NATIONAL INSTITUTE OF TECHNOLOGY, DURGAPUR

DEPARTMENT OF EARTH AND ENVIRONMENTAL STUDIES

Curriculum and Syllabi for the Degree of
2 Yr. M. Sc. in Applied Geology and Geoinformatics

(To be effective from the batches admitted in the Academic Session 2020-2021 Onwards)
Approved in PGAC meeting on 28/08/2020

Date: 28th August, 2020

Annexure-1

Curriculum and Syllabi

Master of Science

In

Applied Geology and Geoinformatics

Duration of Course: Two years (4 Semesters)

Department of Earth and Environmental Studies

National Institute of Technology Durgapur

Mahatma Gandhi Road, Durgapur, West Bengal, India, Pin –713209

M.Sc. (Applied Geology and Geoinformatics) SEMESTER SYSTEM w.e.f. SESSION 2020-21

Candidates who have passed the three-year B.Sc. (Hons.) examination from a University with Geology as its major subject will be considered eligible for admission to the Four Semester M.Sc. course in Applied Geology and Geoinformatics.

The M.Sc. course in Applied Geology and Geoinformatics shall be imparted to the students for two academic sessions consisting of four semesters as given below. Candidates will be examined and evaluated on grade basis at the end of each semester in the different courses of theory and practical as per the credits given against each course. The M.Sc. Applied Geology and Geoinformatics will consist of (a) Core Courses and (b) Elective Courses. The Core courses will be compulsory for all the students admitted to M.Sc. Applied Geology and Geoinformatics.

DEPARTMENT OF EARTH & ENVIORNMENTAL STUDIES				
Curriculum of M.Sc. (APPLIED GEOLOGY AND GEOINFORMATICS)				
FIRST SEMESTER				
Sl. No	**Sub. Code**	**Subjects**	**L-T-S**	**Credits**
1	ES 1101	**Mineral science**	3-0-0	3
2	ES 1102	**Fundamentals of Remote Sensing and Geoinformatics**	3-0-0	3
3	ES 1103	**Structural Geology**	3-0-0	3
4	ES 1104	**Applied Geomorphology and Quaternary Geology**	3-0-0	3
5	ES 1151	**Mineral Science Practical**	0-0-3	2
6	ES 1152	**Fundamentals of Remote Sensing and Geoinformatics Practical**	0-0-3	2
7	ES 1153	**Structural Geology Practical**	0-0-3	2
8	ES 1154	**Computer tools and Techniques**	0-1-3	3
TOTAL				**21**
SECOND SEMESTER				
Sl. No	**Sub. Code**	**Subjects**	**L-T-S**	**Credits**
1	ES 91**	**Elective I**	3-0-0	3
2	ES 2101	**Natural Hazards and Disaster Management**	2-0-0	2
3	ES 2102	**Igneous Petrology**	2-0-0	2
4	ES 2103	**Metamorphic Petrology**	2-0-0	2
5	ES 2104	**Geoinformatics in Geosciences**	3-0-0	3
6	ES 2151	**Igneous Petrology Practical**	0-0-3	2
7	ES 2152	**Metamorphic Petrology Practical**	0-0-3	2
8	ES 2153	**Application of RS and GIS in Petrology, Structural Geology and Geomorphology**	0-0-3	2
9	ES 2154	**Geology Field Training and viva voce**		3 (2+1)
TOTAL				**21**
THIRD SEMESTER				
Sl. No	**Sub. Code**	**Subjects**	**L-T-S**	**Credits**
1	ES 3101	**Hydrogeology**	3-0-0	3
2	ES 3102	**Fuel Geology**	3-0-0	3
3	ES 3103	**Ore Geology**	2-0-0	2
4	ES 3104	**Engineering Geology**	3-0-0	3
5	ES 3105	**Sedimentology**	2-0-0	2
6	ES 3151	**Hydrogeology and Engineering Geology Practical**	0-0-3	2
7	ES 3152	**Fuel Geology Practical**	0-0-3	2
8	ES 3153	**Ore Geology Practical**	0-0-3	2
9	ES 3154	**Sedimentology Practical**	0-0-3	2
10	ES 3155	**Research Project-I and Seminar**		3 (2+1)
TOTAL				**24**
FOURTH SEMESTER				
Sl. No	**Sub. Code**	**Subjects**	**L-T-S**	**Credits**
1	ES 4101	**Environmental Geology**	3-0-0	3
2	ES 91**	**Elective-II**	3-0-0	3
3	ES 91**	**Elective-III**	3-0-0	3
4	ES 4151	**Research Project-II**	0-0-10	10
5	ES 4152	**Seminar and Viva-Voce**		2
TOTAL				**21**
Sum Total				**87**

