B.Sc in Earth Sciences

Model Programme Structure for the Bachelor of Science Degree with Earth Science

Sem.	Discipline Core (DSC) (Credits) (L+T+P)	Credits	Discipline Specific Elective (DSE) / Open Elective (OE) (Credits)(L+T+P)	Ability Enhancement Compulsory Courses (AECC), Languages (Credits) (L+T+P)		Skill Enhancement Courses (SEC) (L+T+P)			Total Credits
						Skill-based (Credits)	Value-based (Credits)		
I	**A1 Theory (4 credits)** Earth System Science - Fundamentals **P1 Practicals (2 credits)** -Maps, Sediment Soil, Field Visit	4+2	**OE-1 (3 credits)** i) Crystallography, Mineralogy, and Economic Minerals ii) Pedology iii) Basics of Earth System Science iv) Geohazards and Mitigation Strategies	L1-1 (3) L2-1 (3) (3+1+0) Each		Digital Fluency (2) (1+0+2)	Physical Education for fitness (1) (0+0+2)	Health and Wellness (1) (0+0+2)	25
	Discipline B1 (6)	6							
II	**A2 Theory (4 credits)** - Basics of Crystallography, Minerology and Petrology (4 credits) **P2 Practicals (2 credits)**- Crystallography, Minerology and Petrology	4 2	**OE-2 (3 credits)** i) Medical Geology ii) Industrial minerals iii) Paleobiology iv) Gems and Ornamental Stones	L1-2 (3) L2-2 (3) (3+1+0) Each	Environmental Studies (2)		Physical education-Yoga (1) (0+0+2)	NCC/NSS/R&R(S&G)/Cultural (1) (0+0+2)	25
	Discipline B2 (6)	6							
Exit option with Certificate (50 credits) A coherent understanding of Geology, ability to identify rocks and Minerals, and developing analytical skills. Its linkages with related interdisciplinary areas/subjects like Geography, Environmental Geology, Physics, Chemistry, Statistics, etc.									
III	**A3 Theory (4 credits)** - Principles of Stratigraphy Paleontology & Geology of India	4	**OE-3 (3 credits)** i) Dimensional State Technology ii) Climatology iii)Watershed Management iv) Marine Geology	L1-3 (3), L2-3(3) (3+1+0 each)		SEC-2: Artificial Intelligence (2)(1+0+2)	Physical education-Sports skills (1) (0+0+2)	NCC/NSS/R&R(S&G)/Cultural (1) (0+0+2)	25
	P3 Practicals (2 credits) Stratigraphy and Palaeontology	2							
	Discipline B3 (6)	6							
IV	**A4 Theory (4 credits)** - Structural Geology and Hydrogeology	4	**OE-4 (3 credits)** i) Geology and Society ii) Geostatistics iii) Geophysical Exploration iv) Geotourism	L1-4 (3), L2-4(3) (3+1+0 each)	Constitution of India (2)		Physical education-Games (1) (0+0+2)	NCC/NSS/R&R(S&G)/Cultural (1) (0+0+2)	25
	P4 Practicals (2 credits)- Water Analysis, Surveying and Thin Section Making	2							
	Discipline B4 (6)	6							
Exit option with Diploma (100 credits) The study encompasses the evolution of life through geologic time. Evolution and history of the earth and relate them to their field observations**.** Skills and ability to interpret the climatic conditions, depositional environment, identification of fossils and their evolution. Climatic history. Knowledge about surface and groundwater, its movement, methods of its exploration, its quality, methods of its conservation and recharge.									

A1. EARTH SCIENCE

EARTH SYSTEM SCIENCES (4 Credits)

(L – T – P Model)

Total Teaching Hours: 64
Teaching Hours: 4/Week.
Exam. Duration: 3 Hrs.

UNIT 1: INTRODUCTION TO EARTH SYSTEM SCIENCES

16 hrs

Definition and scope of earth system sciences. Branches of Earth Sciences. Systems concepts for earth system science - fundamental concepts of the five spheres (lithosphere, hydrosphere, atmosphere, biosphere and cryosphere). Energy balance. Interactions between the five spheres; hydrologic cycle; Biogeochemical cycles - carbon cycle; Hydrosphere-atmosphere: Oceanic current system and effect of Coriolis force. Concepts of eustasy. Atmospheric circulation. Weather and climatic changes.

Interrelationships between biological, geological, climatological, and human systems on continental and global scales. Anthropogenic influences on the Earth systems; Human-environment interactions - policy.

The universe and solar system: Origin of the universe - Big bang theory. Solar system. Members of solar system – planets (Terrestrial and gaseous planets), satellite, comets, asteroids, meteorite.
Earth in the solar system. Size, shape, mass and density of the earth.
Origin of the Earth – Gaseous hypothesis, Nebular hypothesis, Planetesimal hypothesis, Tidal hypothesis, Supernova hypothesis, Interstellar or dust or meteoric hypothesis. Evolution of earth.
Age of the Earth: Geochronology; Absolute and relative methods; (a) Relative Methods - Sedimentation, Salinity method, varve chronology, Rate of cooling of earth. (a) Radiometric dating, atomic energy, decay scheme, half life, method - K-Ar; Rb-Sr; U-Pb, Pb-Pb.
Age of the earth.
Earth's internal structures and its composition. Evidence for the Earth's composition and mineralogy – 1. Seismic data, 2. Density studies, 3. Meteorites. Earth's internal layers - Crust, mantle and core. Lithosphere, asthenosphere, mesosphere and barysphere.

UNIT 2: GEOMORPHOLOGY - I **16 hrs**

Introduction:- Basic concepts of Geomorphology, Definition and scope, Geomorphic agents, Geomorphic processes; endogenetic (epigene) and exogenetic (hypogene). Land forms. Weathering - physical, chemical, biological.
Soil - Definition, Formation, Types of soils. Soil Profile.

Rivers and fluvial landforms:- Introduction, Development of rivers - Drainage system and patterns. Stages of rivers – Davi's concept; youth, mature, old. Geologial actions: Erosion - hydraulic action, abrasion, attrition, solution. Erosional landforms – Pot holes, V shaped valleys, gorges and canyons, waterfalls and types, river meanders, ox-bow lakes, river terraces, structural benches. Transportation - suspension , solution. Deposition and depositional landforms - alluvial fans and cones, flood plains, natural levees, deltas, channel deposits.

Wind and Aeolian landforms: Types of wind – Breeze, Gale, Tempest, Cyclone. Geological action of wind: Wind erosion - Deflation, abrasion, attrition. Erosional features - mushroom rocks, yardangs, Hamda, ventifacts, pedestal rocks, zeugen, milletseed sands. Transportation - suspension, saltation, traction. Deposition and depositional landforms - Sand dunes and types, Loess.

UNIT 3. GEOMORPHOLOGY - II **16 hrs**

Glaciers and glacial landforms. Growth and movement of glaciers. Types of glaciers – Mountain or valley glaciers, Piedmont glaciers, continental ice-sheets or ice caps. Glacier imprints. Geological action of glaciers; Erosional work by glaciers – Plucking/ Excavation, Frost wedging., Abrasion. Erosional landforms - Whaleback forms. Glacial valley - U shaped valley and V- shaped valley, Crag and Tail, Hanging valley, Cirques, Fiords, Arete, Cols, Horns, Roches Moutonnes. Transportation - glacial drift. Deposition and depositional landforms - Glacial Moraines and types, Drumlins, Kames, Eskers, Outwash plains, Kettles.

Groundwater:- Meaning and components of groundwater. Geological action of groundwater: Erosion and erosional landforms (lapis, solution holes and associated features, poljes, caves and caverns: valleys of karst topography, natural bridges). Transportation; solution. Depositional work; concretions, stalactites and stalagmites,

Oceans and Coastal landforms:- Topography of ocean floor – continental slope, shelf, abyssal zone, mid-oceanic ridges. Geological action of oceans: Agents of coastal erosion; Waves, Tides, Currents and circulation of water. Process of marine erosion, erosional landforms (Headlands and Bays, Sea Cliffs, Wave-cut Terraces, Sea caves, stacks). Transportation. Depositional landforms (Beaches and barriers, wave built terraces, Spits and bars, Tombola). Deep sea water deposits – terrigeneous and pelagic deposits. Corals - its types and origin.

