B.Sc. (Honours) Geology

(Under the Framework of Honours School System)

PREAMBLE

The Centre of Advanced Study in Geology was established in the Panjab University in 1958. The Centre was soon recognized for its contribution by the University Grant Commission (UGC), which raised its status to that of the Centre of Advanced Study (CAS) in Palaeontology and Himalayan Geology in the year 1963. The Centre has continued to get funding under SAP-CAS programme of the UGC. The Centre has also received funding from the Department of Science and Technology, Government of India under COSSIST (1984-1989) and FIST (2002-2007) for improving the infrastructure in research and teaching.

Now the Centre has been renewed as Centre of Advanced Study under Special Assistance Programme of the UGC for a period of 5 years (1-4-2012 to 31-3-2017) in Phase-VII with the financial assistance of Rs. 148 Lacs in the following thrust areas: Palaeontology - Stratigraphy; Petrology; Hydrogeology & Environmental Geology.

The centre has received national and international honours and distinctions for seminal scientific contributions. The centre is endowed with well-equipped student-faculty interfaced laboratories, such as Scanning Electron Microscopy, Optical Microscopy, Sample Preparation Laboratory, and comfortable academic working environs. Besides, an internationally famous museum, a pride of the centre, is the mainstay for school children and lay public, where all and sundry are served hands-on activity for observing and understanding various aspects of earth sciences.

The Centre strives to maintain high standards of teaching by making its students not only aware of various geological problems, but also to study Geology as a quantitative science. The core subjects are taught at undergraduate levels, while interdisciplinary and modern courses are covered in the postgraduate level. The curriculum pertaining to B.Sc. (Honours) (3 Year course & 6 Semesters) in the subject of Geology under Honours School Framework has been upgraded as per provision of the UGC module for CHOICE BASED CREDIT SYSTEM and demand of the academic environment.

Outlines of Tests, Syllabi and Courses of Reading for B.Sc. (Honours: under the Framework of Honours School System) I Year in Geology (Choice Based Credit System) Examinations 2016-2017, 2017-18 and 2018-19

COURSE STRUCTURE

SEMESTER I		SEMESTER II	
C1	GEO-C1: Earth System Science	C3	GEO-C3: Elements of Geochemistry
C2	GEO-C2: Mineral Science	C4	GEO-C4: Structural Geology
AECC1	English	AECC2	Environmental Science
GE1*		GE2*	
GE3*		GE4*	

SEMESTER III		SEMESTER IV	
C5	GEO-C5: Igneous Petrology	C8	GEO-C8: Metamorphic Petrology
C6	GEO-C6: Sedimentary Petrology	C9	GEO-C9: Stratigraphic Principles & Stratigraphy
C7	GEO-C7: Palaeontology	C10	GEO-C10: Hydrogeology
SEC1		SEC2	
GE5*		GE6*	

SEMESTER V		SEMESTER VI	
C11	GEO-C11: Economic Geology	C13	GEO-C13: Engineering Geology
C12	GEO-C12: Geomorphology	C14	GEO-C14: Remote Sensing & GIS
DSE1		DSE3	
DSE2		DSE4	

C: Core Courses; GE: General Elective; AECC: Ability Enhancement Compulsory Courses; SEC: Skill Enhancement Courses; DSE: Discipline Specific Elective

***: GE subjects are to be selected by the students from the pool of GE Subjects offered by various Departments of the University.**

****GENERIC ELECTIVE SUBJECTS (Offered by Geology Department)** ***for students of other departments***

1. GEO-GE1: Essentials of Geology
2. GEO-GE2: Rocks and Minerals
3. GEO-GE3: Structural Geology
4. GEO-GE4: Fossils & their Applications
5. GEO-GE5: Stratigraphy
6. GEO-GE6: Hydrogeology

****SKILL ENHANCEMENT COURSES (any one per semester in semesters 3-4)**

1. GEO-SEC1: Field Geology 1 – Basic Field Training
2. GEO-SEC2: Field Geology 2 – Geological Mapping
3. GEO-SEC3: Field Geology 3 – Himalayan Geology Field
4. GEO-SEC4: Field Geology 4 – Stratigraphy and Paleontology Related Field

****DISCIPLINE SPECIFIC ELECTIVE (any two per semester in semesters 5-6)**

1. GEO-DSE1: Earth and Climate
2. GEO-DSE2: Evolution of Life Through Time
3. GEO-DSE3: Introduction to Geophysics
4. GEO-DSE4: Fuel Geology
5. GEO-DSE5: River Science
6. GEO-DSE6: Urban Geology

Courses under these will be offered only if a minimum of 10 students opt for the same

Pattern of end-semester question paper

The theory question paper for the end-semester examination will have nine questions, with 20 marks reserved for first question, which is compulsory. Further, the latter would comprise of 10 short answer questions, without any choice, covering the whole syllabus. The remaining 4 questions carrying 15 marks each, are to be attempted from the 4 Units. Each unit would comprise of two questions.

B.Sc. (Hons.)
Geology
I Year
Semester I and II

I Semester Examination

Paper	Course	Title	Credit	Mid-Semester Test	End-Semester Examination	Total Marks
Theory: Core Course						
I	GEO-C1	Earth System Science	4	20	80	100
II	GEO-C2	Mineral Science	4	20	80	100
Practical: Core Course				**Continuous Assessment**		
I	GEO-C1P	Earth System Science	2	10	40	50
II	GEO-C2P	Mineral Science	2	10	40	50
Total Credits & Marks			**12**			**300**

Paper I: EARTH SYSTEM SCIENCE - (Course No. GEO-C1)

Total Marks: [100 (Mid-Semester Test M.M. 20, End-Semester Exam. M.M. 80)]

Total Lectures: 60 **Credits: 4**

Objective: This basic fundamental course aims to understand various conceptual aspects of Earth's evolution and its constitution. It is also aimed to study a brief account of plate tectonic processes, about hydrosphere and atmosphere and also to understand fundamentals of stratigraphy including the geological time scale.