	List of Professional Electives						
Sl. No	**Sub. Code**	**Subjects**				**L-T-S**	**Credits**
El-I	ES 9101, 02, 03, and 04	**Geodynamics**	**Applied Geochemistry**	**Isotope Geology and Geochronology**	**Paleoclimatology**	3-0-0	3
El-II	ES 9105, 06, 07, and 08	**Exploration Geophysics**	**Applied Micropalaeontology**	**Mineral Exploration**	**Geostatistics**	3-0-0	3
El-III	ES 9109, 10, 11, and 12	**Hydrocarbon Exploration**	**Oceanography**	**Contaminant Hydrogeology**	**Precambrian Geology**	3-0-0	3

COMPULSORY COURSES

ES1101	MINEARAL SCIENCE		L	T	S	C
			3	**0**	**0**	**3**
Designation	**Compulsory**	Course type	**Theory**			
Pre-requisites	--	Contact hours:	**42**			
Department	**Earth and Environmental Studies**					

Course Content

Unit I: (**15 Hours**)

Structural formulae; Substitution of elements/solid solution and experimental work on pressure-temperature stability of the minerals; Chemical composition and unit cell content; Crystal structures of common silicate and non-silicate minerals.

Unit II: (**15 Hours**)

Energetics of crystal systems; Unit Cells; Crystal structure; Symmetry Elements – External and Internal symmetry; Bravais Lattice; Concept of Space group; derivation of 32 point groups; crystal defects; Introduction to X-ray crystallography; X-ray Diffractometer.

Unit III: (**12 Hours**)

Uniaxial and Biaxial Minerals; Optical Indicatrix, Birefringence, pleochroism and interference phenomena in minerals; dispersion in minerals; Optical anomalies; Optical accessories: quartz, mica, and gypsum plate.

Essential Reading:

1. D. Perkins, *Mineralogy 3rd Edition* (English, Paperback), Pearson Publications, 2015.
2. D. W. Nesse, *Optical Mineralogy*, McGraw Hill, 1986
3. A. Putnis, *Introduction to Mineral Sciences,* Cambridge University Press, 1992.

Supplementary Reading:

1. P.F. Kerr, *Optical Mineralogy,* McGraw Hill, 1977.
2. P.K. Verma, *Optical Mineralogy*, CRC Press, 2010.

ES1102	Fundamentals of Remote Sensing and Geoinformatics		L	T	S	C
			3	**0**	**0**	**3**
Designation	**Compulsory**	Course type	**Theory**			
Pre-requisites	--	Contact hours:	**42**			
Department	**Earth and Environmental Studies**					

Course Content

Unit I: (**18 Hours**)

