Annexure-IA

List of Courses for B.Sc. Geology Honors/General Degree program (w.e.f. AY 2017-18)

	Course Name	Credits	
		Theory	Practical
A. Discipline Specific Core Courses (DSC)- Code: GEC; (6 Credits each)			
1	GEC-101 Fundamentals of Mineral Science	**4**	**2**
2	GEC-102 Introduction to Petrology	**4**	**2**
3	GEC-103 Earth's Dynamics & Structural Geology	**4**	**2**
4	GEC-104 Principles of Stratigraphy and Paleontology	**4**	**2**
5	GEC-105 Mineralogy	**4**	**2**
6	GEC-106 Structural Geology	**4**	**2**
7	GEC-107 Igneous Petrology	**4**	**2**
8	GEC-108 Sedimentary Petrology	**4**	**2**
9	GEC-109 Metamorphic Petrology	**4**	**2**
10	GEC-110 Indian Stratigraphy	**4**	**2**
B. Discipline Specific Elective (DSE); Code: GED (4 Credit each)			
1	GED-101 Engineering Geology	**3**	**1**
2	GED-102 Economic Geology	**3**	**1**
3	GED-103 Mining Geology	**3**	**1**
4	GED-104 Project	**3**	**1**
5	GED-105 Geomorphology	**3**	**1**
6	GED-106 Remote Sensing & Photogeology	**3**	**1**
7	GED-107 Coal & Petroleum Geology	**3**	**1**
8	GED-108 Environmental Geology	**3**	**1**
9	GED-109 Hydrogeology	**3**	**1**
10	GED-110 Gemology	**3**	**1**
C. Generic Elective (GE); Code: GEG (4 Credit each)			
1	GEG-101 Minerals & Rocks	**3**	**1**
2	GEG-102 Physical Geology	**3**	**1**
3	GEG-103 Essentials of Geology	**3**	**1**
4	GEG-104 Environmental Geology	**3**	**1**
D. Skill Enhancement Course (SEC); Code: GES (4 Credit each)			
1	GES-101 Basics of Remote Sensing		
2	GES-102 Water Quality Assessment	**3**	**1**
3	GES-103 Field Geology	**3**	**1**
4	GES-104 Environmental Impact Assessment	**3**	**1**
5	GES-105 GIS Fundamentals	**3**	**1**

Course Structure of B.Sc. Geology Honors/General Degree program (w.e.f. AY 2017-18)

Year	Semester	Discipline Specific Core DSC (GEC)	Discipline Specific Elective DSE (GED)	Skill Enhancement Course SEC (GES)	Generic Elective GE (GEG)
Credits		**6 credits each**	**4 credits each**	**4 credits**	**4 credits**
First Year	**I**	GEC101: Fundamentals of Mineral Science			GEG101 Minerals & Rocks GEG103 Essentials of Geology
	II	GEC102: Introduction to Petrology			GEG102 Physical Geology GEG104 Environmental Geology
Second Year	**III**	GEC103: Earth's Dynamics & Structural Geology		GES101 Basics of Remote Sensing	
	IV	GEC104: Principles of Stratigraphy and Paleontology		GES102 Water Quality Assessment	
Third Year	**V**	GEC105 Mineralogy GEC106 Structural Geology GEC107 Igneous Petrology	GED101 Engineering Geology GED102: Economic Geology GED104 Project GED106 Remote Sensing & Photogeology GED107 Coal & Petroleum Geology	GES103 Field Geology GES104 Environmental Impact Assessment	
	VI	GEC108 Sedimentary Petrology GEC109 Metamorphic Petrology GEC110 Indian Stratigraphy	GED103 Mining Geology **OR** GED105: Geomorphology GED104 Project GED108 Environmental Geology GED109 Hydrogeology GED110 Gemology	GES105 GIS Fundamental	

Note: The field training programs are compulsory components and the evaluation of the performance will be carried out during and after the field trainings. The field training programs will be preferably conducted in the intervening period between the semesters. Field training duration in FY, SY and TY BSc Geology is integrated in the practical components of the relevant courses.

Annexure-II (BSc-Geology Syllabus)

GEC-101	**Fundamentals of Mineral Science**	**Credit: 6** **(Theory-4; Practical-2)**

Course Objectives:

1. To acquire knowledge about the origin, shape and size of Earth
2. To understand the characteristics of common rock-forming minerals
3. To understand the states of matter, atomic arrangement in crystals, and classification of crystals based on crystal symmetry

THEORY	
Introduction to Geology, Earth in the Solar system- origin, size, shape and its age. Internal structure of the Earth. Introduction to Plate Tectonics. Mineralogy: Elemental and Oxide composition of the Earth's Crust; Definition of a mineral; Important and abundant mineral groups: Silicates, Sulphides, Sulphates, Carbonates, Oxides, Halides, Native metals with examples. Physical Properties of Minerals: Colour, Streak, Luster, Transparency, Habit (Imitative form), Cleavage, Hardness, Fracture, Specific Gravity, luminescence.	15H
Classification of Silicates according to Structure: Orthosilicates: Olivine Group; Inosilicates: Pyroxene and Amphibole groups; Tectosilicates: Silica and Feldspar Groups; Phyllosilicates: Mica Group. Mineralogy of Carbonate, Sulphides, Phosphates, Oxide and hydroxide groups. Distribution of following economic minerals in India: Diamond, Gold, Copper, Lead-Zinc, Iron, Manganese, Bauxite and Mica.)	15H
Crystallography: Definition of a crystal; crystalline state and amorphous state; Atomic arrangement in crystalline matter; Types of Bonds. Three-dimensional order and repetitions in crystal space lattice and unit cell; Bravais lattices as building blocks for the crystal system.	15H
Crystallographic axes and classification of crystals into Crystal systems and 32 point groups; Symmetry in crystals: Planes, Axes and Centre of Symmetry; Interfacial angle and Contact Goniometer; Parameters and Indices; Polymorphism, Isomorphism and Pseudo-morphism.	15H
PRACTICAL:	
Study of minimum 20 Crystal models representing all the crystal systems. Identification and Description of the Physical Properties, Composition, Occurrences and Uses of minimum 20 common rock forming minerals.	60H

Learning Outcome:

1. Students will be able to identify common rock-forming minerals in hand specimen based on their physical properties
2. Students will be able to find the symmetry in crystals and classify crystals based on symmetry elements
3. Students will be able to plot crystal faces on stereographic projection

Books:

1. Rutley's Elements of Mineralogy by H. H. Reed (27th Ed) (CBS Publishers)
2. Dana's textbook of Mineralogy by W. E. Ford, 4th Ed
3. Mineralogy by Dexter and Perkins (3rd Ed, 2012)
4. Introduction to Mineral science by Putnis Andrew, Cambridge Uni. Press (2012)

GEC-102	Introduction to Petrology	Credit: 6 (Theory-4; Practical-2)

Course Objectives:

1. To acquire knowledge on different types of rocks, their distinction from each other and the rock cycle.
2. To understand the modes of formation of different types of rocks
3. To understand their origin
4. To understand the similarities and differences of the rock types

THEORY	
Rocks; Classification of rocks into three classes: Igneous, Sedimentary and Metamorphic. Rock cycle. Igneous Petrology: Definition, Magma, Properties of Magmas, Types of magmas, Plutonic, Hypabyssal and Volcanic Types. Mode of Occurrence of Igneous rocks: Intrusive (major, minor), Extrusive, Dykes (Radiating, Arcuate, Ring dykes, and cone-sheets), Sills, Laccoliths, Phacoliths, Volcanic necks, Lopoliths, Batholiths (stocks, bosses, plugs), lava flows, puys, volcanic cones, stratovolcanoes, composite volcanoes and cinder cones. Structures: Vesicular and Amygdaloidal, Sheet, Platy and Columnar, Block lava, Ropy lava, Pillow and Flow structures; Textures: Degree of crystallization [Crystallinity]; Absolute sizes of crystal grains [Granularity], Shapes of crystals and Mutual relations of crystals – Equigranular (allotriomorphic, hypidiomorphic, & panidiomorphic), Inequigranular (Porphyritic) intergrowth (graphic, perthite), directive(trachytic)	15H
Classification of igneous rocks based on Colour Index, Grain size & Mineral composition into the following groups – Felsic, Intermediate, Mafic, Ultramafic; Plutonic, Hypabyssal, Volcanic, Bowen's reaction series. Study of mineral composition, texture and mode of occurrence of following rocks: Granite, Syenite, Gabbro, Dolerite, Basalt, Dunite.	15H
Sedimentary petrology: Weathering of Rocks; Types and products of weathering; Sedimentation and Diagenesis; Primary Structures, Textures and composition, Classification based on Grain size and Mode of formation; Sedimentary depositional environments: marine, lacustrine, aeolian, glacial. Study of following rocks in brief: Conglomerate, breccia, sandstone, shale, limestone, coal and laterite.	15H
Metamorphic petrology: Definition, Agents of metamorphism, Types of metamorphism, Index Minerals; Structures and Textures of metamorphic rocks; Metasomatic Processes: Hydrothermal, Pneumatolysis, Classification based on types of metamorphism and composition; Nomenclature of metamorphic rocks. Introduction to facies concept. Study of following metamorphic rocks: slate, schist, gneiss, marble, quartzite.	15H
PRACTICAL:	
Identification, megascopic description and classification of 30 common rocks (Igneous-10, Sedimentary-10, Metamorphic-10.	30H 15P