Instructions for the Paper Setters and Examiners:

Question paper will have four sections. Examiner will set a total of nine questions comprising two questions from each unit and one compulsory question of short answer type covering the whole syllabus. The students will attempt one question from each unit and the compulsory question. All questions may carry equal marks, unless specified.

UNIT 1: Earth as a planet (15 hrs)

Introduction to earth sciences and its various branches. Objectives and applications of earth sciences. Understanding of earth through geology, astronomy, oceanography and meteorology. Earth in solar system. Origin of earth and its various theories and models. Role of meteorites in earth sciences. Mass and density of other planetary bodies and their origin. Elemental abundance in solar system. Earth's size, shape, mass, density and rotational parametres.

UNIT 2: Plate tectonics (15 hrs)

Internal structure of the earth and chemical composition of various layers. Structure of lithosphere through oceans and continents. Major features of continents and oceans. Rock cycle-its role in origin of different rock types and processes. Earthquakes- histories, patterns, origin, properties of seismic waves, scale types and

effects of earthquakes. Volcanoes- structure, types and products. Distribution of belts of earthquake and volcanoes. Plate tectonics and sea floor spreading. Evidences of plate processes.

UNIT 3: Hydrosphere and atmosphere (15 hrs)

Weathering and erosion: types and factors controlling erosional processes. Exogenic processes associated with various features of erosion, transportation and deposition of rivers. River profiles. Role of groundwater in hydrological cycle. Groundwater flow in relation to sediment properties and textures. Exogenic features of erosion and deposition of groundwater. Distribution and types of glacial belts. Glacial erosional and depositional features and their origins. Aeolian action related to origin and distribution of deserts. Sand dunes-origin and geometries. Erosional, transportational and depositional features in major deserts of the world. Oceans-distribution and application in global climates and hydrospheric cycles. Types of oceanic waves. Erosional, transportational and depositional processes and relief features resulting from wave action. Soils-origin and types. Landforms related to soils. Climatic changes and role in controlling geomorphology

UNIT 4: Understanding the past from stratigraphic records (15 hrs)

Introduction to stratigraphy- scope, objectives and applications in geology. Uniformitarianism and catastrophism. Concept of stratigraphic correlation and techniques. Fundamentals of stratigraphic classification and applications in earth histories. Concept of geologic time scale through geologic and evolutionary episodes. Geochronologic, radiometric and relative methods of dating. Introduction to geomorphology. Stratigraphic and age-wise chronology of major geologic and palaeontologic histories in India. Stratigraphic successions, fossils and ages of Precambrian and Phanerozoic basins.

SUGGESTED READING

1. Brown, G.C. and Baily, W. (1981). Earth Science.
2. Duff, D. (1992). Homes' Principles of Physical Geology, 4th Ed. Chapman & Hall.
3. Emmons, W.H. Allison, I.S. Stauffer, C.R. and Thiel, G.A. (1960). Geology: Principles and Processes. McGraw Hill.
4. Foster, R.J. (1988). Physical Geology.
5. Gass, I.G. Smith, P.J and Wilson, R.L. (1979). Understanding the Earth – A Reader in Earth Science. 2nd Ed.
6. Hamblin, W. K. (1996). Introduction to Physical Geology. McMillan Publishing Company.
7. Levin, H.L. (1995). Contemporary Physical Geology. Saunders College Publishing.
8. Leet, L.D. and Judson, S. (1969). Physical Geology, 3rd Ed. Prentice Hall of India, New Delhi.
9. Leet, L. D., Judson, S. and Kauffman, M.E. (1992). Physical Geology. Prentice – Hall.
10. Monroe, J.S. and Wicander, R. (2003). Physical Geology. Books/Cole, Thomnson Learing, Australia.
11. Tarbuck, F.K. Lutgens. (2015). Earth Science, Prentice-Hall.

Paper II: MINERAL SCIENCE - (Course No. GEO-C2)

Total Marks: [100 (Mid-Semester Test M.M. 20, End-Semester Exam. M.M. 80)]

Total Lectures: 60 **Credits: 4**

Objective: This course aims to understand the basic concepts of crystals and crystal systems, and the characteristics and properties of various crystal systems. This course also introduces the general physical and optical characteristics of minerals with an aim to carry out a detailed study of physical & optical properties and chemical compositions of some important rock-forming silicate minerals and some non-silicates.

UNIT 1: Crystallography (15 hrs)

Elementary ideas about crystal morphology: Forms and morphology of crystals; Open and closed forms, Zone and Zone axes, Like and unlike faces, Interfacial angle and its measurements; Law of constancy of interfacial angle; Crystal parameters and indices: Weiss and Miller's systems of notation; Law of rational indices.

Study of Elements of crystal symmetry and aspects of crystal structures. Classification of crystals into six systems and principles of classification into 32 classes. Study of holohedral class of cubic, tetragonal, orthorhombic, monoclinic, triclinic and hexagonal crystal systems, and hemihedral classes of cubic and hexagonal crystal systems.

UNIT 2: Physical and optical characters of Minerals (15 hrs)

Minerals-definition and classification, physical characters of minerals: habit, colour, streak, cleavage, fracture, lustre, hardness and specific gravity; Nature of light and principles of optical mineralogy: polarized light and crossed polarized light; reflection, critical angle, total reflection, refraction and Snell's law; optical properties of minerals: isotropic and anisotropic minerals, refractive index, relief, colour, pleochroism, birefrengence and retardation, interference colours, extinction and its measurement.