Overview of Remote Sensing: Definition, concepts and types; Electromagnetic Radiation; Radiometric Terms and Definitions; Radiation laws; EM Spectrum, Sources of EMR, Atmospheric windows, Interaction of EMR with atmosphere and target; Colour concept. Imaging Spectrometry: Spectral signature for various land cover feature; RS Data Acquisition Mechanism, Data Types and Errors; Platform: Types of platforms, ground, airborne and space borne platforms; Basics of Aerial photographs; Orbit of satellite: Kepler's law, satellite characteristics; satellites for earth observation studies and planetary missions (e.g., Chandrayan); Sensors: Types and classification of sensors, Imaging modes, characteristics of optical sensors, Sensor resolution- spectral, spatial, radiometric and temporal; Data quality and sources of RS data: Global and Indian data products Panchromatic (B &W) and False Colour Composite (FCC); Aerial survey using Digital cameras.
Visual image Interpretation: Principles of visual interpretation of aerial photos and satellite imagery; Recognition elements and interpretation keys for Visual Interpretation; techniques of visual interpretation and interpretation equipment; Relief and tilt corrections for aerial photographs; Interpretation of Multispectral Imagery; Principles of Microwave Remote Sensing (imaging and non-imaging), Microwave Bands, Active and Passive Microwave Sensors, Imaging Radar Geometry, Synthetic Aperture Radar (SAR), SAR versus other Earth Observation Instruments; Thermal and Hyper spectral Remote Sensing: Physics of Thermal Remote Sensing, Kinetic & Radiant temperature, emissivity of different material Atmospheric effects, Thermal properties of materials, Satellite Thermal systems (Characteristics of sensors, Resolutions), Characteristics of images and different types of available data products, Thermal Image Interpretation, Information extraction from thermal imagery:

Unit II: (**18 Hours**)

Fundamentals of GIS: Introduction to GIS, Understand the difference between GIS and Information Systems in general; GIS Components and functions of GIS: Data types and spatial data models; Idea of conceptual, logical and physical models. RDBMS, Database normalization Representation of the real world via a vector and raster representation model; Coordinate systems and map projections, concepts of measurements by triangles traversing, planer polar, and spherical coordinate systems, concept of Datum and its parameters, Horizontal and vertical Datums; Internet GIS, location based services, 3D GIS, crowdsourcing

Data Input and Output: Spatial and Non spatial data: Spatial data and attribute data, their sources, types of attributes; geographical data formats; Spatial input techniques and devices used; Digitizing, Editing and structuring map data, Topology Creation, concepts of adjacency, connectivity and area (containment); Spaghetti vs topological vector data.

Spatial and Network Analysis: Vector & raster based analysis: Attribute data analysis, Integrated spatial and attribute data analysis: Single and multi-layer raster and vector analysis.

Unit III: (**6 Hours**)

Introduction to GNNS: History, Transit, Timation, NAVSTAR GPS, GLONASS, GALILEO;

Essential Reading:

1. J. George, *Fundamentals of Remote Sensing*; University Press (India) Pvt. Ltd., Hyderabad, India, 2005.
2. M. T. Lillesand, W. K. Ralph, J. Chipman, *Remote Sensing and Image Interpretation*, 6th Edition, John Wiley, 2008.
3. J. B. Campbell, *Introduction to Remote Sensing*, Guilford Press, 2002.
4. Sabins, F.F, Remote sensing: Principles and interpretation. W.H.Freeman& Co. New York.1986.
5. Jensen, R.Jhon, The Remote Sensing Process. 2009
6. Llifffe, Jonathan and Lott, Roiger (2008):Datum and Map Projections: For Remote sensing and GIS Surveying. 2nd ed.: CRC Press, 2008
7. Sanjib K. Ghosh (2005): Fundamentals of Computation Photogrammetry. Concept Publishing, New Delhi.
8. Kraak Menno-Jan and Ormelling Ferjan (2003). Cartography: Visualization of Geospatial data, 3rd ed.,Harlow: Prentice Hall, 2003. IX, 205 p.
9. deMers, M.N. (1997) Fundamentals of Geographic Information Systems. John Wiley and Sons.

ES1103	STRUCTURAL GEOLOGY		L	T	S	C
			3	**0**	**0**	**3**
Designation	**Compulsory**	Course type	**Theory**			
Pre-requisites	--	Contact hours:	**42**			
Department	**Earth and Environmental Studies**					

Course Content

Unit I: **(6 Hours**)

Mechanical properties of rocks; Concept of dynamic and kinematic analyses of rocks in two dimensions.