Learning Outcome:

1. Distinguish and discriminate all three rock types based on their respective properties
2. Categorize and identify the rocks in hand specimen
3. Compare and contrast between various igneous, sedimentary and metamorphic rocks
4. Apply knowledge in identification in the field to establish relationship/lineage of different rock types

Field Training (30 hours/ Four days) – (Compulsory module for 25 marks)

Orientation of Topographic sheet in field, marking location on toposheet, Bearing (Fore and back). Concepts of map reading, Distance, height and pace approximation. Identification of rock types in field; structures and texture of rocks, Use of hand lens. Basic field measurement techniques: Bedding dip and strike, Reading contours and topography. Field applications of GPS. (To be assessed as field Viva for 10 marks and in laboratory – field report and viva for 15 marks)

Books:

1. The Principles of Petrology by G. W. Tyrell (B. I. Publications Pvt. Ltd.)
2. A Textbook of Engineering and General Geology (Seventh Ed) by Parbin Singh
3. Understanding the Earth (Fourth Ed) by Press, Siever, Grotzinger & Jordan
4. The Changing Earth: Exploring Geology and Evolution (Third Ed) by Monroe & Wicanter
5. A textbook of Geology by P. K. Mukherjee (World Press)
6. A textbook of Geology by G. B. Mahapatra (CBS)
7. Essentials of Geology by Wicander Reed and Monroe, J.S. (11th Edition)
8. Field geology by Frederic Lahee (Sixth Edition)
9. Petrogenesis of Metamorphic Rocks by HGF Winkler (1979)
10. Sedimentary Rocks by FJ Pettijohn (Third Edition)

GEC-103	Earth's Dynamics & Structural Geology	Credit: 6 (Theory-4; Practical-2)

Course Objectives:

1. Acquire knowledge about the Earth's interior and its dynamics nature.
2. Understand the concept of plate tectonics.
3. Recall the principles of topographic mapping
4. Understand compass bearings and Interpret basic geological maps.
5. Apply the principles of plate tectonics and geological mapping to analyze Earth''s geomorphology

THEORY	
Earth as a planet, holistic understanding of Earth, General characteristics. Origin of Solar System (Planetesimal hypothesis) and formation of a layered Earth; Earth's interior: Crust, Mantle and Core. Atmosphere, Hydrosphere. Seismic exploration of Earth's interior. Earth's Gravity: acceleration due to gravity, change with latitude and altitude, mass and density; Isostasy. Earth's Magnetism: Earth as a magnet, lines of force, inclination and declination, geomagnetic axis and geographic axis. Convection in the Earth's core and production of its magnetic field	15H
Theory of continental drift: Geographical and geological evidences pointing to the continental drift. Introduction to Plate tectonics, Lithospheric plates, Plate boundaries and associated activities. Earthquakes: Seismic waves, Magnitude (Mercalli Scale), Intensity (Richter Scale), Types of Earthquakes (shallow, intermediate, deep); Tsunamis; Volcanoes: Types and distribution, Ring of fire.	15H
Topography: high-grounds, plains, valleys, major topographic features on continents (mountains, hills, ridges, plateaus, plains, deserts, bad-lands, permafrost regions) and oceans (continental shelf, slope, rise, abyssal plains, mid-oceanic ridges, trenches, islands, reefs). Contours, contour reading and contour patterns; Scale and compass bearing, Stratification, Strike, Dip (true and apparent dip), Strike and Dip symbols Clinometer compass: construction, working and uses; Outcrop patterns of Horizontal, Inclined and Vertical strata on various types of ground surfaces; Rule of 'V's	15H
Folds: Causes and types of folds: symmetrical, asymmetrical, overturned, recumbent, isoclinal, fan, chevron, monocline, structural terrace, open and closed, plunging; importance of folds Joints: Geometric classification, importance; Faults: general characteristics, geometric classification and importance, Horst, Graben and Thrust faults; Unconformities: Stages of development, types and importance of unconformities; Off-lap and Overlap, Outliers, Inliers	15H
PRACTICAL:	
Description and Drawing of Vertical sections of minimum 10 Geological Maps involving a Single Series of Horizontal, Dipping strata with vertical intrusive. Graphical Solution of Structural Geology Problems involving a) Strike, True and Apparent Dips, b) Thickness and width of outcrop. Clinometer compass- Fore and back bearings.	60H

Learning Outcome:

1. Explain the internal structure of the Earth and its gravity and magnetic.
2. Recognise the various structures exhibited by rocks.
3. Relate the rock structures to the forces involved in their formation.
4. Infer the nature of the rocks from geological maps.
5. Measure the attitude of the beds and Create topographic maps.

Books:

1. A textbook of Geology by P. K. Mukherjee (World Press)
2. A Textbook of Engineering and General Geology (Seventh Ed) by Parbin Singh
3. Understanding the Earth (Fourth Ed) by Press, Siever, Grotzinger & Jordan
4. The Changing Earth: Exploring Geology and Evolution (Third Ed) by Monroe &Wicanter
5. Holmes' Principles of Physical Geology by Arthur Holmes (Third Ed) (ELBS)
6. Holmes' Principles of Physical Geology edited by P. McL. D. Duff (ELBS)
7. Physical Geology by C. W. Montgomery (Second Ed) (Wm C. Brown Publishers)
8. Structural Geology by M. P. Billings (Prentice Hall)
9. A Manual of problems in Structural Geology by NW Gokhale.
10. Structural Geology: Fundamentals and Modern Developments, S K Ghosh (1st Ed, 1993) Elsevier publications
11. The Making of India: Geodynamic Evolution, K S Valdiya (2016) Springer publications.

GEC-104	Principles of Stratigraphy & Paleontology	Credit: 6 (Theory-4; Practical-2)

Course Objectives:

1. Students will acquire knowledge about stratigraphic principles.
2. Students will acquire knowledge about occurrence of fossils in different Indian Formations.

THEORY	
Stratigraphy: scope and importance; Principles of Stratigraphy: Laws of uniformitarianism, original horizontality, order of superposition, faunal succession, cross-cutting relationship, inclusions; Correlation and methods of correlation: Structural relations (tectonic criteria), Lithological similarity (Marker horizon or key bed), Paleontological criteria (Index fossils), Standard Stratigraphic timescale; Indian stratigraphic timescale; Geological Time Units: - Eon, Era, Period, Epoch, Age, Phase. Chronostratigraphic Units: - Erathem, System, Series, Stage and Zone. Lithostratigraphic Units: - Group, Formation, Member, Bed and laminae.	15H
Fossils: Definition and types: Mega fossils (dinosaurs), Microfossils, Ichnofossils; Conditions for fossilization; Modes of preservation of organic remains: Biologic, mechanical and chemical destruction; Factors limiting distribution of organisms: sunlight, depth of water, oxygen, seawater temperature, salinity, substratum & food	15H
Modes of fossilization; Derived fossils; transported fossils; Index fossils and Endemic fossils; Uses of fossils; Introduction to taxonomy and species concept.	15H
Study of general characteristics, morphology, habitats and geological history of the following Phylla with their biostratigraphic significance: Phylum Mollusca: Pelecypoda, Gastropoda, Cephalopoda (Classes Nautiloidea, Ammonoidea, Belemnoidea) with Indian examples, if any; Significance of ammonites. Phylum Brachiopoda: Articulata, Inarticulata; Phylum Echinodermata: Echinoidea, Crinoidea; Phylum Arthropoda: Trilobita; Phylum Protozoa: Foraminifera with examples. Origin of Vertebrates and major steps in vertebrate evolution, Mesozoic reptiles with special reference to diversity and extinction of Dinosaurs with Indian examples. Human evolution. Gondwana flora.	15H
PRACTICAL:	
Plotting of major geological formations on outline map of India and Goa. Identification, Classification, Description and Geological Time Range of minimum 25 Fossils.	30H 15P

Learning Outcome:

1. Students will be able to apply this stratigraphic principles during field investigations.
2. Students will be able to identify and classify common fossils.

Field Training (30 hours/Four days)- Compulsory module for 25 marks

Geological mapping: Basic concepts of outcrop mapping, geological mapping, mapping of structural features and stratigraphy. Visit to a mineral deposit / open cast mine. Visit to igneous / metamorphic rocks terrain.
(To be assessed in field by conducting Viva for 10 marks and in laboratory – field report and viva for 15 marks)

Books:

1. The Elements of Palaeontology by Rhona Black (Cambridge University Press, 1972)
2. Invertebrate Paleontology and Evolution by E. N. K. Clarkson. (Second Ed) (ELBS/Allen & Unwin)
3. Introduction to Invertebrate Palaeontology by Koregave
4. Simon & Schuster's Guide of Fossils by Paolo Arduini& Giorgio Teruzzi (Simon & Schuster Inc., New York)
5. A Textbook of Engineering and General Geology (Seventh Ed) by Parbin Singh
6. Understanding the Earth (Fourth Ed) by Press, Siever, Grotzinger& Jordan
7. The Changing Earth: Exploring Geology and Evolution (Third Ed) by Monroe &Wicanter
8. Basic concepts of Historical Geology by E. W. Spencer (Oxford Hill)
9. Fundamentals of Historical Geology and Stratigraphy of India by Ravindra kumar (Wiley Eastern Ltd.)
10. Geology of India and Burma by M.S. Krishnan (Sixth Ed) (CBS)
11. Physical Geology by C. W. Montgomery (Second Ed) (Wm C. Brown Publishers)
12. Invertebrate Paleontology by Woods Henry
13. Principles of Stratigraphy by Marvin Weller
14. The Making of India: Geodynamic Evolution, K S Valdiya (2016) Springer publications.
15. Geology of India (Vol 1 and 2) by M Ramakrishnan and R Vaidyanathan

GEC-105	Mineralogy	Credit: 6 (Theory-4; Practical-2)

Course Objectives:

1. This course will provide knowledge on mainly the optical properties of minerals and their identification
2. It will also provide the general description and distinction of silicate group of minerals.

