Kazi Nazrul University

Learning Outcomes based Curriculum Framework (LOCF)

For

Six Semester Course Under

Choice Based Credit System (CBCS)

Syllabus for B.Sc. (Hons.)

in Geology

2020

Preamble

The **University Grants Commission** (UGC) took the initiative of bringing significant reforms in the undergraduate education through introduction of the **Learning Outcomes-based Curriculum Framework** (LOCF), which makes it student-centric, interactive and outcome-oriented with well-defined aims, objectives and goals to achieve. The LOCF has been formulated on the basis of a set of learning outcomes projected to be achieved for enhancing the employability and providing further opportunities for higher education and research. These Learning Outcomes (LO) determine the structure of the undergraduate programs to be offered by the Higher Educational Institutions (HEI) of our country. The key component of the planning and development of LOCF are given in terms of clear and unambiguous description of the Graduate Attributes, Qualification Descriptors, Program Learning Outcomes (PLO) and Course Learning Outcomes (CLO) to be achieved at the end of the successful completion of each undergraduate program to be offered by the HEI.

According to the philosophy of the proposed LOCF the teaching-learning process is being designed on a proportionate scale of 30:30:40 principle, where lectures (listening/hearing) constitute 30 percent of the delivery; laboratory (scientific analysis and experiments) 30 percent of the learning methods and participation learning [assignment-based presentation, group discussion, field work, and laboratory and computer simulations (wherever applicable)] 40 percent. Hence, in this undergraduate program, the course structure and detailed contents of the courses regarding the various components like the class room teaching (theory), laboratory (experiments), tutorials, and industrial / field visits and projects have been designed and planned to achieve the stated Learning Objectives (LO).

Majority of the primary sources in Geology are collected through field survey and excavations. Study Tours/ Field trips provide opportunities to the learners to test their in-class learning in real life situations as well as to understand the functional diversity in the learning spaces. It is thus recommended to encourage them to carry out daylong field trips from time to time. These may include visits to sites of knowledge creation, preservation, dissemination and application. Students will greatly strengthen their observational accuracy in the field, and this skill will translate

into other aspects of data description and interpretation. Students will gain new field experience, perspective, competence, and confidence as a field geologist. Students will develop the capability to produce geologic maps and cross sections of unknown terrains working individually and/or in groups. Production of geological maps will allow students to demonstrate the capacity for synthesizing and interpreting field data and compiling that information into a working understanding of the assigned field area.

A Discipline Specific Elective (DSE) on Research Project in Geosciences (Dissertation) has been introduced. This will help in the development of ability to devise and carry out an independent field-based project, including the formulation and testing of hypotheses whilst in the process of carrying out the project. The integration of field-based, experimental and theoretical principles needed for the Earth Sciences as recommended in the LOCF advisory.

(Prabir Dasgupta)
Coordinator, Geology
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Course Structure

YEAR	SEMESTER	CORE COURSE (14)	ABILITY ENHANCEMENT COMPULSORY COURSES (2)	SKILL ENHANCEMENT COURSE (2)	DISCIPLINE SPECIFIC ELECTIVE (DSE) (4)	GENERIC ELECTIVE (GE) (4)
FIRST YEAR	I	1. EARTH SYSTEM SCIENCE 2. MINERAL SCIENCE	ENVIRONMENTAL SCIENCE			GE-1
	II	3. ELEMENTS OF GEOCHEMISTRY 4. STRUCTURAL GEOLOGY	COMMUNICATIVE ENGLISH			GE-2
SECOND YEAR	III	5. IGNEOUS PETROLOGY 6. SEDIMENTOLOGY AND PRINCIPLES OF STRATIGRAPHY 7. PALAEONTOLOGY		SEC-I (Basic Field Training)		GE-3
	IV	8. METAMORPHIC PETROLOGY 9. GEOLOGY OF INDIA 10. GLOBAL TECTONICS AND GEODYNAMICS OF THE LITHOSPHERE		SEC-II (Geological Field Methods and Mapping)		GE-4
THIRD YEAR	V	11. ECONOMIC GEOLOGY 12. FUEL GEOLOGY			DSE – 1 DSE - 2	
	VI	13. ENGINEERING GEOLOGY 14. HYDROGEOLOGY			DSE – 3 DSE - 4	

Discipline Specific Electives:

Semester V (any two out of four)	Semester VI (any two out of four)

1. Remote Sensing and GIS	1. Mineral Exploration and Mining
2. Oceanography and Marine Geology	2. Climatology
3. Environmental Geology	3. Mine visit & Field Analysis of Fossiliferous Sedimentary Succession
4. Introduction to Geophysics	4. Research Project in Geology (Dissertation)

SEMESTER	COURSE OPTED	COURSE NAME	CREDIT
I	Ability Enhancement: compulsory course - I	Communicative English	4
	Core Course - I	Earth System Science	4
		Practical	2
	Core Course - II	Mineral Science	4
		Practical	2
	Generic Elective – I	GE - I	6
	Total Credit		**22**
II	Ability Enhancement: compulsory course - II	Environmental Science	4
	Core Course - III	Elements of Geochemistry	4
		Practical	2
	Core Course - IV	Structural Geology	4
		Practical	2
	Generic Elective – II	GE - II	6
	Total Credit		**22**
III	Core Course - V	Igneous Petrology	4
		Practical	2
	Core Course - VI	Sedimentology & Principles of Stratigraphy	4
		Practical	2
	Core Course - VII	Palaeontology	4
		Practical	2
	Generic Elective - III	GE - III	6
	Skill Enhancement Course - I	Basic Field Training	4
	Total Credit		**28**
IV	Core Course - VIII	Metamorphic Petrology	4
		Practical	2
	Core Course - IX	Geology of India	4
		Practical	2
	Core Course - X	Global Tectonics and Geodynamics of the Lithosphere	4

		Practical	2
	Generic Elective - IV	GE - IV	6
	Skill Enhancement Course - II	Geological Field Methods and Mapping	4
	Total Credit		**28**

SEMESTER	COURSE OPTED	COURSE NAME	CREDIT
V	Core Course - XI	Economic Geology	4
		Practical	2
	Core Course - XII	Fuel Geology	4
		Practical	2
	Discipline Specific Elective - I	DSE - I	4
		Practical	2
	Discipline Specific Elective - II	DSE - II	4
		Practical	2
	Total Credit		**24**
SEMESTER	**COURSE OPTED**	**COURSE NAME**	**CREDIT**
VI	Core Course - XIII	Engineering Geology	4
		Practical	2
	Core Course - XIV	Hydrogeology	4
		Practical	2
	Discipline Specific Elective - III	DSE - III	4
		Practical	2
	Discipline Specific Elective - IV	DSE - IV	4
		Practical	2
	Total Credit		**24**
Grand Total of Credits in Six Semesters			**148**

CORE COURSES

FIRST SEMESTER

Course Name: EARTH SYSTEM SCIENCE
Course Code: BSCHGELC101
(CREDITS: THEORY-4, PRACTICAL-2)

THEORY

Unit 1: Earth System Science
Introduction to Earth System Science
General characteristics and origin of the Universe, Solar System and its planets; the Terrestrial and Jovian planets; Meteorites and Asteroids; Earth in the solar system: origin, size, shape, mass, density, rotational and revolution parameters and its age.

Unit 2: Solid Earth and its fluid cover
Internal constitution - its recognition vis-à-vis solid earth geophysics: crust, mantle, core, evidence from seismic waves and rocks
Hydrosphere, atmosphere and biosphere: Elementary idea
Nature of Earth's magnetic field

Unit 3: Tectonics
Brief idea about plate tectonics, Plate boundaries
Internal process and its superficial manifestation – volcanoes and volcanism, distribution of volcanoes: causes of earthquakes and their effects, intensity and magnitude, earthquake belts, seismic zones of India.

Unit 4: Hydrosphere and Atmosphere
Oceanic current system and effect of Coriolis force
Concepts of eustasy
Weather and climatic changes
Land-sea interaction along coast; Coastal processes and products

Unit 5: Earth surface processes
Weathering; erosion; mass wasting; Geological work of wind, river and glacier; Geomorphological features: Geoid, Topography, Hypsometry and Bathymetry, Drainage Basin and Drainage Patterns
Formation of soil, soil profile and soil types

Unit 6: Introduction to the concept of time in geological studies
Stratigraphy: definition and scope
Brief history of development of stratigraphic principles; concepts of Neptunism, Plutonism and Uniformitarianism
Geological Time Table, introduction to geochronological methods and their application in geological studies
Fundamental laws of stratigraphy: Superposition, Faunal succession and correlation

PRACTICAL

Study of major geomorphic features and their relationships with outcrops through physiographic maps; Detailed study of topographic sheets and preparation of physiographic description of an area, Preparation of topographic profile; Morphometry of a drainage basin, Calculating different morphometric parameters

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. Robert S. Anderson and Suzzane P. Anderson, 2010. *Geomorphology - The Mechanics and Chemistry of Landscapes.* Cambridge University Press.

