Course Structure and Detailed Syllabus

M.Sc. Applied Geology

(Choice Based Credit System)

Effective from 2020-21

Rajiv Gandhi University

Rono Hills, Doimukh

Arunachal Pradesh - 791112

Brief Profile of the University

Rajiv Gandhi University (formerly Arunachal University) is the premier institution of higher education in the state of Arunachal Pradesh completing thirty-two years of its existence. Late Smt. Indira Gandhi, the then Prime Minister of India, laid the foundation stone of the University on 4th February 1984. Subsequently, it started its postgraduate teaching from the academic session 1988-89 at Rono Hills, where the present campus is located. The University was converted into a Central University by Act of Parliament of India which came into force from 9th April 2007 as per a notification of Ministry of Human Resource Development (MHRD), Government of India. The affiliating jurisdiction of the University encompasses all the existing colleges in the state of Arunachal Pradesh. The campus at Rono Hills is nestled on a picturesque tableland in the outskirts of Itanagar, the capital of Arunachal Pradesh. It is at a distance of 7 km from the National Highway (NH-415) which leads to Itanagar.

The University has been striving to maintain high standards both in teaching and research in order to achieve excellence. Years of concerted efforts of the University have shown the signs of qualitative as well as quantitative progress. The research activities of the University are being strengthened by increasing the number of registered Ph.D. scholars and also by taking up many research projects funded by external agencies. The total number of published books and research articles has shown a significant rise. The University has been organizing a number of conferences, seminars, symposia and workshops in order to generate disseminate and upgrade knowledge on various key issues.

About the Department

The Department of Geology has started its journey in 2017 with recruitment of two Assistant Professors and enrolment of 18 (eighteen) students to B.Sc. (Hons.) Geology programme in the session 2017-18. Being located at the foothills of eastern part of the Himalaya, the department has a brighter vision to engage the students in academic and research activities to better understand various aspects of geology of the eastern Himalaya and of the NE India.

Arunachal Pradesh is the largest state in NE India with availability of natural laboratory for geoscientists in the form of rock exposures to unravel the surface and subsurface geological processes. Large part of the state is still geologically unexplored while the state has a large potential for natural resources in term of mineral wealth, coal, hydrocarbon etc. besides huge potential for hydropower. Since the state lacks any institution offering higher education in geoscience, even at undergraduate level, this department was established as a consequence to the recommendation and suggestion made during the 19th convention of 'Indian Geological Congress' held in November, 2014 in Rajiv Gandhi University.

Initially the department started offering three-year undergraduate programme (B.Sc.) with honours in Geology and subsequently postgraduate (M.Sc.) and Ph.D. programmes were started from session 2020-21. The curricula are designed in such a way to lay strong foundation in theoretical, practical and field knowledge for the students. Besides, the department is also committed to play a pivotal role for high quality research in different geoscientific aspects of Eastern Himalaya.

About the Programme

A postgraduate degree in any branch of Earth Science is indispensable for a career in the field of Geoscience, be it in government sector, public sector or private sector industries or even in research institutes. This Programme (**M.Sc. Applied Geology**) has been designed in compliance with the '***Choice Based Credit System***' as per the guidelines of University Grant Commission and keeping in view the modern development of the subject in national and international level with an emphasis on regional context.

This is a four semester (two year) full-time programme consisting of ***Core Courses***, ***Departmental Elective Courses*** and ***Open Elective Courses***. The core courses are compulsory for all the students, which, depending on the requirement, has been categorised into: classroom based theory component, laboratory based practical component and field based study (fieldwork). The students will have the liberty to choose different courses of their choice from a pool of Departmental Elective Courses in third and fourth semester. Besides these, the Open Elective Course is offered for the students of other departments of the university. In order to fulfil the requirement of the programme the students have to opt for an open elective course offered by other departments. Each student must complete at least one SWAYAM course of 4 Credit either in second semester and/or in third semester. The SWAYAM course may be opted as an Open Elective Course in third semester. The students are required to submit the SWAYAM course completion certificate before fourth semester final examination.

Course Coding

Each course offered by the department is designated by a three-letter alphabetical course followed by a hyphen and three-digit numerical code (followed by one letter alphabetical code in case of elective papers). The first two letters (**GL**) represent the departmental code which is followed by **C**, **E** or **O**. **C** represents Core Course, **E** represents Departmental Elective Course and **O** represents Open Elective Course. Three-digit numerical code represent the year number, semester number and the course number in that semester respectively. For departmental elective and open elective courses, the numerical code is followed by either A, B, C, or D which represents the option to be chosen by a student from the pool of elective courses offered.

Choice Based Credit System (CBCS) and Letter Grades

The CBCS flexibilities in which the students have a choice of pursuing courses of their area interest in the form of electives. It also provides flexibility in designing curriculum and assigning credits, based on the course content and hours of teaching. ***Credit*** is the unit by which the course work is measured. It determines the number of hours of instructions required per week. One credit is equivalent to one hour of teaching (lecture or tutorial) or two hours of practical work/field work per week. ***Credit point*** is the product of grade point and number of credits for a course and ***grade point*** is a numerical weight allotted to each letter grade on a 10-point scale. ***Semester Grade Point Average*** is a measure of performance of work done by a student in a semester. ***Cumulative Grade Point Average*** is a measure of overall cumulative performance of a student over all semesters. The Choice Based Credit System (CBCS) in all postgraduate degree, diploma and certificate programmes shall be guided by the regulations to this effect by Academic Council from time to time.

Course Structure for M.Sc. Applied Geology

Course Code	Course Title	Teaching hours/week (L + T + P)	Credit#
First Semester			
GLC- 411	Crystallography and Mineralogy	3 + 1 + 0	4
GLC- 412	Structural Geology and Tectonics	3 + 1 + 0	4
GLC-413	Geomorphology and Quaternary Geology	3 + 1 + 0	4
GLC-414	Geochemistry	3 + 1 + 0	4
GLC-415	Practical 1: Crystallography, Mineralogy and Geochemistry	0 + 0 + 6	3
GLC-416	Practical 2: Geomorphology, Structural Geology and Surveying	0 + 0 + 6	3
			22
Second Semester			
GLC-421	Igneous and Metamorphic Petrology	3 + 1 + 0	4
GLC-422	Sedimentology and Principles of Stratigraphy	3 + 1 + 0	4
GLC-423	Palaeontology	3 + 1 + 0	4
GLC-424	Practical 3: Igneous and Metamorphic Petrology	0 + 0 + 6	3
GLC-425	Practical 4: Sedimentology, Stratigraphy and Palaeontology	0 + 0 + 6	3
GLC-426	Fieldwork 1	--	3
			21
Third Semester			
GLC-531	Indian Stratigraphy	3 + 1 + 0	4
GLC-532	Economic Geology	3 + 1 + 0	4
GLC-533	Geoexploration, Mining and Environmental Geology	3 + 1 + 0	4
GLC-534	Practical 5: Economic Geology and Geoexploration	0 + 0 + 6	3
GLE-535	Departmental Elective 1	--	4
GLO-536	Open Elective/SWAYAM Course	--	4
			23
Fourth Semester			
GLC-541	Engineering Geology and Hydrogeology	3 + 1 + 0	4
GLC-542	Practical 6: Engineering Geology and Hydrogeology	0 + 0 + 6	3
GLC-543	Fieldwork 2	--	3
GLE-544	Departmental Elective 2	--	4
GLE-545	Departmental Elective 3	--	4
GLE-546	Departmental Elective 4: Project Oriented Dissertation	--	6
			24
Total Credit			**90**

Departmental Elective Courses**			
GLE-535A	Remote Sensing and GIS	3 + 0 + 2	4
GLE-535B	Exploration Geophysics	3 + 1 + 0	4
GLE-535C	Geodesy, Surveying and Mapping	3 + 1 + 0	4
GLE-535D	Summer Internship	--	4
GLE-544A	Himalayan Geology	3 + 1 + 0	4
GLE-544B	Isotope Geology	3 + 1 + 0	4
GLE-544C	Statistics and Data Analysis in Geology	3 + 1 + 0	4
GLE-544D	Advanced Hydrogeology	3 + 1 + 0	4
GLE-544E	Basin Analysis	3 + 1 + 0	4
GLE-545A	Fuel Geology	3 + 1 + 0	4
GLE-545B	Atmospheric Science	3 + 1 + 0	4
GLE-545C	Marine Science	3 + 1 + 0	4
GLE-545D	Computer Application in Geology and Numerical Modelling	3 + 1 + 0	4
GLE-545E	Glacial Geology	3 + 1 + 0	4

Open Elective Courses**			
GLO-536A	Earth System Science	3 + 1 + 0	4
GLO-536B	Natural Hazard and Disaster Management	3 + 1 + 0	4
GLO-536C	Fundamentals of Remote Sensing	3 + 1 + 0	4

* Internal assessment of theory courses will be based on continuous evaluation through periodic internal/sessional tests, assignments and classroom seminar presentations. Internal assessment of practical courses will be based on performance during practical hours and internal/sessional practical tests.

** Offering numbers of elective courses in a semester shall be decided by the department at the beginning of the semester.

Teaching hours per credit per week: 1 hour for theory and 2 hours for practical courses.

GLC-411

Crystallography and Mineralogy

Total Credit: 4

Total Marks: 100

(Internal Assessment: 20, End-semester Examination: 80)

Objective

The main objective of the course is to introduce the students to the basics of crystallography and crystal chemistry; physical characteristics and chemistry of major rock forming minerals, and optical properties of different minerals and their identification.

Course Outcome

On completion of the course the students shall have the basic understanding of fundamentals of crystallography and crystal chemistry, various analytical methods, various characteristics of important rock-forming minerals and optical properties of mineral thin section in petrographic microscope.

Unit 1: Crystals and their symmetry elements; point groups, space groups and Bravais lattices; crystal chemistry; Pauling's rules; crystal structure; compositional variation in minerals; crystal defects.

Unit 2: Fundamentals of techniques in identifying mineral phases and mineral chemical composition; x-ray crystallography; electron microscopy; chemical analysis of minerals; recalculation of mineral chemical composition.

Unit 3: Descriptive mineralogy: structure, chemistry, paragenesis and economic significance of important rock forming minerals belonging to silicates, carbonates, oxides and sulphides.

Unit 4: Optical characteristics of isotropic and anisotropic minerals; colour and pleochroism; refractometry; optical indicatrix; interference phenomena; extinction angle and sign of elongation; interference figure and optic sign.

GLC-411

Crystallography and Mineralogy

Recommended Books

Text Books:

1. **An Introduction to Rock Forming Minerals** - W. A. Deer, R. A. Howie and J. Zussman, *The Mineralogical Society*
2. **Introduction to Mineralogy** - William D. Nesse, *Oxford University Press*
3. **Introduction to Optical Mineralogy** - William D. Nesse, *Oxford University Press*
4. **Mineralogy** - Dexter Perkins, *Pearson India*
5. **Mineralogy** - L. G. Berry, B. Mason and R. V. Deitrich, *CBS Publishers*
6. **Optical Mineralogy -** P. F Kerr, *CBS Publishers*
7. **Optical Mineralogy** - Pramod K. Verma, *CRC Press*
8. **Practical approach to Crystallography and Mineralogy** - R. N. Hota, *CBS Publishers*
9. **The Manual of Mineral Science** - Cornelis Klein and Barbara Dutrow, *Wiley India Pvt. Ltd*

Reference Books:

1. **Dana's Text Book of Mineralogy** - W. E. Ford, *CBS Publishers*
2. **Rutley's Elements of Mineralogy** - C.D. Gribble, *CBS Publishers*
3. **A Key for Identification of Rock-forming Minerals in Thin Section** - Andrew J. Barker, *CRC Press*
4. **A Practical Introduction to Optical Mineralogy** - C. D. Gribble and A. J. Hall, *Springer*
5. **Atlas of Rock-Forming Minerals in Thin Section** - W. S. MacKenzie and C. Guilford, *Routledge*
6. **Rock Forming Minerals, Volume 1A: Orthosilicates** - W. A. Deer, R. A. Howie and J. Zussman, *The Geological Society of London*
7. **Rock Forming Minerals, Volume 1B: Disilicates & Ring Silicates** - W. A. Deer, R. A. Howie and J. Zussman, *The Geological Society of London*
8. **Rock Forming Minerals, Volume 2A: Single-Chain Silicates** - W. A. Deer, R. A. Howie and J. Zussman, *The Geological Society of London*
9. **Rock Forming Minerals, Volume 2B: Double-Chain Silicates** - W. A. Deer, R. A. Howie and J. Zussman, *The Geological Society of London*
10. **Rock Forming Minerals, Volume 3A: Micas** - W. A. Deer, R. A. Howie and J. Zussman, *The Geological Society of London*
11. **Rock-Forming Minerals, Volume 3B: Layered Silicates (Excluding Micas and Clay Minerals)** - W. A. Deer, R. A. Howie and J. Zussman, *The Geological Society of London*
12. **Rock-Forming Minerals, Volume 3C: Sheet Silicates (Clay Minerals)** - W. A. Deer, R. A. Howie and J. Zussman, *The Geological Society of London*
13. **Rock Forming Minerals, Volume 4A: Framework Silicates (Feldspars)** - W. A. Deer, R. A. Howie and J. Zussman, *The Geological Society of London*
14. **Rock Forming Minerals, Volume 4B: Framework Silicates (Silica Minerals, Feldspathoids and the Zeolites)** - W. A. Deer, R. A. Howie and J. Zussman, *The Geological Society of London*
15. **Rock-Forming Minerals, Volume 5A: Non-Silicates (Oxides, Hydroxides and Sulphides)** - W. A. Deer, R. A. Howie and J. Zussman, *The Geological Society of London*
16. **Rock Forming Minerals, Volume 5B: Non-Silicates (Sulphates, Carbonates, Phosphates and Halides)** - W. A. Deer, R. A. Howie and J. Zussman, *The Geological Society of London*
17. **Rocks and Minerals in Thin Section -** W. S. MacKenzie, A. E. Adams andK.H. Brodie , *CRC Press*

GLC-412

Structural Geology and Tectonics

Total Credit: 4

Total Marks: 100

(Internal Assessment: 20, End-semester Examination: 80)

Objectives

The main objective of this course is to introduce the students to rock deformation mechanisms and their interpretation. This will also enable the students to understand different brittle and ductile deformation structures, their genesis, identification and interpretation. Also, this course will introduce the students to the plate tectonics and the tectonic setup of different types of plate boundaries.

