, floods, droughts, earthquakes, and volcanoes, their causes, classifications, assessment, prediction and prevention their zoning, and management. Different hazards posing danger to coastal areas like cyclones, tsunamis, and shoreline and sea level changes are also studied.
CLO 7	Assess the impact of mining on the environment especially generated waste disposal, acid mine drainage, heavy metal pollution, environmental impacts of coal utilization, fly ash, recycling of resources and management.
CLO8	Generate (interpretation, writing, compilation and presentation) a detailed report based on the above knowledge.

Unit/Hour	Course Contents	Mapping with CLO
I/05	The fundamental concepts of environmental geoscience, its scope and significance **Learning Activities:** Understanding of geoscience with illustration and group discussion.	CLO1
II/05	Complete understanding of structure, composition and general characteristics of lithosphere, hydrosphere, atmosphere and biosphere and their interrelationship will be studied. **Learning Activities:** Best illustrations in books with statistics will be used.	CLO2 CLO8
III/05	Principals and Concepts of ecology, ecosystem, its structure and functions, ecosystem types, and its development and impact will be analyzed. **Learning Activities:** Reading a classical and recent book.	CLO3 CLO8
IV/05	Study of components of biogeochemical cycles like carbon, nitrogen, phosphorus and sulfur. Their formation, factors associated with and significance will be highlighted. **Learning Activities:** Exercises on illustrations of cycles	CLO4 CLO8
IV/10	Characteristics of water, drinking water sources, quality criteria and standards Water pollution and its types, groundwater pollution sources, pathways and mechanism, attenuation processes, case histories of natural (arsenic and fluoride poisoning) and man-made water pollution water logging, causes,	CLO5 CLO8

	effects and remedial measures, declining groundwater tables, subsidence and compaction of aquifers will be studied. Soil studies containing soil formation, classification and properties, soil pollution sources, its causes and effects, soil salinity and alkalinity, characteristics of saline/alkali soils, soil amendments and measures to control soil pollution. Definition, terminology, sources and classification of air pollutants, effects of air pollution on the ecosystem, acid rain, greenhouse effects and ozone layer depletion will be studied and appended with its control and management. **Learning Activities:** Study in detail with the help of Spatiotemporal maps and Illustrations.	
VI/10	Study of extreme events and catastrophic geological hazards including landslides, subsidence, floods, droughts, earthquakes, volcanoes, their causes, classifications, assessment, prediction and prevention along with coastal hazards, cyclones, tsunamis, and shoreline and sea level changes with strategies for hazard mitigation. **Learning Activities:** Hazards zone maps available with current case studies published in journals.	CLO6 CLO8
VII/05	A detailed study on mining and its impact on the environment, wastes from the mining industry, waste disposal methods, acid mine drainage, heavy metal pollution due to mining, environmental impacts of coal utilization, fly ash, recycling of resources and management. **Learning Activities:** Old classic along with recent case studies published in books and research papers.	CLO7 CLO8

Course Code: GL 603 C**P**

Course Title: GL 6CP: Environmental Geology (Practical)

Total Hours: 15

Course Learning Outcomes (CLO):

CLO 1	Chemical analysis of Water and Soil samples
CLO 2	Plotting the data / available geochemical data on variation diagrams
CLO 3	Preparation of a world map showing hazards like volcanoes, and plate boundaries with their velocity and movement
CLO 4	Preparation of map showing hazards like floods, landslide, earthquakes, rainfall patterns etc
CLO 5	Preparation of hazard zonation maps
CLO 6	Flood recurrence interval studies

Unit/ Hour	**Contents**	**Mapping with CLO**
I/15	Collection of water and soil samples and their analysis using standard methods.	**CLO1**
	Plotting the produced data / available geochemical data of water and soil analysis will be plotted on Gibb's plot, Piper Trilinear Diagram and textural diagram respectively and their interpretations.	**CLO2**
	Understanding the seismic hazards on a global scale, especially along plate boundaries, the location of major volcanoes and their impact on the global environment will be studied.	**CLO3**
	Preparation of a hazards map of India including flood, landslide, earthquake, and rainfall patterns and discussion about their causes, effects, and mitigation with management.	**CLO4**
	Preparation of different hazard zonation maps to understand the low-risk to high-risk regions with appropriate measures.	**CLO5**
	Flood frequency/recurrence interval studies are helpful in finding the probability of extreme possible floods in future considering past flood studies.	**CLO6**

Transactional Modes: Demonstration, practical with real specimens, calculation, laboratory analysis, PPT, Video, Animation, etc

Suggested Readings:

1. Keller: Environmental Geology
2. Tank : Environmental Geology
3. A.D.Howward and I. Remson : Geology in Environmental Planning
4. Strahler and Strahler: Environmental Geology
5. Ordway: Earth Science and Environment

6. Turk and Turk: Environmental Geology
7. K.S.Valdiya : Environmental Geology
8. Frampton S. and others. Natural Hazards.
9. Selnius (Ed). Essentials of Medical Geology.

1	**Course Code: GL 604 CT 2 Credits: 30hrs**
2	**Course Title: Geophysical Exploration**
3	**Type: Core and Skill based**

CLO1	Develop a comprehensive understanding and memorize the principles, theories, and concepts underlying various geophysical methods used in exploration.
CLO2	Students will be able to explain the factors controlling geophysical anomalies and interpret the significance of anomalies in various geophysical methods such as gravity, magnetic, seismic, and electromagnetic methods.
CLO3	Students will use the operational principle behind gravity, magnetic and seismic methods, perform corrections to acquired data and interpret geophysical data using appropriate analysis techniques, such as inversion, modelling, and imaging.
CLO4	Plan and compare different research projects that apply principles, design, and execution of geophysical surveys for subsurface investigation. Distinguish between the noise and signal and organize the geophysical data.
CLO5	Evaluate and select appropriate geophysical instruments and techniques for specific exploration objectives. Apply critical thinking to formulate geophysical survey objectives and methodologies.
CLO6	Students will design and communicate geophysical exploration concepts effectively, both in written and oral formats.

Unit /Hour	**Course Contents**	**Mapping with CLO**
I/3	Concept of scientific methods of exploration- Principles of exploration geophysics, geophysical survey design and data acquisition. Concept of Geophysical Anomaly – factors controlling Geophysical Anomalies. Signal processing and noise reduction in geophysical data Role of geophysics in detection and exploration of the resource and environmental studies.	**1, 2**
II/6	Principles behind gravity method; Relative measurement of earth gravity; Types of gravimeter; Field procedure corrections to gravity data; Concept of Bouguer Anomaly; Generalized Interpretation of Gravity data- Salient case studies.	**2, 3**

III/6	Principles of magnetic method; Anomalies magnetic field associated with the earth – concepts of total field intensity; Intensity of magnetization and magnetic susceptibility measurement of magnetic field; Types of magnetometers; Magnetic anomalies and their interpretation – salient case studies.	**2, 3, 4**
IV/06	Seismic Method: Principles of seismic method – Types, movement of seismic waves within subsurface – instruments and field procedures. Reflection, refraction, and diffraction seismology. Seismic Reflection Method: Principles of reflection method – zero offset time – NMO - CDP and multiple coverage techniques. Seismic Refraction Method: Principles of refraction method – shallow subsurface models - measurement of seismic velocities and layer thickness. Advanced seismic imaging techniques (e.g., 3D seismic tomography) Processing of seismic data – salient case studies	**1, 4, 6**
V/06	Electric Method – Principles of electrical method – electrical properties of rocks Resistivity Method – factors controlling resistivity of rocks measurement of resistivity – Electrode configurations and field procedures – Interpretation of resistivity data – salient case studies Self-potential method – origin of self-potential instrumentation and field procedure Induced polarization method – electrolytic and electrode polarization – instruments and field procedure – salient case studies.	**4, 5, 6**
VI/03	Electromagnetic Method – Principles – instruments – parallel line and Horizontal loop method-salient case studies. Ground-based and airborne EM surveys, controlled-source electromagnetic (CSEM) methods. GPR. Interpretation and modelling of EM data.	**1, 4, 6**

Reference Books

1. M. B. Dobrin and C. H. Savit 1988. Introduction to Geophysical Prospecting. Publisher : McGraw-Hill Education; 4th edition.
2. Philip Kearey, Michael Brooks and Ian Hill 2002. An Introduction to Geophysical Exploration Publisher: Blackwell Science
3. Parasnis D.S. 1979. Principles of Applied Geophysics. Publisher: Springer Dordrecht
4. W. M. Telford, L. P. Geldart, and R. E. Sheriff 1990. Applied Geophysics Publisher: Cambridge University Press; 2nd edition (26 October 1990)
5. Öz Yılmaz 2001. Seismic Data Analysis: Processing, Inversion, and Interpretation of Seismic Data
6. M. N. Nabighian 1987. Electromagnetic Methods in Applied Geophysics Volume 1 -3, Society of Exploration Geophysicists P.O. Box 702740/Tulsa, Oklahoma 74170-2740
8. V. L. S. Bhimasankaram 1977. Exploration Geophysics: An Outline Publisher: Association

of Exploration Geophysicists
9. P V Sharama -Geophysical Methods in Geology. Publisher: Amsterdam Elsevier scientific pub. 1976
10. Rose, A.W Hawkes -Geochemistry in mineral exploration . H.E & Webb J.S. 1979. Academic press.
11. Dmitrii Petrovich Malyuga. Biochemical Methods of Prospecting, Published in 1964 by Consultants Bureau.
12. Vladimir M. Kreiter · 2004, Geological prospecting and exploration. Publisher: University Press of the Pacific

List of Journals:

https://www.longdom.org/geology-geosciences.html

https://www.tandfonline.com/journals/texg20

https://agupubs.onlinelibrary.wiley.com/journal/21699356

Practical

	Course Code : GL 606CP				
	Course Title: Geophysical Exploration (Practical)				
		Total Hours: 30			

	Course Learning Outcome
CLO1	Recognizing and recalling the patterns of geophysical responses from various geological mediums and defining the relationships between geological structures and subsurface features/ anomalies.
CLO2	Apply related corrections to observed gravity data, plot drift curves, and interpret geophysical profiles to identify subsurface features. Solve the problems based on real time geophysical data to compute the thickness of individual layers and physical property of the layer to understand the subsurface strata. Describe data processing in geophysical methods and techniques.
CLO 3	Analyze rock density models using a subsurface sphere, circle, horizontal cylinder, or vertical cylinder, and interpret their geological significance.
CLO 4	Identify, differentiate and relate lithophile, siderophile, chalcophile, and atmophile elements using the periodic table and categorize them according to their geochemical properties.
CLO 5	Appraise geophysical models based on exploration data and correlate them with geological structures and subsurface features. Integrate data from electric, electromagnetic, and other geophysical methods to develop a comprehensive understanding of subsurface structures.
CLO 6	Interpret resistivity data using free-domain software, plot resistivity data, and correlate strata with their geophysical properties through log-log plots. Develop the RMS velocity mode to generate the subsurface.