THEORY	
Introduction to mineralogy: definition of a mineral, Phase rule, system, Phase components, degrees of variance, Mineralogical Phase rule. Binary system-with eutectic (Di-An) and with solid solution (Ab-An). Description of following mineral groups with respect to chemical composition, structure, physical properties, optical properties and paragenesis: silica, feldspar, mica, amphibole, pyroxene, olivine and feldspathoids	30H
Optical Mineralogy: nature of light, polarized light, polarizing microscope. Properties in plane polarized light and between cross polars: colour, pleochroism, relief, twinkling, birefringence, interference colors, twinning, zoning, extinction, inclusions.	15H
Properties under conoscopic light and its applications in the study of uniaxial and biaxial minerals. Uniaxial and Biaxial indicatrix. Accessory plates: Mica, Quartz, Gypsum, 2v, 2e.	15H
PRACTICAL:	
Megascopic identification of minimum 20 minerals. Microscopic identification of minimum 15 mineral thin-sections. Optical methods: (Determination of order of polarization, birefringence, sign of elongation, optic sign, An- content). Calculation of 2v. Calculation of mineral formula, end member calculations and structural formula.	60H
Learning Outcome:	
1. Explain to a peer the working of a petrological microscope and differentiate and distinguish from biological microscopes 2. Identify the optical properties and use them in subdividing minerals 3. Distinguish and differentiate between different silicate group minerals 4. Compare the working of various binary systems and their applications to magmatic textures and processes	

Books:

1. Berry and Mason: Mineralogy CBS Publ. and Distr.
2. Phillips, W. R and Griften, D.T: Optical Mineralogy CBS Publ and Distr.
3. Kerr, Paul : Optical Mineralogy McGraw Hill
4. Deer W. A. Howie R.A. Zussman J. : Rock forming minerals, Longman
5. Gribble Colin D. and Hall Allan J. : Optical Mineralogy- Principles and practice
6. Michael Railh, Peter Raese and Jurgen Reinhardt: Guide to Thin section microscopy
7. Dana's Textbook of Mineralogy

GEC-106	Structural Geology	Credit: 6 (Theory-4; Practical-2)

Course Objectives:

Students will acquire knowledge about the scope and importance of Structural Geology
Students will understand the concept of stress and strain and the forces operating in the Earth
Students will get an overview of the various geological structures and the processes involved in their formation
Students will understand the concept of plate tectonics and get an overview of the present day plate tectonics

THEORY	
Concept of rock deformation, Stress and strain in rocks, Principles of mechanical behavior of rocks, factors controlling their behavior. Planar and linear features, concept of strike and dip, Folds: recognition, types and causes of folding. Genetic classification of folds. Determination of top of beds with the help of primary and secondary features.	15H
Joints: principles of failure by rupture, genetic classification of joints. Faults: Effects on disrupted strata, separation, genetic classification, Criteria for faulting, types of faults (normal, strike-slip, reverse, thrust, overthrust)	15H
Foliation, lineation, cleavage and schistosity: description and origin, relationship with major structures, significance. Unconformities: types of unconformities, recognition and distinction from faults and intrusive contacts. Effects of topography on structural features, Outcrop patterns of different structures.	15H
Introduction to Plate Tectonics and sea floor spreading: Lithosphere, Asthenosphere, Mesosphere, Lithospheric plates, Types of Plate boundaries and associated major activities. Orogenic and epeirogenic movements.	15H
PRACTICAL:	
Description and drawing of cross-sections of 10 structural maps involving two series, inclined faults, folds and intrusives and 5 completion of outcrops. Graphical and stereographic solutions of structural problems.	30H 15P
Learning Outcome:	

1. Students will be able to identify geological structures in field and collect structural data
2. Students will be able to generate strain ellipsoid and infer past stress fields
3. Students will be able to solve structural problems graphically and using stereo-net
4. Students will be able to construct geological cross section using geological map

Books:

1. Billings: Structural Geology Oxford CBS
2. Hobbs: Outline of Structural Geology Prentice Hall
3. Condie: Plate Tectonics and Crustal Evolution, Pergamon Press
4. The Evolving Continents by B. F. Windley
5. Structural and Tectonic Principles by P. G. Badgley
6. Structural Geology: Fundamentals & Modern Developments, S K Ghosh (1st Ed, 1993) Elsevier

GEC-107	Igneous Petrology	Credit: 6 (Theory-4; Practical-2)

Course Objectives:

1. Students will acquire knowledge about the different types of Igneous rocks and understand their modes of occurrence in nature
2. Students will understand the processes involved in the formation of igneous rocks and their diversity
3. Students will understand the various classifications of igneous rocks based on different criteria
4. Students will acquire knowledge about magmas and their origin in different tectonic settings

THEORY	
Igneous activity in relation to plate margins and plate interiors. Magmas, their nature, temperature, density, viscosity, chemical composition and role of volatiles. Mode of occurrence, Kindred and suite, structures.	15H
Classification (IUGS), and textures of igneous rocks. Generation and ascent of magma. Magmatic evolution (differentiation, magma mixing and assimilation).	15H
Crystallization trend of Di-Ab-An system and Ne-Ka-Si system, Study of following suite (clans) of rocks: granites, syenites, gabbroic and ultramafic.	15H
Study of lamprophyres, anorthosites, carbonatites, kimberlites. Geology of layered igneous intrusions with examples. Flood basalts and large igneous provinces.	15H
PRACTICAL:	
Megascopic identification of minimum 20 igneous rocks. Normative analysis of igneous rocks. Microscopic identification of 12 Igneous rock thin-sections.	30H 15P
Learning Outcome:	

1. Students will be able to identify common igneous rocks both in hand specimen and thin section
2. Students will be able to identify and describe igneous structures and textures, and infer the geological processes involved in their formation and classify them
3. Students will be able to interpret phase diagrams of common igneous systems

Books:

1. Middlemost E.A.K. Magmas and Magmatic Rocks, Longman
2. Best M.: Igneous and Metamorphic rocks, Wiley-Blackwell, 2002.
3. Barker D.S. Igneous Rocks, Prentice Hall
4. Raymond, Loren : Igneous and Metamorphic Petrology, John Wiley Sons
5. Winter John: Igneous and metamorphic petrology, Prentice Hall, 2010.
6. Bose Mihir: Igneous Petrology, World Press, 1997.
7. G. W. Tyrell: The Principal of Petrology
8. Anthony Hall: Igneous petrology, Longman press, (Second Edition) 1997.
9. Igneous Petrology: Principles and Practice by Gautam Sen (Springer Publications), 2014.
10. Petrology and Genesis of Igneous Rocks by Alok Gupta (Narosa Publications, 2007
11. Petrology of the Igneous Rocks by FH Hatch, AK Wells and MK Wells

GEC-108	Sedimentary Petrology	Credit: 6 (Theory-4; Practical-2)

Course Objectives:

1. To make students understand physical, chemical and biological processes that generate sediments
2. To discuss the various sedimentary rocks, their mode of formation and occurrence in nature
3. To explain the environments of deposition and diagenesis of various sedimentary rocks
4. To classify various sedimentary rocks as per different criteria
5. To identify and describe various economic minerals associated with sedimentary rocks

THEORY	
Introduction, sedimentary processes weathering, (types and products), erosion and transportation, deposition, compaction and lithification. Diagenesis. Textures in Sedimentary rocks: grain size (Udden-Wentworth scale), size frequency distribution, causal factors. Grain size and depositional processes, shape of grains: sphericity and roundness, fabric and framework geometry, porosity and permeability, Fabrics in gravels, sands and clays, carbonate rocks and organic sedimentary rocks.	15H
Classification of sedimentary rocks, textures, composition and distribution and diagenesis of various groups of sedimentary rocks: clastic, (rudaceous, arenaceous, argillaceous rocks); Non-clastic: chemical (limestones, dolomites, ferruginous, silicious and phosphatic sediments and evaporarites.	15H
Organic (limestones, silicious and calcareous oozes, phosphatic rocks, bog ores and coal; Residual: laterite, bauxite and soil. Primary sedimentary structures: depositional, erosional. Secondary structures: chemical, biogenic. Heavy minerals, authigenic, allogenic minerals and provenance.	15H
Basins of deposition – structural, morphological and tectonic basins, geosynclines. Depositional environments: physical, chemical, organic factors. Characteristics of flysch and molasses sediments.	15H
PRACTICAL:	
Megascopic identification of minimum 15 sedimentary rocks. Exercises on sorting, sphericity & roundness Microscopic identification of 10 sedimentary rocks in thin-sections.	30H 15P
Learning Outcome:	

1. Categorise unknown rocks into the class of sedimentary rocks
2. Compare the characteristics of sedimentary rocks from different regions
3. Interpret the environments of deposition from the study of nature of sediments & depositional structures.
4. Determine the order of superposition of rocks
5. Assess the grain size and grain size parameters

Books:

1. Pettijohn, F.G.: Sedimentary Rocks, CBS Publ and Distr
2. Maurice Tucker: Sedimentary Petrology, Third Edition, 2001.
3. Petrology of Sedimentary rocks: Greensmith
4. Sedimentary structures by Collinson and Thompson
5. Origin of Sedimentary Rocks by Blott, H., Middletin and Murray, R.
6. Procedures in sedimentary petrology by Carver, R. C.
7. Sedimentology processes and products: Leader, M.R.
8. Sam Boggs: Sedimentary Petrology
7. Sedimentology and Stratigraphy by Gary Nichols

GEC-109	Metamorphic Petrology	Credit: 6 (Theory-4; Practical-2)

Course Objectives:

1. This course will mainly focus on the occurrence, appearance, formation and distribution of metamorphic rocks.
2. It will provide an insight into the mineralogy, texture and structure of metamorphic rocks
3. It will create lineage between different metamorphic, igneous and sedimentary rocks
4. Also highlight the field characters, facies and ultimately the tectonic settings in which the rocks formed.