Course Outcome

After completing this course, the students will have the basic understanding of stress and strain, behaviour of rocks under stress, different types of structures, their geological significance and deformation history. The students will also be able to understand plate tectonic process and their effects associated with different types of plate boundaries.

Unit 1: Classification of geologic structures; primary structures; microstructures; force and stress: two-dimensional stress and three-dimensional stress; principal planes and principal stresses; Mohr diagram for stress; mean and deviation stress; stress tensor; deformation and strain: homogeneous and inhomogeneous deformation, strain path, strain quantities; rheology: strain rate, the creep curve, behaviour of rocks under stress.

Unit 2: Brittle deformation; joints: surface morphology and arrays, origin and interpretation of joints; veins and vein arrays; lineaments; faults and faulting: fault geometry and displacement, mechanism of faulting, recognizing and interpreting faults, relation of faulting to stress, fault systems: geometrical classification.

Unit 3: Ductile deformation processes; folds and folding: anatomy of a folded surface, fold classification and geometry, superposed folding, mechanics of folding; foliations: geometry and relationship with folds and fault zones; lineation: categories and tectonic interpretation; shear zones: nature and types, shear zone rocks, shear-sense indicators, strain in shear zones, shear zone development; boudinage.

Unit 4: Plate tectonics: theory and mechanism; convergence tectonics: subduction and collision, fold-thrust belts; extensional tectonics: rifting and seafloor spreading, transform faults and mid-oceanic ridges; strike-slip tectonics.

GLC-412

Structural Geology and Tectonics

Recommended Books

Text Books:

1. **An Introduction to Structural Geology -** A. K. Jain, *Geological Society of India*
2. **Earth structure: An Introduction to Structural Geology and Tectonics** - B. A. van derPluijm and S. Marshak, *W. W. Norton & Company*
3. **Global Tectonics** -P. Kearey, K. A. Klepeis and F. J. Vine, *Wiley-Blackwell*
4. **Plate Tectonics and Crustal Evolution**- Kent C. Condie, *Butterworth-Heinemann*
5. **Structural Geology** - H. Fossen*, Cambridge University Press*
6. **Structural Geology** - R. J. Twiss and E. M. Moors, *W. H. Freeman & Co.*
7. **Structural Geology of Rocks and Regions** - G. H. Davis, S. J. Reynolds and C. Kluth, *Wiley*
8. **Structural Geology: Fundamentals and Modern Developments -** S. K. Ghosh, *Pergamon Press*

Reference Books:

1. **Atlas of Structural Geology** - Soumyajit Mukherjee, *Elsevier*.
2. **Basic methods of structural geology** - S. Marshak and G. Mitra, *Prentice Hall*
3. **Evolution of Geological Structures in Micro- to Macro-scales** - Sudipta Sengupta*, Springer*
4. **Folding and Fracturing of Rocks** - John G. Ramsay, *McGraw Hills Book Company*
5. **Plate Tectonics: A Comprehensive Introduction** - F. Morrison, *Larsen and Keller Education*
6. **Plate Tectonics: Continental Drift and Mountain Building** - W. Frisch, M. Meschede and R. Blakey, *Springer*
7. **Structural Geology: An Introduction to Geometrical Techniques** - D. M. Ragan, *Cambridge University Press*
8. **Structural Geology: The Mechanics of Deforming Metamorphic Rocks** - Bruce E. Hobbs and Alison Ord, *Elsevier*
9. **Tectonics** - E. M. Moors and R. J. Twiss, *Waveland Press, Inc.*
10. **Tectonics and Structural Geology: Indian Context** - Soumyajit Mukherjee, *Springer*
11. **The Techniques of Modern Structural Geology Vol. 1: Strain Analysis** - J. G. Ramsay and M. I. Huber, *Elsevier.*
12. **The Techniques of Modern Structural Geology Vol. 2: Folds and Fractures** - J. G. Ramsay and M. I. Huber, *Elsevier*.
13. **The Techniques of Modern Structural Geology Vol. 3: Applications of Continuum Mechanics in Structural Geology** -J. G. Ramsay and Richard Lisle, *Elsevier.*

GLC-413

Geomorphology and Quaternary Geology

Total Credit: 4

Total Marks: 100

(Internal Assessment: 20, End-semester Examination: 80)

Objective

The main objective of this course is to introduce students to the basic concepts of landforms and the processes that produce and modify them. The course is aimed to enable the students to understand different geomorphic processes and the landforms produced as a result of their interaction with the existing earth surface features. It is also aimed to introduce the students about basic concepts of Quaternary Geology.

Course Outcome

On completion of this course the students will be able to systematically study different landform features and analyse these to identify geomorphic processes responsible for their development and modifications. They will also be able to interpret the age of different landforms through different dating techniques.

Unit 1: Principles of geomorphology; landscape development and modification; scale of landscape analysis; energy flow in geomorphic system; weathering and soil formation; hillslopes and hillslope processes; mass wasting.

Unit 2: Fluvial geomorphic system; hydraulic geometry; fluvial processes; drainage basin development and morphometry; channel pattern; floodplain, alluvial fan and delta: classification, morphology and processes; fluvial response to active tectonics and climate change.

Unit 3: Aeolian processes and landforms; glaciers and glacial landforms; coastal geomorphology: relative movement of land and sea, waves, coastal processes and landforms; tectonic geomorphology and geomorphic markers; geomorphic indices and active tectonics.

Unit 4: Subdivisions of Quaternary Period; Anthropocene; Quaternary boundary problems; Earth's climate and climate change during Quaternary period; Quaternary dating techniques; Quaternary sedimentary records from India.

GLC-413

Geomorphology and Quaternary Geology

Recommended Books

Text Books:

1. **Active Tectonics: Earthquakes, Uplift and Landscape -** Edward A. Keller and Nicholas Pinter, *Prentice Hall*
2. **Fundamentals of Geomorphology** - Richard John Huggett, *Routledge*
3. **Geomorphology** - Mateo Gutiérrez, *CRC Press*
4. **Geomorphology: A systematic Analysis of Late Cenozoic Landforms** - A. L. Bloom, *Pearson*
5. **Geomorphology: The Mechanics and Chemistry of Landscapes** - R. S. Anderson and S. P. Anderson, *Cambridge University Press*
6. **Principles of Quaternary Geology and Environmental Study** - A. B. Goswami, *Books Way, Kolkata*
7. **Tectonic Geomorphology** - D. W. Burbank and R. S. Anderson**,** *Wiley-Blackwell*
8. **Understanding Earth** - J. Grotzinger, T. Jordan, F. Press and R. Siever, *W. H. Freeman & Co.*

Reference Books:

1. **Aeolian Geomorphology: A New Introduction** - Ian Livingstone and Andrew Warren, *Wiley-Blackwell*
2. **An Introduction to Coastal Processes and Geomorphology -** Robin Davidson-Arnott, *Cambridge University Press*
3. **Arid and Semi-Arid Geomorphology** - Andrew S. Goudie, *Cambridge University Press*
4. **Coastal Geomorphology: An Introduction**- Eric Bird, *John Wiley & Sons Ltd*
5. **Earth**: **An introduction to Physical Geology** - E. J. Tarbuck, F. K. Lutgens and D. Tasa, *Pearson*
6. **Earth's Climate: Past and Future** - William F. Ruddiman, *W. H. Freeman and Company*
7. **Encyclopedia of Geomorphology -** A. S. Goudie, *Routledge*
8. **Fundamentals of Fluvial Geomorphology -** Ro Charlton, *Routledge*
9. **Introduction to Process Geomorphology** - Vijay K. Sharma, *CRC Press*
10. **Key Concepts in Geomorphology** - Paul R. Bierman and David R. Montgomery, *W. H. Freeman & Co.*
11. **Physical Geology** - C. C. Plummer, D. H. Carlson and L. Hammersle, *McGraw Hill*
12. **Quaternary Dating Methods -** Mike Walker, *Wiley*
13. **Quaternary Geology: Indian Perspective** - U. B. Mathur, *Geological Society of India*
14. **River Dynamics: Geomorphology to Support Management** - Bruce L. Rhoads, *Cambridge University Press*
15. **River Morphology** - R. J. Garde, *New Age International (P) Limited, Publishers*
16. **River Processes: An Introduction to Fluvial Dynamics** - André Robert, *Arnold*
17. **River Variability and Complexity** - Stanley A. Schumm, *Cambridge University Press*
18. **Rivers in the Landscape** - Ellen Wohl, *Wiley-Blackwell*
19. **Tectonically Active Landscapes** - William B. Bull, *Wiley-Blackwell*
20. **The SAGE Handbook of Geomorphology** - Kenneth J. Gregory and Andrew S Goudie, *SAGE Publications Ltd*
21. **Treatise on Geomorphology -** John F. Shroder, Vols. 1- 14, *Academic Press*

GLC-414

Geochemistry

Total Credit: 4

Total Marks: 100

(Internal Assessment: 20, End-semester Examination: 80)

Objective

The important objectives of the course are to introduce the students to fundamental principles of geochemistry, analytical techniques used in geochemical studies, and geochemical nature of various reservoirs of the Earth. The course also aims to introduce basic principles of isotope geology and its applications in geochemistry as well as in various branches of geosciences.

Course Outcome

Upon the completion of the course, the students would be expected to have a good knowledge about basic principles of geochemistry and its applications in various branches of geosciences. They will also have fair knowledge about geochemical nature of the Earth and its different reservoirs as well as basic principles of isotope geology and its applications in geosciences.

Unit 1: Introduction to geochemistry and its applications in Earth Sciences; internal structure of atoms; ionization energy; electronegativity; elements in the Solar System; chemical evolution of the Earth; major and minor elements; distribution coefficients; applications of trace elements in geochemistry; sampling techniques for geochemical analyses.

Unit 2: Different reservoirs of the Earth and their composition; mass conservation and element fractionation; element transport - advection, diffusion, reaction rates and adsorption; mixing and dilution.

Unit 3: Composition of the Earth's crust; chemistry of surface water and groundwater; chemistry of the atmosphere; global biogeochemical cycles - interaction of geosphere-hydrosphere-atmosphere-biosphere; chemical weathering; use of variation diagrams.

Unit 4: Principles of radioactivity; radiogenic and stable isotopes; applications of radiogenic and stable isotopes to geochemistry; introduction to cosmogenic radionuclides.

GLC-414

Geochemistry

Recommended Books

Text Books:

1. **Geochemistry: An Introduction -** Francis Albarede, *Cambridge University Press*
2. **Principles and Applications of Geochemistry: A Comprehensive Textbook for Geology Students** - Gunter Faure, *Prentice Hall*
3. **Introduction to Geochemistry: Principles and Applications** - Kula C. Misra, *Wiley-Blackwell*
4. **Geochemistry** - William M. White, *Wiley-Blackwell*
5. **Isotope Geochemistry** - William M. White, *Wiley-Blackwell*
6. **Isotopes: Principles and Applications** - Gunter Faure and Teresa M. Mensing, *John Wiley*

Reference Books:

1. **Treatise on Geochemistry (Vol-I): Meteorites, Comets and Planets** - H.D. Holland and K.K. Turekian, *Elsevier*
2. **Radiogenic Isotope Geology** - Alan P. Dickin, *Cambridge University Press*
3. **Essentials of Geochemistry** - John V. Walther, *Jones and Bartlett Publishers*
4. **Geochemistry: Pathways and Processes** - Harry Mcsween, Sterven M Ricardson and Maria Uhle, *Columbia University Press*
5. **Inorganic Geochemistry** - Paul Henderson, *Pergamon Press*
6. **Radiogenic Isotope Geochemistry: A Guide for Industry Professionals** - Bruce F. Schaefer, *Cambridge University Press*

GLC-415

Practical 1: Crystallography, Mineralogy and Geochemistry

Total Credit: 3

Total Marks: 100

(Internal Assessment: 20, End-semester Examination: 80)

Objective

The main objective of this course is to introduce the students to different laboratory techniques pertaining to the crystals, mineral hand specimens and mineral thin section as well as analytical techniques. The course is also aimed to teach basic geochemical analyses and interpretation of major and trace element data.

Course Outcome

After completion of the course the students should be able to study and analyse different minerals based on their physical, chemical and optical characteristics. They will also be able to learn geochemical analytical techniques and interpretation of data.