Unit /Hour	Course Contents	Mapping with CLO
I/6	Gravity Methods: Study of patterns of geophysical responses from various geological mediums and generate models using the geophysical exploration data.	**1, 2**
II/6	Plotting a Drift curve for a gravimeter application of elevation correction to observed gravity data–plotting and interpretation of gravity profiles–simulation of causative bodies. To generate models using the geophysical exploration data.	**2, 3**
III/3	Study of rock density of a model by a subsurface sphere, circle, horizontal cylinder/ vertical cylinder and its interpretation. To identify lithophile, siderophile, chalcophile and atmophile elements using periodic table.	**1, 2, 4**
IV/10	Study of patterns of geophysical responses from various geological mediums. Identify geological structures, map subsurface features, and generate models using the geophysical exploration data.	**1, 2**
	Analysis of seismic reflection and refraction data for velocities and thickness of subsurface layers and understand the relationship between geophysical properties and subsurface characteristics. Calculate critical distance, cross over distance and NMO	**1, 2**
	Plotting the resistivity data using software available in free domain and interpretation of resistivity data. Exercises to plot the data using log-log paper and prepare the curves to correlate the strata with geophysical properties.	**2, 5**
V/05	Plotting and analysis of Electric and Electromagnetic data, integration of data from different geophysical methods to gain a comprehensive understanding of subsurface structures data.	**5, 6**

Course Code: GL 605C**T; 2 Credits; 30 Hrs**

Course Title: Remote Sensing
Type: Core and Skill based

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to:

CLO 1	To know the fundamental aspects of Remote Sensing, acquisition of Remotely sensed data products, types of remote sensing techniques.
CLO 2	Able to use both pocket and mirror stereoscope. Will be able to utilize different types of aerial photographs for different types of studies.
CLO 3	Acquainted with photorecognition elements, their limitations, and use of aerial photographs for lithological.
CLO 4	Know types Sensors of different satellite programmes and their characteristics, applications of Space borne remote sensing technology.
CLO 5	Familiar with applications of space borne remote sensing techniques in geology, oceanic and other important applications.
CLO 6	Use of aerial photographs for structural identifications and geological mapping

Unit/Hour	**Course Contents**	**Mapping with CLO**
I/8	**Remote Sensing:** Basic concepts in remote sensing, electro-magnetic spectrum. Energy sources, energy interaction in the atmosphere, atmospheric windows, atmospheric effects on remotely sensed data, signatures in remote sensing. Introduction to aerial photographs, aerial camera, types of aerial photographs, classification, principles of stereoscopic viewing, conditions and cause for stereovision. Aerial photography mission. Aerial photo interpretation, photo-recognition elements, methods of photo-interpretation, advantages and limitations of aerial photographs.	CLO 4 CLO 5 CLO 6
II/7	Remote Sensing from space – sensors and sensor platforms. Visual image interpretation of satellite imagery, image enhancement, digital analysis, preparation of thematic maps. Thermal Infrared remote sensing, microwave remote sensing for geological applications. Orbital, sensor characteristics and applications of Remote sensing satellites i.e. LANDSAT: LANDSAT1-5,- 7 and- 8, Indian Remote Sensing Satellite programme IRS satellites - Oceansat, Cartosat, Resourcesat. **Learning activities:** Learning with the help of PPT in which efforts will be made to demonstrate identification, characterization of lithology, geological structures supported with examples of actual field characteristics. Students Seminars and assignments.	CLO 7 CLO 8

Transactional Modes: Lecture, Demonstration, Lecture cum demonstration, Seminar, Group discussion.

Text / Reference Books

Sagan, C. (1973). , Planetary Engineering on Mars, Icarus, 20, 513.
Sharma.H.S. (1990) Indian Geomorphology. Concept Pub. Co., New Delhi.
Thornbury, W.D., (2004) Principles of Geomorphology. II edition. Wiley Eastern Ltd. New Delhi.
Wyllie., P.J, (1971), Dynamic Earth, John Wiley & sons, New York.
Miller V. C. and Miller C. F. 1961. Photogeology, McGraw-Hill. Inc., US.
Ramasamy S. M. 1996. Trends in Geological Remote Sensing Jaipur : Rawat Publication, Jaipur.
Lillysand T., Kiefer R. W. and Chipman J. 2015. Remote Sensing and image interpretation, 7th Edition, John Wiley & Sons.
Pandey Shiv. N. 1987. Principles and Applications of Photogeology, Wiley.
Gupta Ravi P. 2018. Remote Sensing Geology, 3rd ed. Springer.
Drury S.A. 1990. A Guide to Remote Sensing - Interpreting Images of Earth, Oxford Science Publications

List of Journals:

1. Remote Sensing, MDPI, Academic Open Access Publishing.
2. Journal of Indian Society of Remote Sensing, Springer.
3. Journal of Applied Remote Sensing, SPIE.
4. Transactions on Geoscience & Remote Sensing, IEEE.
5. International Journal of Remote Sensing.
6. Geomorphology

Remote sensing in Geology (Practical)

	Course Code : GL 606 CP	**L**	**T**	**P**	**Credits**
	Course Title: Remote sensing in Geology			**1**	**1**

Course Outcome (CO) On the successful completion of the course, the student will be able to

	Course Outcome
CLO1	Students are capable to understand geomorphological symbols and drainage patterns and their significance
CLO2	Students are capable to understand why landscapes look the way they do, to understand landform history and dynamics and to predict changes through a combination of field observations, physical experiments and numerical modelling.
CLO3	Solve the stratum contours, V-rule, geometric and borehole problems related to the Structural geology.
CLO4	Solve various stereonet problems and construct stereographic projections of the field data.
CLO5	Interpret various maps and identify the geological structures of deformed continental regimes with microstructural analysis.
CLO6	Fault plane solution to interpret seismic data

Unit/ Hour	Contents	Mapping with CLO
I/15	Identification of Geomorphological symbols.	CLO1
	Identify and describe different types of drainages patterns and their significance	CLO1
	Identification of landforms on toposheets, aerial photographs and satellite images. Drainage basin and network morphometry.	CLO2
	Calculation of morphometric parameters of basin. Annotation, Determination of photo scale. Study of landforms and interpretation of lithology and structure from standard Aerial stero photographs from book, aerial photographs and satellite images, Determination of height of objects, dip of bed, slope and thickness of beds by Parallax bar. Tracing of lineament rosettes and their interpretation **Learning activities:** Learning with stereo pairs of aerial photographs and satellite images for interpretation of lithology and geological structures.	CLO2 CLO 3 CLO 4 CLO 5 CLO 6

Transactional Modes: Demonstration and practicals with standard Aerial Stereo photographs from books, aerial photographs using stereoscopes. Study of different satellite images to interpret lithology and geological structures. Demonstration of photogrammetric measurements with stereoscope and parallax bar.

Suggested Readings:

Wanless H. R.1969. Introduction to aerial Stereo Photographs, Hubbard Press.

Semester III
Major Electives

Course: Geoinformatics, GL 610E

Course Code: **GL610E: 2 credits, 30 lectures**
Course Title: Geoinformatics
Type: Core and Skill based, Total Hours: 30

CLO1	Define Geoinformatics and explain its scope within geosciences. Identify key applications of Geoinformatics in geosciences such as environmental monitoring, resource management, and disaster risk reduction.
CLO 2	Describe the interdisciplinary nature and importance of Geoinformatics.
CLO 3	Acquire skills in performing spatial analysis using GIS tools and techniques, design spatial queries, spatial interpolation techniques.
CLO 4	Analyze case studies where Geoinformatics has been applied to solve geoscience-related challenges. Acquire knowledge and utilize techniques for creating effective maps, symbolization, thematic mapping, and interactive mapping tools.
CLO 5	Query designing on attribute data. Understand the role of geoinformatics in addressing real-world challenges. Gain exposure to various domains and applications of geoinformatics, such as watershed management, natural resource analysis and disaster management.
CLO6	Develop practical skills in utilizing geospatial technologies such as Geographic Information Systems (GIS), Image Processing, Global Positioning Systems (GPS), and spatial databases to collect, manage, analyze, and present geospatial data.