UNIT 3: Rock forming mineral groups/minerals-I (15 hrs)

Silicate structures and classification of silicate minerals. A detailed description of the petrological or polarising light microscope (PLM): its parts and functioning. Physical and chemical composition of following common rock-forming minerals/groups of minerals: *Tektosilicates* – feldspar group, feldspathoid group and silica group. *Nesosilicates* – olivine group, garnet group, zircon and aluminium silicate group, titanite, staurolite and chloritoid. Optical identification of common rock-forming minerals: *Tektosilicates and Nesosilicates*.

UNIT 4: Rock forming mineral groups/minerals-II (15 hrs)

Physical and chemical composition of following common rock-forming minerals/groups of minerals: *Nesosilicates* –titanite, staurolite and chloritoid, *Sorosilicates* – epidote; *Cyclosilicates* –beryl, tourmaline and cordierite; *Inosilicates* – pyroxene group and amphibole group; *Phyllosilicates*– mica group, talc, serpentine and chlorite; apatite, calcite, barite, fluorite and corundum. Optical Identification of common rock-forming minerals: *Nesosilicates, Sorosilicates, Cyclosilicates, Inosilicates and Phyllosilicates*.

UGGESTED READING

1. Berry, L.G. and Mason, B. (1985). Mineralogy. CBS Pub. Delhi.
2. Dana, E.S. (1983). A text Book of Mineralogy. Wiley Eastern Ltd., New Delhi.
3. Flint, E. (1971). Essentials of Crystallography. Wiley Eastern Ltd., New Delhi.
4. Gribble, C.D. (1988). Rutley's Elements of Mineralogy. CBS Publishers, Delhi.
5. Kerr, P.E. (1959). Optical Mineralogy, McGraw Hill Book Co., NY.
6. Nesse, W.D. (2000). Introduction to Mineralogy. Oxford University Press.
7. Perkins, D. (1998). Mineralogy. Prentice Hall.

8. Phillips, F.C. (1977). An Introduction to Crystallography. ELBS Book Society, London.

Practical I: EARTH SYSTEM SCIENCE - (Course No. GEO-C1P)

Total Marks: [50 (Continuous Assessment M.M. 10, End-Semester Exam. M.M. 40)]

Total Lectures: 60 **Credits: 2**

1. Study of topographic sheets: features and scales.
2. Physiographic description of an area.
3. Study of major geomorphic features.
4. Distribution of lithostratigraphic units.
5. Major oceanic currents of the world.
6. Seismic record of an area.

Practical II: MINERAL SCIENCE - (Course No. GEO-C2P)

Total Marks: [50 (Continuous Assessment M.M. 10, End-Semester Exam. M.M. 40)]

Total Lectures: 60 **Credits: 2**

1. Clinographic projections and study of element of symmetry of the following crystal modals: Cube, Octahedron, Rhombdodecahedron; Tetrahexahedron, Trisoctahedron and Trapezohedron; Zircon, Barite, Gypsum, Hornblende, Beryl, Calcite, Pyritohedron and Tetrahedron.

2. Study of physical properties of mineral group/minerals in hand specimen:
Feldspar group, feldspathoid group and silica group. olivine group, garnet group, aluminium silicate group, titanite, staurolite, beryl and tourmaline; pyroxene group and amphibole group; mica group, talc, serpentine and chlorite; apatite, calcite, barite, fluorite and corundum.

3. Study of some key silicate minerals under optical microscope and their characteristic properties.

II Semester Examination

Paper	Course	Title	Credit	Mid-Semester Test	End-Semester Examination	Total Marks
Theory: Core Course						
I	GEO-C3	Elements of Geochemistry	4	20	80	100
II	GEO-C4	Structural Geology	4	20	80	100
Practical: Core Course				**Continuous Assessment**		
I	GEO-C3P	Elements of Geochemistry	2	10	40	50

II	GEO-C4P	Structural Geology	2	10	40	50
Total Credits & Marks			**12**			**300**

Paper I: ELEMENTS OF GEOCHEMISTRY - (Course No. GEO-C3)

Total Marks: [100 (Mid-Semester Test M.M. 20, End-Semester Exam. M.M. 80)]

Total Lectures: 60 **Credits: 4**

Objective: The aim of this course is to provide elementary idea about concepts of geochemistry, beginning with basic concepts of chemistry, geochemical classification of elements, rules of substitution and types of various elements. An overview of the structure of Earth and use of isotopes in geochronology is also provided. The course also aims to provide basics of aqueous geochemistry and solid earth.

Instructions for the Paper Setters and Examiners:

Question paper will have four sections. Examiner will set a total of nine questions comprising two questions from each unit and one compulsory question of short answer type covering the whole syllabus. The students will attempt one question from each unit and the compulsory question. All questions may carry equal marks, unless specified.

UNIT 1: Concepts of geochemistry (15 hrs)

Matter and its nature, elements and the periodic table of elements: periods and groups, atomic number, atomic mass and isotopes, ions, molecules and chemical bonding; states of matter, thermal energy and temperature, heat and heat transfer,
Geochemical classification of elements; Goldschmidt's rules of substitution and their modification ; Types of elements: transition elements, large-ion lithophile elements, high-field strength elements, incompatible and compatible elements, mobile and immobile elements.

UNIT 2: Layered structure of Earth and geochemistry (15 hrs)

Differentiation of the earth, Composition of different layers of Earth; the nuclides and physics of the nucleus; radioactivity: radioactive decay; the law of radioactive decay; Concept of radiogenic isotopes in geochronology and isotopic tracers; Decay schemes of Rb-Sr method, Sm-Nd method, U-Th-Pb method.