Crystallography

1. Stereographic projection of holohedral classes of different crystal systems
2. Calculation of axial ratio
3. Calculation of cell parameters using XRD data

Mineralogy

1. Study of minerals in hand specimen and under polarizing microscope
2. Determination of refractive index, pleochroic scheme, order of interference colour and optic sign
3. Determination of plagioclase compositions using Michel-Levy method
4. Recalculation of mineral formula using mineral chemical composition

Geochemistry

1. Determination of Loss on Ignition (LOI) of rock samples
2. Plotting of major element data in Harker diagrams
3. Plotting of trace element data in multi-element diagrams

Practical records

Viva-voce

Practical 1: Crystallography, Mineralogy and Geochemistry

Recommended Books

Text Books:

1. **A Key for Identification of Rock-forming Minerals in Thin Section** - Andrew J. Barker, *CRC Press*
2. **A Practical Introduction to Optical Mineralogy** - C. D. Gribble and A. J. Hall, Springer
3. **Atlas of Rock-Forming Minerals in Thin Section** - W. S. MacKenzie and C. Guilford, *Routledge*
4. **Laboratory Manual of Geology** - A. K. Sen, *Modern Book Agency, Kolkata*
5. **Practical approach to Crystallography and Mineralogy -** R. N. Hota, *CBS Publishers*
6. **Rock-forming Minerals in Thin Section** - H. Pichler, C. Schmitt-Riegraf and L. Hoke, *Chapman &. Hall*
7. **Rocks and Minerals in Thin Section -** W. S. MacKenzie, A. E. Adams andK.H. Brodie , *CRC Press*
8. **Using Geochemical Data: Evaluation, Presentation, Interpretation** - H.G. Rollinson, *Routledge*

GLC-416

Practical 2: Geomorphology, Structural Geology and Surveying

Total Credit: 3

Total Marks: 100

(Internal Assessment: 20, End-semester Examination: 80)

Objective

The main objective of this course is to introduce the students to different landform features and their analysis to interpret the genesis and tectonic evolution. The course is also aimed to acquaint the students about different field and laboratory techniques related to structural geology. It is also aimed to familiarize the students to different surveying techniques related to geological mapping.

Course Outcome

After completion of the course the students will be able to study and analyse different geomorphic features from topographic maps and elevation models as well as can interpret active tectonics from different data. They also will be able to study, analyse and interpret various structural features from maps, sections, photographs and field data. The students will also be able to use different surveying equipment and techniques required for geological mapping.

Geomorphology

1. Study of geomorphic models and topographic maps
2. Drainage basin morphometry
3. Longitudinal profile of rivers and SL index
4. Study of active tectonics from geomorphic indices
5. Geomorphological mapping using Remote Sensing and GIS

Structural Geology

1. Interpretation of structure from hand specimen, photograph and map
2. Preparation of cross sections representing different structural settings
3. Completion of outcrop in a map
4. Stereographic analysis of structural data
5. Construction and study of dip isogon from fold profile
6. Strain analysis of rocks using deformed objects
7. Construction of balanced cross sections

Surveying

1. Measurement of distance using various instruments and techniques
2. Measurement of horizontal and vertical angles using various instruments
3. Handling and use of Abney level and dumpy level
4. Handling and use of Theodolite and Total Station
5. Use of hand held GPS

Practical records

Viva-voce

Practical 2: Geomorphology, Structural Geology and Surveying

Recommended Books

1. **A Manual of Problems in Structural Geology** - N. W. Gokhale, *CBS Publishers*
2. **Active Tectonics: Earthquakes, Uplift and Landscape** - Edward A. Keller and Nicholas Pinter, *Prentice Hall*
3. **Atlas of Structural Geology** - Soumyajit Mukherjee, Elsevier
4. **Basic Methods of Structural Geology** - S. Marshak and G. Mitra, *Prentice Hall*
5. **Drawing Geological Structures** - Jörn H. Kruhl, *Wiley Blackwell*
6. **Geological Structures and Maps: A Practical Guide** - Richard J. Lisle, *Elsevier*
7. **Geomorphological Techniques** - Andrew Goudie, *Routledge*
8. **Introduction to Geological Maps and Structures** - John L. Roberts, *Pergamon*
9. **Laboratory Manual of Geology** - A. K. Sen, *Modern Book Agency, Kolkata*
10. **Map Interpretation for Structural Geologists** - Narayan Bose and Soumyajit Mukherjee, *Elsevier*
11. **Stereographic Projection Techniques for Geologists and Civil Engineers** - Richard J. Lisle and Peter R. Leyshon, *Cambridge University Press*
12. **Surveying (Vols. 1 & 2)** - B. C. Punmia, Ashok K. Jain and Arun K. Jain, *Laxmi Publications*
13. **Surveying (Vols. 1 & 2)** - S. K. Duggal, *McGraw Hill*
14. **The Mapping of Geological Structures** - Ken R. McClay, John Wiley and Sons
15. **Tools in Fluvial Geomorphology** - G. Mathias Kondolf and Hervé Piégay, W*iley Blackwell*

GLC-421

Igneous and Metamorphic Petrology

Total Credit: 4

Total Marks: 100

(Internal Assessment: 20, End-semester Examination: 80)

Objective

The main objective of the course is to introduce the igneous processes and rocks and how the properties of magma and magmatic processes are reflected in igneous rocks. The course is also aimed to introduce the students to metamorphic processes and rocks.

Course Outcome

On completion of the course the students will be able to understand various igneous and metamorphic processes, petrography of igneous and metamorphic rocks and applications of thermodynamics in petrology.

Unit 1: Magma - physical properties and chemical composition; magma generation, intrusion and cooling; introduction to thermodynamics - laws of thermodynamics, concept of Gibbs phase rule, phase equilibrium studies of unary, binary and ternary systems, and their petrogenetic implications.

Unit 2: Magmatic process - crystal nucleation, crystal settling, magma convection, diffusion and magma mixing, magma assimilation and assimilation and fractional crystallization (AFC); role of volatiles in magmatic systems; definition, classification, petrography, geochemistry, paragenesis, tectonic setting and economic importance of important igneous rocks.

Unit 3: Basic concepts of metamorphism; paired metamorphic belts; metamorphic reactions; phase rule and phase equilibrium studies in metamorphic rocks; petrogenetic grid and Schreinmakers' rule; construction and projection of ACF, AKF and AFM diagrams; geothermometric and geobarometric studies; P-T-time path.

Unit 4: Anatexis and origin of migmatites; charnockites; metamorphism of carbonate rocks, pelitic rocks, mafic and ultramafic rocks, and granitoid rocks.

GLC-421

Igneous and Metamorphic Petrology

Recommended Books

Text Books:

1. **Essentials of Igneous and Metamorphic Petrology** - B. R. Frost and C. D. Frost, *Cambridge University Press*
2. **Igneous and Metamorphic Petrology** - Myron G. Best, *Wiley-Blackwell*.
3. **Petrology: The study of Igneous, Sedimentary, and Metamorphic Rocks** - Loren A. Raymond, *Waveland Press Inc*
4. **Principles of Igneous and Metamorphic Petrology** - Anthony R. Philpotts and Jay J. Ague, *Cambridge University Press*
5. **Principles of Igneous and Metamorphic Petrology** - John D. Winter, *Pearson India*
6. **Petrology: Principles and Practice -** Gautam Sen, *Springer*
7. **Petrography of Igneous and Metamorphic Rocks -** Anthony R. Philpotts, *CBS Publishers*

Reference Books:

1. **Earth Materials -** Cornelis Klein and Anthony R. Philpotts, *Cambridge University Press*
2. **Petrogenesis of Metamorphic Rocks** - Kurt Bucher and Rodney Grapes, *Springer-Verlag*
3. **An Introduction to Metamorphic Petrology** - Bruce W. D. Yardley, *Longman*
4. **Igneous Rocks and Processes: A Practical Guide** - Robin Gill, *Wiley-Blackwell*
5. **Igneous Rocks: A Classification and Glossary of Terms -** R. W. Le Maitre, *Cambridge University Press*
6. **Igneous Petrogenesis: A Global Tectonic Approach -** Marjorie Wilson, *Springer*
7. **Principles of Metamorphic Petrology** - Ron H. Vernon and Geoffrey L. Clarke, *Cambridge University Press*
8. **Petrography: An Introduction to the Study of Rocks in Thin Section** - H. Williams, F. C. Turner and C. M. Gilbert, *CBS Publishers*

GLC-422

Sedimentology and Principles of Stratigraphy

Total Credit: 4

Total Marks: 100

(Internal Assessment: 20, End-semester Examination: 80)

Objective

The main objective of this course to introduce the students to different sedimentary processes and rocks, sedimentary structures and texture, sedimentary facies analysis, and principles of stratigraphy.

Course Outcome

On completion of the course the students will be able to analyse different sedimentary rocks and interpret their origin, environmental and tectonic setting as well as correlation of sedimentary sequences.

Unit 1: Production of sediment at the Earth's surface; fluid flow, entrainment and sediment transport; flow regime and bedforms; diagenesis; sedimentary environment; sedimentary structures; sedimentary textures.

Unit 2: Sandstones: composition and classification; conglomerates and breccias; mudstones and shales; provenance of siliciclastic sedimentary rocks; limestones: composition, classification and texture; other chemical and biochemical sedimentary rocks.

Unit 3: Sedimentation and plate tectonics; sedimentary basins and basin analysis; heavy mineral assemblage; palaeocurrent analysis; facies analysis and facies models.

Unit 4: Evolution of stratigraphic concept; geological time scale; code of stratigraphic nomenclature; principles and methods of correlation of stratigraphic units; types of stratigraphic units; lithostratigraphy; chronostratigraphy; biostratigraphy; sequence stratigraphy; event stratigraphy; magnetostratigraphy; chemostratigraphy.

GLC-422

Sedimentology and Principles of Stratigraphy

Recommended Books

Text Books:

1. **Applied Sedimentology** - Richard C. Selley, *Academic Press*
2. **Introduction to Sedimentology**- S. M. Sengupta, *CBS Publishers*
3. **Principles of Sedimentology and Stratigraphy**- S. Boggs Jr, *Pearson Education India*
4. **Sedimentary Geology: An Introduction to Sedimentary Rocks and Stratigraphy -** D. R. Prothero, *W. H. Freeman and Co.*
5. **Sedimentary Structure** - J. D. Collinson, N. P. Mountney and D. B. Thompson, *Terra Publishing*
6. **Sedimentology and Stratigraphy** - G. Nichols, *CBS Publishers*

Reference Books:

1. **Applied Sedimentology**- R. K. Sukhtankar, *CBS Publishers*
2. **Depositional Sedimentary Environments** - H. E. Reineck and I. B. Singh, *Springer-Verlag*
3. **International Stratigraphic Guide: A Guide to Stratigraphic Classification, Terminology and Procedure** - Amos Salvador, *The International Union of Geological Sciences & Geological Society of America*
4. **Petrology of Sedimentary Rocks** - Sam Boggs Jr., *Cambridge University Press*
5. **Petrology: The study of Igneous, Sedimentary, and Metamorphic Rocks** - Loren A. Raymond, *Waveland Press Inc*
6. **Sedimentary Petrology**- M. E. Tucker, *CBS Publishers*
7. **Sedimentary Rocks**- F. J. Pettijohn, *CBS Publishers*
8. **Stratigraphy: A Modern Synthesis** - Andrew D. Miall, *Springer*

GLC-423

Palaeontology

Total Credit: 4

Total Marks: 100

(Internal Assessment: 20, End-semester Examination: 80)

Objective

The main objective of the course is to introduce the students to different types of vertebrate and invertebrate fossils, microfossils and plant fossils, their geological significance and applications.

Course Outcome

After completion of the course the students will be acquainted with various types of fossils, their morphological characters, evolutionary changes, identification, geological significance and their applications.

Unit 1: General principles of palaeontology; morphology, classification, evolutionary trend and geological significance of Bryozoa, Coelentrata, Graphotoloidea, Echinoides, Mollusca, Brachiopoda and Trilobita.

Unit 2: Evolution and geological significance of vertebrates; study of fossil vertebrates; origin and evolution of dinosaur, horse, elephant and human; vertebrate fossil records of Siwaliks; Mesozoic reptiles of India.

Unit 3: Classification, sampling methods and sample processing of microfossils; methods of study of microfossils; morphology, classification, composition, ecology and geologic history of foraminifera, ostracoda, radiolaria, diatoms, conodonts and dinoflagellates; applications of microfossils.

Unit 4: Introduction to palaeobotany; sampling methods and sample processing of plant fossils; morphology, classification and geological significance of spores and pollens; Gondwana plant fossils and their significances.

GLC-423

Palaeontology

Recommended Books

Text Books:

1. **Invertebrate Fossils** - Raymond C. Moore, Cecil G. Lalicker and Alfred G. Fischer, *CBS Publishers & Distributors*
2. **Micropaleontology: Principles and Applications** - Pratul K. Saraswati and M.S. Srinivasan, Springer
3. **Paleobotany: The Biology and Evolution of Fossil Plants** - E. Taylor, T. Taylor and M. Krings, *Elsevier*
4. **Principles of Invertebrate Paleontology** - Robert R. Shrock and William H. Twenhofel, *CBS Publishers*
5. **Principles of Paleontology** - David M. Raup and Steven M. Stanley, *CBS Publishers & Distributors*
6. **Understanding Fossils: An introduction to Invertebrate Palaeontology** - Peter Doyle, *John Wiley & Sons*
7. **Vertebrate Paleontology** - Michael Benton, *Wiley Blackwell*
8. **Palaeontology (Palaeobiology): Evolution and Animal Distribution** - P. C. Jain and M. S. Anantharaman, *Vishal Publishing Co.*

Reference Books:

1. **Bringing Fossils to Life: An Introduction to Paleobiology** - Donald Prothero, *Columbia University Press*
2. **Fundamentals of Invertebrate Palaeontology: Macrofossils** - Sreepat Jain, *Springer*
3. **Fundamentals of Invertebrate Palaeontology: Microfossils** - Sreepat Jain, *Springer*
4. **Introduction to Paleobiology and the Fossil Record** - Michael J. Benton, David A. T. Harper, *Wiley-Blackwell*
5. **Organic Evolution** - Veer Bala Rastogi, *Medtech*

GLC-424

Practical 3: Igneous and Metamorphic Petrology

Total Credit: 3

Total Marks: 100

(Internal Assessment: 20, End-semester Examination: 80)

Objective

The main objective of this course is to introduce the students to different types of rocks in hand specimen, thin section as well as in the field and also to introduce them to analyse various types of petrological data and interpret them.