Unit/Hour	**Course Contents**	**Mapping with CLO**
I/15	Introduction to Geoinformatics, Definition and scope of Geoinformatics. Applications of Geoinformatics in Geoscience. Principles and concepts of Geographical Information System. GIS data acquisition, storage, and management. Map/Image Georeferencing, projection and mosaic. Data models and spatial data structures, GIS analysis techniques and spatial operations. DEMs. Spatial data exploration, analysis and visualization techniques Spatial statistics and interpolation techniques	1, 2, 3
II/15	Geospatial modeling and simulation. Preparation of raster and vector database and maps. Web-based mapping and interactive visualization Query languages and data analysis (e.g., SQL, Spatial SQL). Multi-criteria Decision Making, Analytical Hierarchy Process and Frequency Ratio method.	1, 4, 5

Reference books:

1. Paul A. Longley, Michael F. Goodchild, David J. Maguire, and David W. Rhind. Geographic Information Science and Systems
2. Paul Bolstad. GIS Fundamentals: A First Text on Geographic Information Systems
3. Kang-tsung Chang. Introduction to Geographic Information Systems

4.Michael J. de Smith, Michael F. Goodchild, and Paul A. Longley. Geospatial Analysis: A Comprehensive Guide.
5.Shashi Shekhar and Sanjay Chawla. Spatial Databases: A Tour.
6.Chris Brunsdon and Lex Comber. Geocomputation: A Practical Primer
7.John P. Snyder. Map Projections: A Working Manual.
8.C. Dana Tomlin. GIS and Cartographic Modeling.
9.Xuan Zhu and Robert P. Scheller. GIS for Environmental Applications: A Practical Approach.
10. Ajith H. Perera and Carol L. Kline.Geospatial Technologies in Environmental Management.

List of Journals:

Journal of GIS https://www.springer.com/journal/190
Journal of Geodetic Science https://www.degruyter.com/journal/key/jogs/html?lang=en
Journal of Applied Geoinformatics
https://www.degruyter.com/journal/key/jag/html?lang=en

Electives: GL 611E: Urban Geology

GL 611 E; Major Elective; 2 Credit; 30 Marks
Course Title: GLE 106: Urban Geology
Type: Core and Skill based

Course Learning Outcomes (CLO):

CLO1	Understand the scope, application, and importance of study of urban geology and hydrogeology.
CLO2	Study the urban geology and geomorphology in detail to understand the previous terrain of the cities. Also familiarize with the application of geological knowledge in availability of in situ geology and construction material as well as the planning and management of cities.
CLO3	Acquainted with availability of water resources (surface and groundwater) for drinking purposes and irrigation purposes and their quantification and fluctuation in time and space.
CLO4	Know about the geologic hazards associated with cities including volcanic, earthquakes, land slide and floods.
CLO5	Understand the effect of geologic hazards like volcanic, earthquakes, land slide and floods on urban areas.
CLO6	Know more about effect of anthropogenic activities and environmental issues in the urban areas.
CLO7	Generate (interpretation, writing, compilation and presentation) of a detailed report based on the above knowledge.

Unit/Hour	Course Contents	Mapping with CLO
I/5	Nature, scope, application, and significance of urban geology and hydrogeology History and development of urban Geology and hydrogeology and its components.Soil degradation due to urban air pollution, particulate dust loading and heavy metal contamination.	CLO 1
II/6	Detail study of geology and geomorphology of urban domains in understanding the terrain and LULC of the cities. Geological problems in construction of underground structures in urban areas. Availability of building materials, excavation, cutting and subsurface studies like Urban Tunneling, Tunneling for road and metro rail in urban areas can be done.	CLO 2 CLO3 CLO7
III/5	Spatial and temporal scale, availability of water resources (surface and groundwater). Seasonal fluctuation in groundwater level, quantification of groundwater resources of aquifers can be studied using pumping test, VES and RS-GIS.	CLO 3 CLO4 CLO7
IV/7	Geologic hazards associated with cities including volcanic, earthquakes, landslides and floods. Zonation of urban areas into high to low in terms of stormflow, landslide and Seismic hazard into micro-zonation, engineering geological features, and Remedial measures.	CLO 5 CLO6

V/7	Anthropogenic activities and their effects on urban environment. Treatment and disposal of generated solid wastes, Industrial waste and mapping for selection of waste disposal sites.	CLO 5 CLO7

Reference Books:

1. Hal M J, Urban Hydrology, 2nd Edition, Wlsevier Applied Science Publishers, 1984.
2. Viessman W.I., Knapp J.W., Leuis G.L. and Heutrough, T.E.,Introduction to Hydrology, 2nd edition, Harper and Row Publishers, 1977.
3. Stephenon D. Stormwater Hydrology and Drainage 2nd edition, Elwiver publishers, 1981.
4. Chertus D.E., and Madana M.E., StormWater Modelling Academic Press, 2 nd edition, NY, 1976.
5. Genger, W.F., Marsaiek, J. Zudimaand Rawis, G. J, (1987) Manual on Drainage in Urban Areas 2 volumes, UNESCO, Press.
6. Overterns D.E., and Medows M.E., Urban Hydrology,Acadmic Press, NY 1976.

Course Code: GL 612 E
Course Title: Computer Applications in Geoscience
Type: Core and Skill based, Total Hours: 30

Course Learning Outcomes (CLO):

CLO1	Understanding of basic computer organization, operating systems, data representation, and number systems relevant to computational processes.
CLO2	Apply Boolean Algebra and Logic Circuits to design and analyze logic circuits, and convert between binary, octal, and hexadecimal number systems for problem-solving.
CLO 3	Design Algorithms for Problem Solving: Develop algorithms and flowcharts using conditional, sequential, and iterative processes to solve computational problem
CLO 4	Apply database concepts to design relational database schemas and use SQL for data manipulation and query execution.
CLO 5	Differentiate between supervised and unsupervised learning and apply basic machine learning techniques to analyze datasets.
CLO 6	Utilize computer graphics and mathematical modeling to visualize and simulate geological processes for scientific problem-solving.

Unit/Hour	Course Contents	Mapping with CLO
I/15	Computer Fundamentals – Basic Computer Organization, Data Representation: Non – positional and Positional Number Systems, Binary, Octal and Hexadecimal Number Systems, Computer Arithmetic. Computer Codes, Boolean Algebra and Logic Circuits, Computer Software, Operating Systems. Planning the Computer Programme, Algorithms.	1, 2, 4
II/15	Database architecture; Data management systems; relational database; Structured Query Language. Algorithm design: Condition, sequence and repetition. Machine Learning, Supervised, Unsupervised. Introduction to Computer Graphics – Scientific visualization based on computer graphics technologies, Computer Graphics Applications. Mathematical Modeling in Geosciences.	3, 5, 6

Reference books:

Rajaraman V. Fundamentals of Computers
Shrivastava C. Fundamentals of Information Technology
Sinha Pradeep Computer Fundamentals
Tonge. Fred M.: Computing – Introduction to Procedures
Greg Harvey: Excel for Windows 95
Rick Altman: Mastering Corel Draw 6
Jinjer L Simon: VB Script Superbible – The complete reference to Programming in Microsoft VB Scripting edition
Noel Jerke : Visual Basic 6 : The Complete Reference
John C Davis: Statistics and Data Analysis in Geology
Association of Indian Universities: Handbook of Computer Education
James H Earle: Graphics Technology

Course Name: Sequence Stratigraphy

GL-613-E: Sequence Stratigraphy, 2 Credit, theory, 30 hrs
Type: Core and Skill based

Course Learning Outcomes (CLO):

CLO1	Understand the History and development of Sequence Stratigraphy.
CLO2	Familiarize with the basic concept related to sequence stratigraphy.
CLO 3	Understand the Concept of Seismic Stratigraphy.
CLO 4	Application of well log analysis in sequence stratigraphy
CLO5	Study of sequence stratigraphy of carbonate platforms,
CLO 6	Study of fluvial sequence stratigraphy.
CLO 7	Application of sequence stratigraphy

Unit/Hour	Course Contents	Mapping with CLO
I/03	History and development of Sequence Stratigraphy. Basic principles used in the sequence stratigraphy.	CLO1 CLO2
II/05	Concept of base level, concept of creation of accommodation space and sediment supply due to sea level rise and fall. Concept of facies and unconformities.	CLO2
III/05	Understand in detail the Concepts of Seismic Stratigraphy.	CLO3
IV/04	Application of well log analysis in sequence stratigraphy	CLO4
IV/04	Study of sequence stratigraphy of carbonate platforms	CLO5
VI/04	Study of fluvial sequence stratigraphy.	CLO6
VII/05	Sedimentary ore deposits and hydrocarbon resources in relation to sequence stratigraphy	CLO7

Reference Books:

Catuneanu, O., 2006. Principles of Sequence Stratigraphy. Elsevier, Amsterdam, 375 pp.

Dunbar C. O. & Rogers J. Principles of Stratigraphy

Boggs, S., 1995. Principles of Sedimentology and Stratigraphy, Prentice Hall, New Jersey

Semester III: GL 614E: Industrial Mineralogy
CourseTitle: Industrial Mineralogy
Type: Elective based
Course Coordinator: Dr. Aditi Mookherjee

Course Learning Outcomes (CLO):

Upon successful completion of this course, the student will be able to:

CLO1	Identify various types of Industrial Minerals
CLO2	understand the essential facts, concepts, and theories which are related to Industrial Minerals and their uses

CLO3	Illustrate the applications of mineralogy to technology which are related to Industrial Minerals and their uses
CLO4	Categorize new products and new uses according to their physical and chemical properties
CLO5	Assess some of the analytical methods of research to evaluate the industrial minerals
CLO6	Construct a Database of various industrial minerals as per their specifications in different industries

Unit/ Hour	Course Contents	Mapping with CLO
I/12	Introduction to various industrial minerals and their resources, with emphasis on geological and economic aspects of the minerals. the actual uses of various industrial minerals, their possible future uses Understanding the essential facts, concepts, theories and applications which are related to Industrial Minerals and their uses new products and new uses according to their physical and chemical properties	CLO1 CLO2 CLO3 CLO4
II/8	some of the analytical methods of research to identify and evaluate the industrial minerals Outline of techniques used in testing raw materials,	CLO5
III/10	Introduction to industrial specifications and preparations of raw material used in Ceramics and Refractories, Abrasives, Construction / Building Materials, Cement, Paints, Fertilizers, Electronics, Chemical Industry, Glass Industry, Metallurgical Industry.	CLO6

SuggestedReadings:

- Chang, L.L.Y. Industrial Mineralogy: Materials, Process and Uses, Prentice Hall, New Jersey, 2002
- Manning, D. A. C. Introduction to Industrial Minerals, Kluwer Academic Press, 1994
- Sinha, R. K. Treatise of Industrial Minerals of India, Allied Publishers, New Delhi, 1967
- Deb, S. Industrial Minerals and Rocks of India: Non Metallic Minerals and Constructional Rocks Including Solid and Liquid Fuels, Allied Publishers, New Delhi, 1980
- Klein, C. Manual of Mineral Sciences, 22 Edition, John Wiley & Sons, New York, 2002
- Ciullo, P.A. 1996 Industrial Minerals and Their Uses New York: Noyes Publ. Kuzvart, M. 1984.