Unit II: (**18 Hours)**

Mathematical treatment of stress, strain, flow, Strain measurements, Micro-structures and Grain scale deformation mechanisms; Paleostress analysis.

Unit III: (**18 Hours)**

Superposed fold analysis; Faulting - Thrust Belts, Normal fault systems, Dynamics of faulting; Shear zones – Classification and geometry of different types of shear zones, Strain variation in shear zones, shear sense indicators; GPS and active tectonics; Earthquake and fault analysis.

Essential Reading:

1. Haakon Fossen, *Structural Geology,* Cambridge University Press; 1st edition, 2010.
2. G. H. Davis, S. J. Reynolds, C. F. Kluth, *Structural Geology of Rocks and Regions,* Wiley; 3rd edition, 2011.
3. J. Jaeger, N. G. Cook and R. Zimmerman, *Fundamentals of Rock Mechanics,* Wiley-Blackwell; 4th edition, 2007.
4. S. K. Ghosh, *Structural Geology: Fundamentals and modern development*, Pergamon; 1st edition, 1993.
5. Passchier, C. W. and Trouw, R.A.J., *Microtectonics,* Springer-Verlag, Berlin, Heidelberg; 2nd Edition, 2005.

Supplementary Reading:

1. J.G. Ramsay, M.I. Huber, *Techniques of Modern Structural Geology, Vol. II, Folds and Fractures,* Academic Press, 1987.
2. J.G. Ramsay, R.J. Lisle, *Techniques of Modern Structural Geology, Vol. III (Application of continuum mechanics),* Academic Press, 2000.

ES 1104	APPLIED GEOMORPHOLOGY AND QUATERNARY GEOLOGY		L	T	S	C
			3	**0**	**0**	**3**
Designation	**Compulsory**	Course type	**Theory**			
Pre-requisites	--	Contact hours:	**42**			
Department	**Earth and Environmental Studies**					

Course Content

Unit I: (**14 Hours**)

Introduction to earth surface processes and historical development in concepts; terrestrial relief, scales in geomorphology; Dynamics of geomorphology, energy flow and relative energy of surface processes; Climatogenetic geomorphology; Weathering and formation of soils, karst and speleology, slope and catchment erosion processes, fluvial, aeolian, glacial, periglacial and coastal processes and resultant landforms; Water and sediment flux in river systems; geomorphic processes and resulting landforms geomorphic features of Indian sub continents; Geomorphological mapping based on genesis of landforms; morphometric analysis and modelling terrain evaluation for strategic purpose.

Unit II: (**10 Hours**)

Rates and changes in surface processes; Techniques for process measurement-sediment budgeting, rock magnetism, isotope geochemical tracers, cosmogenic nuclides, OSL & C-14 dating. Controlling factors (tectonics, climate, sea level changes and anthropogenic) and surface processes; Climate change and geomorphic response of fluvial systems of arid and humid regions; Geomorphic response to tectonics, sea level/base level change, anthropogenic affects.

Unit III: (**12 Hours**)

Definition, character and duration of Quaternary; Quaternary geomorphology; Quaternary time scale; Quaternary climate - Sea level changes, glacial/interglacial cycles, tectonics-climate coupling, sea floor spreading, BLAG hypothesis, Uplift-weathering hypothesis, carbon reservoir, vegetation dynamics, migration history, response of vegetation to climatic reversals; Quaternary Stratigraphy - oxygen isotope stratigraphy, biostratigraphy and magnetostratigraphy; Quaternary dating methods - Radiocarbon, Uranium series, Luminescence, Cosmogenic nuclides, Amino acid, Relative dating methods; Proxy indicators of paleoenvironmental/paleoclimatic changes; Quaternary Stratigraphy of India- continental records and marine records; Geoarchaeology; Introduction to Anthropocene, Meghalayan age.