Course Outcome

After completion of the course the students should be able to study and analyse different rocks based on their physical, chemical and optical characteristics. They will also be able to handle, analyse and interpret chemical data, textural data and structural data of different rock types.

Igneous Petrology

1. Study of structure, texture, mineral assemblages and identification of igneous rocks in hand specimens and in thin sections
2. Calculation of mode and CIPW norm
3. Plotting of rock composition in IUGS classification diagrams

Metamorphic Petrology

4. Study of structure, texture, mineral assemblages, grade, facies and identification of metamorphic rocks in hand specimens and in thin section
5. Construction of ACF, AKF and AFM diagrams
6. Preparation of thin section slides

Practical records

Viva-voce

Practical 3: Igneous and Metamorphic Petrology

Recommended Books

1. **A Practical Guide to Rock Microstructure** - Ron H. Vernon, *Cambridge University Press*
2. **Atlas of Metamorphic Rocks and Their Textures** - B. W. D. Yardley, W.S. MacKenzie and C. Guilford, *Prentice Hall*
3. **BGS Rock Classification Scheme Volume 1 Classification of igneous rocks** -M. R. Gillespie and M. T. Styles, *British Geological Survey*
4. **Introduction to Metamorphic Textures and Microstructures** - A. J. Barker, *Routledge*
5. **Laboratory Manual of Geology** - A. K. Sen, *Modern Book Agency, Kolkata*
6. **Microtextures of Igneous and Metamorphic Rocks** - J. P. Bard, *Springer*
7. **Petrography of Igneous and Metamorphic Rocks**-Anthony R. Philpotts, *CBS Publishers*
8. **Practical Approach to Petrology** - R. N. Hota, *CBS Publishers*
9. **Quantitative Textural Measurements in Igneous and Metamorphic Petrology** - Michael D. Higgins, *Cambridge University Press*
10. **Rocks and Minerals in Thin Section** - W. S. MacKenzie, A. E. Adams andK.H. Brodie , *CRC Press*

GLC-425

Practical 4: Sedimentology, Stratigraphy and Palaeontology

Total Credit: 3

Total Marks: 100

(Internal Assessment: 20, End-semester Examination: 80)

Objective

The main objective of this course is to introduce the students to analyse geological maps and sections to interpret geological history, depositional environment and correlation of different sections. This is also aimed to introduce the students to study morphological characters of different invertebrate and micro fossils and plant fossils.

Course Outcome

After completion of this course the students will be able to analyse and interpret various maps and sections to evaluate geological history, environment of deposition etc. They will also be able to classify and to identify different types of fossils.

Sedimentology

1. Study of sedimentary rocks and sedimentary structure in hand specimen
2. Petrography of clastics and carbonates
3. Granulometry - plotting of grain size data and statistical analysis
4. Separation of heavy minerals and their study under microscope
5. Paleocurrent analysis

Stratigraphy

1. Interpretation of geological history from geological maps and sections
2. Preparation and interpretation of facies map
3. Preparation of fence diagram
4. Preparation of lithologs and lithologic correlation

Palaeontology

1. Megascopic identification of molluscs, brachiopods, echinoids and trilobites
2. Microscopic study of foraminifera, radiolaria and ostracoda
3. Megascopic study of important plant fossils of Gondwana
4. Microscopic study of spores, pollens and dinoflagellate

Practical records

Viva-voce

Practical 4: Sedimentology, Stratigraphy and Palaeontology

Recommended Books

1. **A Practical Approach to Sedimentology** - Roy C. Lindholm*, Springer*
2. **Historical Geological Lab Manual** - Pamela J. W. Gore, *Wiley*
3. **Interpreting Earth History: A Manual in Historical Geology** - Scott Ritter and Morris Petersen, *Waveland Press*
4. **Laboratory Manual of Geology** - A. K. Sen, *Modern Book Agency, Kolkata*
5. **Practical Approach to Petrology** - R. N. Hota, *CBS Publishers*
6. **Rocks and Minerals in Thin Section** - W. S. MacKenzie, A. E. Adams and K. H. Brodie, *CRC Press*
7. **Paleontology: A Practical Manual** - L. Mahesh Bilwa, *Studera Press*
8. **Practical Manual in Palaeontology** - V. Manivannan and K. Subramani, *Vishal Publishing Co.*

GLC-426

Fieldwork 1

Total Credit: 3

Total Marks: 100

(Field Performance: 40, Field Report: 40, Viva-Voce: 20)

Objective

The main objective of the course is to teach geological field techniques such as mapping techniques in different geological terrains, recording, presenting and interpretation of field data. The course is also aimed to develop field skills of students.

Course Outcome

On completion of the course, the students would be having knowledge about carrying out mapping in different geological terrains, different types of data collection and interpretation. They will also be able observe and understand various geological features to enhance their professional skills.

Fieldwork

In this course, students will be carrying out geological fieldwork for a period of two weeks in which, they will be taught about techniques of mapping in igneous, sedimentary and metamorphic terrains. They will also be taught on lithological, structural, palaeontological and geomorphological data collection methods and preparation of lithologs. Field training will also focus on recording geological features in notebook and photographic techniques. Seminar presentation by students in the field will be evaluated by the concerned teacher in-charge. Report on the fieldwork shall be submitted by the students individually or in groups, as decided by the teacher in-charge, before the commencement of semester examinations, which will be followed by viva-voce.

GLC-426

Fieldwork 1

Recommended Books

1. **A Guide to Field Geology** - N. W. Gokhale, *CBS Publishers*
2. **Basic Geological Mapping** - J. W. Barnes and R.J. Lisle*, Wiley-Blackwell*
3. **Field Geology** - F. H. Lahee, *CBS Publishers*
4. **Geological Field Techniques** - Angela L. Coe, *Wiley-Blackwell*
5. **Geology in The Field** - R. R. Compton*, Earthspun Books*
6. **Sedimentary Rocks in the Field** - M. E. Tucker, *Wiley-Blackwell*
7. **Sedimentary Rocks in the Field: A Colour Guide** - D. A. V. Stow, *Manson Publishing*
8. **The Field Description of Igneous Rocks** - D. Jerram and N. Petford, *Wiley-Blackwell*
9. **The Field Description of Metamorphic Rocks** - N. Fry, *Wiley-Blackwell*
10. **The Mapping of Geological Structures** - K. R. McClay, *Wiley-Blackwell*

GLC-531

Indian Stratigraphy

Total Credit: 4

Total Marks: 100

(Internal Assessment: 20, End-semester Examination: 80)

Objective

The main objectives of the course are to introduce the students to the structure, stratigraphy, tectonics, age and evolution and mineral wealth of various geological terrains and formations of India, and to study important geological problems such as K-Pg boundary, Mesozoic volcanism, evolution of eastern Himalaya and sedimentary basins in eastern India.

Course Outcome

After completion of the course, students would be able to understand about various geological formations and their stratigraphic successions, tectonic settings, evolution, and mineral wealth.

Unit 1: Structure, stratigraphic succession, tectonic settings, evolution, mineral wealth and radiometric ages of Archaean cratons, Proterozoic Mobile Belts and Proterozoic sedimentary basins of India.

Unit 2: Structure, stratigraphic succession, distribution, fossils assemblage and geologic and economic importance of Gondwana formations; Pan-African orogeny; Palaeozoic rock formations in India.

Unit 3: Stratigraphic succession, distribution, fossil assemblage, economic importance of Mesozoic formations; Cretaceous-Palaeogene (K-Pg) boundary; volcanism in Mesozoic.

Unit 4: Stratigraphic succession, distribution, classification, fossil assemblage and igneous activity of Cenozoic formations; geology of eastern Himalayan belt; geology of Ganga and Brahmaputra plains; geology of Bengal basin.

GLC-531

Indian Stratigraphy

Recommended Books

Text Books:

1. **Fundamentals of Historical Geology and Stratigraphy of India** - Ravindra Kumar, *New Age International, Delhi*
2. **Geodynamics of Northeastern India and the Adjoining Region** - D. R. Nandy, *Scientific Book Centre, Guwahati*
3. **Geology of Arunachal Pradesh** - G. Kumar, *Geological Society of India*
4. **Geology of Assam** - A. B. Das Gupta and A. K. Biswas, *Geological Society* of *India*
5. **Geology of India (Vol. 1 & 2)** - R. Vaidyanandhan and M. Ramakrishnan, *Geological Society of India*
6. **Historical Geology of India** - S. K. Shah, *Scientific Publishers (India)*
7. **The Making of India: Geodynamic Evolution** - K. S. Validya, *Springer*

Reference Books:

1. **Geology and Evolution of the Indian Plate (From Hadean to Holocene 4 Ga to 4 Ka)** - S. M. Naqvi, *Capital Publishing Company*
2. **Geology and Mineral Resources of Arunachal Pradesh -** *Geological Survey of India*
3. **Geology and Mineral Resources of Assam -** *Geological Survey of India*
4. **Geology of the Himalayan Belt: Deformation, Metamorphism, Stratigraphy** - B. K. Chakrabarti, *Elsevier*
5. **Understanding an Orogenic Belt: Structural Evolution of the Himalaya** - A. K. Dubey, *Springer*
6. **Geology of India and Burma** - M. S. Krishnan, *CBS Publishers*

GLC-532

Economic Geology

Total Credit: 4

Total Marks: 100

(Internal Assessment: 20, End-semester Examination: 80)

Objective

The main objectives of the course are to teach fundamentals of ore deposits, major ore forming processes, ore formation and related geological phenomena, ore microscopy and its application, and application of geochemistry in ore genesis. The course is also aimed to teach characteristics of some of the important mineral deposits. The course is designed to give an introduction in fuel geology.

Course Outcome

After the completion of the course, the students would be expected to have a sound knowledge about ore deposits, ore genesis and various tools used in ore genesis. They will also have a good geological knowledge about various ore deposits in India and in the world as well as geology of fossil fuels.

Unit 1: Ore deposit: nature and morphology; major ore forming processes: magmatic, hydrothermal, sedimentary and metamorphic processes; distribution of mineral deposits; crustal evolution and metallogenesis; metallogeny through time; plate tectonics and ore deposits.

Unit 2: Ore microscopy and its applications in ore geology; texture of ore minerals; hydrothermal alteration; zoning; fluid inclusion studies: principles and applications; trace element distribution in ore deposits; applications of stable and radiogenic isotopes in ore geology.

Unit 3: Types, composition, origin and metallogeny of selected ore deposits: chromite, nickel, copper, platinum group elements, lead-zinc, uranium, iron, gold and industrial minerals; world class deposits in India.

Unit 4: Introduction to fuel geology; composition, origin, migration and entrapment of hydrocarbons; origin, classification and ranking of coal; major coal, petroleum and CBM deposits in India.

Recommended Books

Text Books:

1. **Coal Geology -** Larry Thomas, *Wiley Blackwell*
2. **Economic Geology** - Umeshwar Prasad, *CBS Publishers and Distributors*
3. **Economic Geology Principles and Practice** - Walter L. Pohl, *Wiley-Blackwell*
4. **Economic Mineral Deposits** - Mead L. Jensen and Alan M. Bateman, *Book Selection Centre*
5. **Elements of Petroleum Geology**- Richard C. Selley and Stephen A. Sonnenberg, *Academic Press*
6. **Introduction to Ore Forming Processes** - Laurence Robb, *Blackwell Publishing Company*
7. **Introduction to Ore Microscopy** - J. P. Shrivastava and Nishi Rani, *Prentice Hall India*
8. **Ore Microscopy and Ore Petrography** - James R. Craig and David J. Vaughan, *John Wiley & Sons*
9. **Understanding Mineral Deposits** - Kula C. Misra, *Springer Netherlands*

Reference Books:

1. **Geology of Petroleum** - A. L. Leverson, *CBS Publishers*
2. **Hydrothermal Processes and Mineral Systems** - Franco Pirajno, *Springer Netherlands*
3. **Ore Deposit Geology** - John Ridley, *Cambridge University Press*
4. **Ore Deposit Geology and Its Influence on Mineral Exploration** - R. Edwards and K. Atkinson, *Chapman and Hall*
5. **Ore Deposits in an Evolving Earth** - G. R. T. Jenkin, P. A. J. Lusty, I. McDonald, M. P. Smith, A. J. Boyce, and J. J. Wilkinson, *The Geological Society London*
6. **Ore Deposits: Origin, Exploration, and Exploitation** - Sophie Decree and Laurence Robb, *Wiley*
7. **Ore Geology and Industrial Minerals: An Introduction -** Anthony M. Evans, *Wiley India Pvt. Ltd*
8. **The Ore Minerals Under the Microscope: An Optical Guide** - Bernhard Pracejus, *Elsevier*
9. **The World of Mineral Deposits** - Florian Neukirchen and Gunnar Ries, *Springer*
10. **Uses of Metals and Metallic Minerals** - K. K. Chatterjee, *New Age International Publications*

GLC-533

Geoexploration, Mining and Environmental Geology

Total Credit: 4

Total Marks: 100

(Internal Assessment: 20, End-semester Examination: 80)

Objective

The main objective of this course is to introduce the students to different exploration methods such as geological, geochemical and geophysical explorations, mining elements, basic mining techniques and basics of environmental geology.

Course Outcome

On completion of this course the students are expected to understand the basics of explorations methods, mining methods including surface and underground mining techniques of metallic and non-metallic resources as well as fundamentals of environmental geology.

Unit 1: Mineral prospecting and exploration; geological, geochemical and geophysical exploration; sampling methods; mineral resources and ore reserve classification; ore reserve estimation; mineral economics.

Unit 2: Elements of mining; stages in the life of a mine; planning and design of mine; mining method selection; mine safety; unit operations and auxiliary operations in mining; mine machinery; mine development and design; mine openings.

Unit 3: Surface mining: open pit mining, quarrying, open cast mining, auger mining, placer mining, solution mining; underground mining: unsupported methods, supported method, caving methods; coal mining methods.