- Industrial Minerals and Rocks (Development in Economic Geology, Vol. 18). Amsterdam: Elsevier
- Bates, R.L. 1960.Geology of the Industrial Rocks and Mineral. New York: Harper.Carr, D.D. 1994.
- Industrial Minerals and Rocks. New York: Soc. For Mining Metallurgy and Exploration Lefond, S.J. 1975.
- Industrial Minerals and Rocks. New York: Amer. Inst. of Mining, Metallurgical and Petroleum Engineers Manning, D.A.C. 1995.
- Introduction to Industrial Minerals. London: Chapman &Hall.
- Indian Mineral Resources – Roy

List of Journals:

- American Mineralogist
- Clay Minerals
- International Journal of Mineralogy
- Mineralogy and Petrology
- Mineralogical Magazine

Course Code: GL615E

Course Title: GL 615E: Advanced Structural Geology

Type: Core and Skill based, 30 hrs

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to:

CLO1	Learn advanced theoretical knowledges in structural geology.
CLO2	Learn application based techniques for paleo stress calculation and strain measurements.
CLO 3	Adopt a Case study for a given data set to plot and analyze them
CLO 4	Generate (interpretation, writing, compilation and presentation) a detailed report based on the above knowledge.

Unit/Hour	Course Contents	Mapping with CLO
I/15	Various Stress conditions. Construction of Stress ellipsoid. Paleo stress analysis from conjugate fractures and fault slip data, PT method. Application of Mohr Circle methods. Flin's Plot and its application. Strain Measurements. Plain strain analysis. Methods of Structural mapping. Computational Structural Analysis of deformed outcrops.	1 2 4
II/15	Fold Mechanism. Biot's Law of Buckling. Ramp-Flat Structures, Duplex Structures, Fault Bend Folds, Fault Propagated Folds. Shear Zone analysis. Kinematic indicators and Microstructural studies. Construction of Balanced Cross Sections. Salt Tectonics.	2 3 4

Suggested Readings:

1. Haakon Fossen, 2016. *Structural Geology*, Cambridge University Press.
2. Ramssay and Lisle 2003.
3. Donal M. Ragan, 2009. *Structural Geology: An Introduction to Geometrical Techniques*, Cambridge University Press.
4. Ramsay, J. G. and Huber, M. I., 1983. *Techniques of Modern Structural Geology. Vol. I. Strain Analysis*, Academic Press.
5. Ramsay, J.G. and Huber, M.I., 1987.*Techniques of Modern Structural Geology. Vol. II. Folds and Fractures*, Academic Press.
6. Ramsay, J.G., 1967. *Folding and fracturing of rocks*, McGraw Hill.

List of Journals:

1. Journal of Structural Geology, Elsevier.
2. Journal of Geodynamics, Elsevier

Transactional Modes: Demonstration, practical with real specimens, Problem solving, Group discussion, Tools used: PPT, Video, Animation, Software Tool: MS Office, CorelDraw

Semester IV
Major Core

Major Core	GL651CT: Mining Geology GL652CT: Petroleum Geology GL653CT: Engineering Geology GL654CT: Hydrogeology GL655CP: Practical's related to above subjects including field component	02 02 02 02 04
Major elective	GL660E TO 667E: Select any two 2 Credit courses from the elective Course basket	02 02
Res Method.	0	0
O.J.T.	0	0
Res. Project	Dissertation Project	06

Course Code: GL 651C**T**
Course Title: Mining Geology
Type: Optional and Skill based, 2 Credits, Total Hours: 30

Course Learning Outcomes (CLO):

CLO1	Detailed knowledge on the ore deposits and the sample collecting technique.
CLO 2	Develop understanding on basic concepts of geochemical and geophysical exploration processes.
CLO 3	Able to estimate the ore reserve.
CLO 4	Carryout individual mine survey using surveying methods
CLO 5	Carryout ore reserve estimation for surface and underground deposits
CLO 6	Gain knowledge on surface and underground mining methods
CLO 7	Knowledge of mineral beneficiation

Unit/Hour	Course Contents	Mapping with CLO
I/10	Guides to ore: Ringed Target and Intersecting loci; Regional and Topographical Guides; Mineralogical Guides; Structural Guides; Stratigraphic Guides	CLO1 CLO2 CLO3
II/15	Drilling & Mining Methods: Percussion Drills – Jumper bar drills-Pneumatic drills - Churn drills-Reich drills; Rotary Drills, Auger drills, Calyx drills, Turbo drills, Diamond drills; Miscellaneous Drills: Jet Drills, High temperature flame drills, Banka drills (Empire drills), Burnside drills; Mining Methods - Alluvial Mining, Open Cast Mining, Underground Mining; Ore Dressing-Crusher's, Grinder's, Jig, Tabling, Flotation	CLO4 CLO5 CLO6 CLO7

Reference Book:

1. Arogyaswamy, R.N.P. (1996) Courses in Mining Geology – Oxford & IBH, New Delhi.
2. Arogyaswamy, 2017, Courses in mining Geology, Oxford & IBH publisher 23 Co.Pvt.ltd

3. Thamus, P.J. (1979) An introduction to mining, Methun.
4. Mc Kinstry, H.E (1960) Mining Geology, Prentice Hall, Englewood New york.
5. Singh,1997, Principles & practices of modern coal mining, New age international publishers
6. Gaudin, A.M. Principles of Mineral Dressing. McGaw Hill Pub. Co. Ltd. Bombay
7. Wills, BA. 1988. Mineral Processing Technology. Pergamon Press. Oxford.
8. Vijayendra, MG. 1995. Handbook of Mineral Dressing. Vikas Publishing House Pvt Ltd.
9. Clifts, N.J. • Clark, G.B. (1967) Elements of Mining, III ed. John Wiley.
10. Waveland Evans, A.M., "Ore Geology and Industrial Minerals": An Introduction"

List of Journals:

Journal of Mining and Geology eISSN: 1116-2775

Journal of *Geology* and *Mining Research*. Abbreviation: J. Geol. Min. Res. ISSN: 2006-9766; DOI: 10.5897/JGMR;

Journal of Geology & Mining is a peer reviewed, open access scientific *journal* that publishes research articles,

Journal of Mining Science Electronic ISSN 1573-8736 Print ISSN 1062-7391

International Research Journal of geology and Mining **(ISSN:2276-6618)**

Open Geosciences ISSN: 2391-5447 Editor-in-chief: Piotr Jankowski

Course Code: GL 655C**P**
Course Title: Mining Geology (Practical); **Total Hours: 30**

Course Learning Outcomes (CLO):

CLO 1	Reserves and reserve estimation of mineral deposit
CLO 2	Volume and tonnage estimation, cut-off grade, ROM grade,
CLO 3	Classification of ore reserves
CLO 4	Ore beneficiation General techniques of ore beneficiation
CLO 5	Different type of geochemical exploration method

Unit/ Hour	**Contents**	**Mapping with CLO**
I/15	Isograde Maps preparation	**1,2**
	Plotting of faulted orebody	**1,2**
	Calculation of ore deposit reserve estimation	**3,4**
	Calculation of ore reserve estimation of extended and limited areas	**3,4**
	Calculation of ore reserve estimation regular and irregular spaced sample	**3,5**

Course Code: GL652CT; **2 Credit; 50 Marks**
Course Title: Petroleum Geology
Type: Core and Skill based

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to:

CLO 1	Acquainted with elemental and chemical composition of Petroleum.
CLO 2	Familiar with physical properties of Crude oil that are important from detection, clues to origin, handling, transportation and refining of Petroleum.
CLO 3	Familiar with surface and subsurface occurrences of Petroleum. Well versed with source rock characteristics and precursor of Petroleum.
CLO 4	Will get adequate knowledge of pertaining to different theories of origin of petroleum and its current status. Will have adequate knowledge of fundamental properties of sedimentary rocks i.e. porosity and permeability that affect migration of petroleum and conditions under which accumulation of petroleum takes place.
CLO 5	Basic idea about unconventional hydrocarbon resources
CLO6	To fully understand techniques of geological, geophysical and geochemical prospecting for hydrocarbons. How to read old and modern logs, and how to extract petrophysical parameters.
CLO 7	How to assess log quality, how to qualitatively extract fundamental information such as horizon-based water salinity changes, how to derive basic lithologies, and how to differentiate between tight and permeable zones. Applying fundamental petrophysical equations and how to extract properties such as porosity, shale volume, permeability and main lithologies.
CLO8	Generate (interpretation, writing, compilation and presentation) of a detailed report based on the above knowledge. To evaluate elements and processes in a petroleum system that convert the organic matter in source rocks into trapped hydrocarbons