UNIT 3: Element transport (15 hrs)

Advection and diffusion, Mass Transport Processes: Fick's Law of diffusion; Molecular diffusion, turbulent diffusion and mechanical dispersion.
Chromatography: Techniques by physical state of mobile phase; Chromatographic bed shape and separation mechanism.
Aqueous geochemistry: basic concepts and speciation in solutions, Eh, pH relations and mineral solubility.
Chemistry of Natural Water: River Water, Seawater, Evaporation of Seawater, Seafloor Hydrothermal System, Groundwater and Lakes.
Chemical control on Diagenesis, Metamorphism and Hydrothermal reactions.

UNIT 4: Geochemistry of solid Earth (15 hrs)

Cosmic elemental abundances; Composition of the bulk silicate Earth: major and minor elements in the crust. Analytical methods and results, sources of error, precision and accuracy. The solid Earth – geochemical variability of magma and its products: composition of magma, volatiles in magma, variation diagrams: bivariate and triangular plots; Rare earth elements (REE) diagrams; Spider diagrams. Meteorites.

SUGGESTED READING

1. Albarède, F. (2003). Geochemistry: an introduction. Cambridge University Press.
2. Brocker, W.S. and Virginia, M. (1971). Chemical Equilibrium in the Earth. McGraw Hill.
3. Faure, G. and Mensing, T.M. (2004). Isotopes: Principles and Applications, Wiley India Pvt. Ltd.
4. Konard, B. (1985). Introduction to Geochemistry. McGraw Hill.
5. Mason, B. (1986) Principles of Geochemistry. 3rd Edition, Wiley New York.
6. Rollinson, H. (2007) Using geochemical data – evaluation, presentation and interpretation. 2nd Edition. Publisher Longman Scientific & Technical.
7. Walther, J. V. (2009). Essentials of Geochemistry. Jones & Bartlett Publishers.

Paper II: STRUCTURAL GEOLOGY - (Course No. GEO-C4)

Total Marks: [100 (Mid-Semester Test M.M. 20, End-Semester Exam. M.M. 80)]

Total Lectures: 60 **Credits: 4**

Objective: This course introduces the fundamentals of structural geology with an objective to study in detail the structures related to processes of fracturing. The main aim of this course is to appraise the structures related to deformation and tectonics.

UNIT 1: Structure and Topography (15 hrs)

Effects of topography on structural features; Topographic and structural maps; Important representative factors of the map; Concept of dip and strike; Stratum contour, clinometer compass and Brunton compass, bearing and back bearing. Stereographic projection and its use in structural geology. Thickness and width of outcrops, outlier, inlier. Unconformities: significance, onlap, offlap, types and recognition of unconformities.

UNIT 2: Stress and strain in rocks; Foliation and lineation (15 hrs)

Concept of rock deformation: stress and strain in rocks, strain ellipses of different types and their geological significance. Factors controlling behaviour of rocks; Methods of determination of top and bottom of beds.

Description (definition and types) and origin of foliation: axial plane cleavage and its significance; its relationship with bedding. Description (definition and types) and origin of lineation and relationship with the major structures.

UNIT 3: Folds (15 hrs)

Fold morphology; Geometric and genetic classification of folds; Introduction to mechanics of folding: buckling, bending, flexural slip and flow folding. Causes of folding.

UNIT 4: Joints and faults (15 hrs)

Joints: general characteristics, joint sets, joint system, major joints and their relation with other structure; use of Rose diagram and stereographic projection; joint intensity.

Fault: parts; geometric and genetic classification; geologic/geomorphic criteria for recognition of fault and fault plane solution. Difference between fault and unconformity. Effects of faulting on outcrop pattern. Throw of the fault, horst and graben. Mechanics of faulting; Introduction to Thrust, Nappe, Klippe and window.

SUGGESTED READING

1. Davis, G.R. (1984). Structural Geology of Rocks and Region. John-Wuley.
2. Billings, M.P. (1990): Structural Geology. Prentice Hall of India, New Delhi.
3. Hobbs, B.E, Means, W.D. and Williams, P.F. (1976). An Outline of Structural Geology, John-Wiley.
4. Lahee, F.H. (1962). Field Geology. McGraw Hill.
5. Park, R.G. (2004). Foundation of Structural Geology. Chapman & Hall.
6. Pollard, D.D. (2005). Fundamental of Structural Geology. Cambridge University Press.
7. Ragan, D.M. (2009). Structural Geology: An Introduction to Geometric Techniques. 4the Ed. Cambridge University Press.

Practical I: ELEMENT OF GEOCHEMISTRY - (Course No. GEO-C3P)

Total Marks: [50 (Continuous Assessment M.M. 10, End-Semester Exam. M.M. 40)]

Total Lectures: 60 **Credits: 2**

1. Types of geochemical data analysis and interpretation of common geochemical plots.
2. Geochemical variation diagrams, rare earth elements (REE) and spider diagrams and their interpretations.
3. Analysis of natural waters. Estimation of major cations and anions.

Practical II: STRUCTURAL GEOLOGY - (Course No. GEO-C4P)

Total Marks: [50 (Continuous Assessment M.M. 10, End-Semester Exam. M.M. 40)]

Total Lectures: 60 **Credits: 2**

1. Basic idea of topographic contours; Topographic sheets of various scales.
2. Introduction to geological maps: Lithological and Structural maps.
3. Structural contouring and 3-point problems of dip and strike.
4. Drawing profile sections and interpretation of geological maps of different complexities. Completion of outcrops.
5. Exercises of sterographic and orthographic projections of mesoscopic structural data (planer, linear, folded, etc.).

Outlines of Tests, Syllabi and Courses of Reading for B.Sc. (Honours: under the Framework of Honours School System) I Year (Generic Elective) in Geology (Choice Based Credit System) Examinations 2016-2017, 2017-18 and 2018-19.