UNIT 4 : GEODYNAMICS **16 hrs**

Introduction to Geodynamics. Origin of oceans, continents and mountains. Concepts and theories of isostasy. Concept of palaeomagnetism, application of palaeomagnetism. Continental drift. Sea floor spreading. Concept of plate tectonics. Nature and types of plate margins, Midoceanic ridges and trenches. Origin and distribution of Island arcs.

Earthquakes:- definition, Elements of an earthquake, types of earthquake waves, intensity and magnitude, seismographs and seismometers, causes and prediction of earthquake, Effects of earthquake, Seismic zones of India.

Volcanoes:- A typical volcano parts, volcanic activity, types of volcanoes, composition of lava, distribution of volcanoes. Volcanic landforms; depressed landforms: Volcanic cone (Cinder Cone), Volcanic craters, Calderas (Caldera Lake). Landforms due to the accumulation of lava: Volcanic mountains, Volcanic plateaus, Volcanic plains, Volcanic necks.

SUGGESTED READINGS:

1. Duff, P. M. D., & Duff, D. (Eds.). (1993). Holmes' principles of physical geology. Taylor & Francis.
2. Emiliani, C. (1992). Planet earth: cosmology, geology, and the evolution of life and environment.Cambridge University Press.
3. Gross, M. G. (1977). Oceanography: A view of the earth.

4. Brian, J. S., Barbara, W.M., 2010. The Blue Planet: An Introduction to Earth System Science,
   3rdEdition, Wiley.
5. Ernst, W.G., 2000. Earth Systems: Processes and Issues, Cambridge University Press.
6. Sarah, E., Cornell, I., Prentice, C., Joanna, I.H., Catherine, J.D., 2012. Understanding the Earth
   System Global Change Science for Application, Academic Press.
7. Jacobson, M., Charlson, R., Rodhe, H., Orians, G., 2000.Earth System Science: From Biogeochemical Cycles to Global Changes, Elsevier.
8. Ehlers, E., Krafft, T., 2006. Earth System Science in the Anthropocene, Springer.
9. *Jacobson, M. C., Charlson, R. J., Rodhe, H., and Orians, G. H., 2000, Earth System Science: San Diego, CA, Academic Press, 523 p., ISBN 0-12-379370-X*
10. The Earth System, Lee R. Kump, James F. Kasting, and Robert G Crane; Prentice Hall, 2nd Ed., 2004.
11. Principles of Geology – Arthur Holmes
12. Physical Geology – Longwell & Flient
13. General Geology – Radhakrishnan. Y
14. The Dynamic Earth – Wyllie. P.J
15. The way earth works - Wyllie. P.J
16. Physical Geology – Springfield
17. Geomorphology – Thornbury
18. Geomorphology – Davies
19. Physical Geography Today – Muller & Oberlander

I SEMESTER B.Sc. DEGREE PROGRAMMEEARTH SCIENCE
DSC/P-1: PRACTICAL-1

Total Teaching Hours: 56
LTP/Credits: /2
Teaching Hours/Week: 4
Exam. Duration: 4 Hrs.

1. Introduction to maps. Study of maps. Types of maps. Types of scale. 1 Practical
2. Reading topographical maps of the Survey of India; Detailed study of topographic sheets 2 Practicals
3. Preparation of topographical map 1 Practicals
4. Identification of drainage patterns 2 practical
5. Preparation of LU/LC maps. 2 Practicals
6. Study of soil profile and determination of soil texture 2 Practicals
7. Study of major geomorphic features and their relationships with outcrops through physiographic models and also using lens stereoscope and mirror stereoscope. 3 Practicals
8. Field visit to a place of geological/geomorphological interest. 1 Pratical

Open Elective **OE-1 (3 Credits)**

Crystallography, Mineralogy and Economic Minerals

Unit 1. 16 Hours

Crystals, crystalline solids and their formation; Symmetry in crystals; Axial ratio, indices, order of the crystallographic axes; Crystallographic notation (Weiss and Miller indices and convention in notation); Classification of crystals, introduction to 32 classes; The crystal systems and symmetry types; Stereographic representation of crystal symmetry and their uses; Imperfection of crystals and crystal defects; Twinning- causes, effects and genetic types.

Unit 2

Isotropic and anisotropic substances; Reflection, refraction and refractive index; Relief, birefringence and Becke line effect; Optically uniaxial and biaxial minerals; Determination of optic sign of uniaxial and biaxial minerals; interference figures; Pleochroism and determination of pleochroic scheme in minerals; X-ray crystallography and Bragg's equation; Application of X-ray diffraction spectrometry in mineral characterization; Application of techniques in mineralogy: Differential Thermal Analysis (DTA), Thermogravimetric Analysis (TGA), Scanning Electron Microscope (SEM), Transmission Electron Microscope (TEM), Electron Probe Micro Analyser (EPMA); Application of thermal, magnetic and radioactive properties of minerals.

Unit 3 16 Hours

Definition of ore, ore mineral and gangue; Classification of ore deposits; Chemical composition, diagnostic characters, uses and distribution in India of the following minerals: Gold, Copper, Iron, Manganese, Lead, Zinc, Bauxite, Chromite, magnesite, pyrite, diamond, muscovite, beryl, fluorite, gypsum, barite, halite, phosphorite, talc, kyanite, graphite, asbestos, monazite and corundum; Origin, uses and distribution of coal and petroleum in India.

OPEN ELECTIVE O.E.-1 B.Sc DEGREE PROGRAMME

EARTH SCIENCE

OE-1: PEDOLOGY

Total Teaching Hours: 48 **LTP/Credits: 300/3**

Teaching Hours: 3/Week.
Exam. Marks Total: 100 **Exam. Duration: 3 Hrs.**
(C_1 Test-10 mark: C_2 Test-10 mark: C_3 Main-80 mark)

UNIT – 1 **16 Hours**

Soil pedological and edaphological concepts. Composition of earth crust and its relationship with soils; Rocks, minerals and other soil forming materials; Weathering of rocks and minerals; Factors of soil formation. Weathering sequences of minerals with special reference to Indian soils.

Morphological properties of soil profile in different landforms. Pedogenic evolution of soils; soil composition and characterization. Soil development; Pedon, polypedon, soil profile, horizons and their nomenclature. Assessment of soil profile development by mineralogical and chemical analysis.

Soil texture, textural classes, mechanical analysis, specific surface. Soil consistence; dispersion and workability of soils; soil compaction and consolidation; soil strength; swelling and shrinkage - basic concepts.

Soil structure - genesis, types, characterization and management soil structure; soil aggregation, aggregate stability, soil conditioners. Soil water: content and potential, soil water retention, soil-water constants, measurement of soil water content, energy state of soil water, soil water potential.

UNIT – 2 **16 Hours**

Classification of soils using soil taxonomy: historical developments and modern systems of s oil classification with special emphasis on soil taxonomy; soil classification, soil mineralogy and soil maps – usefulness.

Soil Erosion And Conservation: History, distribution, identification and description of soil erosion problems in India.

Forms of soil erosion; effects of soil erosion and factors affecting soil erosion; types and mechanisms of water erosion; raindrops and soil erosion; rainfall erosivity; factors affecting water erosion; soil losses in relation to soil properties and precipitation.

Soil survey and its types; soil survey techniques - conventional and modern; soil series – characterization and procedure for establishing soil series; benchmark soils and soil correlations; soil survey interpretations;soil mapping, thematic soil maps, cartography, mapping units, techniques for generation of soil maps.

Soil conservation planning; land capability classification; soil conservation in special problem areas such as hilly, arid and semi-arid regions, waterlogged and wet lands.