Unit/Hour	Course Contents	Mapping with CLO
I/8	**Occurrence and Source rocks :** Classification and composition of Petroleum; Physical properties of petroleum; Occurrence of petroleum; Nature of source rock, composition of biomass; Kerogen: Composition and types	CLO 1 CLO 2 CLO 3
II/7	**Reservoir, Traps, Origin & Migration:** Reservoir rocks, pore space and fluids; Reservoir Traps; Origin, migration and accumulation; Introduction to Unconventional hydrocarbon resources **Learning Activities:** Learning with the help of PPT in which efforts will be made to demonstrate salient characteristics pertaining to aforesaid topics . Students Seminars and assignments on topics related with Petroleum Geology.	CLO3 CLO 4 CLO 5
III/15	Geophysical prospecting for petroleum: Introduction, Drilling, Zones of invasion, Well logs, Log run, Log presentation, Classification of Logs, Logs: Tools, Units and Scale, Log presentation, Log interpretation and significance and Principal uses; Temperature Logs; Caliper Log; Self-potential log; Radioactive Logs; Resistive Logs; Density Log; Neutron Log; Sonic log. Petroliferous basins of India: Geological Setting, Tectonic, Stratigraphy and Depositional Environments, Hydrocarbon Prospects of;	CLO 5 CLO 6 CLO 7 CLO 8

	***Learning Activities**:* Evaluation and analysis of well data i.e. well cutting, cores, logs, Log Formation Evaluation, productive and potential oil and gas reservoirs and source rocks and their distribution in the basins, Geological Interpretation of Well Logs, Understand the methods used for the exploration of hydrocarbon.	

Suggested Readings:

Dobrin M. B.1988. Introduction to geophysical prospecting, Mc-Grew Hill Book Company.

Levorson A. I. 2004. Geology of Petroleum, CBS Publication.

Russel W. L. 1960. Principles of Petroleum Geology, McGraw-Hill Book Company, Inc.

Leroy L. W. & Leroy D. O. 1977. Subsurface Geology Petroleum, mining, Construction, Colorado School of Mines.

Selley R. C. 1998. Elements of Petroleum Geology, IInd Edition, Academic Press.

Tissot B. P. and Welte D. H. 1984. Petroleum Formation and Occurrence, Springer-Verlag Berlin New York.

North F. K. 1985. Petroleum Geology, Kluwer Academic Publishers.

Geology of Petroliferous Basins of India, 1997. KDM Institute of Petroleum Exploration.

Bhandari L. L. 1983. Petroliferous Basins of India, Himachal Times Group.

Singh L. 2000. Oil and Gas Fields of India, Indian Petroleum Publishers.

Tissot, B.P. and Welte, D.H., 1984: Petroleum Formation and Occurrence, Springer – Verlalg. .. Gebruder Borntraeger, Stuttgart.

Selley, R.C., 1998: Elements of Petroleum Geology. Academic press.

Boyle, R.W., 1982: Geochemical prospecting for Thorium and Uranium deposits, Elsevier.

Holson, G.D. and Tiratso, E.N., 1985: Introduction to Petroleum Geology. Gulf Publishing, Houston, Texas.

Singh, M.P. (Ed.) 1998: Coal and organic Petrology. Hindustan Publishing Corporation, New Delhi.

List of Journals:

1.Journal of Petroleum Geology, Wiley.

2.Marine and Petroleum Geology, Elsevier.

3.Petroleum Geoscience, Geological Society Publications.

4.Indian Journal of Petroleum Geology, Indian petroleum Publishers.

5.American Association of Petroleum Geologists.

Course Code: GL655CP	
Course Title: Petroleum Geology (Practical),	**Total Hours: 15**

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to:

CLO 1	Will be acquainted with construction and interpretation of different types of subsurface maps such as lithofacies maps, isopach map, structural contour maps in terms of subsurface facies variation, thickness variation and identification of subsurface geological structures.
CLO 2	Will be able to identify the lithology, facies variation and correlation of lithology in subsurface
CLO 3	Acquainted with correlation of subsurface lithology encountered in wells together with log data and document subsurface facies variation, identification of geological structures and favorable hydrocarbon locales.
CLO4	Understand the methods used for the exploration of hydrocarbon. Application of different logs in the evaluation of hydrocarbon bearing formations.

Unit/ Hour	**Contents**	**Mapping with CLO**
I/7	1. Lithofacies analysis 2. Preparation of structural contour maps 3. Preparation of isopach maps 4. Preparation of carbonate concentration maps 5. Correlation of electrical logs 6. Preparation of geologic cross section from well data **Learning Activities:** Plotting of various types of subsurface data from books and journal articles and to prepare different types subsurface maps, stratigraphic cross sections.	CLO 1 CLO 2 CLO 3 CLO 4
I/8	Logging environment (Pressure/Temperature) Calculations of Geothermal gradient, True Bottom Hole Temperatures (Horner's Plot), Hydrocarbon maturity. Fundamentals of Reservoir Fluid Behavior: Calculation for predicting the physical properties of pure compounds and undefined hydrocarbon mixtures. Calculation of physical parameters, flow rate, permeability of the hydrocarbon mixture that exists as a gas both in the reservoir and in the surface facilities	

Suggested Readings:

1. Leroy L. W. & Leroy D. O. 1977. Subsurface Geology Petroleum, mining, Construction, Colorado School of Mines.

Semester IV: Major Core: GL653 CT

Course Title: GL653CT: Engineering Geology

Type: Core and Skill based

Course Learning Outcomes (CLO):

CLO1	Know the scope and importance of Engineering Geology
CLO2	Understand the various methods used in determining engineering properties of rocks and Rock failure mechanisms in stress-strain conditions.
CLO3	Acquainted with different geological considerations used for the selection of sites for engineering structures.
CLO4	Study the types of Tunnels and locate suitable sites for tunnel alignment and construction. Familiar with types of bridges, Y- ducts, Roads & similar structures in consideration of geological conditions.
CLO5	Recognize the importance of geology from the civil engineering point of view. Categorize different building materials, properties and their uses.
CLO6	Acquire knowledge about the usage & suitability of construction equipment, Recognize rock drilling applications. Recognize properties and characteristics of explosives.
CLO7	Able to understand the different methods of geological exploration Appreciate the use of modern technology in the field of geo-synthetics engineering, attain the fundamental knowledge in the concept of remote sensing and its components
CLO8	Generate (interpretation, writing, compilation and presentation) of a detailed report based on the above knowledge.

Unit/Hour	**Course Contents**	**Mapping with CLO**
I/06	The scope and importance of Engineering Geology in general. To study and determine the engineering properties of rocks in the field as well as in the lab numerous methods are used.	CLO1 CLO2
II/05	Different geological considerations used for the selection of sites for engineering structures taking into account rock type, subsurface studies, geological structures, soil thickness, climatic conditions etc . Selection of suitable sites for dam construction and types of dam with different types of Spillways considering lithology, structures etc. Estimation of different forces acting on dam wall with calculations and major problems of siltation in reservoirs and measures to control silt in dam reservoirs.	CLO2 CLO3 CLO4
III/04	Studying the Tunnels types and locating suitable sites for tunnel alignment and construction considering the soundness of rock, depth from the surface, and water flow. Selection of sites for bridge construction, types of bridges, Y-ducts, Roads & similar structures in consideration of geological conditions. The concept of Slope stability analysis including slicing methods in summation of total stress calculation and suggestion of remedial measures to minimize it.	CLO3 CLO4 CLO7

IV/06	Geo-material in Engineering Construction; Building stones and road metals; Characteristics of rocks as building stones and road metals; Aggregate and its classification; Planning of quarry, hill slope side or open pit; Removal of overburden and its disposition at suitable site; Methods of extraction of aggregate resources.	CLO4 CLO5
V/06	Selection of drilling, blasting method for main blasting and secondary breaking for given size of fragmentation. Selection of equipment for drilling, loading, and hauling to the crusher site. Geo-techniques; Applications of Remote Sensing and geophysical exploration methods in Engineering Geology: Case Studies.	CLO6 CLO7 CLO8
VI/03	Types of synthetic materials used as remedial measures; Estimation of overburden thickness & rock strata classification; Preparation of Report and Presentation of Engineering data.	CLO7 CLO8

Reference Books:

Krynine and Judd: Principles of Engineering Geology and Geotechniques
Rise and Wateson: Elements of Engineering Geology
Blyth, F.G.H. and M. H. de Freitas (1984) Geology for Engineers, Butterworth Heinemann Title
Ries, H. and T. L. Watson, (1949) Elements of Engineering Geology, New York, JohnWiley & Sons, Inc.
Tony Waltham (2009) Foundations of Engineering Geology, Taylor and Francis.
ChennaKeshvallu (2018) Text book of Engineering Geology, Laxmi Publications.
Gokhale, K.V.G. (2006) Principles of engineering geology, BS publications.