I Semester Examination

Paper	Course	Title	Credit	Mid-Semester Test	End-Semester Examination	Total Marks
Theory: Generic Elective						
I	GEO-GE1	Essentials of Geology	4	20	80	100
II	GEO-GE2	Minerals and Rocks	4	20	80	100
Practical: Generic Elective				**Continuous Assessment**		
I	GEO-GE1P	Essentials of Geology	2	10	40	50
II	GEO-GE2P	Minerals and Rocks	2	10	40	50
Total Credits & Marks			**12**			**300**

Paper I: ESSENTIALS OF GEOLOGY - (Course No. GEO-GE1)

Total Marks: [100 (Mid-Semester Test M.M. 20, End-Semester Exam. M.M. 80)]

Total Lectures: 60 **Credits: 4**

Objective: The aim of this course is to introduce the subject of geology along with its various branches and also to provide an introduction to some basic concepts in geology, such as about age of Earth, internal structure of Earth and various internal and external processes, which modify the landscapes and relief of the earth.

Instructions for the Paper Setters and Examiners:

Question paper will have four sections. Examiner will set a total of nine questions comprising two questions from each unit and one compulsory question of short answer type covering the whole syllabus. The students will attempt one question from each unit and the compulsory question. All questions may carry equal marks, unless specified.

UNIT 1: Introduction to earth and planetary sciences (15 hrs)

Introduction to earth sciences, and its role in relation to other sciences disciplines. Its various branches, relationships and applications. Understanding of earth through geology, astronomy, oceanography and meteorology. Role of physical and biological sciences in interpretation of earth. Universe and planetary systems. Earth in solar system. Origin of the earth. Elemental abundance in solar system. Fundamentals of chemistry of earth's various layers. Earth's size, shape, mass, density and rotational parametres.

UNIT 2: Internal structure and rock-air-water interactions (15 hrs)

Internal structure of the earth in relation to its origin. Chemical composition of its various layers. Hydrosphere and hydrologic cycle. Role of atmospheric circulation and climates in earth. Biosphere: its distribution and origin through ages. Oceans, continents and mountains- their origin, types, relief features and their structures.

UNIT 3: Earth history (15 hrs)

Stratigraphy and its role in interpretation of history of the earth. Principles of straigraphy. Stratigraphic classification and fundamentals of nomenclature. Geological time scale- interpretation of earth history through geologic and evolutionary episodes. Age of the Earth. Methods of age determination: absolute and relative techniques. Radioactivity and its application in determining the age of the Earth, rocks, minerals and fossils.

UNIT 4: Evolution of Earth's landscape and origins (15 hrs)

Rock cycle-its interpretation of earth processes. Endogenic processes in understanding earthquakes, volcanoes and interior of earth. Origin of earthquakes- various theories. Seismic waves in interpreting structure of earth. Volcanoes- origin, structures, types. Belts of earthquake and volcanoes. Exogenic processes of weathering, erosion, transportation and deposition. Role of relief and global climates in interpreting landscapes and geomorphologic features. Erosion, transportation and depositional processes, relief features and landscapes and evolution of rivers, groundwater, glaciers, wind and oceanic waves.

SUGGESTED READING

1. Duff, D. (1992). Homes' Principles of Physical Geology, 4th Ed. Chapman & Hall.
2, Emiliani, C. (1992). Planet Earth, Cosmology, Geology and the Evolution of Life and Environment. Cambridge University Press.
3. Emmons, W.H. Allison, I.S. Stauffer, C.R. and Thiel, G.A. (1960). Geology: Principles and Processes. McGraw Hill.
4. Gross, M.G. (1977). Oceanography: A view of the Earth. Prentice Hall.

Paper II: MINERALS AND ROCKS - (Course No. GEO-GE2)

Total Marks: [100 (Mid-Semester Test M.M. 20, End-Semester Exam. M.M. 80)]

Total Lectures: 60 **Credits: 4**

Objective: This course introduces the general physical characteristics of minerals with an aim to carry out a detailed study of physical properties and chemical compositions of some important rock-forming silicate

minerals and some non-silicates. The course also introduces the fundamentals of petrology in order to have broad idea of forms, textures and classification of igneous, metamorphic and sedimentary rocks.

Instructions for the Paper Setters and Examiners:

Question paper will have four sections. Examiner will set a total of nine questions comprising two questions from each unit and one compulsory question of short answer type covering the whole syllabus. The students will attempt one question from each unit and the compulsory question. All questions may carry equal marks, unless specified.

UNIT 1: Physical characters of minerals (15 hrs)

Introduction and scope of mineralogy. Physical characters of minerals: form, cleavage, parting, fracture, luster, colour, streak, hardness and specific gravity. Classification of silicate minerals. Physical properties, chemical composition, occurrence and uses of following minerals/groups of minerals: *Tektosilicates* – feldspar group, feldspathoid group and silica group. *Nesosilicates* – olivine group, garnet group, zircon and aluminium silicate group.

UNIT 2: Rock forming mineral groups/minerals-I (15 hrs)

Physical properties, chemical composition, occurrence and uses of following minerals/groups of minerals: *Nesosilicates* – titanite, staurolite and chloritoid. *Sorosilicates* – epidote; *Cyclosilicates* – beryl, tourmaline and cordierite; *Inosilicates* – pyroxene group and amphibole group; *phyllosilicates* – mica group, talc, serpentine and chlorite; apatite, calcite, barite, fluorite and corundum.

UNIT 3: Introduction to Igneous Petrology (15 hrs)

Introduction to petrology. Igneous petrology: introduction to magma; igneous environments; forms and structures of extrusive and intrusive igneous rocks; igneous textures; classification (mineralogical including IUGS and chemical) and nomenclature of igneous rocks; and petrography of common igneous rocks.