Unit IV: (**6 Hours**)

Applied Geomorphologic mapping: Geomorphic classification systems, Role of geomorphic maps in different geo-scientific applications; Broad Geo-morphological setting of Indian Peninsula and surrounding; Isostasy and Climate-Tectonic interaction and feedback mechanism.

Essential Readings:

1. Bradley, F., *Paleoclimatology: Reconstructing Climates of the Quaternary,* Springer. Verlag 2000.
2. Maher and Thompson, *Quaternary Climates, Environments and Magnetism,* Cambridge University Press. 2000.
3. Williams, Durnkerley, Decker, Kershaw and Chhappell, *Quaternary Environments,* Wiley and Sons, 1998.
4. Selby,M.J (1985): Earth's Changing Surface- An Introduction to Geomorphology. Clarendon Press, Oxford. 607p.
5. Goswami,A.B. (2010): Principles of Quaternary Geology and Environment Study-Concept, Methodology and Technique. Books Way, Kolkata. 157p.
6. Van Zuidam,A.Robert (1985):Aerial Photo- Interpretation in Terrain Analysis And Geomorphologic Mapping. ITC.Smit Publishers, The Hague, The Netherlands.422p

Supplementary Readings

1. William F. Ruddiman*, Earth's Climate: Past and future,* W. H. Freeman & Co Ltd., 1st edition, 2001.

ES1151	**MINEARAL SCIENCE PRACTICAL**		L	T	S	C
			0	**0**	**3**	**2**
Designation	**Compulsory**	Course type	**Laboratory**			
Pre-requisites	--	Contact hours:	**36**			
Department	**Earth and Environmental Studies**					

Mineralogy: Identification of rock-forming minerals in hand specimens.

Optical Mineralogy: Determination of length fast and length-slow characters of minerals Scheme of pleochroism and absorption of a given mineral in thin section. Determination of extinction angle and composition of plagioclase. Study of interference figures of uniaxial and biaxial crystals, determination of optic signs.

Crystallography: Representation of symmetry elements of crystals belonging to 32 classes of symmetry and study of their stereograms; Indexing and calculation of cell parameters of cubic, tetragonal and hexagonal crystals; Identification of minerals from study of XRD data. Use of SEM; Calculation of structural formula from chemical data.

ES1152	Fundamentals of Remote Sensing and GIS Practical		L	T	S	C
			0	**0**	**3**	**2**
Designation	**Compulsory**	Course type	**Laboratory**			
Pre-requisites	--	Contact hours:	**36**			
Department	**Earth and Environmental Studies**					

Study of Satellite Image Annotation (information) LANDSAT, SPOT and IRS and Referencing Scheme (Analog); Digital Referencing Scheme (NRSC/Digital globe/space imaging etc); IR - Thermal Radiation Measuring Instruments and drawing of Isotherms and plotting diurnal variation curve; Spectral Response Pattern of different Land cover objects; Study of Satellite Imagery (B/W) in Different bands and Visual Interpretation; Ground Data collection instruments, Radiometers, Spectrometers etc. and Ground Data collection in a given area with the help of Radiometers and Spectrometers; Digital Interpretation and preparation of Land use and geological Mapping at 1:50,000 scale; Field exercise on visual Image interpretation and validation using ground data.

Familiarization With GIS Software; Geo-referencing and Projection (Overview of Projections & Datums); Spatial data Entry; Spatial Data Editing & Topology Creation; Linking Spatial and Non Spatial Data Entry; Practical exercise on DBMS; Spatial and Non spatial Query and Analysis (Raster based analysis); Vector Data Analysis, Network Analysis and Modelling; Output Map Generation; Multi criteria Analysis

ES1153	STRUCTURAL GEOLOGY PRACTICAL		L	T	S	C
			0	**0**	**3**	**2**
Designation	**Compulsory**	Course type	**Laboratory**			
Pre-requisites	--	Contact hours:	**36**			
Department	**Earth and Environmental Studies**					

Analysis and interpretation of geological maps; Stereographic analysis of structural data; Use of specialized software, (Ge-orient, Global Mapper, etc.); Stereographic techniques: Significance of contour diagrams: orientation analyses of foliation and lineation data for regional structural geometry; Structural problems related to borehole data; Mohr Circle problems, Rf-ϕ method, Fry method; Microstructures in thin sections; Balanced cross sections.