Course Code: GL655 CP
Course Title: GL655CP: Engineering Geology (Practical)

Course Learning Outcomes (CLO): to:

CLO 1	The use of geophysical signature in understanding subsurface geology
CLO 2	The strength of the rock samples using rock quality designation
CLO 3	The strength of geological samples with rock mass quality indices
CLO 4	Interpret the given borehole data and prepare the bore logs / Lithologs.
CLO 5	The geological cross section for locating the suitable sites for engineering site construction
CLO 6	Understand the working principles of survey instruments, interpret survey data and compute areas and volumes
CLO 7	Apply the surveying and measurement to real problems. Able to survey the area using different methods of plane tabling and compass survey

Unit/ Hour	**Contents**	**Mapping with CLO**
I/30	The use of geophysical signatures especially vertical electrical sounding in understanding subsurface geology, depth-to-bedrock, resistivities of strata etc.	**CLO1**
	The strength of the rock core samples using rock quality designation (RQD).	**CLO2**
	Strength of geological samples with rock mass quality indices (RMR) , includes various parameters giving values indicating best or poor quality.	**CLO3**
	Interpretation of the borehole data and prepare the bore logs / Lithologs are useful in locating sites suitable for engineering construction.	**CLO4**
	Geological maps with cross-sections helpful in locating feasible and suitable sites from an engineering point of view.	**CLO5**
	Various methods of Surveying used in engineering geology including chain Surveys, Plane table surveys along with various surveying equipment also important.	**CLO6 CLO7**

Course Title: GL654CT**: Hydrogeology**

Type: Core and Skill based: 2 Credits, 30 hours

CLO1	Understanding the scope, importance, and components of the hydrological cycle and analyze the factors affecting the occurrence and movement of groundwater
CLO2	Understand the concept of groundwater quality, geochemical processes in the groundwater, water types and water quality classification.Apply an integrated approach to groundwater prospecting by utilizing topographic maps, remote sensing-GIS, and exploration techniques to assess recharge potential, artificial recharge methods and managed aquifer recharge.
CLO3	Explain the characteristics of unsaturated and saturated zones, hydrogeological properties of rocks and classify aquifers with examples from Indian groundwater systems.
CLO4	Use Darcy's law to understand hydraulic gradients, conductivity, and groundwater flow under laminar and turbulent conditions, and trace groundwater movement through flow nets and velocity measurements.
CLO5	Design and analyze pumping tests to evaluate aquifer properties such as storativity, transmissivity, and specific capacity, and interpret data to assess groundwater storage and flow potential.
CLO6	Evaluate groundwater quality for various uses, understand geochemical processes, and apply software tools like AquaChem to analyze data. Propose remedial measures for seawater intrusion and assess groundwater legislation for sustainable management in India.

Unit/Hour	**Course Contents**	**Mapping with CLO**
I/05	Scope and importance of groundwater. Different components of the hydrological cycle: Evaporation, condensation, precipitation, interception, runoff (surface, subsurface and groundwater), and infiltration. Factors that affect occurrence of groundwater: Climate, topography, geology etc.	1, 2
I/05	Integrated approach to groundwater prospecting. Various groundwater exploration techniques. Role of toposheets and Remote sensing in groundwater exploration. Measurement of groundwater recharge, various artificial recharge techniques along with surface water/ rain water harvesting and construction of structures for groundwater augmentation, conjunctive use of surface water and groundwater. Managed Aquifer Recharge.	1, 2
I/05	Characteristics of unsaturated and saturated zones. Hydrogeological properties of Rocks – Porosity, intrinsic permeability, hydraulic conductivity. Specific yield and specific retention. Anisotropy and heterogeneity in aquifers.	

I/05	Unconfined and confined aquifers. Significance of perched and leaky aquifers. Aquifer properties. Behaviour of sedimentary, crystalline and volcanic rocks as aquifers. Aquifers of India. Impact of drought, groundwater overexploitation and mining on aquifers. Stable isotope hydrogeology.	3, 4
I/05	Darcy's Experiment: Hydraulic gradient and hydraulic conductivity. Applicability and Validity of Darcy's law: laminar and turbulent flow – Upper and Lower limits of groundwater flow velocity. Velocity measurements in fractured media. Principles of groundwater flow; Steady and unsteady flow. Tracing of groundwater movement with flow nets. Pumping tests – principles – types of wells and pumping tests, procedures, analysis and evaluation of pumping test data. Storativity, transmissivity and specific capacity.	4, 5
I/05	Introduction to quality of groundwater and suitability for various purposes. Geochemical processes in the groundwater, the interaction of water with its ambient environment: chemical, physical and kinetic. Groundwater types and classification. Seawater intrusion: Ghyben-Herzberg relation. Various remedial measures to control it. Assessment of groundwater quality using available software like AquaChem. Groundwater provinces of India. Groundwater legislation	2, 6

Course Code: GL655CP

Course Title: GL655CP: Hydrogeology (Practical)

CLO 1	Understand the hydrological cycle and its components, Demonstrate knowledge of groundwater provinces in India, their geological variations, and their impact on the quantity and quality of groundwater.
CLO 2	Apply techniques/plots to analyze hydrogeochemical data, identify major factors influencing water chemistry, and evaluate soil salinity.
CLO 3	Calculate water quality indices to assess the suitability of water for agricultural irrigation and propose strategies for water management based on analysis
CLO 4	Analyze groundwater table contour maps to determine flow direction, recharge and discharge areas, and hydraulic gradients.
CLO 5	Develop Field and Analytical Skills in Hydrogeology:Plan and execute field investigations. Apply classroom knowledge of field hydrogeology to conduct

	pumping tests and slug tests to determine aquifer properties, and analyze test data using open-source software.
CLO 6	Utilize statistical methods and software tools to analyze and visualize hydrogeological and hydrogeochemical data, enhancing decision-making for groundwater resource management.

Unit/ Hour	**Contents**	**Mapping with CLO**
I/15	Map the groundwater provinces of India , global hydrological cycle with its components; Availability of surface and groundwater resources of the world and of India pinpointing the sporadic distribution of water resources	**1**
	Plotting and analysis of hydrogeochemical data and interpret; Piper Trilinear Plots, US salinity plots, Gibbs plots; Plotting and analysis of hydrogeochemical data on s signify the soil salinity. Calculations of different water quality Indices used for agriculture purposes like SAR, RSC, %Na, KR to assess the suitability.	**2, 3, 6**
	Analysis of hydrogeological data, interpret groundwater level fluctuations, aquifer responses, and recharge processes. Utilize statistical techniques and software tools for data analysis and visualization.Interpret various maps and apply classroom practical knowledge of hydrogeology to design and execute field investigations. Apply appropriate field techniques for groundwater monitoring, sampling, and conduct pumping tests and slug tests to determine aquifer properties. Develop soft skills. Hands on open source software to analyze pumping test data.	**4, 5** **5, 6**

Reference Books:

1. Davies, S.N. and De-West, R.J.N., 1966. *Hydrogeology*, John Wiley & Sons, New York.
2. Fetter, C.W., 1984. *Applied Hydrogeology*, McGraw-Hill Book Co., New York.
3. Fitts, C.R., 2006. *Groundwater Science*, Academic Press.
4. Freeze, R.A. and Cherry, J.A., 1979. *Groundwater*, Englewood Cliffs, New Jersey: Prentice-Hall.
5. Karanth K.R., 1987. *Groundwater: Assessment, Development and Management*, Tata McGraw-Hill Pub. Co. Ltd.
6. Raghunath, H.M., 1987. *Ground Water*, Wiley Eastern Ltd., Calcutta.
7. Todd, D.K., 2004. *Ground Water Hydrology*, John Wiley & Sons, New York.

Semester II

Major Electives

Course Code: GL660E Major Elective; 2 Credit; 50 Marks
Course Title: Marine Geology
Type: Core and Skill based

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to:

CLO1	Familiar with geophysical characteristics of ocean basins.
CLO2	Will be acquainted with stratigraphic aspects of marine sediments. Will know techniques utilized for, limitations dating of marine sediments and rocks.
CLO 3	Acquainted with tectonic history of ocean basins and paleoocanographic history.
CLO 4	Will know sequence of rocks of oceanic crust as well as their seismic velocity characteristics
CLO5	Will be acquainted with oceanic circulation pattern, causes and effects of sea level changes, marine stratigraphic aspects and will have idea of near shore processes.

Unit/Hour	Course Contents	Mapping with CLO
I/8	**Morphology, Stratigraphy and Tectonics of Oceans** ➢ Geophysics and Ocean morphology ➢ Marine Stratigraphy ➢ Tectonic history of the oceans **Learning Activities:** With help of diagrams and maps published in reference books and journal articles in the form of PPT, the oceanic morphology will be known. With help of reference books and journal articles the different aspects of Marine stratigraphy and tectonic evolution of ocean basins will be understood. Assignment and student seminar on related topics.	CLO 1 CLO 2 CLO 3
II/7	**Ocean Circulation** ➢ Oceanic Crust ➢ Ocean circulation ➢ Sea level history and seismic Stratigraphy ➢ Near shore geological processes and the continental shelf **Learning Activities:** Oceanic crustal structure and their correlation with seismic sequences will be understood by studying the cross sections of oceanic crust. On the basis of published maps oceanic circulation pattern will be understood. Causes and effects of sea level changes will be explained. Near shore geological processes and characteristics of shallow marine environments will be explained.	CLO 4 CLO 5
III/8	**Ocean margins and Oceanic sediments** ➢ Continental margin type ➢ Terrigenous deep-sea sediments ➢ Biogenic and authigenic oceanic sediments\	
IV/7	**Bottom currents and Paleoceanography** ➢ Geological effects of bottom currents ➢ Approaches to Paleoceanography	

	➢ Palaeo oceanographic and sediment history of ocean basins ➢ Critical events in ocean history	

Suggested Readings:

1. Menard H. W. 1964. Marine Geology, Mc Grew Hill Publications.
2. Keen M. J. 1968. Introduction to marine geology, Oxford Pergamon Press.
3. Kennett J. P. 1982. Marine Geology, Prentice-Hall.
4. Anderson J. B. 1999. Antarctic Marine Geology, Cambridge University Press, UK.

List of Journals:

1. Marine Geology, Elsevier.
2. Marine and Petroleum Geology, Elsevier.
3. Frontiers in Earth Science: Marine Geosciences.
4. Geomarine letters, Springer.
5. Journal of Geophysical Research: Oceans,
6. Anderson J. B. 1999. Antarctic Maribne Geology, Cambridge University Press, UK.