THEORY	
Definition of metamorphism. Factors responsible for metamorphism: temperature (radioactive, magmatic, tectonic heat), geothermal gradient (in different crustal regions); pressure (P) (directed and load pressure); composition of the parent rock (*X)*; fluids (H_2O and CO_2) (X_f). Metamorphism in relation to the plate tectonic environments: divergent and convergent boundary environments.	15H
Types of metamorphism: Local – contact metamorphism and cataclastic metamorphism; Regional- burial metamorphism and dynamothermal metamorphism, other types of metamorphism: ocean floor metamorphism, hydrothermal metamorphism, dislocation metamorphism, impact metamorphism and their relationship with the major types of metamorphism. Contact metamorphism its characteristics and products (e.g. hornfels, skarns). Regional metamorphism its characteristics and products (e.g. slates, schists, gneisses and granulites).	15H
Fabric of metamorphic rocks: definition (size and shape, and mutual relationship between and with adjacent minerals). Fabric types: relict fabric-primary features such bedding, fossil outlines, grain boundaries). Isotropic fabric, anisotropic fabric (imposed) foliation viz., slaty cleavage, schistosity, gneissic banding, flaser & augen fabric; Lineation (crenulation, mineral lineation) appearance in field and in hand specimen. Origin of fabric of metamorphic rocks. Porphyroblasts - definition and examples. Idioblastic series. Classification of metamorphic rocks based on mineralogy and fabric. Protoliths (metapelites, metabasites, metagreywackes)	15H
Field characters of metamorphic rocks: variations in mineralogy and fabric. Concept of depth zones and index minerals, their significance in mapping and understanding tectonic history. ACF and AFM (AKFM) diagrams their advantages and limitations. Facies concept after Golschmidt and Eskola. Facies of contact metamorphism and characteristic mineral assemblages in shales and limestone. Facies of regional metamorphism and their characteristics: zonation in mineralogy, Barrovian- (relatively higher P) and Buchan- (relatively lower P) series, and their significance. Products of regional metamorphism- rocks and characteristic minerals in different facies in different kinds of rocks such as shales, limestones and basalts.	15H
PRACTICAL:	
Megascopic identification of minimum 15 metamorphic rocks. ACF & AFM diagrams. Microscopic identification of minimum 10 metamorphic rocks in thin-sections.	30H 15P
Learning Outcome:	

1. Distinguish metamorphic rocks from other types of rocks
2. Categorize and relate the metamorphic mineral assemblages according to their modes of formation
3. Describe and discern the textures and structures exhibited by metamorphic rocks
4. Interpret tectonic settings based on the type of metamorphic rock

Books:

1. Turner F.J.: Metamorphic rocks field mineralogical & tectonic aspects Longman
2. Raymond, Loren: Igneous and Metamorphic Petrology, John Wiley Sons
3. Winter John: Igneous and metamorphic petrology
4. Bhaskar Rao: Metamorphic petrology
5. Buchan and Grapes; Petrology of metamorphic rocks
6. Best M. G.: Igneous and metamorphic petrology.
7. Yardly, V.M.; An introduction to Metamorphic Petrology
8. Philpots, A.R. Principles of Igneous and Metamorphic Petrology.
9. Wood, B.J. and Fraser, D.G.: Elementary Thermodynamics for Geologists.
10. Metamorphic Petrology: concepts and methods (Textbook series in Geological Sciences) by Ram S Sharma (2016)

GEC-110	Indian Stratigraphy	Credit: 6 (Theory-4; Practical-2)

Course Objectives:

1. Students will acquire knowledge about stratigraphic principles.
2. Students will acquire knowledge about the distribution, lithology, stratigraphic sequence, structures and economics of different rock formations of India.
3. Students will acquire knowledge about the different geologic changes that occurred in the Indian subcontinent with time and correlate it with the other rock formations in the world.

THEORY	
Tectonic and Physiographic divisions of India – their characters and peculiarities with respect to geo-tectonics, stratigraphy and physiography. Stratigraphy of Peninsular India: Dharwar Supergroup and Peninsular Gneissic Complex with their distribution, lithology, stratigraphic sequence, structures and economics, Geology and stratigraphy of Goa Group of rocks.	15H
Proterozoics of Peninsular India: Cuddapah Supergroup, Vindhyan Supergroup and Kaladgi Supergroup; their distribution lithology, stratigraphic sequence, structure and economics.	15H
Palaeozoic succession of India: marine palaeozoic formation, Palaeozoic succession of Spiti and Kashmir, Mesozoic succession: Triassic, Jurassic, and Cretaceous formations of Extra peninsula (Spiti and Kashmir regions), marine Mesozoics of Peninsular India: Jurassic of Kutch, Cretaceous of Trichinopoly. Gondwana Supergroup. Ancient Gondwanaland, climatic changes during Gondwanas. Distribution, classification, tectonic relations, origin of Gondwana rocks and their economic importance.	15H
Cenozoic Era: Palaeogeography of World, Life during Cenozoic, Tertiary formations in India (Gujarat, Assam & Tamil Nadu). Deccan Basalt Group (Traps): distribution and age, inter-trappean and infra-trappean beds. Siwalik Group: structure, classification, lithology, climate, fossils. Pleistocene glaciation. Ice age, Pleistocene ice age in India, evidences of ice age, Rise of Himalayas.	15H
Field training (60 hours/Eight days) (60 hours of field work is equal to 30 practical sessions of two hours each which is equal to 2 credits)	
Observation and recording of primary and secondary planar and linear features in the rocks such as bedding planes, schistosity, cleavage, lineation and their measurements. Mapping of tectonic and stratigraphic features, stratigraphic correlation. Study of igneous/sedimentary/ metamorphic rock exposures. Preparation and submission of Geological report. Field transect in a Precambrian/ Phanerozoic terrain of India. Field study of a horizontal/ incline/ folded/ faulted sedimentary succession. Preparation and submission of Geological report. (To be assessed in field by conducting Viva for 20 marks and in laboratory – field report and viva for 30 marks)	60H
Learning Outcome:	

1. Students will be able to understand the mode of formation of different rock formations of India and correlating it with other formations will help in deciphering the geological history.
2. Students will be able to apply this stratigraphic principles during field investigations.
3. Students will be able to propose further refinement if needed in the already established stratigraphy of India.

Books:

1. Krishnan, M. S.: Geology of India and Burma CBS Publ and Distrib.
2. Wadia D. N.: Geology of India Oxford IBH
3. Ravindra kumar: Fundamentals of Historical Geology & Stratigraphy of India Oxford IBH
4. Geology of India,GSI Volumes: Ramakrishnan, M and Vaidyanathan, R.
5. Dunbars and Rodgers: Principles of Stratigraphy
6. Geology and Mineral Resources of Goa by A G Dessai, New Delhi publishers, 2018.
7. Natural Resources of Goa – A Geological Perspective by Geological Society of Goa (2009).