UNIT 3: Introduction to Sedimentary & Metamorphic Petrology (15 hrs)

Sedimentary petrology: formation of sediments; types and formation of sedimentary rocks (siliciclastic, biochemical, organic and chemical); sedimentary structures; and diagenesis. Metamorphic petrology: definition of metamorphism; limits and types of metamorphism; metamorphic agents; types of metamorphic protoliths; textures and structures; and classification and names of metamorphic rocks.

SUGGESTED READING

1. Berry, L.G. and Mason, B. (1985). Mineralogy. CBS Pub. Delhi.
2. Blatt, H. and Tracy, R.J. (1996). Petrology: Igneous, Sedimentary and Metamorphic. 2nd ed. W.H. Freeman and Company. NY.
3. Dana, E.S. (1983). A text Book of Mineralogy. Wiley Eastern Ltd., New Delhi.
4. Gribble, C.D. (1988). Rutley's Elements of Mineralogy. CBS Publishers, Delhi.
5. Hyndman, D.W. (1985). Petrology of Igneous and Metamorphic Rocks, McGraw Hill, N.Y.
6. McBirney, A.R. (1984). Igneous Petrology, Freeman, San Francisco.
7. Tyrrel, G.W. (1987). The Principles of Petrology. B.I. Pub., Bombay.

Practical I: ESSENTIALS OF GEOLOGY - (Course No. GEO-GE1P)

Total Marks: [50 (Continuous Assessment M.M. 10, End-Semester Exam. M.M. 40)]

Total Lectures: 60 **Credits: 2**

1. Major geomorphic features and relationship with outcrops.
2.Topographic sheets and scales.
3.Study of topographic maps of selected areas.

Practical II: MINERALS AND ROCKS - (Course No. GEO-GE2P)

Total Marks: [50 (Continuous Assessment M.M. 10, End-Semester Exam. M.M. 40)]

Total Lectures: 60 **Credits: 2**

1.Study of various physical properties of minerals. Study of the following minerals in hand specimen: olivine, garnet, kyanite, andalusite, sillimanite, orthoclase, plagioclase, sodalite, quartz and its varieties, titanite, staurolite, beryl, tourmaline, hypersthene, diopside, augite, anthophyllite, tremolite, actinolite, hornblende, muscovite, biotite, lepidolite, phlogopite, talc, chlorite, serpentine, asbestos, apatite, calcite, barite, fluorite and corundum.

2. IUGS classification of igneous rocks.

3.Magascopic study of the following igneous, metamorphic and sedimentary rocks: Igneous rocks**:** granite, pegmatite, syenite, diorite, granodiorite, gabbro, rhyolite, dacite, trachyte, andesite and basalt. Metamorphic rocks: phyllite, schist, gneiss, amphibolite, marble and quartzite. Sedimentary rocks**:** shale, sandstone, grit, limestone, arkose and conglomerate.

II Semester Examination

Paper	Course	Title	Credit	Mid-Semester Test	End-Semester Examination	Total Marks
Theory: Generic Elective						
I	GEO-GE3	Structural Geology	4	20	80	100
II	GEO-GE4	Fossils & their Applications	4	20	80	100
Practical: Generic Elective				**Continuous Assessment**		
I	GEO-GE3P	Structural Geology	2	10	40	50
II	GEO-GE4P	Fossils & their Applications	2	10	40	50
Total Credits & Marks			**12**			**300**

Paper I: STRUCTURAL GEOLOGY - (Course No. GEO-GE3)

Total Marks: [100 (Mid-Semester Test M.M. 20, End-Semester Exam. M.M. 80)]

Total Lectures: 60 **Credits: 4**

Objective: This course introduces the fundamentals of structural geology with an objective to study in detail the structures related to processes of fracturing. The main aim of this course is to appraise the structures related to deformation and tectonics.

Instructions for the Paper Setters and Examiners:

Question paper will have four sections. Examiner will set a total of nine questions comprising two questions from each unit and one compulsory question of short answer type covering the whole syllabus. The students will attempt one question from each unit and the compulsory question. All questions may carry equal marks, unless specified.

UNIT 1: Structure and Topography (15 hrs)

Effects of topography on structural features; Topographic and structural maps; Important representative factors of the map; Concept of dip and strike; Stratum contour, clinometer compass and Brunton compass, bearing and back bearing. Stereographic projection and its use in structural geology. Thickness and width of outcrops, outlier, inlier. Unconformities: significance, onlap, offlap, types and recognition of unconformities.

UNIT 2: Stress and strain in rocks; Foliation and lineation (15 hrs)

Concept of rock deformation: stress and strain in rocks, strain ellipses of different types and their geological significance. Factors controlling behaviour of rocks; Methods of determination of top and bottom of beds.

Description (definition and types) and origin of foliation: axial plane cleavage and its significance; its relationship with bedding. Description (definition and types) and origin of lineation and relationship with the major structures.

UNIT 3: Folds (15 hrs)

Fold morphology; Geometric and genetic classification of folds; Introduction to mechanics of folding: buckling, bending, flexural slip and flow folding. Causes of folding.

UNIT 4: Joints and faults (15 hrs)

Joints: general characteristics, joint sets, joint system, major joints and their relation with other structure; use of Rose diagram and stereographic projection; joint intensity.

Fault: parts; geometric and genetic classification; geologic/geomorphic criteria for recognition of fault and fault plane solution. Difference between fault and unconformity. Effects of faulting on outcrop pattern. Throw of the fault, horst and graben. Mechanics of faulting; Introduction to Thrust, Nappe, Klippe and window.