Course Code: GL662 E**; 2 credits; 30 lectures; 25 Marks**
Course Title: Oil Field Services (Theory)
Type: Core and Skill based

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to:

CLO1	Have knowledge and the skills of types of drilling, coring and its types.
CLO2	Acquainted with monitoring parameters during drilling, mud logging, types of drilling mud
CLO 3	Acquainted with types of drilling rigs
CLO 4	Able to identify lithology from the log data. Undertake well to well correlation of lithology.

Unit/Hour	Course Contents	Mapping with CLO
I/15	**Introduction to Oil Well Drilling:** Types oil wells and geotechnical order; Methods of Oil well drilling: Cable tool drilling and rotary drilling; Components of rotary drilling system; Monitoring of drilling process i.e. depth ROP, WOB, sampling; Concept of Subsurface pressure; Types of Drilling Rigs: Onshore and offshore rigs; Controlled Directional Rotary Drilling, Horizontal Drilling; Drilling Mud: Mud hydraulics, uses and functions of drilling mud.; Coring**:** Introduction, Techniques and Applications of Coring in Petroleum Geology.	CLO 1 CLO 2 CLO 3
II/15	**Formation Evaluation:** Wire line logs: Introduction; Basic Principles, tools of SP, gamma ray, Neutron,; Density, Caliper, Dipmeter, Temperature and Sonic; Logs and their interpretation. Mud logging: Principle, techniques and tools of mud logging. Interpretation of gas, drilling and mud parameters. MWD (Measurement While Drilling)/LWD (Logging While Drilling): Principle and tools of MWD/LWD, data analysis and interpretation. Formation (Drillstem) Testing: Introduction, Tools and Techniques of DST.	CLO 4

Suggested Readings:

1. Sahay, B., Rai, A. and Ghosh, M. 1997. Wellsite Geological Techniques for Petroleum Exploration, Oxford & IBH, New Delhi.
2. Olivier A. 2019. Drilling and reservoir Appraisal, World Scientific Publishing.
3. Geological and md logging in drilling control, 1982, Gulf Publishing Company.
4. Bommer P. M. 2008. Primer of Oil well drilling, The University of Texas at Austin, Petroleum Extension Service.
5. Arther W. and Frank W Cole McCray 2005. Oil & well drilling technology, Bio green Books.
6. Hearst J. R. and Nelson P. H., 1985. Well logging for physical properties, Mc Graw Publications.
7. Chilinger, G.V. and Vorabutr, P. 1981. Drilling and Drilling Fluids, Elsevier Science, Amsterdam.
8. Hyne N. J. 2012. Nontechnical Guide to Petroleum Geology, Exploration, Drilling & Production, PennWell Books.
9. Toby. D. 2005. Well logging and Fomation evaluation, Elsevier, Amsterdam.
10. Serra O, Serra L. 2003. Well Logging and Geology, Serralog.
11. Serra O, Serra L. 2004. Well logging data acquisition and application, Sera.
12. Natraj Vaddadi 2014. Introduction to Oil Well Drilling:A laymen guide to Fascinating world of oil Exploration, Amazon Asia Pacific Holdings.

List of Journals:

1. Journal of Petroleum Exploration and Production Technology.
2. SPE Journal
3. Journal of Petroleum Science and Engineering.

GL 663E: Watershed Development and Management

Course Code: GL 663 E
Course Title: Watershed Development and Management
Type: Elective and Skill based: 30 hrs

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to:

CLO1	Learn about the delineation of watershed, its types, shapes, Natural Resources, their divisions, conditions to classify different resources.
CLO2	Selection of sites and types of watershed structures
CLO 3	Understand importance of Govt, NGO and peoples participation and their limitations
CLO 4	Case study to understand Water balance of a watershed

Unit/Hour	Course Contents	Mapping with CLO
I/15	**Watershed Development** Concept of a watershed - watershed characteristics – Importance of water resources in watershed – concept of watershed development concerning water resources – salient features of development measures like counter bunding, gully plugs, stream bunds, percolation tank, subsurface dams, afforestation etc Use of morphometric analysis in planning watershed development Calculation of water balance for a watershed etc	CLO1 CLO2 CLO4
II/15	**Watershed Management** Concept of watershed management in relation to water resources –water balance equation for watershed – sustainability of water resources - conjunctive use of surface and groundwater resources – concepts of people participation in community based watershed management – concept of water users group – Role of NGO's and State Government in watershed management.	CLO3 CLO4

Suggested Readings:

1. Todd, D.K. – Groundwater Hydrology
2. Karanth K.R. – Groundwater Assessment Development and Management
3. Raghunath H.M. – Groundwater
4. Davis S.n. and Dewiest R.J.M. – Hydrogeology
5. Freeze and Cherry – Groundwater
6. Dhravabaraya V.V., Sastry and patnaik V.S. - Watershed Management
7. Holechek, J. L., R. A. Cole, J. T. Fisher, and R. Valdez. 2003. *Natural Resources Ecology, Economics and Policy* (2nd Edition). Prentice Hall Education.
8. Shenk, T. M., and A. M. Franklin. 2001. *Modeling in Natural Resource Management Development,mmInterpretation, and Application*. Island Press.
9. Wondolleck, J. M. and S. L. Yaffee. 2000. *Making Collaboration Work Lessons from*

Innovation in Natural Resource management. Island Press
10. Paine, D. P. 1981. Aerial Photography and Image Interpretation for Resource Management. John Wiley and Sons. New York, New York. 571 p.
11. Pandey, B.W. 2005. Natural Resource Management. Mittal Publications
12. B. K. Kakade. Watershed Manual: A Practical Guide for Watershed Development Practioners and Trainers. BAIF Development Research Foundation Pune
13. Isobel W. Heathcote,Integrated Watershed Management: Principles and Practice,Wiley
14. J. V. S. MurtyWatershed Management, New Age International
15. Robert J NaimanWatershed Management · 1994, 3Island Press
16. Timothy Randhir,Watershed Management, IWA Publishing

List of Journals:

1.Journal of Natural Resources and Environmental Management (2086-4639 (PRINT)/ 2460-5824 (ONLINE)
2.Society & Natural Resources: An International Journal
3.JOURNAL OF WATER RESOURCES DEVELOPMENT (JWRD)
4.Watershed Management Research
5.**Watershed Management Research Journal**,
6.Journal of Sustainable Watershed Science and Management
7.Watershed Ecology and the Environment

Course Code: GL 664e
Course Title: Groundwater Survey and Modelling
Type: Core and Skill based

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to:

CLO1	Strengthen the knowledge about the principles, methods, and applications of groundwater surveying and modeling.
CLO2	Develop an understanding of the environmental implications of hydrogeology, including the interaction between groundwater and surface water,
CLO 3	Develop the application of groundwater modeling techniques and software tools commonly used in hydrogeology .
CLO 4	The ability to interpret and communicate groundwater survey and modeling results effectively. Familiarize students with various techniques used for groundwater data collection and analysis.
CLO5	Perform sensitivity analysis to assess the sensitivity of the model outputs to changes in input parameters. Identify critical parameters that significantly influence model results.
CLO 6	Develop predictive models to assess the potential impacts of future changes, such as climate change, land-use modifications, or groundwater management strategies. Explore different scenarios by modifying boundary conditions

Unit/Hour	Course Contents	Mapping with CLO
I/15	Hydrogeological Conceptualization. Aquifer characterization: aquifer properties, hydraulic conductivity, storativity. Artificial recharge methods and design. Benefits and challenges of managed aquifer recharge. Governing equations of groundwater flow (e.g., Darcy's law, continuity equation). Groundwater and surface water interaction Real-world case studies of groundwater surveys	1, 2, 3
II/15	Introduction to groundwater modeling: purpose, types, and applications. Analytical models: Dupuit assumptions, steady-state and transient flow. Introduction to numerical groundwater models and modeling software. Numerical modeling software applications (e.g. MODFLOW). Groundwater Contaminant Transport Modeling. Discretization methods: Finite difference, finite element, and finite volume. Calibration and verification of groundwater flow models. Sensitivity analysis and uncertainty assessment.	3, 4, 5

Reference Books:

Mary P. Anderson and William W. Woessner. Applied Groundwater Modeling: Simulation of Flow and Advective Transport

Ne-Zheng Sun and Mary P. Anderson. Numerical Methods in Subsurface Hydrology

Christopher M. Palmer.Principles of Contaminant Hydrogeology

Reinhard Kirsch.Groundwater Geophysics: A Tool for Hydrogeology

Martin S. Søndergaard and Ole Christensen. Groundwater Modeling by the Finite Element Method

Paul Pavelic and Brian J. Alloway. Groundwater and Ecosystems

Chunmiao Zheng. Applied Contaminant Transport Modeling: Theory and Practice

David M. Nielsen and Robert E. Simons Practical Handbook of Ground-Water Monitoring.

1	Course Code : GL 665E
2	Course Title : **Geothermal Energy Resources**
3	Type : Core and Skill based
4	Course Coordinator : Dr. Milind A. Herlekar

Course Learning Outcome (CLO) A practical understanding on the various Geothermal energy conversion technologies and its relevance towards solving the present energy crisis.

CLO1	To have an exposure on the types of Geothermal energy, its surplus availability and characteristics.
CLO2	Analyze the technologies available for conversion of Geothermal Energy in terms of its technical competence and economic implications.