Unit 4: Foundations of environmental geology; Earth processes and natural hazards: earthquakes, tsunami, volcanic activity, rivers and flooding, slope processes, coastal processes; resources and pollution: water resources and water pollution, mineral resources and environment, energy resources, soil and environment; global climate change.

Recommended Books

Text Books:

1. **Courses in Mining Geology** - R. P. N. Arogyaswamy, *Oxford and IBH Publishing*
2. **Environmental Geology: Ecology, Resource and Hazard Management** - K. S. Validya, *Tata McGraw-Hill*
3. **Introduction to Environmental Geology** - Edward A. Keller, *Prentice Hall*
4. **Introductory Mining Engineering** - Howard L. Hartman, *John Wiley and Sons*
5. **Mineral Exploration: Principles and Applications** - Swapan K. Haldar, *Elsevier*

Reference Books:

1. **Environmental Geology** - C. W. Montgomery, *McGraw Hill*
2. **Environmental Geology: Geology and The Human Environment** - M. R. Bennett and P. Doyle, *Wiley India*
3. **Essentials of Mineral Exploration and Evaluation** - S. M. Gandhi and B. C. Sarkar, *Elsevier*
4. **Exploration Geophysics** - Mamdouh R. Gadallah and Ray Fisher, *Springer*
5. **Geological Methods in Mineral Exploration and Mining** - Roger Marjoribanks, *Springer*
6. **Introduction to Mineral Exploration** - C. J. Moon, M. K. G. Whateley and A. M. Evans, *Blackwell Publishing*
7. **Mineral Exploration: Practical Application** - G. S. Roonwal, *Springer*
8. **Surface Mining** - Bruce A Kennedy, *Society for Mining, Metallurgy, and Exploration*
9. **Underground Mining Methods** - W. A. Hustrulid and R. L. Bullock, *Society for Mining, Metallurgy, and Exploration*

GLC-534

Practical 5: Economic Geology and Geoexploration

Total Credit: 3

Total Marks: 100

(Internal Assessment: 20, End-semester Examination: 80)

Objective

The main objectives the course are to study ore and industrial minerals in hand specimen and under microscope, identification and interpretation of various textures, and estimation of P-T environment using various data. The course is also aimed to study different types of coal and their grade, and problems related to petroleum exploration. It also aims to carry out calculations related to ore exploration.

Course Outcome

After completion of the course, the students would be able to study and interpret different types of ores and industrial minerals and solve problems related to ore genesis. They will also be able to study different types of coal and to solve problems related to petroleum exploration and ore reserve estimation using various methods.

1. Megascopic identification of ore minerals and industrial minerals
2. Microscopic identification of ore minerals
3. Petrography of ore and associated minerals and interpretation of their paragenesis
4. P-T estimation of ore minerals from geochemical and fluid inclusion data
5. Megascopic identification of coal
6. Determination of grade of coal
7. Petrography of coal
8. Preparation of structure contour, isopay and isopach maps
9. Estimation of oil and gas reserves
10. Ore reserve estimation

Practical records

Viva-voce

Practical 5: Economic Geology and Geoexploration

Recommended Books

1. **An Introduction to Coal Petrography: Atlas of Petrographic Constituents in the Bituminous Coals of Southern Africa** - R. M. S. Falcon and C. P. Snyman, *Geological Society of South Africa*
2. **Coal Exploration, Mine Planning and Development** - Roy Merritt, *Elsevier*
3. **Elements of Petroleum Geology**- Richard C. Selley and Stephen A. Sonnenberg, *Academic Press*
4. **Introduction to Ore Microscopy** - J. P. Shrivastava and Nishi Rani, *Prentice Hall India*
5. **Ore Microscopy and Ore Petrography** - James R. Craig and David J. Vaughan, *John Wiley & Sons*
6. **Petrographic Atlas of Indian Coal -** Shibananda Sen Gupta, *Geological Survey of India*
7. **The Ore Minerals Under the Microscope: An Optical Guide** - Bernhard Pracejus, *Elsevier*
8. **Uses of Metals and Metallic Minerals** - K. K. Chatterjee, *New Age International Publications*

GLE-535A

Remote Sensing and GIS

Total Credit: 4

Total Marks: 100

(Internal Assessment: 20, Practical: 20, End-semester Examination: 60)

Objective

The main objective of this course is to introduce students to the principles of remote sensing and GIS and their application in geology for mapping and analysis.

Course Outcome

On completion of this course the students will be able to understand principles of remote sensing, digital image processing, microwave, thermal and hyperspectral remote sensing and GIS techniques.

Unit 1: Principles of remote sensing; sensors and platforms; digital image data formats; digital image processing: image pre-processing, image enhancement, multi-image manipulation, image classification.

Unit 2: Microwave remote sensing; transmission characteristics of RADAR signals; processing and interpretation of RADAR data; SAR interferometry; application of RADAR data; principles of thermal radiation; thermal properties of materials; thermal image characteristics and interpretation; hyperspectral remote sensing: spectral library, application of hyperspectral data in geology.

Unit 3: Spatial data and spatial data models; GIS data acquisition, spatial data accuracy and quality; data editing; attribute data management; vector data analysis; raster data analysis; terrain mapping and analysis; watershed analysis; spatial interpolation; integration of remote sensing and GIS; GIS applications.

Unit 4: Practical: digital image processing using various software; satellite image interpretation; georeferencing of satellite images and maps; creation and editing of GIS database; spatial data analysis and terrain analysis; map composition in GIS.

GLE-535A

Remote Sensing and GIS

Recommended Books

Text Books:

1. **An Introduction to Geographical Information Systems** - I. Heywood, S. Cornelius and S. Carver, *Pearson*
2. **Fundamentals of Remote Sensing** - George Joseph and C. Jeganathan, *Universities Press*
3. **Remote Sensing and GIS** - Basudeb Bhatta, *Oxford University Press*
4. **Remote Sensing and Image Interpretation** - T. M. Lillesand, R. W. Kiefer and J. W. Chipman, *John Wiley and Sons*
5. **Textbook of Remote Sensing and Geographical Information Systems** – M. Anji Reddy, *B. S. Publications*
6. **ERDAS IMAGINE Tour Guides** - *ERDAS Inc.*
7. **Getting to Know ArcGIS Desktop** - Michael Law, *ESRI Press*

Reference Books:

1. **Concepts and Techniques of Geographic Information Systems** - C. P. Lo and A. K. W. Yeung, *Pearson*
2. **Image Interpretation in Geology** - S. A. Drury, *Nelson Thornes*
3. **Introduction to Geographic Information Systems** - Kang-tsung Chang, *McGraw-Hill*
4. **Principles of Geographical Information Systems** - P. A. Burrough, R. A. McDonnell and C. D. Lloyd, *Oxford University Press*
5. **Remote Sensing Geology** - R. P. Gupta, *Springer-Verlag*
6. **Remote Sensing of the Environment** - J. R. Jensen, *Pearson Education*
7. **Introduction to Microwave Remote Sensing** - Iain H. Woodhouse, *CRC Press*
8. **Introductory Digital Image Processing: A Remote Sensing Perspective** - John R. Jensen, *Pearson Education, Inc.*
8. **Remote Sensing Handbook (Vols. 1-3)** - Prasad S. Thenkabali, *CRC Press*
9. **Introducing Geographic Information Systems with ArcGIS: A Workbook Approach to Learning GIS** - Michael D. Kennedy, Michael F. Goodchild and Jack Dangermond, *Wiley*
10. **Learning QGIS** - Anita Graser, *Packt Publishing Limited*

GLE-535B

Exploration Geophysics

Total Credit: 4

Total Marks: 100

(Internal Assessment: 20, End-semester Examination: 80)

Objective

The main objective of this course is to introduce the students to the principles and techniques of different geophysical exploration methods such as gravity, magnetic, electrical, electromagnetic, radiometric and seismic methods.

Course Outcome

On completion of this course the students are expected to acquire knowledge about the principles, tools, techniques and applications about different geophysical methods used for exploration purposes.

Unit 1: Types of geophysical measurement; geophysical data acquisition, processing and interpretation. Gravity methods: Earth's gravity field and its measurement; reduction of gravity data; density in the geological environment; interpretation of gravity data. Magnetic methods: measurement of the Earth's magnetic field; reduction of magnetic data; magnetism in the geological environment; interpretation of magnetic data.

Unit 2: Electrical methods: electrical properties of the natural environment; self-potential (SP) method: sources of natural electrical potentials, measurement display and interpretation of SP data; resistivity methods: resistivity of rocks and minerals, electrode spreads, resistivity surveying equipment, interpretation of resistivity data; induced polarization (IP) method: principles and measurements, field operations and interpretation of IP data; geophysical borehole logging.

Unit 3: Electromagnetic methods: principles of electromagnetic surveying; acquisition; processing and display of EM data; interpretation of EM data; downhole electromagnetic surveying; airborne electromagnetic surveying. Radiometric methods: radioactive decay; radioactive minerals; instruments for measuring radioactivity, measurement of radioactivity in the field; interpretation of radiometric data.

Unit 4: Seismic method: seismic waves; propagation of body waves through the subsurface; variations in seismic properties in the geological environment; acquisition and processing of seismic data; seismic reflection method; interpretation of seismic reflection data; seismic refraction method; application of seismic survey methods.

Recommended Books

Text Books:

1. **An Introduction to Geophysical Exploration** - P. Kearey, M. Brooks and I. Hill, *Blackwell*
2. **Fundamentals of Geophysics** - W. Lowrie, *Cambridge University Press*
3. **The Solid Earth: An Introduction to Global Geophysics** - C. M. R Fowler, *Cambridge University Press*
4. **Applied Geophysics** - W. M. Telford, *Cambridge University Press*

Reference Books:

1. **Geophysics for the Mineral Exploration Geoscientist -** M. Dentith and S. Mudge, *Cambridge University Press*
2. **Encyclopedia of Solid Earth Geophysics** - Harsh K. Gupta, *Springer*
3. **The Encyclopedia of Solid Earth Geophysics** - David E. James, *Van Nostrand Reinhold*
4. **Exploration Geophysics** - Mamdouh R. Gadallah and Ray Fisher, *Springer*
5. **Whole Earth Geophysics: An Introductory Textbook for Geologists and Geophysicists** - Robert J. Lillie, *Prentice Hall*
6. **Environmental and Engineering Geophysics** - Prem V. Sharma, *Cambridge University Press*
7. **Field Geophysics** - John Milsom and Asger Eriksen, *John Wiley & Sons*

GLE-535C

Geodesy, Surveying and Mapping

Total Credit: 4

Total Marks: 100

(Internal Assessment: 20, End-semester Examination: 80)

Objective:

The main objective of this course is to introduce the students to the fundamentals of geodetic methods, surveying methods, global positioning system and geological mapping.

Course Outcome:

On completion of this course the students are expected to know the basics of geodesy, fundamentals of conventional and modern surveying techniques, principles and applications of global positioning system and procedure of geological mapping in the field.

Unit 1: Geodesy: definition and history; coordinate system: ellipsoid and datum, Cartesian and geodetic coordinate system; geodetic methods: ground-based measurements, satellite systems, gravimeters.

Unit 2: Surveying: fundamental principles and types; measurement of distance and angle; surveying techniques: triangulation, trilateration, levelling, traverse, radiation; closed loop and open traverse; conventional surveying tools: chain, prismatic compass, plane table, dumpy level, theodolite; modern surveying tools: total station and global positioning system.

Unit 3: Fundamentals of global positioning system; GPS segments; GPS positioning and measuring principles; GPS data errors; differential GPS; application of GPS in surveying and mapping.

Unit 4: Concepts and scopes of geological survey and mapping; base map and its use; study of outcrop: lithology and structure; field equipment; field notebook and recording of information; photography and sampling; preparation of geological map; geological field report.

Recommended Books

Text Books:

1. **Basic Geodesy** - J. R. Smith, *Landmark Enterprises*
2. **Elementary Surveying : An Introduction to Geomatics** - Charles D. Ghilani, *Pearson*
3. **Geological Field Techniques** - A. L. Coe, *Wiley-Blackwell*
4. **Geology in The Field** - R. R. Compton, *Earthspun Books*
5. **Global Positioning System: Concept, Technique and Application** - A. Rahman and S. Fazal, *New Age International*
6. **Surveying (Vols. 1 & 2)** - B. C. Punmia, Ashok K. Jain and Arun K. Jain, *Laxmi Publications*

Reference Books:

1. **Field Geology** - F. H. Lahee, *CBS Publishers*
2. **Geodesy** - Wolfgang Torge and Jürgen Müller, *de Gruyter*
3. **Global Positioning System: Signals, Measurements and Performance** - P. Misra and P. Enge, *Ganga-Jamuna Press*
4. **Plane and Geodetic Surveying -** Aylmer Johnson, *CRC Press*
5. **Surveying (Vols. 1 & 2)** - S. K. Duggal, *McGraw Hill*
6. **Introduction to GPS: The Global Positioning System** - Ahmed El-Rabbany, *Artech House*

GLE-535D

Summer Internship

Total Credit: 4

Total Marks: 100

Objective

The main objective of the course is to expose the students to preliminary research, develop professional skills, gain hands-on experience, evaluate career opportunities and begin building a professional network.

Course Outcome

Upon completion of the summer internship, the students would be expected to have an introductory knowledge about methods of identifying and investigating geological problems and to solve them systematically. This also gives them an exposure to visit research institutes, industries, mining sectors etc. where the students get opportunity to gain professional knowledge.

Summer Internship

Upon completion of second semester examination the students shall undergo institutional or industrial training for a period of at least four weeks during summer vacation with prior approval from the department. After the completion of the internship students shall submit their report to the department before the commencement of third semester examination. The report should be duly certified by the supervisor under whom the student carried out the internship.