Course Name: MINERAL SCIENCE
Course Code: BSCHGELC101
(CREDITS: THEORY-4, PRACTICAL-2)

THEORY

Unit 1: Crystallography
Elementary ideas about crystal morphology in relation to internal structures; Crystal parameters and indices; Crystal symmetry and classification of crystals into point groups, space groups; Stereographic projections of symmetry elements and forms; Characteristics of crystal systems

Unit 2: Rock forming minerals
Minerals - definition and classification, physical and chemical properties; Substitution principles – Goldschmidt's rule of substitution of elements; partitioning of elements between coexisting phases; Brief idea about Isomorphism, Solid solution, Pseudomorphism and Polymorphism: elementary concept on principle types – common polymorphic forms of C, SiO_2 and Al_2SiO_5; Crystal structure and its controls: bonding and coordination principles. Classification of silicate groups based on structure and derivation of structural formulae based on composition; Non-silicate structures; CCP and HCP structures

Unit 3: Optical mineralogy
Optical behaviour of crystals – Isotropic and anisotropic minerals; Nicol prism and its principle of construction; Polaroid; Refractive index of minerals; Uniaxial & Biaxial minerals; Optical indicatrix of uniaxial and biaxial minerals; Birefringence, Interference colour and use of interference colour chart; Relation between crystallographic and optical axes of crystals; Pleochroism and pleochroic scheme; Extinction; Study of interference figures; Optic sign of uniaxial and biaxial minerals

PRACTICAL

Study of the symmetry of crystals in hand specimen; Solution of crystallographic problems through stereographic projection
Study of physical properties of minerals in hand specimen: Olivine, Garnet, SilIimanite, Kyanite, Staurolite, Beryl, Tourmaline, Pyroxene, Actinolite, Tremolite, Hornblende, Serpentine, Talc, Muscovite, Biotite, Quartz, Alkali feldspar, Plagioclase, Nepheline, Sodalite, Zeolite, Pyrite, Chalcopyrite, Galena, Sphalerite, Graphite, Magnetite, Haematite, Fluorite, Calcite, Dolomite, Gypsum, Asbestos, Ilmenite, Chromite, Pyrolusite, Psilomelane, Bauxite
Study of optical properties of common rock-forming minerals: quartz, orthoclase, microcline, plagioclase, perthite, nepheline, olivine, orthopyroxene, clinopyroxene, hornblende, staurolite, garnet, muscovite, biotite, calcite

SUGGESTED READINGS:

1. Klein, C., Dutrow, B., Dwight, J., & Klein, C., 2007. *The 23rd Edition of the Manual of Mineral Science (after James D. Dana)*. J. Wiley & Sons.
2. Kerr, P. F., 1959. *Optical Mineralogy*. McGraw-Hill.
3. Verma, P. K., 2010. *Optical Mineralogy (Four Colour)*. Ane Books Pvt Ltd.
4. Deer, W. A., Howie, R. A., and Zussman, J., 1992. *An introduction to the rock-forming minerals*. London, Longman.

SECOND SEMESTER

Course Name: ELEMENTS OF GEOCHEMISTRY
Course Code: BSCHGELC201
(CREDITS: THEORY-4, PRACTICAL-2)

THEORY

Unit 1: Concepts of geochemistry
Cosmic abundance of elements: Distribution of elements in solar system and in Earth; Introduction to chemical differentiation and composition of the Earth; General concepts about geochemical cycles; Introduction to properties of elements: The periodic table
Chemical bonding, states of matter and atomic environment of elements
Geochemical classification of elements

Unit 2: Layered structure of Earth and geochemistry
Composition of different Earth reservoirs and the nuclides and radioactivity
Concept of radiogenic isotopes in geochronology and isotopic tracers

Unit 3: Element transport
Advection and diffusion
Aqueous geochemistry- basic concepts and speciation in solutions, Eh, pH relations

Unit 4: Geochemistry of solid Earth
The solid Earth – geochemical variability of magma and its products
Composition of the bulk silicate Earth
Meteorites

Unit 5: Geochemical behavior of selected elements
Si, Al, K, Na, Ca, Fe, Mg, Ti.

Unit 6: Brief introduction to analytical instruments and geochemical data
EPMA, XRF, ICPMS

PRACTICAL

Interpretation of geochemical data: Bivariate and trivariate plots to delineate the control of different compositional variables: Harker variation diagram, AFM diagram, MgO diagram, compatible and incompatible element variation. Simple examples of determining radiometric age from given data on appropriate mother & daughter isotopes.

SUGGESTED READINGS:

1. Mason, B., 1986. *Principles of Geochemistry*. 3rd Edition, Wiley New York.
2. Rollinson, H., 2007. *Using geochemical data – evaluation, presentation and interpretation*. 2nd Edition. Longman Scientific & Technical.
3. Walther, J. V., 2009. *Essentials of geochemistry*. Jones & Bartlett Publishers.
4. Albarède, F., 2003. *Geochemistry: an introduction*. Cambridge University Press.
5. Faure, G. and Mensing, T. M., 2004. *Isotopes: Principles and Applications.* Wiley India Pvt. Ltd

Course Name: STRUCTURAL GEOLOGY
Course Code: BSCHGELC202
(CREDITS: THEORY-4, PRACTICAL-2)

THEORY

Unit 1: Basic structural elements
Introduction to structural geology; Different schemes of classifying geological structures (Primary vs. Secondary, Diastrophic vs. Non-diastrophic, Penetrative vs. Non-penetrative, Brittle – Brittle-ductile - Ductile, Planar – Linear – Hybrid, etc.); Orientational attributes of planar and linear structures (concepts of dip, strike, trend, plunge, rake/pitch, etc.); Application of primary structures for determining younging/facing direction; Unconformity and its types.

Unit 2: Rock deformation
Concept of rock deformation: Stress and Strain in rocks, Brief discussion of the factors controlling behavior of rocks (i.e. the different stress-strain relationships shown by rocks) during deformation. Introducing Mohr Circle for stress; Strain ellipse and ellipsoids of different types and their geological significance.

Unit 3: Folds
Fold morphology; Geometric classification, mechanics of folding: Buckling, Bending, Flexural slip and flow folding; Shearing and Flattening; genetic classification of folds

Unit 4: Foliation and lineation
Types of foliation and lineation, their tectonic significance and relationship with other structures

Unit 5: Fractures and faults and ductile shear zones (DSZ-s)
Definition, Idea about the situation leading to formation of these structures.
Classification of fractures and faults and their relationship with strain; Brief introduction to Mohr Envelope; Effects of faulting on the outcrops, Techniques of determination of net slip of faults. Criteria for recognition of faults and determination of net slip

PRACTICAL

Introduction to Geological maps: Lithological and Structural maps; Structural contouring and 3-point problems of dip and strike; Simple problems involving vertical and inclined boreholes. Drawing profile sections and interpretation of geological maps of different complexities; Exercises of stereographic projections of mesoscopic structural data (planar, linear, folded etc.)

SUGGESTED READINGS:

1. Ghosh, S.K., 1993. *Structural Geology – Fundamentals and Modern Developments*. Pergamon Press.
2. Davis, G. R., 1984. *Structural Geology of Rocks and Region*s. John Wiley
3. Billings, M. P., 1987. *Structural Geology*. 4th edition, Prentice-Hall.
4. Park, R. G., 2004. *Foundations of Structural Geology*. Chapman & Hall.
5. Pollard, D. D., 2005. *Fundamentals of Structural Geology*. Cambridge University Press.
6. Ramsay, J.G., 1967. *Folding and fracturing of rocks*. McGraw-Hill.
7. Ramsay, J.G. and Huber, M.I., 1984 & 1987. *The Techniques of Modern Structural Geology – Volumes 1 & 2*, respectively. Academic Press.
8. Ragan, D. M., 2009. *Structural Geology: an introduction to geometrical techniques*. 4th Edition, Cambridge University Press (For Practical)
9. Lahee F. H., 1962. *Field Geology*. McGraw-Hill
10. Turner, F.J. and Weiss, L.E., 1963. *Structural Analysis of Metamorphic Tectonites*. McGraw-Hill.