UNIT – 3 **16 Hours**

Soil, water and air pollution problems associated with agriculture, nature and extent. Nature and sources of pollutants - agricultural, industrial, urban wastes, fertilizers and pesticides, acid rains, oil spills etc.; air, water and soil pollutants - their CPC standards and effect on plants, animals and human beings.

Management of problem soils: Area and distribution of problem soils - acidic, saline, sodic and physically degraded soils; origin and basic concept of problematic soils, and factors

responsible.

Morphological features of saline, sodic and saline-sodic soils; characterization of salt-affected soils - soluble salts, ESP, pH; physical, chemical and microbiological properties. Management of salt-affected soils; salt tolerance of crops - mechanism and ratings; monitoring of soil salinity in the field; management principles for sandy, clayey, red lateritic and dry land soils. Acid soils - nature of soil acidity, sources of soil acidity; effect on plant growth, lime requirement of acid soils; management of acid soils; biological sickness of soils and its management.

Reclamation of salt-affected soils; mine land reclamation, afforestation, organic products. Extent, diagnosis and mapping of land degradation by conventional and modern RS-GIS tools; monitoring land degradation by fast assessment, modern tools, land use policy, incentives and participatory approach for reversing land degradation; global issues for twenty first century.

References:

1. Brady NC & Weil RR. 2002. The Nature and Properties of Soils. 13th Ed. Pears on Edu.
2. Biswas TD & Narayanasamy G. (Eds.) 1996. Soil Management in Relationto Land Degradation and Environment. Bull. Indian Society of Soil Science No. 17.
3. Boul SW, Hole ED, MacCraken RJ & Southard RJ. 1997. Soil Genesis andthe Classification. 4 Ed. Panima Publ.
4. Brewer R. 1976. Fabric and Mineral Analysis of Soils. John Wiley & Sons.
5. Buol EW, Hole ED, MacCracken RJ & Southard RJ. 1997. Soil Genesisand Cl assification. 4th Ed. Panima Publ.
6. Dixon JB & Weed SB. 1989. Minerals in Soil Environments. 2nd Ed. SoilScienc e Society of America, Madison.
7. Doran JW & Jones AJ. 1996. Methods of Assessing Soil Quality. Soil Science Society of America, Spl Publ. No. 49, Madison, USA.
8. Grim RE. 1968. Clay Mineralogy. McGraw Hill.
9. Greenland DJ & Szabolcs I. 1994. Soil Resilience and Sustainable Land Use. CABI.
10. Gurmal Singh, Venkataramanan C, Sastry G & Joshi BP. 1990. Manual of Soil and Water Conservation Practices. Oxford & IBH.
11. Hudson N. 1995. Soil Conservation. Iowa State Univ. Press. Indian Society of Soil Science 2002. Fundamentals of Soil Science. ISSS,New Delhi.
12. Jurinak JJ. 1978. Salt-affected Soils. Department of Soil Science & Biometeorology. Utah State Univ
13. Lal R, Kimble J, Levine E & Stewart BA. 1995. Soil Management and Greenhouse Effect. CRC Press.
14. Lal R, Blum WEH, Vailentine C & Stewart BA. 1997. Methods forAssessment of Soil Degradation. CRC Press.
15. Middlebrooks EJ. 1979. Industrial Pollution Control. Vol. I. AgroIndustries. John Wiley Interscience.
    Oswal MC. 1994. Soil Physics. Oxford & IBH.
16. Ross SM. Toxic Metals in Soil Plant Systems. John Wiley & Sons.
17. Sehgal J. 2002. Introductory Pedology: Concepts and Applications. NewDelhi
18. Sehgal J. 2002. Pedology - Concepts and Applications. Kalyani.

19. Sehgal J & Abrol IP. 1994. Soil Degradation in India - Status and Impact. Oxford & IBH.
USDA. 1999. Soil Taxonomy. Hand Book No**.** 436. 2nd Ed. USDA NRCS,Washington.
20. Vesilund PA & Pierce 1983. Environmental Pollution and Control. Ann Arbor Science Publ.
21. Wade FA & Mattox RB. 1960. Elements of Crystallography andMineralogy. Oxford & IBH.
22. Wilding LP & Smeck NE. 1983. Pedogenesis and Soil Taxonomy: II. TheSoil Orders. Elsevier.
23. Wilding NE & Holl GF. (Eds.). 1983. Pedogenesis and Soil Taxonomy. I. Concept and Interaction. Elsevier.

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OPEN ELECTIVE PAPER O.E. – 1 (3 Credits)

Basics of Earth System Sciences

Unit 1: **16 Hours**

Introduction to Earth Sciences with a special focus to Geology, scope, sub-disciplines and relationship with other branches of sciences

Unit 2: **16 Hours**

Earth in the solar system, origin Earth's size, shape, mass, density, rotational and evolutional parameters Solar System- Introduction to Various planets - Terrestrial Planets Solar System- Introduction to Various planets - Jovian Planets Internal constitution of the earth - core, mantle and crust

Unit 3: **16 Hours**

Convections in the earth's core and production of magnetic field Composition of earth in comparison to other bodies in the solar system. Origin and composition of hydrosphere and atmosphere Origin of biosphere Origin of oceans, continents and mountains

Unit 3: Age of the earth; Radioactivity and its application in determining the age of the Earth, rocks, minerals and fossils

SUGGESTED READINGS:

1. Arthur Holmes, Principles of Physical Geology. 1992. Chapman & Hall.
2. Emiliani, C, 1992. Planet Earth, Cosmology, Geology and the Evolution of Life and Environment. Cambridge University Press.
3. Gross,M.G., 1977. *Oceanography: A view of the Earth*, Prentice Hall.
4. The Dynamic Earth – Wyllie. P.J
5. The way earth works - Wyllie. P.J
6. D.R. Johnson, M. Ruzek, M. Kalb, What is Earth System Science? Proceedings of the 1997 International Geoscience and Remote Sensing Symposium Singapore, August 4 - 8, 1997, pp 688 - 691

Open Elective (OE) Paper for First Year B.Sc. Earth Science

Programme/ **Certificate**	Year: **First**	Semester: **First**
Subject: **Earth Science** – **Open Elective (OE)**		
Course Code: (OE) CESOE1	Course Title: **Geohazards and Mitigation Strategies**	

Course outcomes:
After completing the course, student

- can understand the geology behind natural disasters.
- will understand the origin and occurrence of geohazards and evaluate the prediction and mitigations.
- can understand the causes, threats, impact, magnitude and intensity of the natural hazards
- will be able to qualitatively estimate risk, and envisage risk-appropriate mitigation strategies.

Credits: 3	Core: Compulsory
Max. Marks: 70	Min. Passing Marks: as per rules
Total No. of Lectures-Tutorials-Practical (in hours per week): L-T-P: 3-0-0	

Units	**Topics**	**No. of Hours**
I	Geohazards: assessment and planning- Introduction, types of hazards; characteristic features, occurrence and impact of different types, Causes and Strategies for Mitigation of Geological Hazards; Risk assessment, Hazard maps, Land-use planning and hazards	12
II	**Earthquakes, Mitigation Approaches:** – Earthquake, its Causes, Specific threats, Community impacts, and Mitigation strategies. Characteristic features; Earthquake Risk Mitigation Magnitude and Intensity of earthquake; Major earthquakes; Seismic zoning; Earthquake vulnerability of India; Earthquake risk mitigation – Seismic performance examination of RCC	18

	Buildings, retrofitting of vulnerable buildings, Construction of earthquake resistant buildings following proper BIS codes, Earthquake preparedness; Case study – 'Bhuj Earthquake'. **Volcanic hazard**: Introduction, Types of volcanoes, Volcanic form and structure, Types of central eruption, Causes of volcanic eruptions, Volcanic products: volatiles, Volcanic products: pyroclasts, Volcanic products: lava flows, Specific threats, Community impacts, Volcanic hazard and prediction Mitigation strategies	
III	**Tsunami Events, Mitigation Approaches:** An introduction to Tsunami; Magnitude & Intensity of a Tsunami; Types of Tsunami; Features of Tsunamis; Prediction of Tsunamis; Tsunami Hazard Mitigation. **Flood and Mitigation Approaches:** Types of floods**,** Causes of floods**,** Specific threats**,** Community impacts**.** Mitigation strategies**:** Floodplain Management**,** Flood Insurance**,** Flood Mitigation Programs**,** Property Acquisitions**,** Retrofitting Flood Prone Residential Structures **Mass movements:** Soil creep and valley bulging, Causes of landslides, Classification of landslides, Landslides in soils Landslides in rock masses, A brief note on slope stability analysis. Monitoring slopes, Landslide hazard, investigation and mapping, Methods of slope control and stabilization Landslide Specific threats, Community impacts, Mitigation strategies.	18