SUGGESTED READING

1. Davis, G.R. (1984). Structural Geology of Rocks and Region. John-Wuley.
2. Billings, M.P. (1990): Structural Geology. Prentice Hall of India, New Delhi.
3. Hobbs, B.E, Means, W.D. and Williams, P.F. (1976). An Outline of Structural Geology, John-Wiley.
4. Lahee, F.H. (1962). Field Geology. McGraw Hill.
5. Park, R.G. (2004). Foundation of Structural Geology. Chapman & Hall.
6. Pollard, D.D. (2005). Fundamental of Structural Geology. Cambridge University Press.

7. Ragan, D.M. (2009). Structural Geology: An Introduction to Geometric Techniques. 4the Ed. Cambridge University Press.

Paper II: FOSSILS AND THEIR APPLICATIONS - (Course No. GEO-GE4)

Total Marks: [100 (Mid-Semester Test M.M. 20, End-Semester Exam. M.M. 80)]

Total Lectures: 60 **Credits: 4**

Objective: This basic fundamental course aims to understand various conceptual aspects of Earth's evolution and its constitution. It is also aimed to study a brief account of plate tectonic processes, about hydrosphere and atmosphere and also to understand fundamentals of stratigraphy including the geological time scale.

Instructions for the Paper Setters and Examiners:

Question paper will have four sections. Examiner will set a total of nine questions comprising two questions from each unit and one compulsory question of short answer type covering the whole syllabus. The students will attempt one question from each unit and the compulsory question. All questions may carry equal marks, unless specified.

UNIT 1: Introduction to fossils (15 hrs)

Definition of fossil, fossilization processes (taphonomy), taphonomic attributes and its implications, modes of fossil preservation, role of fossils in development of geological time scale and fossils sampling techniques.

UNIT 2: Species concept (15 hrs)

Definition of species, species problem in paleontology, speciation, methods of description and naming of fossils, code of systematic nomenclature

UNIT 3: Introduction to various fossil groups (15 hrs)

Brief introduction of important fossils groups: invertebrate, vertebrate, microfossils, spore, pollens and plant fossils. Important age-diagnostic fossiliferous horizons of India

UNIT 4: Economic and academic application of fossils (15 hrs)

Implication of microfossils in hydrocarbon exploration, correlation of core seams and mineral exploration. Importance of fossils in creating natural history museums and movies. Application of fossils in study of biostratigraphy, evolution, paleoecology, paleobiogeography, paleogeography, paleoclimate, paleoenvironment, astrobiology, paleopathology and paleodiet.

SUGGESTED READING

1. Benton, M.J. (2005). Vertebrate paleontology (3rd edition). Blackwell Scientific, Oxford.
2. Black, R.M. (1988). The Elemetns of Palaeontology. Cambridge University Press.
3. Clarkson, E.N.K. (1998). Invertebrate Paleontology and Evolution. George AlIen & Unwin.
4. Colbert, E. H., Morales, M. and Minkoff, E.C. (2001). Colbert's Evolution of the Vertebrates: A History of the Backboned Animals Through Time. John Wiley & Sons.
5. Prothero, D.R. (1998). Bringing fossils to life - An introduction to Paleobiology. McGraw Hill.
6. Schoch, R.M. (1989). Stratigraphy, Principles and Methods.VanNostrand Reinhold.

Practical I: STRUCTURAL GEOLOGY - (Course No. GEO-GE3P)

Total Marks: [50 (Continuous Assessment M.M. 10, End-Semester Exam. M.M. 40)]

Total Lectures: 60 **Credits: 2**

1. Basic idea of topographic contours; Topographic sheets of various scales.
2. Introduction to geological maps: Lithological and Structural maps;
3. Structural contouring and 3-point problems of dip and strike.
4. Drawing profile sections and interpretation of geological maps of different complexities. Completion of outcrops.
5. Exercises of sterographic and orthographic projections of mesoscopic structural data (planer, linear, folded, etc.).

Practical II: FOSSILS AND THEIR APPLICATIONS - (Course No. GEO-GE4P)

Total Marks: [50 (Continuous Assessment M.M. 10, End-Semester Exam. M.M. 40)]

Total Lectures: 60 **Credits: 2**

1. Study of fossils showing various modes of fossilization.
2. Identification of representative genera of the Phyla: Mollusca: Pelecypoda, Gastropoda and Cephalopoda; Brachiopoda, Arthropoda, Corals and Echinodermata.
3. Distribution of age diagnostic fossils in India
4. Biostratigraphic correlation.

STRATIGRAPHY - (Course No. GEO-GE5)

Total Marks: [100 (Mid-Semester Test M.M. 20, End-Semester Exam. M.M. 80)]

Total Lectures: 60 **Credits: 4**

Objective: The major role of this course is to understand and interpret earth history, both global as well as related to Indian context. Various concepts of stratigraphy, such as its fundamentals, classification and nomenclatural procedures and stratigraphic successions of India are highlighted to clarify and build geologic history of India in time and space.

Instructions for the Paper Setters and Examiners:

Question paper will have four sections. Examiner will set a total of nine questions comprising two questions from each unit and one compulsory question of short answer type covering the whole syllabus. The students will attempt one question from each unit and the compulsory question. All questions may carry equal marks, unless specified.

UNIT 1: Principles of stratigraphy (15 hrs)

Fundamentals, objectives and applications of stratigraphy. Principles of stratigraphy and their applications. Stratigraphic correlation and techniques. Facies concept and facies types. Walther's law of facies. Palaeogeographic reconstruction. Transgressions and regressions. Stratigraphic cycles. Environments of sedimentation.

UNIT 2: Stratigraphic classification and stratigraphic nomenclature (15 hrs)

Stratigraphic classification: concepts and applications. Concepts of lithostratigraphy, biostratigraphy, chronostratigraphy, seismic stratigraphy, chemostratigraphy, magnetostratigraphy Fundamentals of sequence stratigraphy and seismic stratigraphy. Geologic time scale: earth processes and biological episodes. Stratigraphic Code: development of a standardized stratigraphic nomenclature. Concepts of stratotypes. Global Stratotype Section and Point (GSSP).