DISCIPLINE SPECIFIC ELECTIVE in GEOLOGY

GED-101	**Engineering Geology**	**Credit: 4** **(Theory-3; Practical-1)**
Course Objectives: 1. To understand the engineering properties of rocks 2. To learn methods of geological investigations for selection of sites for engineering projects.		
THEORY		
Engineering properties of rocks-Rock as material for construction, rock as site for construction. Geotechnical Projects: Geological Investigations, methods of investigation (geophysical) and the role of geologists.		15H
Dams and reservoirs: types of dams, site selection, stability and failure of dams. Foundation geology, induced seismicity related to dams and environmental impact. Tunnels; stress conditions in tunnels, influence of geological conditions, changes in water table. Buildings (types of foundations), Bridges (types), Roads (construction in different geological terrains), Canals: stability and problems.		15H
Improvement in sites: Grouting, backfilling, soil stabilization. RQD and slope stability study.		15H
PRACTICAL		
Exercises and problems in engineering geology with respect.to tunnel alignment and dam locations. RQD problems		30H
Learning Outcome:		
1. Will be able to identify and select the appropriate sites for engineering projects 2. Will be able to suggest remedial measures for the improvement of sites		
Books:		
1. Valdiya K. S.: Environmental Geology Indian Context TMH (1985) 2. Ronald Tank: A focus on Environmental Geology CBS (1973) 3. Edward Keller: Environmental Geology CBS (1976) 4. Radu Priscu: Earthquake engineering for large dams CBS (1985) 5. Blyth and De Freitas: A Geology for Engineers, ELBS Arnold (Seventh Edition) 6. Engineering geology by Parbin Singh 7. Engineering Geology by Chenna Kesavulu (2009)		

GED-102	Economic Geology	Credit: 4 (Theory-3; Practical-1)

Course Objectives:

1. To define various terminologies related to ores and ore minerals
2. To differentiate between common rock forming minerals from those that are economically important
3. To understand processes of ore formation and their genesis
4. To explain and give examples of various ore minerals found in Indian subcontinent.
5. To distinguish mineral deposits from various regions

THEORY	
Definition of ore, gangue, grade of ore/ tenor, assaying, Classification of mineral deposits. Processes of ore formation and ore genesis. Hypogene, Supergene, Epigenetic and Syngenetic mineral deposits.	15H
Magmatic, sublimation, contact metasomatic (skarn), hydrothermal, Volcanic exhalative, residual (bauxite, iron and manganese) Mechanical concentration. Oxidation and supergene enrichment.	15H
Geology, mode of occurrence, distribution and origin of the following ore/mineral deposits in India: iron, manganese, aluminum, chromium, copper, lead-zinc, gold, coal and petroleum deposits. Industrial Minerals: Iron & steel, Cement, Ceramics, Fertilizers, Abrasives, Refractories, Atomic energy.	15H
PRACTICAL:	
Identification and Description of the Physical Properties, Composition, Occurrences and Uses of minimum 20 economic minerals and 5 polished sections under reflected light. Description and Drawing of Vertical sections of minimum 8 Geological Maps involving Single Series of Folded (Non-plunging) strata with vertical faults and dykes.	30H 15P
Learning Outcome: Students will be able to	
1. Categorise and classify various economic ore minerals into their respective categories 2. Compare and contrast between ore minerals found locally to those found on regional scale. 3. Evaluate different processes of ore enrichment 4. Calculate ore reserves 5. To interpret the possible process of formation of ore from mineral examples.	

Books:

1. Jensen M.L. and Bateman A.M. Economic Mineral Deposits John Wiley and Sons
2. Park C.F. and MacDiarmid R. A. Ore Deposits, Freeman and Co.
3. Gokhale KVGK, Ore Deposits of India: their distribution and processing, CBS Pub (1973)
4. Krishnaswamy: Indian Mineral Resources Oxford IBH
5. Economic Geology by Ajay kumar Sen and P.K. Guha.
6. Anthony Evans, An Introduction To Ore Geology. ELBS Books (1983)
7. John M. Golbert and Charles Park: The Geology of Ore deposits. W. H. Freeman & Co.
8. Stanton, L.: Ore Petrology
9. An Introduction to Economic Geology and its Environment Impact by Anthony Evans (1997)

GED-103	Mining Geology	Credit: 4 (Theory-3; Practical-1)

Course Objectives:

1. To understand the role of geologist in mining industry
2. To understand exploration for minerals, mine planning, and ore beneficiation.

THEORY	
Mining: Introduction to Mining, Mining methods (open cast, underground), Overview of Mining Industry (Exploration stage, planning stage, mining stage, ore processing, exports) Role of a geologist, Mineral exploration, Geological mapping, drilling, drilling equipment and accessories, sampling, borehole logging, core, sludge.	15H
Estimation of ore reserves, categorization of reserves based on UNFC, Grades of Ore, Rules and regulations, Regulating agencies	15H
Mine Planning, Mining machinery, Mining below water table and mine drainage, quality control. Mineral beneficiation (dry, wet) Environmental impact due to mining. Environmental Impact Assessment (EIA), Environmental Management Plan (EMP). Utilization and conservation of mineral resources. Case studies.	15H
PRACTICAL:	
Preparation of lithologs from core data, drawing of cross-section and longitudinal sections based on borehole data. Reserve calculations, mine development plan. Environmental management plans (afforestation, mine drainage, dust suppression), key plans (demarcation of core and buffer zones).	30H 15P
Learning Outcome:	
1. Student will be able to carry out exploration and sampling for economic minerals. 2. Student will be able to estimate reserves and prepare mine plans.	

Books

1. Arogyaswami, R.N.P.: Courses in Mining Geology, III Edition, Oxford and IBH publication Co.
2. McKinstry H.F.; Mining Geology, Prentice Hill Inc.
3. Babu S.K. and Sinha D.K. Practical Manual of Exploration and prospecting. CBS Publishers and Engineers.

GED-104	Project	Credit: 4

Course Objectives:

1. To inculcate the research interest and collaborative work
2. To provide basic training towards undertaking independent research and develop critical thinking and analytical skills
3. To facilitate the students to think, formulate and undertake research ideas.
4. To improve the reading and writing skills

Project

The project work by the students is to be under taken on any topic in consultation with the mentor/guide/supervisor as assigned by the department

Project work is based on geological other related aspects of an area, involving students (independent/group) for mapping/study of an ar ea/ collection and analysis (Field/laboratory) of data and preparation of geological and other maps, charts & report based on the field and laboratory analyses.

Students to work under supervision of the faculty. Student can chose to work for project in lieu of one optional course from the list of courses offered by the department.

Project work can also involve of any work undertaken by the student (individually/in group as assigned by the department) at any national laboratory on a laboratory analytical problem related to geology of any area. The outcome of the project work to be submitted by the student/group will be evaluated as per the evaluation procedure for other optional courses.

Learning Outcome:

It is expected on successful completion of project that the students will able to

1. Oriented towards undertaking research work independently or in collaboration
2. use scientific reasoning to gather, evaluate, and interpret evidence.
3. develop their critical thinking and analytical skills
4. use the various statistical methods for plotting and analyses of scientific data
5. analyze global problems from multiple perspectives to propose solutions
6. write scientific reports

Books:

Books related to the topic of the Project

GED-105	Geomorphology	Credit: 4 (Theory-3; Practical-1)

Course Objectives:

1. To understand the various processes involved in the evolution of landforms
2. To understand geomorphological evolution of a terrain

THEORY	
Geomorphology: Definition and fundamental concepts of Geomorphology, Geomorphic processes, Exogenic processes- gradation, degration and aggradation; Endogenic processes- diastrophism and volcanism. Geoid, Topography, Hypsometry, Global Hypsometry, Major morphological features- Large scale topography of Ocean basins, Large scale mountain ranges (with emphasis on Himalaya). Surfacial Processes and geomorphology, Weathering- physical, chemical and differential weathering; and associated landforms. Formation of soil, soil profile and mass wasting.	15H
Glacial, Periglacial processes and landforms, Fluvial cycle: streams and valleys, drainage patterns and their significance, stream erosion and deposition, processes and landforms. Peneplain concept of Paleosurfaces. Aeolian Processes and landforms, Coastal Processes and landforms, Groundwater cycle and landforms. Karst topography, Effects of rocks on relief, Landforms associated with igneous activities.	15H
Drainage basin morphometry, Linear, Areal and Slope aspects and their implications. Hortons laws of drainage basin composition. Principles of Isostasy, Endogenic- Exogenic interactions, Rates of uplift and denudation, Tectonics and drainage development, Sea-level change, Long-term landscape development.	15H
PRACTICAL:	
Reading toposheets, Preparation of a topographic profile, Preparation of longitudinal profile of a river. Delineation of watershed boundary on toposheets. Morphometry of a drainage basin. Calculating different morphometric parameters. Preparation of geomorphic map and profiles. Preparation of land use and land cover maps.	30H 15P
Learning Outcome:	
1. Student will be able to identify various landforms formed due to action of water, wind, glaciers and volcanoes. 2. Student will be able to carry out morphometric analysis	

Books

1. Sparks: Geomorphology
2. Analysis of landforms by Twidale, C.R.
3. Principles of Geomorphology by Thornbury, W.D.
4. Geomorphology by Arthur Bloom.
5. Principles of Physical geology by Arthur Holmes
6. Geomorphology by Lobeck, A.K.
7. Landscapes and Landforms of India by VS Kale, (Springer publications, 2016)

GED-106	Remote Sensing & Photogeology	Credit: 4 (Theory-3; Practical-1)

Course Objectives:

1. This course will provide students with the introductory knowledge of Remote Sensing
2. Students will understand the different parts of EMR spectrum and how it interacts with the earth surface and atmosphere.
3. Students will acquire knowledge of different platforms and sensors used in remote sensing.
4. Students will be able to classify different types of satellites based on their orbits as well as their utility.
5. Students will understand the terminology and derive an expression for scale of vertical aerial photograph and solve problems on the same.
6. Students will acquire knowledge of different instruments which are used for viewing aerial photographs and requirements and factors affecting stereoscopic vision.
7. Students will determine qualitative data from aerial photographs by using parallax bar and solve problems on height computations.
8. The students will learn how to interpret geological information from aerial photographs.