Suggested Readings:

1. Alexander, D. (1993) Natural Disasters. University College London Press, London.
2. Alden, W. C., 1928. Landslide and Flood at Gros Ventre, Wyoming, Focus on Environmental Geology, Tank R., Ed., Oxford University Press, New York (1973), 1928, pp. 146–153.
3. Baker, P.E. (1979) Geological aspects of volcano prediction. Journal Geological Society, 136, 341-346.
4. Bell, F.G., (1999). Geological hazards: their assessment, avoidance, and mitigation. (an imprint of Routledge). E&FN Spon, London, UK, Hardbound, ISBN 0-419-16970-9;631 Pages.
5. Bell, F.G. (1994) Floods and landslides in Natal and notably the greater Durban region, September 1987: a retrospective view. Bulletin Association Engineering Geologists, 31, 59-74.
6. Broms, B. B., Landslid es , Foundation Engineering Handbook , Winterkorn, H. F. and Fang, H.-Y., eds., Van Nostrand Reinhold Co.,

7. Bernard, E.N. (Ed.), Developing Tsunami-Resilient Communities: The National Tsunami Hazard Mitigation Program, Reprinted from Natural Hazards, 35:1 (2005) 2005, VI, 186 p., ISBN: 978-1-4020-3353-7.
8. Bollinger, G. A., 1976. The seismic regime in a minor earthquake zone, Proc. ASCE Numer. Methods Geomech., 2, 917–937.
9. Bullard, R.M. (1976) Volcanoes of the Earth. University of Texas Press, Austin.
10. Bolt, B.A. (1978) Earthquakes: A Primer, W.H.Freeman, San Francisco.
11. Bolt, B.A. (1993) Earthquakes. W. H. Freeman, New York.
12. Forgione, G., Luongo, G. and Romano, R. (1989) Mt Etna (Sicily): Volcanic hazard assessment. In Volcanic Hazards: Assessment and Monitoring, Latter, J.H. (ed.), Springer-Verlag, Berlin, 137-150.
13. Hamilton, R. M., 1978. Earthquake Hazards Reduction Program-Fiscal Year 1978 Studies Supported by the U.S. Geological Survey, Geological Survey Circular 780, U.S. Dept of the Interior.
14. Leeds, D. J., 1973. The Design Earthquake, in Geology, Seismicity and Environmental Impact, Special Publication Association of Engineering Geology, Los Angeles, CA.
15. Ramesh P. Singh & Darius Bartlett, 2018. Natural Hazards: Earthquakes, Volcanoes, and Landslides.527 Pages.
16. Sassa, K., Fukuoka, H., Yang, Q.J., and Wang, F.W., 1997. Landslide Hazard Assessment in Cultural Heritage, Lishan, Xian, Proceedings International Symposium on Landslide Hazard Assessment, 1–24, Xian, China.
17. Seed, H. B., 1966. A method for earthquake resistant design of earth dams, Proc. ASCE J. Soil Mech. Found. Engrg. Div., 92, 13–41.
18. Thenhaus, P. C. and Campbell, K. W.,2003. Seismic hazard analysis, in Earthquake Engineering Handbook, Chen, W. and Scawthorn, C., Eds., CRC Press, Boca Raton, FL,

A-2. Basics of Crystallography, Mineralogy and Petrology

A2-1 (4 Credits)

Sl. No.	Contents	Hours of teaching
	Pedagogy: Classroom teaching for Earth Science Major students	
	Course outcome with skills, employability and entrepreneurship	
	This paper is the most important and fundamental in Earth Science to understand the basics of Crystallography, Mineralogy and Petrology. The candidate will be exposed to the common crystals and their forms, minerals and their basic properties especially physical and optical. Also it deals with the most common resources viz. rocks which find tremendous applications potential especially in dimensional rock structures. Every student of Earth Science should know the common variety of rocks and minerals occurring and also their economic potential	
1	**Unit 1.** Crystal morphology and internal structures. Crystal parameters and indices. Crystal symmetry and classification of crystals into six systems and 32 point groups. Stereographic projections of symmetry elements and forms. Introduction to analytical techniques like XRD (X-ray diffraction), SEM (secondary electron microscopy).	16
2	**Unit 2** Elements of crystal chemistry and aspects of crystal structures. Minerals: definition and classification, physical and chemical composition of common rock-forming minerals. Nature of light and principles of optical mineralogy. Introduction to the petrological microscope and identification of common rock forming minerals.	16
3	**Unit 3** Rock associations in time and space. Physical aspects of magma generation in crust and mantle. Physical properties of magmas; igneous cumulates, liquid immiscibility, pneumatolitic action, magmatic assimilation and mixing of magmas. Textures of igneous rocks. Classification of igneous rocks. Igneous rock associations.	16
4	**Unit 4** Origin, classification and occurrence of sedimentary rocks. Siliciclastic Sedimentary Rocks: Sedimentary textures, Sedimentary structures. Sandstones,Conglomerates, Mudstones and shales. Diagenesis of sandstones and shales, Limestones, Dolomites. Metamorphic rocks- Metamorphism, types of metamorphism, classification of metamorphic rocks, common textures and Structures.	16

References for further reading:

1. James D Dana. A Textbook of minerology, John Wiley and Sons
2. Verma, P K (2010), Optical minerology. Ane books Pvt. Ltd
3. Philips, RC, An Introduction to crystallography,
4. Buerger, Elementary crystallography
5. JAK Tareen and TRN Kutty,(1989) Elemental crystallography
6. Tyrrel, T.W Principles of Petrology, Chapman and Hall, UK
7. Turner and Verhoogen (1962),Igneous and metamorphic petrology, Allied publisher, Bombay
8. Prasad C (1980), A Textbook of sedimentology

II SEMESTER P2. B.Sc. DEGREE PROGRAMME
EARTH SCIENCE
P- 2: PRACTICALS
Total Teaching Hours: 56

Teaching Hours/Week: 4
Exam. Duration: 4 Hrs.

1. Study of crystals based of geometrical constants. - 1 Practical
2. Measurement of interfacial angle using contact goniometer and Verification of Euler's theorem 1 Practical
3. Study of holohedral forms of six crystal system. 4 Practicals
4. Study of Physical properties of rock forming minerals (list-given below) - 6 Practicals
5. Study of the optical properties of important rock forming minerals using polarizing microscope: Quartz, Plagioclase, Orthoclase, Microcline, Biotite, Hornblende, Augite, Hypersthene, Olivine, Garnet, Calcite. 1 Practical
6. Visit to field to study the mode of occurrence of minerals. – 1 Practical

Silicates*	Non-silicates				Native elements
	Non-Metallic minerals		Metallic minerals		
Important rock forming minerals and all are silica bearing minerals	Hydroxides	-	Hydroxides	Bauxite, Psilomelane	Sulphur, Graphite
	Sulphates	Barite, Gypsum	Sulphides	Chalcopyrite, Galena Realgar, Orpiment, Spalerite (& dodecahedral), Cinnabar, Pyrite, Stibnite	
	Oxides	Corundum	Oxides	Haematite (& botryoidal, micaceous), Magnetite, Pyrolusite, Chromite	
	Carbonates	Dolomite, Calcite, Magnesite	Carbonates	Malachite, Azurite	
	Phosphates	Monazite			