GLO-536A

Earth System Science

Total Credit: 4

Total Marks: 100

(Internal Assessment: 20, End-semester Examination: 80)

Objective

The main objective of this open elective course is to introduce the students to fundamental aspects of the Earth, plate tectonics, various geological processes, minerals, rocks, and ores. The course is also aimed to outline the various geohazards, their causes and resulting calamities.

Course Outcome

After completion of the course, the students would be able to understand basic characteristics of the Earth, plate tectonic activities and resulting geological phenomena, and endogenous and exogenous geological processes. They will also able to understand various earth materials such as minerals, rocks and ores. A fair knowledge about natural hazards such as earthquakes, volcanoes etc and their causes would be expected.

Unit 1: Earth system science - introduction and branches; Solar System and its origin; internal structure of the Earth; shape, size, mass, density, orbital parameters and age of the Earth; magnetic field of the Earth and its origin; historical geology: geological time scale, fossil records in rocks.

Unit 2: Plate tectonics: sea-floor spreading and continental drift; supercontinent cycle; geological structures: fold, fault, joint and unconformity; surface geological processes by wind, water, and glacier; weathering and erosion; subsurface geological processes - magmatism and volcanism.

Unit 3: Earth materials: minerals - atomic structure and physical properties; silicate structure; rock forming minerals; rocks - igneous, sedimentary and metamorphic rocks; common rock types on the Earth's crust; ores and industrial minerals.

Unit 4: Hydrologic cycle; water quality; energy and mineral resources; geohazards: earthquakes, volcanoes and mass wasting; human impact on Earth's environment.

Recommended Books

Text Books:

1. **Earth: An Introduction to Physical Geology** - Edward J. Tarbuck, Frederick K. Lutgens and Dennis G. Tasa, *Pearson*
2. **Understanding Earth** - John Grotzinger and Thomas H. Jordan, *Macmillan*
3. **Earth: Portrait of a Planet** - Stephen Marshak, *W. W. Norton & Company*

Reference Books:

1. **Fundamentals of Physical Geology -** Sreepat Jain, *Springer*
2. **The Blue Planet: An Introduction to Earth System Science -** Brian J. Skinner and Barbara Murck, *John Wiley & Sons*
3. **Earth System History** - Steven M. Stanley and John A. Luczaj, *W. H. Freeman and Company*
4. **Earth Materials -** Kevin Hefferan and John O Brien, *Wiley-Blackwell*
5. **Physical Geology** - Charles C. Plummer, Diane H. Carlson and Lisa Hammersley, *McGraw Hill Education*
6. **Physical Geology Exploring the Earth** - James S. Monroe and Reed Wicander, *West Publishing Company*
7. **Historical Geology: Understanding Our Planet's Past** - Jon Erickson, *Facts On File, Inc.*
8. **Historical Geology: Evolution of Earth and Life Through Time** - Reed Wicander and James S. Monroe, *Cengage Learning*

GLO-536B

Natural Hazard and Disaster Management

Total Credit: 4

Total Marks: 100

(Internal Assessment: 20, End-semester Examination: 80)

Objective

The main objective of this course is to introduce the students to various natural hazards and disasters, their causes, vulnerability, risk assessment, mitigation measures and their management at different stages to reduce the loss of life and property.

Course Outcome

On completion of the course the students will be familiar to different types of natural hazards and disasters such as earthquake, volcanic eruption, flood, landslide, cyclone etc. and will have a knowledge about the risk associated with these and its management.

Unit 1: Hazardous natural processes and energy sources; hazard, risk, disaster, and catastrophe; magnitude and frequency of hazardous events; fundamental concepts for understanding natural processes as hazards; risk assessment.

Unit 2: Earthquake: magnitude and intensity; seismicity of the world; reduction of earthquake hazard. Introduction to tsunamis; causes of tsunamis; tsunami risk and its minimization. Volcanoes and volcanic eruptions; distribution of volcanoes, minimizing the volcanic hazard.

Unit 3: Introduction to landslides; types of landslides; identification of potential landslides; prevention of landslides; landslide warning systems; hazards from ground subsidence. river flooding as natural hazard; magnitude and frequency of floods; nature and extent of flood hazards; adjustments to flood hazards.

Unit 4: Coastal hazards; coastal processes; sea-level change; perception and mitigation of coastal hazards. Hurricanes and cyclones: classification and nomenclature; cyclone development; cyclone prone regions; effects of cyclones; cyclone forecasts and warnings; climate change and related hazards.

Recommended Books

Text Books:

1. **Disaster Education and Management: A Joyride for Students, Teachers and Disaster Managers -** Rajendra Kumar Bhandari, *Springer*
2. **Natural Hazards and Disasters -** Donald Hyndman and David Hyndman, *Brooks-Cole*
3. **Natural Hazards: Earth's Processes as Hazards, Disasters, and Catastrophes -** Edward A. Keller, Duane E. DeVecchio and Robert H. Blodgett, *Pearson*

Reference Books:

1. **Environmental Hazards and Disasters: Contexts, Perspectives and Management -** B. K. Paul, *Wiley-Blackwell*
2. **Geological Hazards** - B. A. Bolt, W. L. Horn, G. A. Macdonald and R. F. Scott, *Springer-Verlag*
3. **Introduction to Emergency Management** - Michael K. Lindell, Carla Prater and Ronald W. Perry, *Wiley*
4. **Natural Disasters** - Patrick L. Abbott, *McGraw-Hill*
5. **Natural Hazards: Earthquakes, Volcanoes and Landslides -** Ramesh P. Singh and Darius Bartlett, *CRC Press*
6. **Environmental Hazards: Assessing Risk and Reducing Disaster** - Keith Smith and David N. Petley, *Routledge*

GLO-536C

Fundamentals of Remote Sensing

Total Credit: 4

Total Marks: 100

(Internal Assessment: 20, End-semester Examination: 80)

Objective

The main objective of this course is to introduce the students to the physical principles of remote sensing, different systems of remote sensing, types of sensors and platforms, processing and interpretation of different remote sensing data.

Course Outcome

On completion of the course the students will have an idea about the principles of remote sensing, different types of remote sensing data, their processing and interpretation techniques and the application of remote sensing data in various fields.

Unit 1: Principles of remote sensing; electromagnetic spectrum; interaction of electro-magnetic radiation with Earth's atmosphere and surface features; atmospheric window; sensors and their resolution; remote sensing platforms.

Unit 2: Satellite remote sensing; geosynchronous and sun synchronous orbit; types of satellite data products; principles of aerial photography, geometry and characteristics of aerial photographs, basic concept of stereoscopy.

Unit 3: Concept of digital image; digital image processing; false colour composite (FCC); elements of image interpretation; sensor characteristics of important Indian and foreign remote sensing satellites.

Unit 4: Basic concepts of thermal, micro-wave, hyper-spectral and LiDAR remote sensing; advantages and limitations of remote sensing; applications of remote sensing.

Fundamentals of Remote Sensing and GIS

Recommended Books

Text Books:

1. **Fundamentals of Remote Sensing** - George Joseph and C. Jeganathan, *Universities Press*
2. **Remote Sensing and GIS** - Basudeb Bhatta, *Oxford University Press*
3. **Remote Sensing and Image Interpretation** - T. M. Lillesand, R. W. Kieferand J. W. Chipman, *John Wiley and Sons*
4. **Textbook of Remote Sensing and Geographical Information Systems** – M. Anji Reddy, *B. S. Publications*

Reference Books:

1. **Remote Sensing of the Environment** - J. R. Jensen, *Pearson Education*
2. **Introductory Digital Image Processing: A Remote Sensing Perspective** - John R. Jensen, *Pearson Education, Inc.*
3. **Remote Sensing Handbook (Vols. 1-3)** - Prasad S. Thenkabali, *CRC Press*

GLC-541

Engineering Geology and Hydrogeology

Total Credit: 4

Total Marks: 100

(Internal Assessment: 20, End-semester Examination: 80)

Objective

The main objective of the course is to introduce the students to the geotechnical engineering and geological investigations related to construction projects. The course also aims to introduce the principles of hydrogeology, systematic study of water wells and their construction methods, groundwater quality, methods of exploration of groundwater and artificial recharge techniques.

Course Outcome

On completion of the course the students will be able to understand the basic engineering properties of soil and rocks as well as geological consideration of site investigation for engineering constructions. The students will also have knowledge about principles of hydrogeology, water wells, exploration of groundwater, problems associated with groundwater exploitation and artificial recharge methods which is highly required in the present global scenario for scarcity of water.

Unit 1: Importance of engineering geology in construction and mining; engineering usage of various rock types; rock mechanics and its applications; construction materials; fundamentals of soil mechanics; ground excavation and slope stability; treatment of rocks and soil; site investigation; geological investigations involved in the construction of bridge, roads, railways and runways; construction challenges in Himalayan terrain.

Unit 2: Dams and reservoirs: types of dams and their functions, geological investigation of dam site, creation and function of reservoir, problems related to the reservoirs; tunnels: components and types of tunnels, tunnelling through rock and soft ground, geological and geotechnical investigation in tunnelling, excavation methods and support system in tunnelling.

Unit 3: Hydrologic cycle and hydrologic equation; application of hydrogeology to human concern; origin of groundwater; rock properties affecting groundwater; vertical distribution of groundwater; geological formations as aquifers; springs; Darcy's law and its validity; groundwater flow rates and directions; water wells and their types; testing wells for yield.

Unit 4: Quality of groundwater; pollution of groundwater; surface and subsurface investigation of groundwater; artificial recharge of groundwater; saline water intrusion.

Recommended Books

Text Books:

1. **Applied Hydrogeology** - C. W. Fetter, *Pearson Education India*
2. **Groundwater Hydrology** - David Keith Todd and Larry W. Mays, *John Wiley & Sons Inc*
3. **Hydrogeology: Principles and Practice** - Kevin M. Hiscock and Victor F. Bense, *Wiley Blackwell*
4. **Engineering and General Geology** - P. Singh, *S. K. Kataria & Sons*
5. **Engineering Geology** - S. Gangopadhyay, *Oxford University Press*
6. **Engineering Properties of Soils and Rocks** - F. G. Bell, *Wiley-Blackwell*
7. **Principles of Engineering Geology and Geotectonics** - D. K. Krynine and W. R. Judd, *CBS Publishers*

Reference Books:

1. **Groundwater Hydrology: Conceptual and Computational Models** - K. R. Rushton, *Wiley India*
2. **Engineering Geology** - F. G. Bell, *CBS Publishers*
3. **Hydrology: Principles-Analysis-Design** - H. M. Raghunath, *New Age International Publishers*
4. **Geotechnical Engineering (Soil Mechanics) -** T. G. Sitharam and T. N. Ramamurthy**,** *S. Chand*
5. **Hydrogeology: Problems with Solutions** - Nandipati Subba Rao, *Prentice Hall India*
6. **Practical and Applied Hydrogeology** - Zekai Sen, *Elsevier*
7. **Ground Water Assessment, Development and Management** - K. R. Karanth, *McGraw Hill Education*
8. **Ground Water** - H. M. Raghunath, *New Age International Publishers*

GLC-542

Practical 6: Engineering Geology and Hydrogeology

Total Credit: 3

Total Marks: 100

(Internal Assessment: 20, End-semester Examination: 80)

Objective

The main objective of this course is to train the students to practically conduct geotechnical investigations and solving problems related to soil, rocks and engineering construction sites. It also aims to provide training related to groundwater investigation and ore exploration.

Course Outcome

On completion of the course the students are expected to test the engineering properties of soil and rocks, solve problems related geotechnical investigation of engineering construction sites, study and prepare water table maps, groundwater related study and ore reserve estimation using various methods.

Engineering Geology

1. Determination of specific gravity of soil
2. Determination of liquid limit, plastic limit, plasticity index, shrinkage limit, liquidity index and consistency index of soil
3. Determination of shear strength parameters of soil
4. Determination of strength of rocks
5. Determination of RQD and RMR
6. Problems related to stability of slopes
7. Study of site maps of important engineering structures such as dams and tunnels

Hydrogeology

1. Preparation of depth to water map and water table map from given data
2. Preparation of groundwater prospect map
3. Estimation of groundwater reserve
4. Determination of various physical and chemical parameters of groundwater
5. Electrical resistivity survey for groundwater exploration

Practical records

Viva-voce

Practical 6: Engineering Geology and Hydrogeology

Recommended Books

1. **Applied Hydrogeology** - C. W. Fetter, *Pearson Education India*
2. **Exploration Geophysics** - Mamdouh R. Gadallah and Ray Fisher, *Springer*
3. **Fundamentals of Geophysics** - William Lowrie, *Cambridge University* Press
4. **Geotechnical Investigation Methods: A Field Guide for Geotechnical Engineers** - Roy E. Hunt, *CRC Press*
5. **Hydrogeology: Problems with Solutions** - Nandipati Subba Rao, *Prentice Hall India*
6. **Principles of Geotechnical Engineering** - Braja M. Das and Khaled Sobhan, *Cengage Learning*

GLC-543

Field work 2

Total Credit: 3

Total Marks: 100

(Field Performance: 40, Field Report: 40, Viva-Voce: 20)

Objective

The main objective of the course is visit to diverse exploration sites, mines, construction sites and oil fields to study methods and activities.

Course Outcome

On completion of the course the students will have fair knowledge about exploration and exploitation activities. They will also get exposure to visit and meet various industries to gain geological and industrial knowledge.

Fieldwork

In this course, students shall carryout geological field work for period of ten days in diverse geological terrains of India, visit to geologically important areas where exploration and mining activities are going on as well as to engineering construction sites and to oil fields. Seminar presentation by students in the field will be evaluated by the concerned teacher in-charge. Report on the fieldwork shall be submitted by the students individually or in groups, as decided by the teacher in-charge, before the commencement of semester examinations, which will be followed by viva-voce.