THEORY	
Remote Sensing: Definition, methods, scope and limitations. Electromagnetic radiation (EMR) Interaction of EMR with atmosphere earth and surface. Remote Sensing Platforms: Active and passive systems, High level and low level satellites, geosynchronous and sunsynchronous satellites, types of sensors, date types and products Resolutions: spatial, spectral, radiometric, temporal resolutions. Global and Indian space missions. Introduction to Image processing (stretching, band ratio).	15H
Photogeology: definition, scope and objectives. Aerial photographs (AP) and their types- advantages and disadvantages. Flight procedure overlap, drift and crab, spectral characteristics of APs. Terminology and geometry of vertical AP. Scale of AP. Stereopairs and mosaics, Radial displacement due to relief and its controlling factors.	15H
Stereoscopic viewing of AP; the instruments used: pocket stereoscope, mirror stereoscope and single prism stereoscope. Study and interpretation of APs for geological information. Introduction and description of photoelements. Identification of different landforms, Interpretation of structure and lithology from APs.	15H
PRACTICAL:	
Visual interpretation of at least 10 aerial stereo-pairs/satellite imageries. Preparation of various maps using google earth, georeferencing and digitisation in GIS.	30H 15P
Learning Outcome: Students will be able to	
1. Know the basic principles of remote sensing. 2. Classify and categorise satellites launched by various countries. 3. Explain utility of different orbits for various types of satellites to their peer. 4. Utilize instruments and interpret quantitative date from aerial photograph. 5. Solve photogrammetric problems. 6. Interpret geological information from aerial photographs.	

Books

1. Rees: Physical Principals of remote sensing Cambridge University Press
2. Lillesand T. M. and Kiefer R.W.: Remote Sensing and Image Interpretation. John Wiley and Sons
3. Image Interpretation by lender
4. Pande: Principals and Applications of Photogeology IBH
5. Photogeology by Miller and Miller
6. Photogrammetry by Moffitt, F.H. and Mikhail, E.M

GED-107	Coal and Petroleum Geology	Credit: 4 (Theory-3; Practical-1)

Course Objectives:

1. To understand the occurrence and distribution of coal and petroleum deposits.
2. To understand the composition and origin of coal and petroleum

THEORY	
Coal: Definition and origin of Coal, Classification of coal. Introduction to lithotypes, microlithotypes and macerals in coal, Coal as a fuel. Global and Indian scenario. Distribution in India and its relation to geology.	15H
Petroleum: Chemical composition and physical properties of crudes in nature, Origin of petroleum. Maturation of kerogen; Biogenic and Thermal effect. Petroleum Reservoirs and Traps, Reservoir rocks: general attributes and petrophysical properties. Classification of reservoir rocks - clastic and chemical.	15H
Hydrocarbon traps: definition, anticlinal theory and trap theory, Classification of hydrocarbon traps - structural, stratigraphic and combination, Time of trap formation and time of hydrocarbon accumulation. Cap rocks - definition and general properties. Plate tectonics and global distribution of hydrocarbon reserves, Geology of important Indian reserves	15H
PRACTICAL:	
Section correlation and identification of hydrocarbon prospect. Panel and Fence diagrams. Plotting of coal and petroleum deposits on outline map of India. Graphical solution of three point problems.	30H 15P
Learning Outcome: Students will be able to	
1. Explain the occurrence and distribution of coal and petroleum deposits. 2. Plot structural data related to coal and petroleum	

Books

1. Chandra D. (2007). Chandra's Textbook on applied coal petrology. Jijnasa Publishing House.
2. Selley R. C. (2014). Elements of Petroleum geology: Third Edition, Academic Press
3. Bjorlykke, K. (1989). Sedimentology and petroleum geology. Springer-Verlag.
4. Bastia, R., & Radhakrishna, M. (2012). Basin evolution and petroleum prospectivity of the continental margins of India (Vol. 59). Newnes.
5. Text Book of Coal (Indian context) by Chandra, D., singh, R.M. and singh, M.P., Tara Book Agency, Varanasi.
6. Petroleum Geology by JinGluvas and Richard Swarbrick, Blackwell Publishers.
7. Petroleum Geology by North, F.K.

GED-108	Environmental Geology	Credit: 4 (Theory-3; Practical-1)

Course Objectives:

1. To understand the environmental pollution associated with mineral resources.
2. To understand environmental pollution indicator parameters

THEORY	
Fundamental concepts of Environmental geology- scope, objectives and aims. Earths's thermal environment and Climates. Global warming. Greenhouse effect. Ozone depletion- Ice sheets and fluctuation in sea levels. Concepts of ecosystem, Earth's major ecosystems- terrestrial and aquatic.	15H
Water, Land and Air pollution, solid waste disposal. ISI standards for water and air quality, Environmental health hazards. Natural hazards: Earthquakes, landslides, Tsunamis, volcanoes, floods. Identification of hazard prone areas, risk evaluation, mitigation. Environmental impact due to mining. Environmental Impact Assessment (EIA). Environmental Management in Mining (EMP), Environmental impact due to oil exploration.	15H
Baseline parameters with respect to air, water, land and noise pollution. Quality Parameters, equipment. Case studies of air, water and land pollution in India. Floods and droughts and their impacts.	15H
PRACTICAL:	
Delineation of core and buffer zones around mining lease. Preparation of Key plan, EMP, Rose Calculation of Mean Rainfall, Study of hazard zoning maps. Analysis of basic parameters of soil and water, Visit to STP/ water purification plant, Preparation of Indian pollution maps with regards to F, As and nitrates. Flood prone area map, natural hazards map.	30H 15P
Learning Outcome: Students will be able to	
1. Carry out EIA associated with mineral deposits	

Books

1. Valdiya K. S.: Environmental Geology Indian Context TMH, McGraw Hill Publ. (1985)
2. Ronald Tank: A focus on Environmental Geology CBS (1973)
3. Edward Keller: Environmental Geology CBS (1976)
4. Priscu: Earthquake engineering for large dams CBS
5. Blyth and De Freitas: Geology for Engineers, ELBS Arnold
6. Bennett, M.R.B., and Doyle, p. 1997. Environmental Geology. John Wiley and Sons, NY.
7. Environmental Assessment Source Book, 1991, Vol. I, II, III. Environment Department, The World Bank, Washington DC.

GED-109	Hydrogeology	Credit: 4 (Theory-3; Practical-1)

Course Objectives:

1. To understand the occurrence and distribution of groundwater
2. To understand the physical properties of rocks that govern the groundwater flow
3. To understand the water quality parameters

THEORY	
Introduction and basic concepts. Scope of hydrogeology and its societal relevance, Hydrological cycle and its components, precipitation, evaporation, transpiration, evapotranspiration. Infiltration and percolation, instruments for measurement. Surface runoff and its measurements. Concepts of watershed, drainage network and their relation to surface runoff and infiltration.	15H
Definition of subsurface water and groundwater, saturated and unsaturated zones, water in the unsaturated zone, vertical distribution of surface water, types of groundwater such as juvenile, connate, magmatic water, meteoric water. Definition of an aquifer, types of aquifers, confining layers and types with examples. anisotropy and heterogeneity of aquifers. Aquifer parameters: porosity, permeability, specific retention, specific yield, transmissivity, storativity, hydraulic conductivity and methods of determination (pumping tests). Groundwater exploration methods: Remote sensing, geophysical methods (electrical, magnetic, seismic, VLF), Groundwater distribution in India.	15H
Groundwater chemistry: Physical and chemical properties of water and water quality, parameters of water quality; physical, chemical and biological, major, minor and trace constituents, ISI standards for drinking water. Introduction to methods of interpreting groundwater quality data using standard graphical plots. Sea water intrusion in coastal aquifers.	15H
PRACTICAL:	
Preparation and interpretation of water level contour maps (flow-nets) and depth to water level maps, Study, preparation and analysis of hydrographs for differing groundwater conditions. Graphical representation of chemical quality data and water classification.	30H 15P
Learning Outcome: Students will be able to	
1. Prepare groundwater contour maps and estimate groundwater flow directions 2. Determine and graphically represent water quality parameters	

Books

1. Raghunath, H. M.: Groundwater, Wiley Eastern
2. Todd, D.K. 2006. Groundwater Hydrology, 2nd Ed., John Wiley & Sons, N.Y.
3. Davis, S.N. and De Weist, R.J.M. 1966. Hydrogeology, John Wiley & Sons Inc., N.Y.
4. Karanth K.R., 1987, Groundwater: Assessment, Development and Management, Tata McGraw-Hill Pub. Co. Ltd
5. Fetter, C.W. 2001. Applied Hydrogeology, Prentice Hall Inc., N.J., U.S.A.
6. Regional groundwater quality by Alley, W.M. VNR, NY
7. Geophysical prospecting for Groundwater by Shankar Kumar Nath, H.P. Patra and S. Shahid

GED-110	Gemology	Credit: 4 (Theory-3; Practical-1)

Course Objectives:

1. To understand the various precious stones and their properties
2. To understand the various techniques to enhance value of gems

THEORY

Nature of gem material: quality necessary in gems-beauty, rarity, durability. Formation of gem materials. Distinction between crystalline, amorphous and metamict materials. Crystal form and habit. Classification of gem stones. Observations with hand lens (10x)-importance and uses. Units of measurement: metric scale, carat, pearl and grain. Physical properties: hardness its applications in gemmology and limitations. Cleavage and parting their importance in gemology and lapidary work. Specific gravity-utility and determination by hydrostatic weighing, heavy liquids, floation and pycnometer. Inclusions and other features of gemstones. Optical properties: the electromagnetic spectrum, reflection and its importance in gemology- lustre, aventurescence, sheen, chatoyancy, asterism. Refraction, refractive index, total reflection- in design of refractometer. Construction and use of refractometer.	15H
Polariscope-construction and use in gemmology. Colour, causes responsible for colour in gem materials, idiochromatism, allochromatism, pseudochromatism, colour centres, charge transfer, organic material, floating electrons, dispersion, scattering, interference, diffraction. Variations in colour, pleochroism. Dichroscope-construction and use. Chelsea colour filter. Spectroscopy. Absorption spectra. Construction and use of spectroscope. Magnetic, electrical and thermal properties. Luminescence. Ultraviolet lamp its applications to gem testing.	15H
Enhancement and treatments- enhancement methods -coloured and colourless impregnation, dyeing, bleaching and its identification. Methods of treatment – laser drilling, irradiation, heat treatment, surface modifications, diffusion treatment and its identification. Composites - types, classification and identification.	15H