	Halides	Rock salt (Halite), Fluorite			

*Silicates		**Group**	**Mineral Name**
Nesosilicates		Olivine Group	Olivine
		Garnet Group	Garnet
		Al_2SiO_5 Group	Andalusite, Sillimanite, Kyanite, Staurolite
		Zircon Group	Zircon
Sorosilicates		Epidote Group	-
Cyclosilicates		Beryl Group	Beryl
		Tourmaline	Tourmaline
Inosilicates	Single Chain Silicates	Pyroxene Group	Augite, Hypersthene
	Double Chain Silicates	Amphibole Group	Actinolite, Hornblende
Phyllosilicates		Serpentine Group	Serpentine, Asbestos
		Clay Minerals Group	Talc, Kaolin
		Mica Group	Muscovite, Biotite, Phlogopite, Vemiculite
Tectosilicates		Quartz Group	Quartz
		Feldspar Group	Orthoclase, Plagioclase, Microcline
		Feldspathoid Group	Nepheline, Sodalite
		Zeolite Group	Zeolite

Open Elective OE: 2 (3 Credits)
Medical geology

Introduction

The Commission on Geological Sciences for Environmental Planning defines medical geology as the science dealing with the influence of the normal environmental factors on the geographical distribution of health problems in man and animals. The elements or other geological materials present in soils, rocks or even water can both harm or benefit human health depending on their concentrations. The topics in medical geology include environmental toxicology, environmental pathology, geochemistry, geo-environmental epidemiology, the extent, patterns and consequences of exposure to metal ions and their analysis, metal ions in environment, biological risk assessment studies, modern methods of trace element analysis, updates on geology, toxicology and pathology of metal exposure. It is proposed to introduce this branch in Earth System Science because of its importance for public health and relevance to the Ayush Programme of the Government of India.

The course content has been planned for Undergraduate and graduate students, environmental geoscientists, epidemiologists, medics, decision makers, environmentally conscious members of general public.

Scope of the subject includes Paracelsus principle of toxicology, Importance of geology in health and disease, Topics in medical geology include environmental toxicology, environmental pathology, geochemistry, geo-environmental epidemiology, the extent, patterns and consequences of exposure to metal ions and analysis, Metal ions in environment, biological risk assessment studies, modern methods of trace element analysis, updates on geology, toxicology and pathology of metal exposure.

The course content in brief can be under the following heads:

UNIT -1 **12 Hours**

Foundations of medical geology :

Ancient findings, More recent findings, Environmental classification of elements in relation to public health ; inorganic poisons affecting public health in addition to pathogens with some examples from India ; developments in medical geology,

Environmental biology

Distribution of elements in Nature - A chemically variable earth; Mineral chemistry, diversity in the composition of rocks, biogeochemical cycle, establishing geochemical baselines, geochemical baseline map of India, Total composition and bioavailability, integrating epidemiological research with high quality geochemical composition of drinking water and food, agriculture and forest management.

UNIT -2 **16 Hours**

Anthropogenic sources of contaminating elements: Mining, Mineral processing and metal refining; power generation, other industrial activities, waste disposal, agricultural practices, contamination from transport industry, atmospheric deposition of contaminants, contamination in urban environment, treatment and transport of drinking water.

Uptake of elements from chemical biological points of view, bioavailability of elements in soil

Gain knowledge about the medicinal value of various minerals by understanding the physical and chemical properties. Study the minerals that have health benefits or cause harm

Geological impacts on nutrition

Geological sources of nutrient elements, quantitative estimates of mineral needs, clinical assessment of mineral status, ecological aspects of mineral nutrients

UNIT -3 **20 Hours**

Pathways of exposure

Volcanic emissions and health, radon and U in water, Arsenic in water and environment, fluoride in drinking and irrigation water, health effects of hardness of water, selenium and iodine deficiency, selenium toxicity

Geophagy ; Soil borne pathogens

Natural aerosolic mineral dusts and human health – dust storms, pnemoconioses, lung diseases, silicosis, asbestosis . tuberculosis

Quality of groundwater

Thresholds for metal and non-metal ions from health point of view: as prescribed by :

WHO, Bureau of Indian Standards, other international standards, AERB India, Methods of analysis of risk factors.

References

1. Selinus, Olle (Ed.), 2013, Essential of Medical Geology, Revised Edition. Springer.

2. Syed E. Hasan, 2020, Medical Geology, PMCID publications.

3. Carlos-Alberto Ríos-Reyes, María-Paula Ríos-Gutiérrez and Santiago Joya-Neira, Archivos de Medicina Volumen, 2021, The importance of minerals in medical geology: impacts of the environment on health. Enero-Junio de.

OE-4 Industrial Minerals

OE-2 (3)

Sl. No.	Contents	Hours of teaching
	Pedagogy: Classroom teaching for Open Elective students	
	Course outcome with skills, employability and entrepreneurship	
	This course is a good opportunity for most of science and social science students not only to know about the mineral resources of India starting the principles of rock formation including minerals genesis during the rock formation and after their formation. Students exit with a certificate course will have skills to work in quarrying, mining, rock polishing, cement, silica/glass, sand mining, brick, ceramic, pottery and refractory industries. They will be exposed to start their own entrepreneurship.	
1	**Introduction to minerals and rocks** Introduction to rock forming and economically important minerals. Principles of rock cycle, origin and classification of economically important mineral deposits.	10
2	**Properties of minerals and rocks, and their occurrences:** Physical properties, chemical composition, and diagnostic criteria for the identification of minerals. Ore minerals and gangue minerals, tenor and grade of the ore for industrial processing of minerals. Selection criteria followed for quarrying of decorative and dimensional rock blocks/slabs. National mineral policy.	14
3	**Properties, occurrences and distribution of the following minerals/rocks in India, with special reference to Karnataka**:	18

Industry	**Minerals**
Jewelry	gold, diamonds, precious minerals, corals, pearl and opals, sapphires, rubies, and emeralds.
Metallic	Bauxite, chromite, ilmenite, magnetite, hematite, sphalerite, galena, chalcopyrite, pyrolusite.
Cement and Refractory minerals	Calcite, lime stone, gypsum, clay minerals, magnesite, graphite, chalk, marble, dolomite, zircon, kaolin, magnesia and alumina minerals,
Ceramics and glass	clay minerals, kaolinite, silica sand and bauxite, limestone and feldspar.
Abrasives, and	industrial diamond, corundum, garnet and quartz

	rock and mineral polishing	magnesite, pumice, and diatomaceous earth	
	Electronic and electrical	rare earth elements, mica, wolframite, native metallic minerals, ores of copper, aluminium,	
	Strategic/defense	rare earth elements, Ilmenite, monazite, mica, vanadium from magnetite, poly metallic nodules and rock encrustation in the ocean to extract cobalt and nickel.	
	Chemicals and fertilizers	Barite, calcite, magnesite, asbestos, diatomite, feldspar, gypsum, kaolinite, phosphorite, mica, talc, zeolite, bauxite, chromite, ilmenite, magnetite, hematite, sphalerite, galena, clay minerals chalcopyrite, pyrolusite, pyrite and monazite.	
	Dimensional and decorative rocks & dimensional stones	Marble, granites, gneiss, dolerite, phylllite, slate, sand stones, sand, gravel, pebble and boulders.	
	Nanotechnology:	Clay minerals, ilmenite, polymorphs of carbon, titanium and anhydrous iron oxide minerals and mineral composite for rare mineral substitutes.	

Internet references/reference books:

Klein, C and Philpotts (2016) Earth Materials Introduction to Mineralogy and Petrology Cambridge University Press.