THIRD SEMESTER

Course Name: IGNEOUS PETROLOGY
Course Code: BSCHGELC301
(CREDITS: THEORY-4, PRACTICAL-2)

THEORY

Unit 1: Introduction to Igneous petrology
Principal modes of magma formation in the crust and upper mantle; physical properties of magma - temperature, viscosity, density and volatile content; formation and types of igneous rocks: volcanic, hypabyssal, plutonic.

Unit 2: Form and structure
Description of different forms and structures of igneous bodies with emphasis on their mode of emplacement - sill, dyke, ring dyke, cone sheet, laccolith, lopolith, phaccolith, batholith, pillow structure, ropy and aa lava structure, columnar joints etc.

Unit 3: Textures and microstructures
Crystallinity, granularity, shapes and mutual relations of grains; nucleation and growth of igneous minerals
Description of the following textures and microstructures with their occurrence in different rocks - panidiomorphic, hypidiomorphic, allotriomorphic, porphyritic, vitrophyric, poikilitic, ophitic, sub-ophitic, intergranular, intersertal, pilotaxitic, trachytic, graphic, granophyric, rapakivi, orbicular, corona, perthitic, myrmekitic, variolitic, speherulitic & spinifex.

Unit 4: Classification of igneous rocks
Bases of classification of igneous rocks: mineralogical, textural, chemical, chemico-mineralogical and associational; Norm and mode; Standard classification schemes – Niggli, Hatch, Wells & Wells and IUGS

Unit 5: Phase diagrams
Elementary idea of Phase Rule and its application to eutectic, peritectic and solid solution system: Phase equilibria in the following binary and ternary systems, and their petrogenetic significance: diopside – anorthite, forsterite – silica, albite – anorthite, albite – orthoclase, diopside – albite – anorthite, forsterite – diopside – silica and nepheline - kalsilite – silica.

Unit 6: Petrography of the common igneous rock types
Granitoids, Pegmatite, Syenite, Monzonite, Diorite, Norite, Gabbro, Anorthosite, Dolerite, Pyroxenites, Peridotite, Lamprophyres, Carbonatite, Rhyolite, Andesite, Dacite, Basalt, Komatiite.

Unit 7: Petrogenesis of igneous rocks
Crystallization – Differentiation of a magma, brief idea on several mechanisms of magmatic differentiation, Bowen's reaction series and its implications; Elementary knowledge of petrogenesis of the following rocks: granite, basalt and ultramafic rocks.

PRACTICAL

Study of important igneous rocks in hand specimens and thin sections - granite, granodiorite, diorite, syenite, nepheline syenite, gabbro, anorthosites, ultramafic rocks, basalts, andesites. Determination of normative composition and name of igneous rocks from given bulk rock chemical analyses.

SUGGESTED READINGS:

1. Philpotts, A., and Ague, J., 2009. *Principles of igneous and metamorphic petrology*. Cambridge University Press.
2. Winter, J. D., 2014. *Principles of igneous and metamorphic petrology*. Pearson.
3. Rollinson, H. R., 2014. *Using geochemical data: evaluation, presentation, interpretation*. Routledge.

4. Raymond, L. A., 2002. *Petrology: the study of igneous, sedimentary, and metamorphic rocks*. McGraw-Hill Science Engineering.
5. McBirney, A. R., 1984. *Igneous Petrology*. San Francisco (Freeman, Cooper & Company) and Oxford (Oxford Univ. Press),
6. Best, M. G., 2001. *Igneous and Metamorphic Petrology.*
7. K. G. Cox, J. D. Bell., 1979. *The Interpretation of Igneous Rocks*. Springer/Chapman & Hall.
8. Bose M.K., 1997. *Igneous Petrology*.
9. Tyrrell, G.W., 1926. *Principles of Petrology*. Springer

Course Name: SEDIMENTOLOGY AND PRINCIPLES OF STRATIGRAPHY
Course Code: BSCHGELC302
(CREDITS: THEORY-4, PRACTICAL-2)

THEORY

Unit 1: Introduction to Sedimentology
Outline of sedimentation process: Definition of sediment; origin of sediments: mechanical and chemical sediments; source rock or provenance.

Unit 2: Sedimentary Texture
Clastic and Non-clastic texture: definition and components; Granulometry: concept and grain size scale, particle size distribution, environmental connotation; particle shape and fabric;

Unit 3: Basic hydraulics and Sedimentary structures
Fluid flow: Types of fluids, Laminar and turbulent flow, subcritical, critical and supercritical flows; concept of mean flow velocity, unit discharge and bed shear stress; flow profile and flow separation; particle entrainment, transport and deposition
Mass flow: types, mechanisms and controlling factors, process-product relationship
Penecontemporaneous deformation: mechanisms and controlling factors
Sedimentary structure: Primary and penecontemporaneous deformation structures
Bedform stability diagram
Paleocurrent analysis: Data acquisition, methodology, different paleocurrent patterns.

Unit 4: Sedimentary rocks
Siliciclastic rocks: Components and classification(s) of conglomerates and sandstones
Tectonic control on sandstone composition
General introduction to mudrocks
Carbonate rocks, controlling factors of carbonate deposition, components and classifications of limestone; dolomite and dolomitization
Diagenesis of siliciclastic and carbonate deposits.

Unit 5: Principles of stratigraphy
Stratigraphic units; Definition of lithostratigraphic, biostratigraphic and chronostratigraphic units; International Stratigraphic Code – development of a standardized stratigraphic nomenclature; Concepts of Stratotypes. Global Stratotype Section and Point (GSSP).
Introduction to concepts of: chemostratigraphy, seismic stratigraphy, sequence stratigraphy, Magnetostratigraphy

Unit 6: Stratigraphic analysis
Principles of stratigraphic correlation; Facies concept in stratigraphy; Walther's Law of Facies; Basic concept of paleogeographic reconstruction

PRACTICAL

Exercises on sedimentary structures; Particle size distribution and statistical analysis, Paleocurrent analysis; Petrographic study of clastic and non-clastic rocks in hand specimens and thin sections

SUGGESTED READINGS:

1. Pettijohn, F.J., 2019. *Sedimentary Rocks*. 3rd e-book Edition. CBS Publishers and Distributers, New Delhi.
2. Allen, J.R.L., 1985. *Principles of Physical Sedimentology*. George Allen and Unwin, London
3. Prothero, D. R., & Schwab, F., 2004. *Sedimentary geology*. Macmillan.
4. Tucker, M. E., 2006. *Sedimenary Petrology*, Blackwell Publishing.
5. Collinson, J. D. & Thompson, D. B., 1988. *Sedimentary structures*, Unwin- Hyman, London.
6. Nichols, G., 2009. *Sedimentology and Stratigraphy*, Second Edition. Wiley Blackwell
7. Doyle, P. and Bennett, M. R., 1996. *Unlocking the Stratigraphic Record*. John Wiley
8. Folk, R.L., 1980. *Petrology of Sedimentary Rocks*. Hemphill Publishing Company.

Course Name: PALAEONTOLOGY
Course Code: BSCHGELC303
(CREDITS: THEORY-4, PRACTICAL-2)

THEORY

Unit I: Fossilization and fossil records
Processes relating to fossilization of invertebrates, vertebrates, and plants; taphonomy and its significance in interpreting depositional environments, modes of preservation; Importance of fossil records – fossil lagerstätten.

Unit II: Systematics
Species concept, species problem in palaeontology, Taxonomic hierarchy, methods of description and naming of fossils, code of systematic nomenclature. Theory of organic evolution: speciation, microevolution, macroevolution, examples from fossil records.

Unit III: Invertebrates
Study of morphological features as preserved in fossils of important invertebrate groups: Class Bivalvia, Class Gastropoda, Class Cephalopoda (Subclass: Ammonoidea and Nautiloidea), Class Echinoidea, Class Anthozoa (coral). Brief morphological features of Phyllum Brachiopoda, Class Trilobita.

Unit IV: Vertebrates
Origin of vertebrates and major steps in vertebrate evolution: origin of jaws, amniotic eggs, diversification of terrestrial habitat and back to water, Mesozoic reptiles with special reference to origin, diversity and extinction of dinosaurs; Endothermy versus Ectothermy in dinosaurs; Origin of mammals; Major traits in horse evolution and intercontinental migrations; Major traits in hominid evolution and records of hominid fossils in Indian subcontinent; Vertebrate fossil records from Gondwana formations.

Unit V: Palaeobotany
Early plant life, colonization of land, important stages in plant evolution, Gondwana flora: role of climate in its evolution.

Unit VI: Microfossils
Introduction to microfossils; Study of Morphological features of Foraminifera and their classification.