UNIT 3: Stratigraphy of India and Precambrian Successions (15 hrs)

An introduction to the overall stratigraphy of India: successions, fossils and ages from Precambrian to the Phanerozoic. Precambrian successions and correlative equivalents in Dharwar, south India, Singhbhum, central India. Aravalli Delhi belt. Precambrian basins in Himalayan regions of Kashmir, Kumaun, Himachal Pradesh and the northeast. Cuddapah (Kurnoo, Kaladgi and Bhima successions) and Vindhan Supergroups: lithostratoigraphic successions, biotas and palaeoenvironmental significance.

UNIT 4: Phanerozoic Stratigraphy of India (15 hrs)

Paleozoic stratigraphy in Tethyan basins of Kahmir, Spiti and Ladakh with particular reference to biotas, palaeoenvironmental implications and biocorrelations. Palaeozoic stratigraphy of the Lesser Himalaya and peninsular India. Mesozoic stratigraphic successions in Peninsular India, with particular reference to Kachchh, Rajasthan, South India. Himalayan Mesozoic stratigraphy of Spiti area. Gondwana Supergroup: stratigraphic successions, biotas, ages, palaeogeography and palaeoclimates. Cenozoic successions of Foreland Basin (Siwalik Group and Palaeogene successions of Lesser Himalaya and Trans-Himalaya) and those of Peninsular India.

SUGGESTED READING

1. Doyle, P. and Bennett, M. R. (1996). Unlocking the Stratigraphic Record. John Wiley.
2. Krishnan, M. S. (1982). Geology of India and Burma. CBS Publishers, Delhi.
3. Ramakrishnan, M. and Vaidyanadhan, R. (2008). Geology of India, Volumes 1 & 2. Geological Society of India, Bangalore.
4. Valdiya, K. S. (2010). The making of India. Macmillan India Pvt. Ltd.

Practical: STRATIGRAPHY - (Course No. GEO-GE5P)

Total Marks: [50 (Continuous Assessment M.M. 10, End-Semester Exam. M.M. 40)]

Total Lectures: 60 **Credits: 2**

1. Study of geological map of India and identification of major stratigraphic units.
2. Study of rocks in hand specimens from known Indian stratigraphic horizons.
3. Drawing various paleogeographic maps of Precambrian and Phanerozoic times.

HYDROGEOLOGY - (Course No. GEO-GE6)

Total Marks: [100 (Mid-Semester Test M.M. 20, End-Semester Exam. M.M. 80)]

Total Lectures: 60 **Credits: 4**

Objective: The main emphasis of this course is on the basic concepts of hydrogeology along with principles of occurrence, chemistry movement, development and management of groundwater resources.

Instructions for the Paper Setters and Examiners:

Question paper will have four sections. Examiner will set a total of nine questions comprising two questions from each unit and one compulsory question of short answer type covering the whole syllabus. The students will attempt one question from each unit and the compulsory question. All questions may carry equal marks, unless specified.

UNIT 1: Introduction and basic concepts (15 hrs)

Scope of hydrogeology and its societal relevance; Origin, occurrence and distribution of water, Types of water; Hydrologic cycle: precipitation, evapo-transpiration, run-off, infiltration and subsurface movement of water; Water balance; Rock properties affecting groundwater; Vertical distribution of subsurface water, Types of aquifer, anisotropy and heterogeneity of aquifers.

UNIT 2: Groundwater flow and well hydraulics (15 hrs)

Laminar and turbulent groundwater flow; Theory of groundwater flow- Darcy's law and its validity; Elementary concepts related to equilibrium and non-equilibrium conditions for water flow to a well in confined and unconfined aquifers; Aquifer parameters-transmissivity, storage coefficient, hydraulic conductivity, transmitivity, hydraulic resistance and likage factor; Intrinsic permeability and hydraulic conductivity; Groundwater flow rates and flow direction.

UNIT 3: Groundwater chemistry (15 hrs)

Physical and chemical properties of water; Quality criteria for different uses-Domestic, Irrigation and Industrial; Graphical presentation of groundwater quality data; Groundwater quality in different provinces in India; Groundwater contamination; natural (geogenic) and anthropogenic contaminants; Saline water intrusion in coastal aquifers.

Unit 4: Groundwater management (15 hrs)

Surface and subsurface water interaction, Conjunctive use of surface and groundwater; Groundwater legislation.; Groundwater level fluctuations; Basic concepts of water balance studies, issues related to groundwater resources development and Management, Artificial Recharge of Ground Water- Concept of artificial recharge – recharge methods, relative merits, Applications of Remote Sensing in Artificial Recharge of Ground water.

SUGGESTED READING

1. Davis, S. N. and De Weist, R.J.M. (1966). Hydrogeology. John Wiley & Sons Inc., N.Y.
2. Karanth K.R. (1987). Groundwater: Assessment, Development and Management. Tata McGraw-Hill Pub. Co. Ltd.
3. Todd, D. K. (2006). Groundwater Hydrology, 2nd Ed. John Wiley & Sons, N.Y.

Practical: HYDROGEOLOGY - (Course No. GEO-GE5P)

Total Marks: [50 (Continuous Assessment M.M. 10, End-Semester Exam. M.M. 40)]

Total Lectures: 60 **Credits: 2**

1. Preparation and interpretation of water level contour maps and depth to water level maps.
2. Study, preparation and analysis of hydrographs for differing groundwater conditions.
3. Graphical representation of chemical quality data and water classification (Trilinear diagrams).
4. Simple numerical problems related to: determination of permeability in field and laboratory, groundwater flow, well hydraulics, etc.