- Jensen M.L. and Bateman, A. (2013) Economic Mineral Deposits, John Wiley & Sons; Revised Edition.
- National Mineral Policy, 2019 approved by Cabinet of the Government of India
- https://pib.gov.in/Pressreleaseshare.aspx?PRID=1566733
- Mineral Distribution in India
- http://ismenvis.nic.in/KidsCentre/Mineral_Distribution_in_India_13948.aspx
- Jetli, K.N. and Narindar, K.J. (2011) Mineral Resources and Policy in India.
- Mineral scenarios of India https://ibm.gov.in/writereaddata/files/09182018162439Mineral%20Scenario%20pdf.pdf
- UNLOCKING INDIA'S MINERAL WEALTH
- https://mines.gov.in/writereaddata/UploadFile/GSI_PDAC_2013.pdf

OE-2 Paleobiology

OE-2 (3)

Sl. No.	Contents	Hours of teaching
	Pedagogy: Classroom teaching for Open Elective students	
	Course outcome with skills, employability and entrepreneurship	
	Scope: Its is an important subject in Earth science dealing with the preservation of fossils, and types. Both vertebrate and invertebrate fossils studies help to unravel the mystery of the life in the past. It can be a highly inter-disciplinary subject to understand the evolution of life on earth. Besides, it can also indicate the rich mineral deposits like petroleum, coal and other minerals.	
1	**Unit 1:** Modes of preservation of fossils- Cast, moulds, petrification, coalification, Tracks and Trails, Foot prints, Burrowing and Boring. Types of fossils – Index fossil, Synthetic fossil, Persistent fossils.	12
2	**Unit 2:** Invertebrate and Vertebrate fossils Definition, Classification, and stratigraphic significance of phylum: Mollusca (Pelecypoda, Cephalopoda, Gastropoda) Phylum: Arthropoda, Class: Trilobita	16
3	**Unit 3:** Paleobotany and Microfossils classification of plants, plants through geological ages, Gondwana plants, Microfossils-Classification of microfossils. Foraminifera, Ostracoda.	20

References:

1. Clarkson, E.N.K., 1998, Invertebrate Paleontology and Evolution, IV edition, Publ., Blackwell.
2. Smith, A.B., 1994, Systematics and the Fossils Record- Documenting Evolutionary Patterns, Publ., Balckwell
3. Colbert, Introduction to Vertebrate Paleontology.
4. D.J.Jones, 1956. Microfossils.

OE-2 GEMS AND ORNAMENTAL STONES

OE-2 (3 Credits)

Sl. No.	Contents	Hours of teaching
	Pedagogy: Classroom teaching for Open Elective students	
	Course outcome with skills, employability and entrepreneurship	
	Very important as gemstones have attracted mankind ever since ma came into existence, because of their beauty and rarity. The gemstones market is ever expanding and also leading to the artificial growth of these stones and imitations.	
1	**Unit-1:** Introduction to Gemology, classification of gemstones, detailed study of different physical characters and Optical properties of minerals with special reference of to gem minerals. Physico-optical effects in gem stones. Colour and cause of color in gems.	16
2	**Unit-2:** Cutting and polishing of gemstones. A detailed study of important precious and semi-precious gem minerals- their characters and occurrences- world occurrences in general and Indian occurrences in particular. Precious Varieties:1. Diamond, 2. Ruby, 3. Sapphire, 4. Topaz, 5. Emerald ii) Semi-Precious varieties: Garnets, Quartz ,Lapislazuli, Turquoise and Organic gems.	16
3	**Unit-3:** Ornamental stones **:**Introduction to petrology, Classification of rocks, Properties of Igneous, Sedimentary and Metamorphic rocks. Suitability of rocks for ornamental purposes. Occurrence and distribution rocks in Indian sub continent with particular reference to Karnataka. Evaluation, Quarrying , cutting and polishing of rocks.	16

Internet references/reference books:

1. Gems and Gem industry in India-GSI Memoir 45- R.V Karanth.
2. Gem and Gem Minerals – EH Kvans and CB Slawsan
3. Encyclopedia of Minerals and Gem stones - Edited by Michael O' Don Oghal.
4. Precious stones - by Max-Bauer Vol. I and II. Publisher Dover publicationsInk. New york.
5. Rutley's Elements of Mineralogy- by H.H. Read, CBS publication
6. Dana's Manual of Mineralogy
7. GEMS by R.Webster - Batter work and co. ltd., London
8. Gemstones - Herbert Smith - Published by Methuen co. Ltd., London
9. Introduction to Rock forming minerals-Deer, Howie and Zussman.
10. Physical Geology-P.K.Mukherjee
11. Geology of India-R.Vaidyanathan and M.Ramakrishnan
12. Geology of Karantaka-B.P.Radhakrishna
13. Mineral Resources of Karnataka-B.P Radhakrishna

B1. EARTH SCIENCE

EARTH SYSTEM SCIENCES (4 Credits)

(L – T – P Model)

Total Teaching Hours: 64
Teaching Hours: 4/Week.
Exam. Duration: 3 Hrs.

UNIT 1: INTRODUCTION TO EARTH SYSTEM SCIENCES

16 hrs

Definition and scope of earth system sciences. Branches of Earth Sciences. Systems concepts for earth system science - fundamental concepts of the five spheres (lithosphere, hydrosphere, atmosphere, biosphere and cryosphere). Energy balance. Interactions between the five spheres; hydrologic cycle; Biogeochemical cycles - carbon cycle; Hydrosphere-atmosphere: Oceanic current system and effect of Coriolis force. Concepts of eustasy. Atmospheric circulation. Weather and climatic changes.

Interrelationships between biological, geological, climatological, and human systems on continental and global scales. Anthropogenic influences on the Earth systems; Human-environment interactions - policy.

The universe and solar system: Origin of the universe - Big bang theory. Solar system. Members of solar system – planets (Terrestrial and gaseous planets), satellite, comets, asteroids, meteorite.
Earth in the solar system. Size, shape, mass and density of the earth.
Origin of the Earth – Gaseous hypothesis, Nebular hypothesis, Planetesimal hypothesis, Tidal hypothesis, Supernova hypothesis, Interstellar or dust or meteoric hypothesis. Evolution of earth.
Age of the Earth: Geochronology; Absolute and relative methods; (a) Relative Methods - Sedimentation, Salinity method, varve chronology, Rate of cooling of earth. (a) Radiometric dating, atomic energy, decay scheme, half life, method - K-Ar; Rb-Sr; U-Pb, Pb-Pb.
Age of the earth.
Earth's internal structures and its composition. Evidence for the Earth's composition and mineralogy – 1. Seismic data, 2. Density studies, 3. Meteorites. Earth's internal layers - Crust, mantle and core. Lithosphere, asthenosphere, mesosphere and barysphere.

UNIT 2: GEOMORPHOLOGY - I **16 hrs**

Introduction:- Basic concepts of Geomorphology, Definition and scope, Geomorphic agents, Geomorphic processes; endogenetic (epigene) and exogenetic (hypogene). Land forms. Weathering - physical, chemical, biological.
Soil - Definition, Formation, Types of soils. Soil Profile.

Rivers and fluvial landforms:- Introduction, Development of rivers - Drainage system and patterns. Stages of rivers – Davi's concept; youth, mature, old. Geologial actions: Erosion - hydraulic action, abrasion, attrition, solution. Erosional landforms – Pot holes, V shaped valleys, gorges and canyons, waterfalls and types, river meanders, ox-bow lakes, river terraces, structural benches. Transportation - suspension , solution. Deposition and depositional landforms - alluvial fans and cones, flood plains, natural levees, deltas, channel deposits.

Wind and Aeolian landforms: Types of wind – Breeze, Gale, Tempest, Cyclone. Geological action of wind: Wind erosion - Deflation, abrasion, attrition. Erosional features - mushroom rocks, yardangs, Hamda, ventifacts, pedestal rocks, zeugen, milletseed sands. Transportation - suspension, saltation, traction. Deposition and depositional landforms - Sand dunes and types, Loess.

UNIT 3. GEOMORPHOLOGY - II **16 hrs**

Glaciers and glacial landforms. Growth and movement of glaciers. Types of glaciers – Mountain or valley glaciers, Piedmont glaciers, continental ice-sheets or ice caps. Glacier imprints. Geological action of glaciers; Erosional work by glaciers – Plucking/ Excavation, Frost wedging., Abrasion. Erosional landforms - Whaleback forms. Glacial valley - U shaped valley and V- shaped valley, Crag and Tail, Hanging valley, Cirques, Fiords, Arete, Cols, Horns, Roches Moutonnes. Transportation - glacial drift. Deposition and depositional landforms - Glacial Moraines and types, Drumlins, Kames, Eskers, Outwash plains, Kettles.