GLC-543

Field work 2

Recommended Books

1. **A Guide to Field Geology** - N. W. Gokhale, *CBS Publishers*
2. **Economic Geology** - Umeshwar Prasad, *CBS Publishers and Distributors*
3. **Field Geology** - F. H. Lahee, *CBS Publishers*
4. **Geological Field Techniques** - A. L. Coe, *Wiley-Blackwell*
5. **Geology in The Field** - R. R. Compton, *Earthspun Books*
6. **Geology of India (Vol. 1 & 2)** - R. Vaidyanandhan and M. Ramakrishnan, *Geological Society of India*
7. **Mineral Resources of India** - D. K. Banerjee, *World Press, Kolkata*
8. **Sedimentary Rocks in the Field** - M. E. Tucker, *Wiley-Blackwell*
9. **Sedimentary Rocks in the Field: A Colour Guide** - D. A. V. Stow, *Manson Publishing*
10. **The Field Description of Igneous Rocks** - D. Jerram and N.Petford, *Wiley-Blackwell*
11. **The Field Description of Metamorphic Rocks** - N. Fry, *Wiley-Blackwell*
12. **The Making of India: Geodynamic Evolution** - K. S. Validya, *Springer*

GLE-544A

Himalayan Geology

Total Credit: 4

Total Marks: 100

(Internal Assessment: 20, End-semester Examination: 80)

Objective

The main objective of this course is to introduce the students to the origin, evolution, litho-tectonic subdivisions of the Himalaya as well as problems, challenges and resources in Himalayas.

Course Outcome

On completion of the course the students will have the knowledge about different litho-tectonic subdivisions and structural elements of the Himalaya, the evolution of Himalaya and Himalayan foreland basin.

Unit 1: Litho-tectonic subdivisions of the Himalaya: Main Frontal Thrust (MFT); Sub-Himalaya; Main Boundary Thrust (MBT); Lesser Himalaya; Main Central Thrust (MCT); Higher Himalaya; South Tibetan Detachment System (STDS); Tethyan Himalaya; Indus-Tsangpo Suture Zone (ITSZ).

Unit 2: Evolution of the Himalaya; India-Asia convergence; collision of India with Asia; bending and bulging up of leading edge; breaking of Himalayan crust; development of Lesser Himalayan terrane and foreland basin; evolution of syntaxial bends; sedimentation and structural development of Siwalik terrane; igneous and metamorphic events in Himalayan region.

Unit 3: Arunachal Himalaya: geology of eastern Himalayan belt, Trans-Himalayan belt and south-eastern Arunachal Pradesh; structure and tectonics of Arunachal Himalaya; tectonic evolution of Arunachal Himalaya; eastern Himalayan syntexis.

Unit 4: Construction challenges in Himalayan terrain; landslide problems in Himalayan region; migration and variability of Himalayan rivers; seismicity and active tectonics along Himalayan belt; mineral deposits and metallogeny in Himalayas, Himalayan climate.

GLE-544A

Himalayan Geology

Recommended Books

Text Books:

1. **Geodynamics of Northeastern India and the Adjoining Region** - D.R. Nandy, *Scientific Book Centre, Guwahati*
2. **Geology of Arunachal Pradesh** - G. Kumar, *Geological Society of India*
3. **Geology of the Himalayan Belt: Deformation, Metamorphism, Stratigraphy** - B. K. Chakrabarti, *Elsevier*
4. **The Making of India: Geodynamic Evolution** - K. S. Validya, *Springer*

Reference Books:

1. **Colliding Continents: A Geological Exploration of the Himalaya, Karakoram and Tibet** - Mike Searle, *Oxford University Press*
2. **Dimensions of Himalayan Geology** - A. K. Biyani, *Satish Serial Publishing House*
3. **Geology of India (Vol. 2)** - R. Vaidyanandhan and M. Ramakrishnan, *Geological Society of India*
4. **Himalaya to the Sea: Geology, geomorphology and the Quaternary -** John F. Shroder, jr., *Routledge*
5. **Himalaya: Geological Aspects (Vols. 1-5)** - P. S. Saklani, *Satish Serial Publishing House*
6. **Historical Geology of India** - S. K. Shah, *Scientific Publishers (India)*
7. **Understanding an Orogenic Belt: Structural Evolution of the Himalaya** - A. K. Dubey, *Springer*
8. **Zagros - Hindu Kush - Himalaya: Geodynamic Evolution -** Harsh K. Gupta and Frances M. Delany, *American Geophysical Union*

GLE-544B

Isotope Geology

Total Credit: 4

Total Marks: 100

(Internal Assessment: 20, End-semester Examination: 80)

Objective

The main objective of the course is to introduce the students to basic principles of radioactivity and isotopes, their applications in geosciences, instruments that is used to carry out isotopic studies, and various isotopic systematics and their applications in geology. The course is also aimed to introduce basic principles of stable and cosmogenic isotopes, and their applications in geosciences.

Course Outcome

After the completion of the course, the students would be expected to have sound knowledge about radioactivity, radiogenic and non-radiogenic isotopes, their systematics and their applications in geosciences. The course has applications in various branches of geology to elucidate geological phenomena that happened in the geologic past as well as in other disciplines too.

Unit 1: Radioactivity: discovery and its impacts on geology; internal structure of atoms; radiogenic and stable isotopes; decay mechanisms of radioactive atoms; radioactive decay and growth; stable isotope fractionation.

Unit 2: Mass spectrometry: principles, varieties, sample preparation and applications; isotope dilution technique; isochron.

Unit 3: Different radioactive isotopic systematics and their applications in geology.

Unit 4: Stable isotopes: scope, terminology and applications in earth sciences; stable isotopic systematics of oxygen, hydrogen, carbon and sulphur; non-traditional isotopic systematics; fractionation of stable isotopes in lithosphere, hydrosphere and atmosphere; introduction to cosmogenic radionuclides.

Recommended Books

Text Books:

1. **Isotope Geology** - Claude J. Allegre, *Cambridge University Press*.
2. **Isotopes: Principles and Applications** - Gunter Faure and Teresa M. Mensing, *John Wiley*.
3. **Stable Isotope Geochemistry** - Hoefs, *Springer*.

Reference Books:

1. **Principles of Stable Isotope Geochemistry** - Zachary Sharp, *Pearson Education Inc*.
2. **Radiogenic Isotope Geology,** Alan P. Dickin - *Cambridge University Press*.
3. **Radiogenic Isotopes in Geological Processes** - S.V. Rasskazov, S.B. Brandt and I.S. Brandt, *Springer*.
4. **Stable Isotope Geochemistry** - John W. Valley and David R. Cole, *Mineralogical Society of America*
5. **Isotope Geochemistry** - William M. White, *Wiley*.

GLE-544C

Statistics and Data Analysis in Geology

Total Credit: 4

Total Marks: 100

(Internal Assessment: 20, End-semester Examination: 80)

Objective

The main objective of this course is to introduce students to the fundamentals of statistical methods and its application in analysing various geological data.

Course Outcome

On completion of this course the students will be able to apply various statistical tools in analysing different types of geological data.

Unit 1: Collection, tabulation and display of geological data; measure of central tendency and dispersion; measurement of moments, skewness and kurtosis.

Unit 2: Probability concept; elements of set theory; statistical independence and conditional probability; Bayes' theorem; mathematical expectation.

Unit 3: Correlation and regression; trend surface analysis; kriging; cluster analysis; principal component analysis (PCA); Markov chain analysis; analysis of directional data, analytical hierarchy process (AHP).

Unit 4: Binomial distribution, Gaussian distribution and Poisson distribution; sampling distribution of mean; test of significance and confidence level; Z-test, t-test, F-test; chi-square (χ^2) test for goodness of fit.

Recommended Books

Text Books:

1. **Statistical Methods**- S. P. Gupta, *Sultan Chand*
2. **Statistics and Data Analysis in Geology**- J. C. Davis, *Wiley India*
3. **Geostatistics Explained: An Introductory Guide for Earth Scientists** - Steve McKillup and Melinda Darby Dyar, *Cambridge University Press*
4. **Applied Geostatistics** - Edward H. Isaaks and R. Mohan Srivastava, *Oxford University Press*

Reference Books:

1. **Fundamentals of Mathematical Statistics** - S. C. Gupta and V. K. Kapoor, *Sultan Chand*
2. **Geostatistics with Applications in Earth Sciences -** D. D. Sarma, *Springer*
3. **Statistics and Analysis of Scientific Data** - Massimiliano Bonamente, *Springer*

GLE-544D

Advanced Hydrogeology

Total Credit: 4

Total Marks: 100

(Internal Assessment: 20, End-semester Examination: 80)

Objective

The objective of the course is to master the knowledge in hydrogeology and solve related problems. The course is aimed to teach principles of hydrogeology and their applicability in field. The course is also aimed to teach construction of different types of wells, and effective management of groundwater.

Course Outcome

Upon completion of the course, students will be able to understand nature of groundwater, different parameters of groundwater, its availability and physical and chemical characters of groundwater. They will also be able to understand the effective management of groundwater which is vital in the present world scenario.

Unit 1: Hydrogeology: sources of information, ethical and business aspects; hydrographs; hydrologic budget; aquifer properties; water table and potentiometric surface; hydraulic conductivity; groundwater flow; transmissivity and storativity; aquifer test.

Unit 2: Occurrence of groundwater in different rock types and in unconsolidated sediments; fresh water-saline water relationships; water wells: test holes and well logs; methods of constructing shallow and deep wells; well completion and well development; well protection and rehabilitation.

Unit 3: Groundwater chemistry: types of chemical reactions in groundwater; carbonate equilibrium; ion exchange; isotope hydrology; major ion chemistry; piper diagram. Physical, chemical and biological properties of groundwater; water quality standards; groundwater monitoring; groundwater contamination and restoration.

Unit 4: Groundwater management: groundwater budget; management of potential aquifers; water law; water quality protection in aquifers; global water issues; groundwater models and its applications; MODFLOW.

GLE-544D

Advanced Hydrogeology

Recommended Books

Text Books:

1. **Applied Hydrogeology** - C. W. Fetter Jr., *Pearson Education Limited*.
2. **Groundwater Hydrology** - David Keith Todd and Larry W. Mays, *John Wiley & Sons Inc*.
3. **Groundwater Hydrology Conceptual and Computational Models** - K. R. Rushton, *Wiley*
4. **Hydrogeology Principles and Practice** - Kevin M. Hiscock, *John Wiley & Sons Inc.*
5. **Hydrogeology Problems with solutions** - Nandipati Subba Rao, *Prentice Hall India Learning Pvt. Limited*
6. **Hydrology: Principles Analysis Design** - H. M. Raghunath, *New Age International (P) Ltd. Publishers*

Reference Books:

1. **Applied Ground-Water Hydrology and Well Hydraulics** - Michael Kasenow, *Water Resource Publications, LLC*
2. **Field Hydrogeology: A Guide for Site Investigations and Report Preparation** - John E. Moore, *CRC Press*
3. **Ground Water Assessment Development and Management** - K. R. Karanth, *Tata McGraw Hills*
4. **Groundwater Geophysics: A Tool for Hydrogeology** - Reinhard Kirsch, *Springer*
5. **Hydrogeology Field Manual** - Willis Weight, *McGraw Hill*
6. **Hydrogeology: Objectives, Methods, Applications** - Eric Gilli, Christian Mangan and Jacques Mudry, *CRC Press*
7. **Practical and Applied Hydrogeology** - Zekai Sen, *Elsevier*
8. **Practical Hydrogeology: Principles and Field Applications** - Willis D. Weight, *McGraw Hill*
9. **Principles of Hydrogeology** - Paul F. Hudak, *CRC Press*

GLE-544E

Basin Analysis

Total Credit: 4

Total Marks: 100

(Internal Assessment: 20, End-semester Examination: 80)

Objective

The main objective of this course is to introduce the students to the fundamentals of sedimentary basins, their classification, mechanism of sedimentary basin formation, mapping techniques of sedimentary basins, and sediment routing system.

Course Outcome

On completion of the course the students will have the knowledge of different types of sedimentary basins, their formation mechanism, basin mapping methods, basin analysis through erosion, transportation, deposition, stratigraphy, subsidence and thermal history.

Unit 1: Definition and scope of basin analysis; sedimentary basins and their geodynamic environment; compositional and rheological zonation of the Earth; physical state of the lithosphere; classification of sedimentary basins.

Unit 2: The mechanics of sedimentary basin formation: basin formation due to lithospheric stretching; basins due to flexure; mantle dynamics and basin development; basins associated with strike-slip deformation.

Unit 3: Basin mapping methods: structure contouring; isopach contouring; lithofacies maps; clastic-petrographic data; palaeocurrent analysis; remote sensing; stratigraphic cross sections; palaeogeographic synthesis.

Unit 4: The sediment routing system in basin analysis; the erosional engine; measurements of erosion rates; channel-hillslope processes; long-range sediment transport and deposition; basin stratigraphy; stratigraphic cycles: definition and recognition; subsidence history and analysis; thermal history.