Unit VII: Application of Palaeontology
Palaeoecology – principles and methods; application of fossils in the study of palaeoecology, and palaeoclimate; Palaeobiogeography: biogeographic provinces, dispersal and barriers.

PRACTICAL

Study of fossils showing various modes of preservation,
Study of diagnostic morphological characters up to family level of Gastropoda, Cephalopoda.
Study of morphological features: Bivalvia, Echinoidea pertaining to their mode of living.
Study of diagnostic morphological characters, generic identification and stratigraphic position of plant fossils.
Identification of molar tooth of *Equus, Hipparion, Rhinoceros, Stegodon* and *Trilophodon* and its functional morphology.

SUGGESTED READINGS

1. Cowen, R.,2000. *History of Life*, Blackwell Science.
2. Clarkson, E. N. K., 2013. *Invertebrate Palaeontology and Evolution*, Blackwell Science
3. Black, R.M., 1989. *The Elements of Palaeontology*, Cambridge University Press
4. Benton, M., 2005. *Vertebrate Palaeontology*, Blackwell Publishing
5. Jackson, P. W., 2019. *Introducing Palaeontology: A Guide to Ancient Life*, Dunedin Academic Press Ltd.
6. Enay, R., 2012. *Palaeontology of Invertebrates*, Springer-Verlag.
7. Doyle, P., 1996.*Understanding Fossils: An Introduction to Invertebrate Palaeontology*, John Wiley and Sons
8. Davies, M., 2008. *An Introduction to Palaeontology*, Read Books.
9. Shukla, A. C., & Misra, S. P., 1975. *Essentials of paleobotany*, Vikas Publisher.
10. Goldring, R, 2014. *Field Palaeontology*, Routledge
11. Johansson, C. Z., Underwood, M. Richter, 2019. *Evolution and development of Fishes*,
12. Cambridge University Press.
13. Saraswati,P.K., Srinivasan, M.S., 2016. *Micropaleontology: Principles and Applications*, Springer International Publishing Switzerland.
14. Benton, M.J., and Harper D. A. T., 2009. *Introduction to Paleobiology and the Fossil Record*, Wiley-Blackwell.

15. Colbert, E.H. and Minkoff, Eli C., 2001. *Evolution of vertebrates*, Wiley
16. Stewart, W.N. and Rothwell G.W., 2001. *Paleobotany and the evolution of plants*, Cambridge University Press.
17. Armstrong, H. A., & Brasier, M.D., 2005. *Microfossils*. Blackwell Publishing.

SKILL ENHANCEMENT COURSE

Course Name: BASIC FIELD TRAINING
Course Code: BSCHGELSEC301
(CREDITS: 4)

Mandatory Field Work for a minimum period of 10 days (on field)

Unit 1: Orientation of Topographic sheet in field, marking location in toposheet, Fixation of locations through bearing (Front and back). Concepts of map reading, Distance, height and pace approximation
Unit 2: Identification of rock types in field; structures and texture of rocks, Use of hand lens
Unit 3: Basic field measurement techniques: Bedding dip and strike, Pitch and Plunge of linear features, Measurement of Paleocurrent direction and palinspastic restoration; Construction of Litholog
Unit 4: Reading contours and topography

FOURTH SEMESTER

Course Name: METAMORPHIC PETROLOGY
Course Code: BSCHGELC401
(CREDITS: THEORY-4, PRACTICAL-2)

THEORY

Unit 1: Metamorphism - controls and types
Definition of metamorphism; factors controlling metamorphism; types of metamorphism - contact, regional, fault zone metamorphism, impact metamorphism.

Unit 2: Quantification of equilibrium in metamorphism
Metamorphic rocks as geochemical systems; Application of chemical thermodynamics in homogeneous phase equilibria; Geothermobarometry

Unit 3: Metamorphic facies and grades
Concept of equilibrium; Index minerals; composition paragenesis diagram (ACF, AKF, AFM projection); metamorphic zones and isograds; Concept of metamorphic facies and grade; mineralogical phase rule of closed and open system

Unit 4: Metamorphism and Tectonism
Relationship between metamorphism and deformation; structure and textures of metamorphic rocks metamorphic mineral reactions (prograde and retrograde); Metamorphic Facies Series; Paired Metamorphic Belt.

Unit 5: Types of metamorphism
Progressive metamorphism of pelitic and basic rocks; Contact metamorphism of impure limestone; Crustal anatexis, Partial melting in metamorhic rocks; Migmatites and their origin; Metasomatism and role of fluids in metamorphism.

Unit 6: Metamorphic rock associations
Slate, Phyllite, Schists, Gneisses, Granulites, Blue schists and Eclogites.

PRACTICAL

Megascopic and microscopic study (textural and mineralogical) of the following metamorphic rocks: Low grade metamorphic rocks: serpentinites, albite-epidote-chlorite-quartz schist, slate, talc-tremolite-calcite-quartz schist.
Medium to high grade metamorphic rocks: Gneisses, amphibolite, hornfels, garnetiferous schists, sillimanite-kyanite-bearing rocks, Granulites, eclogite, diopside-forsterite marble.
Laboratory exercises in graphic plots for petrochemistry and interpretation of assemblages.

SUGGESTED READINGS:

1. Philpotts, A., and Ague, J., 2009. *Principles of igneous and metamorphic petrology*. Cambridge University Press.
2. Winter, J. D., 2014. *Principles of igneous and metamorphic petrology*. Pearson.
3. Rollinson, H. R., 2014. *Using geochemical data: evaluation, presentation, interpretation*. Routledge.
4. Raymond, L. A., 2002. *Petrology: the study of igneous, sedimentary, and metamorphic rocks*. McGraw-Hill Science Engineering.
5. Yardley, B. W., and Yardley, B. W. D., 1989. *An introduction to metamorphic petrology*. Longman Earth Science Series.

Course Name: GEOLOGY OF INDIA
Course Code: BSCHGELC402
(CREDITS: THEORY-4, PRACTICAL-2)

THEORY

Unit 1: Physiographic and tectonic subdivisions of India
Brief introduction to the physiographic and tectonic subdivisions of India.

Unit 2: Precambrian evolution of Peninsular India
Stratigraphy and evolution of the Precambrian cratons, Dharwar, Singbhum, Aravalli, Bastar; Central Indian Suture Zone; Introduction to Proterozoic basins of India, Vindyan and Cuddapah.

Unit 3: Introduction to Himalayas
Divisions and tectono-magmatic evolution of the Himalayas: Paleozoic Succession of Kashmir and its correlatives from Spiti and Zanskar Stratigraphy; Triassic successions of Spiti; Cenozoic succession of Lesser Himalaya and Sub-Himalaya (Siwalik)

Unit 4: Phanerozoic evolution of Peninsular India
Gondwana basin-fills of Peninsular India; Mesozoic basins of India: Kutch, Cauvery; Cenozoic basins of India: Assam, Bengal Basin

Unit 5: Volcanic provinces of India
Deccan Trap, Rajmahal Trap, Sylhet Trap

Unit 6: Important Stratigraphic boundaries in India
Precambrian-Cambrian boundary, Permian-Triassic boundary, and Cretaceous-Tertiary boundary

PRACTICAL

Study of geological map of India and identification of cratons. Mobile belts and major stratigraphic units; Erection of lithologs, correlation between lithologs and construction of fence diagram.
Drawing of various paleogeographic maps of Precambrian time; Study of different Proterozoic supercontinent reconstructions.

SUGGESTED READINGS:

1. Krishnan, M. S., 1982. *Geology of India and Burma*, CBS Publishers, Delhi
2. Ramakrishnan, M. and Vaidyanadhan, R., 2008. *Geology of India*, Volumes 1 & 2. Geological Society of India, Bangalore.
3. Valdiya, K. S., 2010. *The making of India*. Macmillan India Pvt. Ltd.

Course Name: GLOBAL TECTONICS AND GEODYNAMICS OF THE LITHOSPHERE
Course Code: BSCHGELC403
(CREDITS: THEORY-4, PRACTICAL-2)

THEORY

Unit 1: Introduction
Definitions of 'Tectonics' and 'Global Tectonics'. Similarities and differences between Structural Geology and Tectonics. Asthenosphere and Lithosphere in the context of global tectonics. A brief introduction to how our ideas of tectonics on global scale evolved progressively from continental drift concept through sea-floor spreading concept to the comprehensive plate tectonics concept.

Unit 2: Geomagnetism
The concept of geomagnetism, geomagnetic anomaly and geomagnetic polarity reversals. Paleomagnetism: Concept of fossil magnetism, paleo-lattitude and plaeomagnetic evidences in favor of continental drift theory.