Unit /Hour	**Course Contents**	**Mapping with CLO**
I/5	Introduction, Classification and Types of Geothermal Energy Resources; Historical Background of Geothermal Energy Resources	**CLO1**
II/5	Important aspects of Geothermal Energy (GTE), Applications, Geothermal Energy Resources, Origin of Geothermal Thermal Resources,	**CLO1**
III/5	Geothermal Thermal Gradients, Non-uniform Geothermal Thermal Gradients, HydroGeothermal Resources	**CLO2**
IV/10	Vapor dominated GTEP Plant (Steam), Liquid dominated GTEP Plant (Hot Water),	**CLO1**
V/5	Liquid dominated Flashed Steam GTEP Plant, Scope for Geothermal Energy systems in India; Geothermal Drilling Technology and Costs	**CLO2**

Text / Reference Books

1. G D Rai, Non Conventional Energy Sources, Khanna Publishers, New Delhi.
2. The Future of Geothermal Energy Impact of Enhanced Geothermal Systems (EGS) on the United States in the 21st Century November 2006
3. K. C. Lee (1996) CLASSIFICATION OF GEOTHERMAL RESOURCES - AN ENGINEERING APPROACH
4. European Geothermal Energy Council (EGEC), http://www.egec.org/
5. Geo-Heat Center (GHC), http://geoheat.oit.edu/
6. Geothermal Education Office (GEO), http://geothermal.marin.org/
7. Geothermal Engineering Integrating Mitigation of Induced Seismicity in Reservoirs (GEISER), http://www.geiser-fp7.eu/default. aspx
8. Geothermal Resource Association (GEA),http://www.geo-energy.org/
9. Geothermal Resource Council (GRC) and its annual conference in particular, http://www.geothermal.org/ I
10. nternational Energy Agency's Geothermal Implementing Agreement (IEA GIA), http://www.iea-gia.org/ International Geothermal Association (IGA) and its World Geothermal Congress (WGC) (a) , http://www.geothermal-energy.org/

Course Code: **GL 666E: Medical Geology**

GL 666E; Major Elective; 2 Credit; 50 Marks
Course Title: GLE 103: Medical Geology
Type: Core and Skill based

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to:

CLO1	Acquainted with the history and Development of Medical Geology and geochemical classification of elements and relation of Medical Geology from Public Health and Environmental Medicine.
CLO2	Familiar with the natural contaminants in the environment and also describes the importance of geology in understanding human health.
CLO 3	Study the desirable and permissible limit of major, minor and trace elements in the geological environment
CLO 4	Understand the significance of contaminants, pollutants and toxicants in altering the natural geochemical systems.
CLO5	Understand the pathways and exposures of natural as well as anthropogenic contaminants through air, water and soil media.
CLO6	Know the techniques and tools used in mapping geological factors detrimental to human health using geospatial tools and various medical tools.

Unit/Hour	**Course Contents**	**Mapping with CLO**
I/8	Introduction to Medical Geology and its development. Geochemical Classification of the elements in the periodic table and their concentrations with desirable and permissible limits prescribed by BIS and WHO. **Learning Activities:** With the help of diagrams and maps published in reference books and journal articles in the form of PPT, medical geology will be understood. Assignment and student seminar on related topics.	CLO 1 CLO 2 CLO 3
II/7	The pathways and exposure of human health to volcanic Emissions, Radon in Air and Water, Arsenic, and Fluoride in Groundwater will be studied. The bioavailability of elements in soil, selenium deficiency and its toxicity in the Environment will be explained. The hardness of water and its ill effect will be understood. **Learning Activities:** Collection of available and analyzed (rock and water) data will be helpful in understanding the sources of contaminants.	CLO 4 CLO 5
III/8	Anthropogenic Sources of contaminants and their uptake from a Biological Point of View can be studied. The biological Functions of the various Elements, along with geological impacts on Nutrition will be studied. **Learning Activities:** Available print literature with numerous case studies will be useful in this	CLO 4 CLO 5

IV/7	Techniques and tools in understanding the effect of contaminants on human health will be deduced using study of mineralogy of bone, inorganic and organic geochemistry techniques with the help of RS-GIS techniques. **Learning Activities:** Use of case studies along with geospatial techniques can be use in demarcation of highly contaminated zones and its effect on human health.	CLO 6

Suggested Readings:

1. Miomir M. Komatina, Effects Of Geological Environments On Human Health, Burgess Publishers - 2004
2. Olle Selinus, B. J. Alloway, Essentials of medical geology: impacts of the natural environment on public health, Lewis Publishers, USA - 2005
3. C. B. Dissanayake, Rohana Chandrajith, Introduction to Medical Geology, Lewis Publishers, USA - 2009
4. Rolf O. Hallberg, Medical geology , Environmental geology – Burgess Publishers, 2007
5. Miomir Komatina, Base of medical geology , Lewis Publishers, 2007

List of Journals:

1. Environment, Development and Sustainability, Springer.
2. Environmental Earth Sciences, Springer
3. HydroResearch, Elsevier.
3. Modeling Earth Systems and Environment, Springer.
4. Arabian Journal of Geosciences, Springer.

Course Title: GL667E**: Geotechnical Studies**

Type: Core and Skill based

Course Learning Outcomes (CLO):

CLO1	List Soil types, Rock types, hydrogeological properties and factors responsible for slope stability. Gain knowledge of application-based techniques for stress and strain analysis.
CLO2	Understanding the concepts of various geotechnical tests, site investigation techniques to understand its implications for engineering design.
CLO3	Calculate porosity and permeability of rock formation. Operate core drilling machine. Use of field and laboratory test data.
CLO 4	Learn techniques to categorize different types of slopes, rock and soil properties and analyze the data. Adopt case studies of the given data sets for comparison.
CLO 5	Assess the collected, derived and analyzed data and recommend suitable geotechnical investigation sites.
CLO 6	Generate (interpretation, writing, compilation and presentation) a detailed report based on the above knowledge.

Unit/Hour	Course Contents	Mapping with CLO
I/10	Overview of geotechnical investigation methods and techniques. Role of geotechnical surveys in engineering projects. Behavior of different rock types in response to different stress and strain conditions. Shear strength testing. Orientation of the discontinuities and identification of different tectonites. Field based structural and kinematic analysis of rock and soil slopes. Slope failure investigations. Application of Mohr Circle methods. Plain strain analysis. Methods of Structural mapping.	1, 2, 3
II/10	Study of geotechnical properties of soils and the methods of soil investigations. Rock testing: Mechanical test, Chemical test, Durability test; Aggregate resource development; Requirement of primary fragmentation. Petrography and sensu-stricto classification rocks and minerals. Surveys related to quality assessment of rocks, minerals and water in urban areas.	1, 3, 5, 6
III/10	Hydrogeological surveys for tunnels and underground structures. Geophysical surveys for deciphering subsurface strata and study other parameters for understanding the groundwater behavior. Consolidation and permeability tests for structure stability evaluation. Application of statistical tools in geotechnical evaluation.	1, 2, 4

Reference Books:

1.Das, B.M. 2020. Advanced Soil Mechanics. CRC Press, 5th edition. ISBN-10: 0367730103

2.Adeyeri, Joseph, B. 2014. Technology and Practice in Geotechnical Engineering. IGI Global Publisher, 1st edition. ISBN-10: 146666505X

3.Gulhati and Datta. 2017. Geotechnical Engineering (Civil Engineering Series). Mc Graw Hill India. First Edition. ISBN:-10: 9780070588295.

4.Zhang, Ke. 2021. Failure Mechanism and Stability Analysis of Rock Slop: New Insight and Methods. 1st Edition. Springer. ISBN-10: 9811557454.

5.V. N. S. Murthy 2010. Geotechnical Engineering: Soil and Foundation Principles and Practice. Publisher: MARCEL DEKKER, ISBN-10: 0824708733

6.R. B. Peck, E. E. Hanson, and T. H. Thornburn 2002. Site Investigation Publisher: J W and Sons.

7.Roy E. Hunt 2005. Geotechnical Engineering Investigation Handbook. Publisher: CRC Press Inc; 2nd edition (12 April 2005)

8. William Powrie. Soil Mechanics: Concepts and Applications Publisher: CRC Press Inc; 3rd edition (17 December 2013)
9. Braja M. Das and Nagaratnam Sivakugan. Introduction to Geotechnical Engineering: An Essentials Approach. Publisher: Cl-Engineering; 2nd edition (1 January 2015)

List of Journals:

1. Journal of Rock Mechanics and Geotechnical Engineering. Elsevier.
2. Journal of Geodynamics, Elsevier
3. Geotechnical and Geological Engineering. Springer
4. Journal of Geotechnical and Geo-environmental Engineering. ASCE Library.

Semester IV GL 681D Research Project/Dissertation, 6 Credits

Field studies, Laboratory studies / data processing, reference work and presentation of the thesis are four major components of the course. Students opting for this course should adhere to the following procedure.

1. Precise title and outline of work is to be submitted to the Head of the Department.
2. The student shall spend about one week in the field.
3. The field work shall be carried out only during vacation or holidays, and in no case student will be permitted to be absent from regular teaching on account of dissertation.
4. The student shall maintain field diaries and other record relevant to dissertation.
5. Every month the student shall submit the progress report and laboratory work done, through the supervisor to Head of the Department.
6. The student shall do dissertation at his own cost. The department will not spare funds for this purpose.
7. The student shall give a seminar before the submission of the dissertation.
8. The student shall submit the dissertation before the commencement of practical examination.
9. The supervisor shall submit the practical sets based on topic of dissertation develop for the students to Head of the Department prior to the commencement of practical examination.
10. Non-compliance of any of the above rules will disqualify students for grant of terms.

Three copies neatly typed on thesis size paper, well bound together with maps and illustrations of the Dissertation, on the basis of the work carried out by the student, will be submitted, through the supervisor concerned, to the Head of the Department of Geology, before the commencement of the practical examination, for being forwarded to the Board of Examiners.

In case of student receiving help (training and / or participation in ongoing research activities) from other Institution / Organization for their dissertation work, the associated scientist from that Institute / Organization will function as co-supervisor.

Assessment of Dissertation will be out of 100 marks and shall include a viva-voce examination carrying 20 marks. The Dissertation will be examined at the time of the practical examination at the end of IVth Semester, by the board of examiners. The board of examiners consist of supervisor, Head of the Department and one teaching faculty member appointed by Head of Department in consultation with the supervisor.

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