GLE-544E

Basin Analysis

Recommended Books

Text Books:

1. **Basin Analysis: Principles and Application to Petroleum Play Assessment** - Philip A. Allen and John R. Allen, Wiley-Blackwell
2. **Physical Principles of Sedimentary Basin Analysis -** Magnus Wangen, *Cambridge University Press*
3. **Principles of Sedimentary Basin Analysis** - Andrew D. Miall, *Springer*
4. **Sedimentology and Sedimentary Basins: From Turbulence to Tectonics** - Mike Leeder, *Wiley-Blackwell*

Reference Books:

1. **Basin Analysis and Modeling of the Burial, Thermal and Maturation Histories in Sedimentary Basins** - Monzer Makhous and Yu. I. Galushkin, *Editions Technip*
2. **Depositional Sedimentary Environments** - H. E. Reineck and I. B. Singh, *Springer-Verlag*
3. **Sedimentary Basins: Evolution, Facies, and Sediment Budget** - Gerhard Einseie, *Springer*
4. **Seismic Stratigraphy, Basin Analysis and Reservoir Characterisation** - Paul C.H. Veeken, *Elserier*
5. **The Geology of Fluvial Deposits: Sedimentary Facies, Basin Analysis, and Petroleum Geology** - Andrew D. Miall, *Springer*

GLE-545A

Fuel Geology

Total Credit: 4

Total Marks: 100

(Internal Assessment: 20, End-semester Examination: 80)

Objective

The important objectives of the course are to introduce the students to various types of fossil fuels, their characteristics, classification, origin, distribution, and problems in exploitation. The course is also aimed to introduce basic concepts of nuclear geology, radioactive minerals, their occurrences and uses and their hazards.

Course Outcome

After the completion of the course the students will have a sound knowledge about various types of fossil fuels, their characteristics, classification, origin, distribution, and problems in exploitation. They will also have good knowledge about various nuclear energy, radioactive minerals and their occurrences and uses.

Unit 1: Coal Geology: introduction to coal geology; origin, age and occurrence of coal; types of coal; physical description of coal - macroscopic and microscopic descriptions; mineral contents of coal; coal petrography; quality of coal - physical, chemical and combustional properties; important coal deposits of the world; geological and geographical distribution of coal deposits in India; coal production and problems of coal industry in India.

Unit 2: Coalbed Methane: Introduction and early development; conventional natural gas resource; CBM resource; CBM vs. conventional reservoir; significance of coal rank in natural gas reservoirs; gas flow in coal deposits; problems in CBM mining; important natural gas resources in India.

Unit 3: Petroleum Geology: physical and chemical properties of petroleum; origin, migration and entrapment of petroleum; characteristics of reservoir; methods of petroleum exploration; oil well drilling and well logging; onshore and offshore petroliferous basins of India; oil and gas fields of Northeast India.

Unit 4: Nuclear Geology: introduction; radioactive minerals as source of energy; nuclear fuel cycle; mineralogy, geochemistry and mode of occurrence of radioactive minerals; productive geologic horizons of atomic minerals in India; nuclear waste disposal.

Recommended Books

Text Books:

1. **Coal Geology -** Larry Thomas, *Wiley Blackwell*
2. **Elements of Petroleum Geology**- Richard C. Selley and Stephen A. Sonnenberg, *Academic Press*
3. **Principles of Nuclear Geology** - U. Aswathanarayana, *Oxford University Press*
4. **Coal Gassification and its applications -** David A. Bell, Brian F. Towler and Maohong Fan, *Elsevier*
5. **Coal Geology and Coal Technology** - Colin R. Ward, *Blackwell Scientific Publications*
6. **Geology of Petroleum** - A. L. Leverson, *CBS Publishers*
7. **Textbook of Coal** - D. Chandra, R. M. Singh and M. P. Singh, *Tara Book Agency, Varanasi*

Reference Books:

1. **Coalbed Methane: Principles and Practice** - Rudy Rogers, Kumar Ramurthy, Gary Rodvelt and Mike Mullen, *Oktibbeha Publishing*
2. **Petroleum Geoscience** - Jon Gluyas and Richard Swarbrick, *Blackwell Publishing*
3. **Petroleum Geoscience: From Sedimentary Environments to Rock Physics** - Knut Bjorlykke, *Springer*
4. **Petroleum Geosciences: Indian Contexts** - Soumyajit Mukherjee, *Springer*
5. **Coal and Organic Petrology** - M. P. Singh, *Hindustan Publishing Corp*

GLE-545B

Atmospheric Science

Total Marks: 100

(Internal Assessment: 20, End-semester Examination: 80)

Objective

The important objectives of the course are to introduce the students to the fundamentals of atmospheric science, physical and chemical nature of the Earth's atmosphere, and climate. They will also be introduced to the study of clouds, their classification, and precipitation.

Course Outcome

On completion of the course, the students would be able to understand basic concepts of atmospheric science. They will also be able to learn nature of atmosphere, clouds, precipitation and climate by which students will understand the Earth's surface system.

Unit 1: Climatology - definition, scope, aims and objectives; sub-divisions of climatology; weather and climate; weather elements; climatic controls; meteorology and climatology; weather forecasting; collection of climatic data.

Unit 2: Origin, composition and structure of atmosphere; insolation and heat budget; temperature in atmosphere and its distribution.

Unit 3: Air pressure and winds; Earth surface wind systems; Hadley cell and jet stream; Indian monsoon; fog; clouds - classification, application in weather forecasting; distribution of cloudiness; forms of precipitation; cyclones and anti-cyclones.

Unit 4: Classification of climate; types of climate and their distribution; climatic changes - climatic changes through geological time; theories of climatic changes; reconstruction of past climates.

Recommended Books

Text Books:

1. **Basics of Atmospheric Science** - A. Chandrasekar, *Prentice Hall India*
2. **Climatology** - D. S. Lal, *Sharda Pustak Bhawan*
3. **Climatology** - Savindra Singh, *Pravalika Publications*
4. **Climatology and Oceanography** - D. S. Lal, *Sharda Pustak Bhawan*

Reference Books:

1. **An Introduction to Dynamic Meteorology** - James R. Holton*, Academic Press*
2. **Atmosphere, Weather and Climate** - Roger G. Barry and Richard J. Chorley, *Routledge*
3. **Atmospheric Science for Environmental Scientists** - C. Nick Hewitt and Andrea V. Jackson, *Wiley-Blackwell*
4. **Climatology: Atmosphere, Weather & Climate** - K. Siddhartha, *Kitab Mahal*
5. **Essentials of Meteorology: An Invitation to the Atmosphere** - C. Donald Ahrens, *Cengage Learning*
6. **Meteorology Today: An Introduction to Weather, Climate, and the Environment** - C. Donald Ahrens and Robert Henson, *Cengage Learning*

GLE-545C

Marine Science

Total Marks: 100

(Internal Assessment: 20, End-semester Examination: 80)

Objective

The main objectives of the course are to introduce the students to basic concepts of marine science and associated geological phenomena. The course is also aimed to introduce morphological features, sediment nature, interactions of ocean water with various spheres of the Earth and life in marine environment.

Course Outcome

After completion of the course, the students would be able to understand various concepts of marine science, physical and chemical nature of seawater, nature of sediment as well as life in ocean. The students will also understand vital nature of ocean in atmospheric condition and for the life in the Earth

Unit 1: Introduction, history and development of marine science; Deep-Ocean Drilling Programmes; origin of the ocean; physical and chemical properties of sea water.

Unit 2: Oceans and seas; dimensions of the ocean; bathymetry; features of the seafloor; features of continental margin; active and passive margins; turbidity currents.

Unit 3: Ocean sediments: classification, composition and source; atmosphere-ocean interaction; Coriolis effect; ocean water circulation; El Nino and La Nina; waves and tides.

Unit 4: Productivity of the ocean; thermocline and its implications; life in the ocean; resources of the ocean; abuses of the ocean.

Recommended Books

Text Books:

1. **Climatology and Oceanography** - D. S. Lal, *Sharda Pustak Bhawan*
2. **Essentials of oceanography** - Tom Garrison, *Cengage Learning*
3. **Oceanography: A Brief Introduction** - K. Siddhartha, *Kitab mahal*
4. **Oceanography: An Invitation to Marine Science** - Tom Garrison and Robert Ellis, *Cengage Learning*
5. **The Sea Floor: An Introduction to Marine Geology** - Eugen Seibold and Wolfgang Berger, *Springer*

Reference Books:

1. **Essentials of Oceanography** - Alan P. Trujillo and Harold V. Thurman, *Pearson*
2. **Introduction to Physical Oceanography** - Robert H. Stewart, *Prentice Hall*
3. **Invitation to Oceanography** - Paul R. Pinet, *Jones and Bartlett Publishers*
4. **Marine Geology: Exploring the New Frontiers of the Ocean** - Jon Erickson, *Facts On File, Inc.*
5. **Oceanography** - Savindra Singh, *Pravalika Publications*

GLE-545D

Computer Application in Geology and Numerical Modelling

Total Marks: 100

(Internal Assessment: 20, End-semester Examination: 80)

Objective

The main objective of the course is to introduce the students to fundaments of computers, various hardware and software, operating systems, computer languages and their applications in geoscience. The course is also aimed to introduce productivity software such as office, SPSS and geological software. It also focused on the introduction of fundamentals of numerical modelling and MATLAB.

Course Outcome

After the completion of course, students will be able to understand the basics of computer, hardware, software, operating systems, and computer languages particularly R-language. They will get familiar with various productivity software and geological software. Students will also learn basic concepts of numerical modelling and MATLAB.

Unit 1: Components of computer; modern computer accessories; introduction to Operating Systems; LAN and internet protocols; big data technology; internet resources in geosciences.

Unit 2: Introduction to computer languages; fundamentals of R language; programming in R; R graphics; advantages and disadvantages of R language.

Unit 3: Working with word, spreadsheet, presentation, SPSS and publication; introduction to various software used in geosciences and their applications.

Unit 4: Introduction to mathematical and numerical techniques in geosciences; applications of numerical methods in earth sciences; classification of numerical models and solution methods; computing - hardware and software and their issues; guidelines for writing a computer program; introduction to MATLAB.

Recommended Books

Text Books:

1. **Computer Fundamentals -** Anita Goel, *Pearson*
2. **Computer Fundamentals** - Pradeep K. Sinha and Priti Sinha, *BPB Publications*
3. **Fundamental of Computer Science and Information Technology** - U. K. Singh, S. Jain and A. Maheswari, *SSDN Publication*.
4. **Fundamentals of Computers** - ITL ESL, *Pearson*
5. **Numerical Modelling of Earth Systems** - Thorsten W. Becker & Boris J. P. Kaus, *Lecture Notes-University of South California*

Reference Books:

1. **Fundamentals of Computing and Programming** - Meena Vijayabarathi, *Saras Publications*
2. **Hands-On Programming with R: Write Your Own Functions and Simulations** - Garrett Grolemund, *O'Reilly Media*
3. **Introduction to Numerical Geodynamic Modelling** - Taras Gerya, *Cambridge University Press*
4. **Linux in Easy Steps** - David Nash, *IDG Books*
5. **Microsoft: Excel® Functions and Formulas** - Bernd Held, *BPB Publications*
6. **Networking in Easy Steps** - Peter Ingram, *Dreamtech Press*
7. **Numerical Geology -** N. M. S. Rock, *Springer-Verlag*

GLE-545E

Glacial Geology

Total Credit: 4

Total Marks: 100

(Internal Assessment: 20, End-semester Examination: 80)

Objective

The main objective of the course is to introduce the students to the fundamentals of glaciers and glacial geology including glacial processes and landforms as well as past glaciation.

Course Outcome

On completion of the course the students shall have the basic understanding of glaciers, their types and distribution, glacial processes of erosion, transport and deposition, landforms associated with glacial processes and Quaternary glaciation.

Unit 1: Definition and importance of glacial geology; basic types of glaciers; physical characteristics of glaciers; accumulation and ablation; glacier mass balance; global distribution of glaciers.

Unit 2: Mechanism of glacial flow; glacial erosion processes: abrasion and quarrying; rates and patterns of glacial erosion; landscapes of glacial erosion; transport of glacial debris.

Unit 3: Glacial sediments and depositional processes; primary glacigenic deposits (till); glaciofluvial deposits; glaciomarine and glaciolacustrine deposits; glacial depositional landforms.

Unit 4: Palaeoglacial periods in Earth's history; glacial-inter glacial cycles; glaciers and sea level change; response of glaciers to climate change; Quaternary glaciation with special reference to Himalayan glaciers; reconstruction of Quaternary climate from glacial deposits and ice cores; impact of recent climate change on Himalayan glaciers.

Recommended Books

Text Books:

1. **Glacial Geology: Ice Sheets and Landforms** - Matthew R. Bennett and Neil F. Glasser, *Wiley -Blackwell*
2. **Glaciers and Glaciation** - Douglas I. Benn and David J.A. Evans, *Hodder Education*
3. **Principles of Glacier Mechanics** - Roger LeB. Hooke, *Cambridge University Press*

Reference Books:

1. **Encyclopedia of Snow, Ice and Glaciers** - Vijay P. Singh, Pratap Singh and Umesh K Haritashya, *Springer*
2. **Glacial Geology and Pleistocene Epoch** - Richard Foster Flint, *John Wiley and Sons, Inc.*
3. **Glacial Geology: An Introduction for Engineers and Earth Scientists** - N. Eyles, *Pergamon Press*
4. **Glacial Processes Past and Present** - David M. Mickelson and John W. Attig, *The Geological Society of America*
5. **Glacier Science and Environmental Change** - Peter G. Knight, *Blackwell Publishing*
6. **Paleoclimatology: Reconstructing Climates of the Quaternary** - Raymond S. Bradley, *Academic Press*
7. **Himalayan Glaciers: Climate Change, Water Resources, and Water Security** - Henry J. Vaux, Jr., *The National Academic Press*

GLE-546

Project Oriented Dissertation

Objective

The main objective the course is to introduce the students to learn basic methods of research activities carried out in geosciences by which the students will understand how to identify geological problems and the methods to solve them using various tools.

Course Outcome

After the completion of the course, the students will be expected to have basic knowledge about research methods and research techniques in geosciences as well as solving geological problems using various tools.

The project work shall be carried out for a period of minimum one semester under the supervision of a faculty in the department. Students shall be assigned to a supervisor at the beginning of third semester. A research problem in geology shall be identified and solved by systematic scientific study. At the end of fourth semester, students should submit their dissertation, duly signed by their respective supervisor, to the department which will be followed by viva-voce.

Project Work