Unit 3: Continental drift Theory
Wegner's and Du Toit's concepts

Unit 4: Seafloor spreading
Its concept; Linear Magnetic Anomalies; Vine & Mathew's hypothesis.

Unit 5: Plate Tectonics Theory
Plates; Different types of plate boundaries and their characteristic features; Plate motions and driving forces and mechanisms; Special discussion on island arcs and collisional orogenic belts (with the Himalayas in focus).

Unit 6: Isostasy
Concept of isostasy, its development; proposed models explaining isostatic equilibrium – comparative analysis; isostatic condition of India

Unit 7: Changing global tectonics with time
The location, extent and age of the major orogenic belts of the Earth in geological history (referring only to the respective classical occurrences). General idea about the changing pattern of global tectonics with progressive ageing of the Earth.

Unit 8: Supercontinents
Supercontinents through Geological time; concept of assembly and break-up of supercontinents – evidence and explanations

PRACTICAL

The technique of locating the focus (and epicenter) of earthquakes using focal mechanism solutions.
Marking on an outline map of the world: (i) the position and name of all the major present-day plates on the Earth, (ii) the specific nature (convergent, divergent and transform) of the boundaries of those plates and (iii) the sense of relative plate movement across those boundaries.
Study of paleomagnetic and paleotectonic maps.
Interpretation of Isogal maps (i.e. Bouguer Gravity Anomaly maps).

SUGGESTED READINGS:

1. Condie, K.C., 1982. *Plate Tectonics and Crustal Evolution*. 2nd Edition, Pergamon Press.
2. Keary, P., Klepeis, K.A. and Vine, F.J., 2009. *Global Tectonics*. 3rd Edition, Wiley-Blackwell.
3. Brown, G.C. and Mussett, A.E., 1993. *The Inaccessible Earth*. 2nd Edition, Chapman & Hall, London.
4. Moores, E.M. and Twiss, R.J., 1995. *Tectonics*. W.H. Freeman.

SKILL ENHANCEMENT COURSE
Course Name: GEOLOGICAL FIELD METHODS AND MAPPING
Course Code: BSCHGELSEC401
(CREDITS: 4)

Mandatory Field Work for a minimum period of 15 days (on field)

Unit 1: Geological mapping, stratigraphic correlation
Unit 2: Primary (scalars and vectors) and secondary structures (linear and planar)
Unit 3: Trend, plunge, Rake/Pitch
Unit 4: Stereoplots of linear and planar structures, Orientation analyses

FIFTH SEMESTER

Course Name: ECONOMIC GEOLOGY
Course Code: BSCHGELC501
(CREDITS: THEORY-4, PRACTICAL-2)

THEORY

Unit 1: Ores and gangues
Ores, gangue minerals, tenor, grade and lodes; Resources and reserves- definitions and classifications

Unit 2: Mineral deposits and classical concepts of Ore formation
Mineral deposit and Ore deposit; Historical concepts of ore genesis: Plutonist and neptunist concepts of ore formation; Endogenous processes: Magmatic concentration, hydrothermal deposits, skarns, greisens; Metamorphosed ore deposits, metamorphism of ore deposits; Exogenous processes: weathering products and residual deposits, oxidation and supergene enrichment, placer deposits; Sedex, VMS deposits; biogenic ore deposits.

Unit 3: Structure of ore deposits and tectonics of mineralization
Concordant and discordant ore bodies, lodes; Tectonic control of mineralization: Brief idea about mineral deposits of different plate tectonic settings

Unit 4 Ore textures
Different type of ore textures due to free growth and constrained growth.

Unit 5: Economic recovery of ore minerals
Basic ideas about the exploration and exploitation of an ore body; Assessment of grade of ore; reserve estimation;

Unit 6: Metallic and nonmetallic mineral deposits
Metallogenic provinces and epochs; Important deposits of India including atomic minerals Non-metallic and industrial rocks and mineral deposits in India; Introduction to gemstones.

PRACTICAL

Identification of common ore minerals in hand specimen
Study of microscopic properties of ore forming minerals (Oxides and sulfides).

SUGGESTED READINGS:

1. Gilbert, J.M. and Park Jr., C.F., 1986. *The Geology of Ore deposits*. Freeman & Co.
2. Bateman, A.M. and Jensen, M.L., 1990. *Economic Mineral Deposits*. John Wiley.
3. Evans, A.M., 1993. *Ore Geology and Industrial minerals*. Wiley
4. Laurence Robb., 2005. *Introduction to ore forming processes*. Wiley.
5. Gokhale, K.V.G.K. and Rao, T.C., 1978. *Ore deposits of India their distribution and processing*. Tata-McGraw Hill, New Delhi.
6. Deb, S., 1980. *Industrial minerals and rocks of India*. Allied Publishers.
7. Sarkar, S.C. and Gupta, A., 2012. *Crustal Evolution and Metallogeny in India*. Cambridge Publications.

Course Name: FUEL GEOLOGY
Course Code: BSCHGELC502
(CREDITS: THEORY-4, PRACTICAL-2)

THEORY

Unit 1: Coal

Definition and origin of Coal; Classification of Coal: ASTM, Seyler's, National, International and Indian; Coalification: Causes of Coalification; Combustion Properties of Coal: Calorific Value; Ash Fusion Temperatures; Caking Tests; Coking Tests; Physical Properties of Coal: Mechanical Strength, Density, Hardness and Grindability, Abrasion Index; Particle Size Distribution; Float-Sink Tests; Fundamentals of Coal Petrology – Introduction to lithotypes, microlithotypes and macerals in coal; Proximate and Ultimate analysis, Chemical properties of coal

Unit 2: Coal Bed Methane

Coal Bed Methane (CBM): Introduction; Origin / Methanation; Adsorption – Langmuir Model; Production; Global and Indian scenario.
Underground Coal Gasification (UCG): Gasification – UCG and SCG; Basic Chemistry; Advantages and Disadvantages; Indian Scenario.
Coal Liquefaction: Liquefaction – Processes; Advantages and Disadvantages; Indian Scenario.

Unit 3: Petroleum

Chemical composition and physical properties of crudes in nature
Origin of petroleum: favourable geological conditions, source material, maturation of organic matter - Biogenic and Thermal effect; Kerogen: types and relation to the origin of petroleum hydrocarbons

Unit 4: Petroleum system

Source rock: general attributes
Reservoir rocks: general attributes and petrophysical properties
Cap rocks: definition and general properties.
Migration of petroleum hydrocarbons
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.
Petroliferous basins of India

Unit 5: Other fuels

Shale Gas: Formation; Properties; Advantages and Disadvantages; Indian Scenario.
Gas Hydrate: Potentials and Importance; Occurrence of Gas Hydrate and Controls on Gas Hydrate occurrence; Stability of gas hydrates; Advantages and Disadvantages; Indian Scenario.
Nuclear Fuel: Types of Nuclear Reactions; Fuel Types – Uranium, Zirconium, Thorium and Berylium; Geochemistry of U and Th; Important minerals and types of U and Th deposits, Nuclear raw material resources of India; Usage of nuclear energy.

PRACTICAL

Study of hand specimens of coal; Isopach and Isolith Maps; Outcrop completion, fault and borehole problems; Seismic profile interpretation; Preparation of Panel and Fence diagrams

SUGGESTED READINGS:

1. Thomas, L., 2020. *Coal Geology*. 3rd Edition. Wiley-Blackwell
2. Suarez-Ruiz, I. and Crelling, J.C., 2008. *Applied Coal Petrology – The Role of Petrology in Coal Utilization.* Academic Press
3. Chandra D., 2007. *Chandra's Textbook on Applied Coal Petrology.* Jijnasa Publishing House
4. Chandra, D., Singh, R.M. and Singh, M.P., 2000. *Textbook of Coal (Indian Context).* Tara Book Agency, Varanasi
5. Diessel, C.F.K., 1992. *Coal-Bearing Depositional Systems.* Springer
6. Francis, W., 1964. *Coal its Formation and Composition*. Edward Arnold
7. Singh, M.P., 1998. *Coal and Organic Petrology*. Hindustan Publ. Corp., New Delhi.
8. Ward, C.R., 1984. *Coal Geology and Coal Technology*. Blackwell Science
9. Thakur, P., Schatzel, S.J., Aminian, K., Rodvelt, G., Mosser, M.H., D'Amico, J.S., 2020. *Coal Bed Methane – Theory and Applications, 2nd Edition*. Elsevier
10. Flores, R.M., 2014. *Coal and Coalbed Gas – Fueling the Future*. Elsevier
11. Singh, Ajay Kumar and Hajra, Partha Narayan, 2018. *Coalbed Methane in India – Opportunities, Issues and Challenges for Recovery and Utilization*. Springer
12. Letcher, T.M., 2020. *Future Energy – Improved, Sustainable and Clean Options for our Planet, 3rd Edition*. Elsevier
13. Bell, D.A., Towler, B.F. and Fan, M., 2011. *Coal Gasification and Its Applications*. Elsevier
14. Massey, L.G., 1973. *Coal Gasification.* American Chemical Society
15. Whitehurst, D.D., 1980. *Coal Liquefaction Fundamentals*. American Chemical Society
16. Shelly R.C., 2014. *Elements of Petroleum Geology, 3rd Edition.* Academic Press
17. Bjorlykke, K., 1989. *Sedimentology and Petroleum Geology*. Springer
18. Tissot, B.P. and Welte, D.H., 1984. *Petroleum Formation and Occurrence*. Springer
19. Levorsen, A.I., 2004. *Geology of Petroleum*; CBS Publishers and Distributors, India
20. North, F.K., 1986. *Petroleum Geology*, Allen & Unwin
21. Bastia, R. and Radhakrishna, M., 2012. *Basin Evolution and Petroleum Prospectivity of the Continental Margins of India*. Elsevier
22. Doveton, J.H., 1986. *Log Analysis of Subsurface Geology*. Wiley-Interscience
23. Hobson, G.D., 1977. *Developments in Petroleum Geology*. Applied Science Publishers
24. Aswathanarayana, U., 1985. *Principles of Nuclear Geology*. Oxford
25. Boyle, R.W., 1982. *Geochemical Prospecting for Thorium and Uranium Deposits*. Elsevier
26. Dahlkamp, F.J., 1993. *Uranium Ore Deposits*. Springer-Verlag
27. Demirbas, A., 2010. *Methane Gas Hydrate*. Springer-Verlag
28. Durrance, E.M., 1986. *Radioactivity in Geology – Principles and Application.* Ellis Hoorwool

DISCIPLINE SPECIFIC ELECTIVES

Course Name: REMOTE SENSING AND GIS
Course Code: BSCHGELDSE501
(CREDITS: THEORY-4, PRACTICALS-2)

THEORY

Unit 1: Basics of Remote Sensing & Its Applications in Geosciences

Basic concepts in remote sensing, electro-magnetic spectrum, Energy sources, energy interaction in the atmosphere, atmospheric windows, atmospheric effects on remotely sensed data, signatures in remote sensing, sensors and sensor platforms. Introduction to aerial photographs, history of aerial photography, aerial camera, types of aerial photographs, classification, principles of stereoscopic viewing, conditions and cause for stereovision. Aerial photography missions. Use of pocket and mirror stereoscope, scale of aerial photographs, stereoscopic parallax, relief displacement, measurement of height of objects. Aerial photo interpretation, photo-recognition elements, methods of photo-interpretation, advantages and limitations of aerial photographs. Remote Sensing from space: space crafts and sensors. Visual image interpretation of satellite imagery, image enhancement, digital analysis, preparation of thematic maps.Thermal Infrared remote sensing and microwave remote sensing for geological applications. Remote sensing satellites, Indian Remote Sensing Satellite programme.

Unit 2: Digital Image Processing for Geological applications

Introduction to Digital Image Processing and related Terminology. Tasks, Classification-Supervised and unsupervised classification, Feature extraction. Multi-scale signal analyses. Pattern recognition, projection, digital image processing techniques- Anisotropic diffusion, Hidden Markov models, Image editing, Image restoration, Linear filtering, Neural networks, Pixelation, Point feature matching, Principal components analysis, Self-organizing maps, Filtering, Digital Image Processing software.

Unit 3: Geographic Information System in Geology

Introduction to GIS, Components of GIS, Hardware & Software Requirements, Spatial databases and GIS, GIS and the art of digitizing, Geographic phenomena, Geographic object, Regular vs. Irregular tessellations, Triangulated Irregular Network, Topology and spatial relationships, Data input, Data output and visualization, Data storage, Query maintenance and spatial analyses, etc. Different types of vector data: point, line, polygon, Concept of topology. Raster data model and comparison with vector, Sourcing satellite data, Non-spatial data and their types, Georeferencing, Map projections, Applications of GIS, Limitations of GIS, Components of GPS.

PRACTICAL

Aerial Photo interpretation, identification of sedimentary, igneous and metamorphic rocks and various aeolian, glacial, fluvial and marine landforms
Introduction to DIP and GIS softwares. Digital Image Processing exercises including analysis of satellite data in different bands and interpretation of various objects on the basis of their

spectral signatures, Creating a FCC from raw data, Registration of satellite data with a toposheet of the area
Enhancing the satellite images; Generating NDVI images and other image ratio and its interpretation.
Classification of images; DEM analysis: generating slope map, aspect map and drainage network map and its applications.

SUGGESTED READINGS:

1. Miller Victor C. Miller Calvin F., 1961. *Photogeology*, International Series in the Earth Sciences. McGraw-Hill Book Company, Inc.
2. Drury S.A, 1990. *A Guide to Remote Sensing - Interpreting Images of Earth*. Oxford Science Publications, Oxford.
3. Sabins, F.F.Jr., 1978. *Remote Sensing Principles and Interpretation*, Freeman, Sanfrancisco.
4. Paine, D.P., 1986. *Aerial photography and image interpretation for resource management*, Wiley and Sons, New York.
5. Ramasamy, SM., 1999. *Trends in Geological Remote Sensing* - Rawat Publishers, Jaipur
6. Rolf, A. de, 2001. *Principles of Geographic Information Systems-An introductory textbook*. ITC Educational Textbook Series. Enschede, The Netherlands.
7. Lo C.P. and Albert K. W. Yeung, 2002. *Concepts and Techniques of Geographic Information System.* Prentice –Hall, India.
8. Heywood I, el., 2011. *An Introduction to Geographical Information Systems.* Pearson Education Pvt. Ltd., New Delhi.
9. Lillesand T.M. and Kiefer R.W., 2002. *Remote Sensing and Image Interpretation*, John Wiley and Sons, New Delhi.
10. Wilhelm Burger; Mark J. Burge, 2007. *Digital Image Processing: An Algorithmic Approach Using Java*. Springer.
11. R. Fisher; K Dawson-Howe; A. Fitzgibbon; C. Robertson; E. Trucco, 2005. *Dictionary of Computer Vision and Image Processing*. John Wiley.

Course Name: OCEANOGRAPHY AND MARINE GEOLOGY
Course Code: BSCHGELDSE502
(CREDITS: THEORY-4, PRACTICALS-2)

THEORY

Unit 1: Introduction to the Oceans

Oceanography – the concept, brief historical review; Origin of Ocean Basins; Physiography of the Ocean Floor

Unit 2: Wind and Ocean Circulation

Atmospheric Processes - Air Pressure, Coriolis Deflection, General Wind Circulation; Surface Ocean Currents; Deep-Ocean Circulation; Thermohaline Conveyer Belt - impact on Global Climate

Unit 3: Waves in the Ocean

Properties of Ocean Waves; Wave Motions; Standing Waves, Internal Waves, Tsunamis

Unit 4: Tides

Origin of the Tides, Equilibrium Model of Tides, Dynamic Model of the Tides; Tidal Currents

Unit 5: The Dynamic Shoreline

Coastal Water Movement, Shoaling Waves and Refraction, Circulation in the Surf Zone; Beaches; Coastal Dunes; Barrier Islands; Deltas; Estuaries; Lagoons; Mangrove swamps; Anthropogenic impact on the Coastline

Unit 6: Marine Resources

Types of marine resources; Physical, energy, biological and non-extractive resources; Mineral resources; Laws of the sea

PRACTICAL

Term paper and group discussion and presentation on assigned topics

SUGGESTED READINGS:

1. Gross, M. G., 1977. *Oceanography: A view of the earth*.
2. Pinet, Paul R., 2016. *Invitation to Oceanography*, Seventh edition. Jones & Bartlett Learning.
3. Webb, P., *Introduction to Oceanography*. Free Download at http://rwu.pressbooks.pub/webboceanography

Course Name: ENVIRONMENTAL GEOLOGY
Course Code: BSCHGELDSE503
(CREDITS: THEORY-4, PRACTICALS-2)

THEORY

Unit 1: Introduction to Environmental Geology

Definition of Environment; Earth as a System, Earth and Human Population - Population growth rate and Consequences, The Human Response to Hazards, Population Increase, Land Use Change, and Natural Hazards.