PRACTICAL:

Determination of refractive indices, optic figure, pleochroism, absorption spectrum, luminescence, SG of gemstones, using refractometer, polariscope, dichroscope, spectroscope, UV lamp, visual observation of gemstones. Description & Identification of cuts in gemstones. Identification of gemstones- natural, synthetic gemstones and organic products.	30H 15P

Learning Outcome:

1. Identify various precious stones 2. Acquire skills to enhance the value of gems	

Books

1. Read: Gemmology
2. Liddicoat: Handbook of gem identification
3. John Sinkankas: Mineralogy, Oxford
4. Karanth R.V. Gem and Gem Industry, Oxford IBH
5. Babu T.M.: Diamonds in India

GENERIC ELECTIVES

GEG-101	Minerals and Rocks	Credit: 4 (Theory-3; Practical-1)

Course Objectives:

This is an introductory level course in Geology. The objectives of the course are to help the students:

1. To define a mineral.
2. To state the physical properties of minerals.
3. To classify minerals into various groups.
4. To identify different types of minerals.
5. To recall the divisions of the interior of the earth and the discontinuities separating the same.
6. To define a rock.
7. To understand the process of rock formation.
8. To classify rocks into one of the three types.
9. To recognise minerals and rocks in handspecimen.
10. To infer the theory of plate tectonics, and the three types of plate margins.

THEORY

Minerals-Definitions, Physical properties of minerals Mineralogical structure of earth, planetary minerals and native elements Mineral structures Structure and composition of the Earth's crust, mantle and core. Introduction to Plate Tectonics. Rocks- Definitions and types, Basics of rock formation. Rock cycle. Igneous rock- Classification and Bowen's reaction series. Sedimentary rocks – Weathering and erosion, classification. Metamorphic rocks – Agents and types of metamorphism.	15H

PRACTICAL:

1. Study of physical properties of 15 minerals 2. Study of physical properties of 15 rocks	30H

Learning Outcome:

Learning Outcomes:

By the end of this course, the student will be able:

1. To explain the difference between different minerals and rocks to their peers.
2. To identify rocks found in their locality.
3. To summarise the divisions of the interior of the Earth.
4. To outline the theory of plate tectonics.
5. To assess the natural Earth with a renewed perspective.

Books

1. Earth Materials- Introduction to Mineralogy and Petrology, Cornelis Klein and Anthony Philpotts, Cambridge University Press, 2013)
2. Understanding Earth (Sixth Edition), John Grotzinger and Thomas H. Jordan, 2010, W.H. Freeman and company, New York.
3. Babu T.M.: Diamonds in India

GEG-102	Physical Geology	Credit: 4 (Theory-3; Practical-1)

Course Objectives:

This course aims in helping the students:

1. Understand the natural relief features of the Earth's surface (land and ocean floor)
2. To list the types of mountains, plateaus and plains.
3. To associate the naturally occurring landforms with erosive and depositional action of the rivers, wind and glaciers.
4. To interpret the coastal landforms and the processes resulting in their formation..

THEORY

Scope and Importance of Physical Geology, Major Relief features of the Earth, Hypsographic Curve; Morphological features of the ocean floor; Characteristic features of Mountains, Plateaus, and Plains: a) Mountains: Volcanic, Residual, Block, Tectonic; b) Plains: Erosional and depositional; c) Plateaus Geological Work of the following natural agencies: Rivers: Erosion, transportation [suspended and bed load] and deposition; Erosional features: Potholes, Canyons, Gorges, Waterfalls, V-shaped valleys with examples; Depositional features: Channel deposits (Point bars, Ox-bow lakes, Braided streams), Alluvial fans/cones, Deltas, Flood – plains with examples, River discharge,	15H
Oceans and Seas: -Waves and breakers; erosion, transportation & deposition; Erosional landforms: Sea-cliffs, wave-cut platform, sea-arches, sea-caves, sea-stacks with examples; Depositional landforms: Shallow - water deposits: beaches, spits, bars, wave-built terraces, tombolos with examples; Coral reefs: Atolls, Fringing and Barrier reefs with examples	15H
Wind: -Wind erosion (abrasion & deflation), Transportation (suspension, saltation & surface creep) & Deposition; Erosional features :- Deflation hollow, deflation armour, ventifacts, rock columns & pinnacles, mushroom / pedestal rock, yardangs, desert pavements with examples; Depositional landforms :- Sand dunes (transverse, longitudinal, parabolic, barchans), Loess deposits with examples. Geological work of groundwater: erosional and depositional features (caves, caverns, stalactites, stalagmites) with examples. Glaciers: erosional and depositional landforms	15H

PRACTICAL:

1. Description and Drawing of Vertical sections of minimum 2. Geological Maps involving a Single Series of Horizontal, Dipping strata with vertical intrusive. Visit to some geological landforms	30H

Learning Outcome:

On completion of the course, the student will be able to:

1. To explain the results of the action of wind, water and glaciers on the Earth.
2. To compare the various geomorphological features of the Earth and justify their natural occurrence.
3. To evaluate the landforms in field..

Books

1. A textbook of Geology by P. K. Mukherjee (World Press)
2. A Textbook of Engineering and General Geology (Seventh Ed) by Parbin Singh
3. Holmes' Principles of Physical Geology by Arthur Holmes (Third Ed) (ELBS)
4. Holmes' Principles of Physical Geology edited by P. McL. D. Duff (ELBS)
5. Physical Geology by Charles C. Plummer and David McGeary (Wm. C. Brown Publishers)
6. Physical Geology by C. W. Montgomery (Second Ed) (Wm C. Brown Publishers)
7. Understanding the Earth (Fourth Ed) by Press, Siever, Grotzinger& Jordan
8. The Changing Earth: Exploring Geology and Evolution (Third Ed) by Monroe &Wicander
9. Field Geology by Lahee,
10. Field Geology by Compton
11. Structural geology by M. P. Billings

GEG-103	Essentials of Geology	Credit: 4 (Theory-3; Practical-1)

Course Objectives:

The student will be able to:

1) Understand the Earth's position in the solar system and its uniqueness.
2) Understand the origin and composition of Earth
3) Understand the concept of dating of rocks

THEORY

Introduction to geology, scope, sub-disciplines and relationship with other branches of sciences 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 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 Age of the earth; Radioactivity and its application in determining the age of the Earth, rocks, Minerals and fossils .	45H

PRACTICAL:

1. Study of major geomorphic features and their relationships with outcrops through physiographic models. 2. Detailed study of topographic sheets and preparation of physiographic description of an area 3. Study of distribution of major dams on map of India and their impact on river systems 4. Study of major ocean currents of the World	30H

Learning Outcome:

By the end of this course, the student will be able:

1. Identify major geomorphic features
2. Read toposheets and infer physiographic data

Books

1. Holmes' Principles of Physical Geology. 1992. Chapman & Hall.
2. Emiliani, C, 1992. Planet Earth, Cosmology, Geology and the Evolution of Life and Environment.
3. Cambridge University Press.
4. Gross, M. G., 1977. Oceanography: A view of the Earth, Prentice Hall.

GEG-104	**Environmental Geology**	**Credit: 4** **(Theory-3; Practical-1)**

Course Objectives:

This course aims in helping the students:

1. To understand the environmental pollution associated with mineral resources.
2. To understand environmental pollution indicator parameters

THEORY

Fundamental concepts of Environmental geology- scope, objectives and aims. Earth's thermal environment and Climates. Global warming. Greenhouse effect. Ozone depletion- Ice sheets and fluctuation in sea levels. Concepts of ecosystem, Earth's major ecosystems- terrestrial and aquatic	15H
Water, Land and Air pollution, solid waste disposal. ISI standards for water and air quality, Environmental health hazards. Natural hazards: Earthquakes, landslides, Tsunamis, volcanoes, floods. Identification of hazard prone areas, risk evaluation, mitigation.	15H
Baseline parameters with respect to air, water, land and noise pollution. Quality Parameters, equipment. Case studies of air, water and land pollution in India. Floods and droughts and their impacts.	15H

PRACTICAL:

Calculation of Mean Rainfall, Study of hazard zoning maps. Analysis of basic parameters of soil and water, Preparation of Indian pollution maps with regards to F, As and nitrates. Flood prone area map, natural hazards map.	30H

Learning Outcome:

On completion of the course, the student will be able to: 1. Student will be able to carry out EIA associated with mineral deposits	