Groundwater:- Meaning and components of groundwater. Geological action of groundwater: Erosion and erosional landforms (lapis, solution holes and associated features, poljes, caves and caverns: valleys of karst topography, natural bridges). Transportation; solution. Depositional work; concretions, stalactites and stalagmites,

Oceans and Coastal landforms:- Topography of ocean floor – continental slope, shelf, abyssal zone, mid-oceanic ridges. Geological action of oceans: Agents of coastal erosion; Waves, Tides, Currents and circulation of water. Process of marine erosion, erosional landforms (Headlands and Bays, Sea Cliffs, Wave-cut Terraces, Sea caves, stacks). Transportation. Depositional landforms (Beaches and barriers, wave built terraces, Spits and bars, Tombola). Deep sea water deposits – terrigeneous and pelagic deposits. Corals - its types and origin.

UNIT 4 : GEODYNAMICS **16 hrs**

Introduction to Geodynamics. Origin of oceans, continents and mountains. Concepts and theories of isostasy. Concept of palaeomagnetism, application of palaeomagnetism. Continental drift. Sea floor spreading. Concept of plate tectonics. Nature and types of plate margins, Midoceanic ridges and trenches. Origin and distribution of Island arcs.

Earthquakes:- definition, Elements of an earthquake, types of earthquake waves, intensity and magnitude, seismographs and seismometers, causes and prediction of earthquake, Effects of earthquake, Seismic zones of India.

Volcanoes:- A typical volcano parts, volcanic activity, types of volcanoes, composition of lava, distribution of volcanoes. Volcanic landforms; depressed landforms: Volcanic cone (Cinder Cone), Volcanic craters, Calderas (Caldera Lake). Landforms due to the accumulation of lava: Volcanic mountains, Volcanic plateaus, Volcanic plains, Volcanic necks.

SUGGESTED READINGS:

1. Duff, P. M. D., & Duff, D. (Eds.). (1993). Holmes' principles of physical geology. Taylor & Francis.
2. Emiliani, C. (1992). Planet earth: cosmology, geology, and the evolution of life and environment.Cambridge University Press.
3. Gross, M. G. (1977). Oceanography: A view of the earth.

4. Brian, J. S., Barbara, W.M., 2010. The Blue Planet: An Introduction to Earth System Science,
   3rdEdition, Wiley.
5. Ernst, W.G., 2000. Earth Systems: Processes and Issues, Cambridge University Press.
6. Sarah, E., Cornell, I., Prentice, C., Joanna, I.H., Catherine, J.D., 2012. Understanding the Earth
   System Global Change Science for Application, Academic Press.
7. Jacobson, M., Charlson, R., Rodhe, H., Orians, G., 2000.Earth System Science: From Biogeochemical Cycles to Global Changes, Elsevier.
8. Ehlers, E., Krafft, T., 2006. Earth System Science in the Anthropocene, Springer.
9. *Jacobson, M. C., Charlson, R. J., Rodhe, H., and Orians, G. H., 2000, Earth System Science: San Diego, CA, Academic Press, 523 p., ISBN 0-12-379370-X*
10. The Earth System, Lee R. Kump, James F. Kasting, and Robert G Crane; Prentice Hall, 2nd Ed., 2004.
11. Principles of Geology – Arthur Holmes
12. Physical Geology – Longwell & Flient
13. General Geology – Radhakrishnan. Y
14. The Dynamic Earth – Wyllie. P.J
15. The way earth works - Wyllie. P.J
16. Physical Geology – Springfield
17. Geomorphology – Thornbury
18. Geomorphology – Davies
19. Physical Geography Today – Muller & Oberlander

I SEMESTER B.Sc., DEGREE PROGRAMME

EARTH SCIENCE

DSC/B.P-1: PRACTICAL-1 for Minor Geology Students

Total Teaching Hours: 56
LTP/Credits: /2
Teaching Hours/Week: 4
Exam. Duration: 4 Hrs.

1. Introduction to maps. Study of maps. Types of maps. Types of scale. 1 Practical
2. Reading topographical maps of the Survey of India; Detailed study of topographic sheets 2
   Practicals
3. Preparation of topographical map 1
   Practicals
4. Identification of drainage patterns 2 practical
5. Preparation of LU/LC maps. 2
   Practicals
6. Study of soil profile and determination of soil texture 2
   Practicals
7. Study of major geomorphic features and their relationships with outcrops through physiographic models and also using lens stereoscope and mirror stereoscope.
   3 Practicals
8. Field visit to a place of geological/geomorphological interest. 1 Pratical

B-2. Basics of Crystallography, Mineralogy and Petrology

B2-1 (4 Credits)

Sl. No.	Contents	Hours of teaching
	Pedagogy: Classroom teaching for Minor Geology students	
	Course outcome with skills, employability and entrepreneurship	
	This paper is the most important and fundamental in Earth Science to understand the basics of Crystallography, Mineralogy and Petrology. The candidate will be exposed to the common crystals and their forms, minerals and their basic properties especially physical and optical. Also it deals with the most common resources viz. rocks which find tremendous applications potential especially in dimensional rock structures. Every student of Earth Science should know the common variety of rocks and minerals occurring and also their economic potential	
1	**Unit 1.** Crystal morphology and internal structures. Crystal parameters and indices. Crystal symmetry and classification of crystals into six systems and 32 point groups. Stereographic projections of symmetry elements and forms. Introduction to analytical techniques like XRD (X-ray diffraction), SEM (secondary electron microscopy).	16
2	**Unit 2** Elements of crystal chemistry and aspects of crystal structures. Minerals: definition and classification, physical and chemical composition of common rock-forming minerals. Nature of light and principles of optical mineralogy. Introduction to the petrological microscope and identification of common rock forming minerals.	16
3	**Unit 3** Rock associations in time and space. Physical aspects of magma generation in crust and mantle. Physical properties of magmas; igneous cumulates, liquid immiscibility, pneumatolitic action, magmatic assimilation and mixing of magmas. Textures of igneous rocks. Classification of igneous rocks. Igneous rock associations.	16
4	**Unit 4** Origin, classification and occurrence of sedimentary rocks. Siliciclastic Sedimentary Rocks: Sedimentary textures, Sedimentary structures. Sandstones,Conglomerates, Mudstones and shales. Diagenesis of sandstones and shales, Limestones, Dolomites. Metamorphic rocks- Metamorphism, types of metamorphism, classification of metamorphic rocks, common textures and Structures.	16

References for further reading:

1. James D Dana. A Textbook of minerology, John Wiley and Sons
2. Verma, P K (2010), Optical minerology. Ane books Pvt. Ltd
3. Philips, RC, An Introduction to crystallography,
4. Buerger, Elementary crystallography
5. JAK Tareen and TRN Kutty,(1989) Elemental crystallography
6. Tyrrel, T.W Principles of Petrology, Chapman and Hall, UK
7. Turner and Verhoogen (1962),Igneous and metamorphic petrology, Allied publisher, Bombay
8. Prasad C (1980), A Textbook of sedimentology

II SEMESTER B.P2. B.Sc. DEGREE PROGRAMME
EARTH SCIENCE
B.P- 2: PRACTICALS For Geology Minor Students

Total Teaching Hours: 56
Teaching Hours/Week: 4
Exam. Duration: 4 Hrs.