Unit 2: Natural Resources and Pollution

Water Resources: A Brief Global Perspective, Water and Ecosystems, Surface Water, Groundwater, Interactions Between Surface Water and Groundwater, Consumption of Water and Emerging Global Water Shortages; Water Pollution: An Overview, Surface and Groundwater Pollution and Treatment, Water-Quality Standards, Wastewater Treatment.

Mineral Resources: Geology of Mineral Resources, Environmental Impact of Mineral Development, Mining and Toxicity, Recycling Mineral Resources, Minerals and Sustainability.
Energy Resources: Fossil and Nuclear Fuels – The Environmental Impact; Renewable Energy Sources, Conservation, Efficiency, and Cogeneration

Unit 3: Natural Hazards
Hazard and Disaster: Natural Causes - Earthquakes, Tsunami, Volcanism, Flood, Landslides and Subsidence, Coastal Hazards, Prediction, Preventive Measures and Anthropogenic Contributions

Unit 4: Global Climate
Earth's Climate System; Major Controls on Global Climate; The Greenhouse Effect; Coupling of Global Change Processes: Ozone Depletion and Global Warming Consequences of Global Warming, Mitigation.

PRACTICAL

Term paper and group discussion and presentation on assigned topics

SUGGESTED READINGS:

1. Montgomery, C. W., 2011. *Environmental Geology,* Ninth Edition, McGraw-Hill.
2. Keller, E. A., 2012. *Introduction to Environmental Geology*, Fifth Edition, Prentice Hall.
3. Reichard, J. S., 2011. *Environmental Geology*, McGraw-Hill.

Course Name: INTRODUCTION TO GEOPHYSICS
Course Code: BSCHGELDSE504
(CREDITS: THEORY-4, PRACTICALS-2)

THEORY

Unit 1: Geology and Geophysics
Interrelationship between geology and geophysics, Role of geological and geophysical data in explaining geodynamical features of the earth

Unit 2: General and Exploration geophysics
Different types of geophysical methods - gravity, magnetic, electrical and seismic; their principles and applications
Concepts and Usage of corrections in geophysical data

Unit 3: Geophysical field operations
Different types of surveys, grid and route surveys, profiling and sounding techniques
Scales of survey, Presentation of geophysical data

Unit 4: Application of Geophysical methods
Regional geophysics, oil and gas geophysics, ore geophysics, groundwater geophysics, engineering geophysics

Unit 5: Geophysical anomalies
Correction to measured quantities, geophysical anomaly, regional and residual (local) anomalies, factors controlling anomaly, and depth of exploration

Unit 6: Integrated geophysical methods
Ambiguities in geophysical interpretation, planning and execution of geophysical surveys

PRACTICAL

Anomaly and background- Graphical method
Study and interpretation of seismic reflector geometry
Problems on gravity anomaly

SUGGESTED READINGS:

1. Prasaranga, M.B., 1975. *Outlines of Geophysical Prospecting - A manual for geologists by Ramachandra Rao*, University of Mysore, Mysore.
2. Exploration Geophysics - An Outline by Bhimasarikaram V.L.S., Association of Exploration Geophysicists, Osmania University, Hyderabad, 1990.
3. Dobrin, M.B. ,1984. *An introduction to Geophysical Prospecting*. McGraw-Hill, New Delhi.
4. Telford, W. M., Geldart, L. P., & Sheriff, R. E. ,1990. *Applied geophysics* (Vol. 1). Cambridge
5. University Press.
6. Lowrie, W. ,2007. *Fundamentals of geophysics*. Cambridge University Press.
7. North, F.K., 1986.*Petroleum Geology*. Allen & Unwin

SIXTH SEMESTER

Course Name: ENGINEERING GEOLOGY
Course Code: BSCHGELC601
(CREDITS: THEORY-4, PRACTICAL-2)

THEORY

Unit 1: Introduction
Role of Engineering geologists in planning, design and construction of major man-made structural features

Unit 2: Foundation treatment
Grouting, Rock Bolting and other support mechanisms

Unit 3: Intact Rock and Rock Mass properties
Significance as Construction Material; Properties of Building Materials: Physical Properties; Compositions and Structures of Materials; Significance of Building or Dimension Stone: Roofing and Facing Materials; Armourstone; Crushed Rock – Concrete Aggregate; Road Aggregate; Gravels and Sands; Lime; Cement and Plaster; Clays and Clay Products.

Unit 4: Rock Quality Designation (RQD)
Concept, Mechanism and Significance of:

a) Rock Structure Rating (RSR)
b) Rock Mass Rating (RMR)
c) Tunneling Quality Index (Q)

Unit 5: Dams and Reservoirs
Dam: Terminology associated with dams; Types of dams – Masonry, Gravity, Buttress, Arch and Earthen dams. Types of spillways. Causes of Dam failures; Case studies of dam construction and failures. Problems affecting Dams and their remedial measures. Geological, Geotechnical and Environmental considerations for selection of Dams and Reservoirs sites.

Unit 6: Tunnel
Tunnel: Different parts; Types; Geological investigations for site selection for Tunnel; Tunneling problems; Factors effectıng excavatıon of rocks while Tunnelling; Effects of Fold, Fault, Bed Attitude on Tunnelling.

Unit 7: Landslides
Different parts of landslide body; Inducing Factors for Landslides; Role of Gravity and Water

Unit 8: Earthquakes
Causes, Factors and corrective / preventive measures, Predicting Earthquake, Locating Earthquake.

PRACTICAL

Selection of sites using topographic maps for dams, tunnels, bridges and similar civil structures; Computation of reservoir area, catchment area, reservoir capacity and reservoir life; Merits, demerits & remedial measures based upon geological cross sections of project sites; Computation of Index properties of rocks; Evaluation of mechanical properties of concrete aggregates; Surveying related exercises; Computation of RQD, RSR, RMR and 'Q'

SUGGESTED READINGS:

1. Gangopadhyay, S., 2013. *Engineering Geology*, Oxford India
2. Bell, F.G., 2007. *Engineering Geology. 2nd Edition.* Elsevier
3. Gonzalez de Vallejo, L.I. and Ferrer, M., 2011. *Geological Engineering.* CRC Press
4. Bell, F.G., 2007. *Basic Environmental and Engineering Geology*, Whittles Publishing
5. Blyth, F.G.H. and de Freitas, M., 1984. *A Geology for Engineers*, Elsevier
6. Das, B.M., 2011. *Geotechnical Engineering Handbook,* J. Ross Publishing
7. Das, B.M., 2016. *Principles of Foundation Engineering. 8th Edition,* Cengage Learning
8. Fletcher, C.J.N., 2016. *Geology for Ground Engineering Projects*, CRC Press
9. Fookes, P., Pettifer, G. and Waltham, T., 2015. *Geomodels in Engineering Geology – An Introduction.* Whittles Publishing
10. Goodman, R.E., 1993. *Engineering Geology: Rock in Engineering constructions,* John Wiley & Sons, New York
11. Hunt, R.E., 2005. *Geotechnical Engineering Investigation Handbook. 2nd Edition,* CRC Press
12. Johnson, R.B. and De Graf, J.V., 1988. *Principles of Engineering Geology*, John Wiley & Sons, New York

13. Krynin, D.P. and Judd W.R., 1957. *Principles of Engineering Geology and Geotechnique,* McGraw Hill
14. Venkataramaiah, C., 2006. *Geotechnical Engineering. 3rd Edition,* New Age International, New Delhi
15. Waltham, T., 2009. *Foundations of Engineering Geology. 3rd Edition.* Taylor & Francis
16. Smith, M.R., 1999. *Stone – Building Stone, Rock Fill and Armourstone in Construction,* Geological Society of London
17. Zhang, H., 2011. *Building Materials in Civil Engineering*, Woodhead Publishing
18. Duggal, S.K., 2008. *Building Materials., 3rd Edition.* New Age International, New Delhi

Course Name: HYDROGEOLOGY
Course Code: BSCHGELC602
(CREDITS: THEORY-4, PRACTICAL-2)

THEORY

Unit 1: Introduction and Basic Concepts
Scope of hydrogeology and its societal relevance
Hydrologic cycle: precipitation, evapo-transpiration, run-off, infiltration and subsurface movement of water.
Rock properties affecting groundwater, Vertical distribution of subsurface water
Types of aquifer, aquifer parameters, anisotropy and heterogeneity of aquifers

Unit 2: Groundwater flow
Darcy's law and its validity
Intrinsic permeability and hydraulic conductivity
Groundwater flow rates and flow direction
Laminar and turbulent groundwater flow

Unit 3: Well hydraulics and Groundwater Exploration
Basic Concepts (drawdown; specific capacity etc.)
Elementary concepts related to equilibrium and non-equilibrium conditions for water flow to a well in confined and unconfined aquifers.
Surface-based groundwater exploration methods
Introduction to subsurface borehole logging methods

Unit 4: Groundwater chemistry
Physical and chemical properties of water and water quality
Genetic classification of groundwater.
Sea water intrusion in coastal aquifers

Unit 5: Groundwater management
Surface and subsurface water interaction
Groundwater level fluctuations
Geomorphic and geologic controls of groundwater.
Basic concepts of water balance studies, issues related to groundwater resources development and management
Rainwater harvesting and artificial recharge of groundwater
Brief idea about groundwater pollution and its mitigation

PRACTICAL

Preparation and interpretation of water level contour maps and depth to water level maps
Study, preparation and analysis of hydrographs for differing groundwater conditions
Determination of hydraulic gradient / slope from water table depth data.
Three-point problems and determination of groundwater flow direction.
Numerical problems related to Hydrological Cycle, Well Hydraulics, Groundwater Flows etc.