Books

1. Valdiya K. S: Environmental Geology Indian Context TMH, McGraw Hill Publ.
2. Tank: Environmental Geology CBS
3. Keller, E.C., Bell and Howell: Environmental Geology CBS
4. Priscu: Earthquake engineering for large dams CBS
5. Blyth and De Freitas: Geology for Engineers, ELBS Arnold
6. Bennett, M.R.B., and Doyle, p. 1997. Environmental Geology. John Wiley and Sons, NY.
7. Environmental Assessment Source Book, 1991, Vol. I, II, III. Environment Department, The World Bank, Washington DC

Skill Enhancement Courses for BSc in Geology

(Approved in BoS meeting held on 3rd April 2018)

GES-101	**Basics of Remote Sensing**	**Credit: 4** **(Theory-3; Practical-1)**

Course Objectives:

Remote sensing is comparatively a new scientific discipline. This course intends to:

1. Introduce students to the basic concept of Remote Sensing
2. Stages involved in remote sensing
3. Students will understand the different parts of EMR spectrum and how it interacts with the earth surface and atmosphere.
4. Students will acquire knowledge of different platforms and sensors used in remote sensing.
5. Students will be able to classify different types of satellites based on their orbits as well as their utility.
6. Students will understand the terminology and derive an expression for scale of vertical aerial photograph and solve problems on the same.
7. How remote sensing data can be processed

THEORY

Introduction: Concept, definition, history, Types of satellites, applications of remote sensing to various fields; Stages in RS, EMR spectrum, laws of radiation and its interaction; Fundamentals of aerial photograph and photogrammetry, geometry of the vertical aerial photograph, stereo- pairs and mosaics, radial displacement due to relief and its controlling factors; Platforms, sensors and orbits: types of platform, types of orbits, types of sensors, data types and products; Resolutions: Spectral, radiometric, spatial and temporal; Image processing: Histogram, stretching, contrast enhancement, linear stretch, band ratios	45H

PRACTICAL:

Study and interpretation of satellite imageries for geological information, identification of different elements, interpretation of structure and lithology. Visual interpretation of at least 3 satellite imageries.	30H

Learning Outcome: Students will be able to

1. Know the basic principles of remote sensing.
2. Classify and categorise satellites launched by various countries.
3. Explain utility of different orbits for various types of satellites to their peer.
4. Interpret information from satellite imagery with emphasis on geological information

Books

1. Rees: Physical Principals of remote sensing Cambridge University Press
2. Lillesand T. M. & Kiefer R.W.: Remote Sensing and Image Interpretation. John Wiley & Sons
3. Lillesand, Kiefer and Chipman Remote sensing and Image Interpretation. 5 Ed. Wiley& sons.
4. Ravi P. Gupta: Principles of Remote Sensing. 3Ed., Springer-Verlag

GES-102	**Water Quality Assessment**	**Credit: 4** **(Theory-3; Practical-1)**

Course Objectives:

1. Students will acquire knowledge about the occurrence and distribution of water on Earth
2. Students will know the water quality parameters and quality standards
3. Students will realise the sources of water pollution, types of pollutants and their effects on human health and ecosystems

THEORY

Introduction, Water cycle, Precipitation, runoff, evapotranspiration, infiltration, groundwater recharge: measurement and measuring instruments, Occurrence of water, surface and groundwater, water quality parameters, BIS and WHO standards, Point and non-point sources of water pollution, eutrophication, biomagnification, major water pollutants and toxic pollutants, their properties, Arsenic and Fluoride pollution in India, microbiological pollution, sea water intrusion, other water related issues	45H

PRACTICAL:

To conduct water sampling, testing of some water quality parameters and data recording, graphical representation of water quality parameters .	30H

Learning Outcome: Students will be able to

1. Students will be able to identify point and non-point sources of pollution
2. Students will be able to carry out water sampling and test important water quality parameters in field and in laboratory
3. Students will be able to represent water quality data graphically
4. Students will be able to carry out risk assessment in relation to water quality and suggest remedial measure

Books

1. Kevin M. Hiscock: Hydrogeology –Principles and Practice, Blackwell Publishing, 2005
2. H. M. Raghunath: Groundwater, New Age International Publishers, New Delhi, 2009
3. K. R. Karanth: Groundwater assessment development and management, Tata McGraw Hill Education, Pvt. Ltd, New Delhi, 2010
4. Fetter, CW.,Bowing, T & Kreamer, D : Contaminant Hydrogeology, Waveland Press, 2018.
5. BIS: Indian standards for drinking water quality (IS10500:2012)
6. WHO: Drinking water standards, 1993

GES-103	**Field Geology**	**Credit: 4** **(Theory-3; Practical-1)**

Course Objectives:

1. To understand field characters of rocks and rock structures
2. To read toposheet and orient self in the field

THEORY

Introduction to Field Geology, Toposheets: numbering, various features of toposheets, Scale: definition, Latitude and longitude. Geological map: definition, various components of a geological map including scale, legend, contours, bedding junctions, structures, etc.	15H
Field work and sampling: geological items to be carried to the field, use of clinometer compass, Brunton compass, Strike and dip measurements of planar and linear geological features. Sampling and oriented sample, their significance	15H
Geological mapping procedures: Plotting of location on map using latitude and longitude, geological mapping of igneous, sedimentary and metamorphic rocks with special reference to Goa. Techniques of surveying and leveling; Plane table and dumpy level.	15H

PRACTICAL:

Toposheet reading, conversion of scale, enlargement and reduction of maps, use of clinometer, brunton compass. Plane table survey, Dumpy level. Mapping of geological formations in field	30H

Learning Outcome: Students will be able to

1. Identify and collect information about field characters of rocks
2. To prepare geological maps

Use clinometer compass/brunton compass and carry out dumpy level survey

Books

1. Field Geology by Lahee
2. Field Geology by Compton
3. Holmes' Principles of Physical Geology by Arthur Holmes (Third Ed) (ELBS)
4. Understanding the Earth by Gass, Smith and Wilson
5. The Dynamic Earth by P. I. Wyllie

GES-104	**Environmental Impact Assessment**	**Credit: 4** **(Theory-3; Practical-1)**

Course Objectives:

1. To understand the parameters of the environmental impact assessment
2. To understand the impact of environmental pollution on human health and natural environment

THEORY

Introduction; Historical development; Rules and Regulations regarding prevention of water, land, soil, air, noise pollution, Environment Protection Act and CRZ. Baseline environmental information: Land environment (physiography, geology, seismicity, soil, land use, land cover), Water environment (drainage network, water bodies, water quality), Air quality data, Noise level data, Hydro-meteorology (rainfall, humidity, wind pattern, climate), Biological environment (Forest type, flora and fauna), Socio-economic and cultural environment. Environmental Monitoring: Environmental standards, Water, Air, Noise quality parameters, Water sampling, Air sampling, Standard analytical procedures, Carrying capacity and Environmental flow assessment	45H

PRACTICAL:

Case studies of air, water and land pollution in India, Environmental impact due to mining and coastal zone. Morphometric Analysis, Collection of baseline environmental data, Rainfall data analysis	30H

Learning Outcome: Students will be able to

1. To collect baseline information about environmental quality parameters
2. To analyse environmental data

Books

1. Vankhade Ganesh: Environmental Impact Assessment, Biotech Books, New Delhi
2. Barthwal, R. R.: Environmental Impact Assessment, New Age International, New Delhi
3. Trivedi, P.R.: Environmental Impact Assessment, APH Publishing Corporation, New Delhi
4. Hosetti, B : EIA and Management, Darya Publishing House, Delhi,1998
5. Glasson, John: EIA: Principles, Procedures, Process, Practice and Prospects, Research Press, New Delhi, 1994
6. Kulkarni V : A handbook of EIA, Scientific Publishers, Jodhpur 2002
7. Anji Reddy M. : EIA- Theory and Practice, Butterworth-Heinemann, Elsevier, 2017

GES-105	**GIS Fundamentals**	**Credit: 4** **(Theory-3; Practical-1)**

Course Objectives:

1. To understand the concept of GIS and data types.
2. To gain knowledge about coordinate systems and spatial analysis

THEORY

Overview: Definition, Components and Objectives; Coordinate Systems: Types- GCS and PCS, Geo-referencing; Geographic Data: Data Sources, Data types: Spatial and Non-Spatial; Spatial Data Types: Vector (point, line, polygon) and Raster (pixels); Non-Spatial: information about features (roads, schools, census data); Database Management System: Definition, difference between Standard and Spatial Database, Types of database Models Popular DBMS software; Spatial Analysis: Vector based and Raster based Operations for Spatial analysis: Attribute Query and Spatial Query, DEM (Aspect analysis, slope analysis, viewshed); Introduction to QGIS; Concepts of GPS: History, Types, Navigation, Applications	45H

PRACTICAL:

Preparation of various maps using google earth and GIS, QGIS, importing raster and vector images, Geo-referencing raster and vector images. Creating new vector layers (point, line or polygon), Classification by attribute, preparation of maps	30H

Learning Outcome: Students will be able to

1. The student will be able to georeference and prepare thematic maps using various softwares
2. The student will be able to analyse and classify the data

Books

1. Michael Schmandt. GIS Commons: An Introductory Textbook on Geographic Information Systems. Online free ebook. http://giscommons.org/. 2009
2. Delaney, J & Niel K V.. GIS: an Introduction, 2nd Ed., Oxford Publishers, 2003
3. Longley, Geographic Information Systems and Science, 2nd Ed. WILEY, 2003
4. Burrough, P.A. An Introduction to GIS, 1996
5. Chang, K. Introduction to Geographic Information Sc., McGraw Hill, 2002