1. Study of crystals based of geometrical constants. - 1 Practical
2. Measurement of interfacial angle using contact goniometer and Verification of Euler's theorem 1 Practical
3. Study of holohedral forms of six crystal system. 4 Practicals
4. Study of Physical properties of rock forming minerals (list-given below) - 6 Practicals
5. Study of the optical properties of important rock forming minerals using polarizing microscope: Quartz, Plagioclase, Orthoclase, Microcline, Biotite, Hornblende, Augite, Hypersthene, Olivine, Garnet, Calcite. 1 Practical
6. Visit to field to study the mode of occurrence of minerals. – 1 Practical

Silicates*	Non-silicates				Native elements
	Non-Metallic minerals		Metallic minerals		
Important rock forming minerals and all are silica bearing minerals	Hydroxides	-	Hydroxides	Bauxite, Psilomelane	Sulphur, Graphite
	Sulphates	Barite, Gypsum	Sulphides	Chalcopyrite, Galena Realgar, Orpiment, Spalerite (& dodecahedral), Cinnabar, Pyrite, Stibnite	
	Oxides	Corundum	Oxides	Haematite (& botryoidal, micaceous), Magnetite, Pyrolusite, Chromite	

	Carbonates	Dolomite, Calcite, Magnesite	Carbonates	Malachite, Azurite	
	Phosphates	Monazite			
	Halides	Rock salt (Halite), Fluorite			

*Silicates		**Group**	**Mineral Name**
Nesosilicates		Olivine Group	Olivine
		Garnet Group	Garnet
		Al_2SiO_5 Group	Andalusite, Sillimanite, Kyanite, Staurolite
		Zircon Group	Zircon
Sorosilicates		Epidote Group	-
Cyclosilicates		Beryl Group	Beryl
		Tourmaline	Tourmaline
Inosilicates	Single Chain Silicates	Pyroxene Group	Augite, Hypersthene
	Double Chain Silicates	Amphibole Group	Actinolite, Hornblende
Phyllosilicates		Serpentine Group	Serpentine, Asbestos
		Clay Minerals Group	Talc, Kaolin
		Mica Group	Muscovite, Biotite, Phlogopite, Vemiculite
Tectosilicates		Quartz Group	Quartz
		Feldspar Group	Orthoclase, Plagioclase, Microcline
		Feldspathoid Group	Nepheline, Sodalite
		Zeolite Group	Zeolite

Proposed 5 Years Integrated Master of Science in Geology
Structure for 5 years Integrated M.Sc. Course

SEMESTER – I					
Paper	**Subject**	**Total Credits**	**L**	**T**	**P**
Core Course Paper-C1	Dynamic Earth	4	4		
Core Course Practical Paper - C1P	Field Instruments	2			2
Core Course Paper-C2	Mineralogy and Crystallography	4	4		
Core Course Practical Paper – C2P	Mineralogy and Crystallography	2			2
Ability Enhancement Compulsory Courses (AECC-1)	***Language***	2	2		
Ability Enhancement Compulsory Courses (AECC-2)	***Environmental Science***	2	2		
Generic Elective Courses Paper-GE1	***Mathematics***	4	3	1	
Skill-based Elective Courses Paper-SEC1	***Computer Applications***	4	3	1	
	Total Credits in 1st Semester	**24**			
SEMESTER – II					
Core Course Paper-C3	Stratigraphy and Palaeontology	4	4		
Core Course Practical –C3P	Palaeontology	2			2
Core Course Paper-C4	Environmental Geology and Disaster Management	4	4		
Core Course Practical – C4P	Disaster Management	2			2
Ability Enhancement Compulsory Courses (AECC-3)	***Language***	2	2		
Ability Enhancement Compulsory Courses (AECC-4)	***Constitution of India***	2	2		
Generic Elective Courses Paper-GE2	***Physics***	4	3	1	
Skill-based Elective Courses Paper-SEC2	***Field work and Mapping***	4	2		2
	Total Credits in 2nd Semester	**24**			
SEMESTER – III					
Core Course Paper-C5	Tectonics and Dynamics of the lithosphere	6	5	1	
Core Course Paper-C6	Structural Geology	4	4		
Core Course Practical Paper – C6P	Structural Geology	2			2
Core Course Paper-C7	Petrology (Igneous, Sedimentary, Metamorphic)	6	6		
Core Course Practical Paper – C7P	Petrology	2			2
Generic Elective Courses Paper-GE3	***Chemistry***	4	3	1	
	Total Credits in 3rd Semester	**24**			
SEMESTER – IV					
Core Course Paper-C8	Applied Geophysics	4	4		
Core Course Practical Paper – C8P	Applied Geophysics	2			2
Core Course Paper-C9	Marine Geology and Oceanography	4	4		
Core Course Practical Paper – C9P	Marine Geology and Oceanography	2			2
Core Course Paper-C10	Mining methods, Mineral processing, Surveying	4	4		
Core Course Practical Paper – C10P	Mining methods, Mineral processing, Surveying	2			2
Generic Elective Courses Paper-GE4	***Climate Change-Past, Present***	6	5	1	

	and Future				
	Total Credits in 4th Semester	**24**			
SEMESTER – V					
Core Course Paper-C11	Geology of India and Indian Mineral Deposits	6	5	1	
Core Course Paper-C12	Ore Geology	4	4		
Core Course Practical Paper – C12P	Ore Geology	2			2
Skill-based Elective Courses - SEC3	***Analytical Techniques in Geology***	4	3	1	
Discipline Specific Electives –DSE1	Engineering Geology	4	3	1	
Discipline Specific Electives - DSE2	Meteorology	4	3	1	
	Total Credits in 5th Semester	**24**			
SEMESTER – VI					
Core Course Paper-C13	Remote Sensing and Geographic Information System	4	4		
Core Course Practical Paper – C13P	Remote Sensing and Geographic Information System	2			2
Core Course Paper-C14	Hydrogeology	4	4		
Core Course Practical Paper – C14P	Hydrogeology	2			2
Skill-based Elective Courses-SEC4	***Medical Geology***	4	3	1	
Discipline Specific Electives – DSE3	Isotope Geology and Geochemistry	4	3	1	
Discipline Specific Electives – DSE4	Research Project (Dissertation)	6			6
	Total Credits in 1st Semester	**26**			
	Grand Total for B.Sc., Exit	**146**			
	Exit with B.Sc.				
SEMESTER – VII					
Core Course Paper-C15	Advanced Mineralogy and Geochemistry	4	4		
Core Course Practical Paper – C15P	Advanced Mineralogy and Geochemistry	2			2
Core Course Paper-C16	Advanced Petrology	4	4		
Core Course Practical Paper – C16P	Petrology	2			2
Skill Enhancement Course -1	***Computer Applications in Geosciences***	4	3	1	
Ability Enhancement Compulsory Courses-1	***Earth Surface Processes***	4	3	1	
Generic Elective Courses Paper-1	***Global Climate Change***	6			6
	Total Credits in 7th Semester	**26**			
SEMESTER – VIII					
Core Course Paper-C15	Ore Genesis, Ore Geology	4	4		
Core Course Practical Paper – C15P	Ore Microscopy	2			2
Core Course Paper-C16	Hydrogeology	4	4		
Core Course Practical Paper – C16P	Hydrogeology	2			2
Skill Enhancement Course -1	***Analytical Instruments***	4	3	1	
Ability Enhancement Compulsory Courses 1	***Applied Geophysics***	4	3	1	
Generic Elective Courses Paper-1	***Disasters Management and Mitigation***	6	5	1	6
	Total Credits in 8th Semester	**26**			

SEMESTER – IX					
Core Course Paper-C15	Remote Sensing Applications	4	4		
Core Course Practical Paper – C15P	Remote Sensing Applications	2			2
Core Course Paper-C16	Geographic Information System-	4	4		
Core Course Practical Paper – C16P	Geographic Information System-	2			2
Skill Enhancement Course -1	***Basic Computer Programming, Python***	4	3	1	
Ability Enhancement Compulsory Courses 1	***Field Mapping***	4	3	1	
Generic Elective Courses Paper-1	***Research Methods in Geology***	6	5	1	6
	Total Credits in 9th Semester	**26**			
SEMESTER – X					
Core Course Paper-C15	***Dissertation***	8			8
Core Course Practical Paper – C15P	***Dissertation Viva***	4			4
	Total Credits in 10th Semester	**12**			
	Grand Total of Credits for M.Sc.,	**90**			