SUGGESTED READINGS:

1. Chahar, Bhagu R., 2015. *Groundwater Hydrology*. McGraw Hill Education (India)
2. Todd, D.K., 2006. *Groundwater Hydrology. 3rd Edition.* John Wiley & Sons, N.Y.
3. Karanth K.R., 1987. *Groundwater: Assessment, Development and management,* Tata McGraw-Hill, New Delhi
4. Davis, S.N. and De Weist, R.J.M., 1966. *Hydrogeology.* John Wiley & Sons Inc., N.Y.
5. Raghunath, H.M., 1987. *Groundwater*. New Age International, New Delhi
6. Bear, J., 1979. *Hydraulics of Groundwater,* Dover Publications
7. Brassington, R., 2017. *Field Hydrogeology. 4th Edition,* Wiley-Blackwell
8. Das, S., 2011. *Groundwater Resources of India. 1st Edition,* National Book Trust, New Delhi
9. Domenico, P.A. and Scbwartz, F.W., 1998. *Physical and Chemical Hydrogeology. 2nd Edition,* John Wiley & Sons, New York
10. Freeze, R. Allan and Cherry, John A., 1979. *Groundwater,* Prentice Hall.
11. Hiscock, K.M. and Bense, V.F., 2014. *Hydrogeology – Principles and Practice. 2nd Edition.* Blackwell Science
12. Hudak, P.F., 2000. *Principles of Hydrogeology. 2nd Edition,* CRC Press
13. Kresic, N., 2007. *Hydrogeology and Groundwater Modeling. 2nd Edition,* CRC Press
14. Mukherjee, Abhijit, 2018. *Groundwater of South Asia,* Springer
15. Patra, H.P., Adhikari, S.K. and Kunar, S., 2016. *Groundwater Prospecting and Management,* Springer
16. Pawar, N.J, Das, S. and Duraiswami R.A., 2012. *Hydrogeology of Deccan Traps and Aassociated Formations in Peninsular India.* Memoir – 80, Geol. Soc. India, Bangalore.
17. Stober, I. and Bucher, K., 2000. *Hydrogeology of Crystalline Rocks,* Springer

DISCIPLINE SPECIFIC ELECTIVES

Course Name: MINERAL EXPLORATION AND MINING
Course Code: BSCHGELDSE601
(CREDITS: THEORY-4, PRACTICALS-2)

THEORY

Unit 1: Mineral Resources
Resource reserve definitions, Mineral resources in industries – historical perspective and present; brief overview of classification of mineral deposits with respect to processes of formation in relation to exploration strategies

Unit 2: Prospecting and Exploration
Principles of mineral exploration; Prospecting and exploration- conceptualization, methodology and stages; Sampling, subsurface sampling including pitting, trenching and drilling; Geochemical exploration

Unit 3: Evaluation of data
Evaluation of sampling data
Mean, mode, median, standard deviation and variance

Unit 4: Drilling and Logging
Core and non-core drilling
Planning of bore holes and location of boreholes on ground
Core-logging

Unit 5: Reserve estimation
Principles of reserve estimation, density and bulk density
Factors affecting reliability of reserve estimation
Reserve estimation based on geometrical models (square, rectangular, triangular and polygon blocks)
Regular and irregular grid patterns, statistics and error estimation

Unit 6: Elements of Mining
Surface Mining; Underground Mining; Mine Machinery; Mine Explosive; Rock Mechanics and Support System; Mine Ventilation; Mine Closure; Mining Software.

PRACTICAL

Identification of anomaly
Concept of weighted average in anomaly detection
Geological cross-section
Models of reserve estimation

SUGGESTED READINGS:

1. Clark, G.B. 1967. *Elements of Mining*. 3rd Ed. John Wiley & Sons.
2. Arogyaswami, R.P.N. 1996 *Courses in Mining Geology*. 4th Ed. Oxford-IBH.
3. Moon, C.J., Whateley, M.K.G., Evans, A.M., 2006, *Introduction to Mineral Exploration*, Blackwell Publishing.

4. Marjoribanks, R., 2010. *Geological Methods in Mineral Exploration and Mining*, Second Edition, Springer-Verlag.
5. Haldar, S.K., 2013. *Mineral Exploration: Principles and Applications*. Elsevier.

Course Name: CLIMATOLOGY
Course Code: BSCHGELDSE602
(CREDITS: THEORY-4, PRACTICALS-2)

THEORY

Unit 1: Climate system
Forcing and Responses; Components of the climate system; Climate forcing, Climate controlling factors; Climate system response, response rates and interactions within the climate system; Feedbacks in climate system

Unit 2: Heat budget of Earth
Incoming solar radiation, receipt and storage of heat; Heat transformation; Earth's heat budget. Interactions amongst various sources of earth's heat

Unit 3: Atmosphere - Hydrosphere
Layering of atmosphere and atmospheric Circulation; Atmosphere and ocean interaction and its effect on climate; Heat transfer in ocean; Global oceanic conveyor belt and its control on earth's climate; Surface and deep circulation; Sea ice and glacial ice

Unit 4: Response of biosphere to Earth's climate
Climate Change: natural vs. anthropogenic effects; Humans and climate change; Future perspectives; Brief introduction to archives of climate change; Archive based climate change data from the Indian continent

Unit 5: Orbital cyclicity and climate
Milankovitch cycles and variability in the climate; Glacial-interglacial stages; The Last Glacial maximum (LGM); Pleistocene Glacial-Interglacial cycles; Younger Dryas; Marine isotope stages

Unit 6: Monsoon
Mechanism of monsoon; Monsoonal variation through time; Factors associated with monsoonal intensity; Effects of monsoon

PRACTICAL

Study of distribution of major climatic regimes of India on map
Distribution of major wind patterns on World map
Preparation of paleogeographic maps (distribution of land and sea) of India during specific geological time intervals
Numerical exercises on interpretation of proxy records for paleoclimate

SUGGESTED READINGS:
1. Rudiman, W.F., 2001. *Earth's climate: past and future*. Edition 2, Freeman Publisher.
2. Rohli, R.V., and Vega, A.J., 2007. *Climatology*. Jones and Barlatt

3. Lutgens, F., Tarbuck, E., and Tasa, D., 2009. *The Atmosphere: An Introduction to Meteorology*. Pearson Publisher
4. Aguado, E., and Burt, J., 2009. *Understanding weather.*

Course Name: MINE VISIT & FIELD ANALYSIS OF FOSSILIFEROUS SEDIMENTARY SUCCESSION
Course Code: BSCHGELDSE603
(CREDITS: 6)

FIELD WORK

Mandatory Field Work for a minimum period of 7 days (on field)

Unit 1: Mine Visit

Onsite Study of underground and opencast mine including principles of underground mapping/ Bench mapping.

Mandatory Field Work for a minimum period of 7 days (on field)

Unit 2: Study of Fossiliferous Sedimentary Succession

Identification of strategic sections through field reconnaissance, acquisition of field data, erection of litholog and recording of fossil content, collection of representative samples, litholog correlation and preparation of fence diagram, Facies mapping.

LABORATORY

Preparation of thin section of rock samples, petrographic study, study of fossils
Reconstruction of depositional setting

Course Name: RESEARCH PROJECT IN GEOLOGY (DISSERTATION)
Course Code: BSCHGELDSE604
(CREDITS: 6)

The student will have to carry out one project work on specific geological problem. The problem must be field-based supplemented by laboratory studies. The result of the work has to be submitted in form of a thesis duly certified by the supervising teacher. The work will have to be presented before a board of Examiners (including external expert) in an open house seminar for final assessment.

(Prabir Dasgupta)
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