ES1154	COMPUTER TOOLS AND TECHNIQUES		L	T	S	C
			0	**1**	**3**	**3**
Designation	**Compulsory**	Course type	**Laboratory**			
Pre-requisites	--	Contact hours:	**48**			
Department	**Earth and Environmental Studies**					

Course Content

Unit I: (**18 Hours**)

Problem solving using computer program, Algorithm, Data Structures and program, Compilers, Software tools, IDE, Example of common scientific computing languages (C, C++, MATLAB, Python, etc.), Demonstration of program writing and execution using suitable sample examples.

Unit II: (**18 Hours**)

Familiarisation with a programming language like SEJLAB or Python, Identification of appropriate libraries related to geoscience and illustration of the usage thereof.

Unit III: (**12 Hours**)

Familiarising few popular software tools related to geoscience (such as MODFLOW, ROCK WARE, RSE GLS, Aquachem, PHREEQC, SPSS, etc.)

Essential Reading:

1. Rajaraman V. 2004, Computer Programming in Fortran 90 and 95. Prentice-Hall of India Pvt. Ltd (PHI).
2. Brainerd W. S. 2015, Guide to Fortran 2008 Programming. Springer-Verlag, London.
3. Chivers I. and Sleightholme J. 2015, Introduction to Programming with Fortran (With Coverage of Fortran 90, 95, 2003, 2008 and 77). Springer, Cham.
4. Kanetkar Y. P. 2016, Let us C. BPB publications. Brief overview of C language.

ES2101	NATURAL HAZARD AND DISASTER MANAGEMENT		L	T	S	C
			2	0	0	2
Designation	**Compulsory**	Course type	**Theory**			
Pre-requisites	--	Contact hours:	**28**			
Department	**Earth and Environmental Studies**					

Course Content

Unit I: **(7 Hours)**

Introduction to Disasters: Definition: Disaster, Hazard, Vulnerability, Resilience, Risks– Disasters: Types of disasters anthropogenic and natural: Earthquake, Landslide, Flood, Drought, Forest Fire, etc–Classification, Causes, Impacts including social, economic, political, environmental, health, psychosocial, etc.- Differential impacts- in terms of caste, class, gender, age, location, disability – Global trends in disasters: urban disasters, pandemics, complex emergencies, Climate change- Dos and Don'ts during various types of Disasters.

Unit II: **(7 Hours)**

Approaches to Disaster Risk Reduction (DRR): Disaster cycle – Phases, Culture of safety, prevention, mitigation and preparedness community based DRR, Structural- nonstructural measures, Roles and responsibilities of- community , Panchayati Raj Institutions/Urban Local Bodies (PRIs/ULBs), States, Centre, and other stakeholders- Institutional Processess/ capacity building and Framework at State and National Levels- State Disaster Management Authority(SDMA)/ NDMA – Early Warning System – Advisories from Appropriate Agencies.–

Unit III: **(7 Hours)**

Disaster Risk Management in India: Hazard and Vulnerability profile of India, Components of Disaster Relief: Water, Food, Sanitation, Shelter, Health, Waste Management, Institutional arrangements (Mitigation, Response and Preparedness, Disaster Management Act and Policy, Coastal Regulation Zone – Other related policies, plans, programmes and legislation.

Unit IV: **(5 Hours)**

Applications And Case Studies: Landslide Hazard Zonation, Earthquake Vulnerability Assessment of Buildings and Infrastructure, Drought Assessment, Cyclone and Tsunamis; Floods: Fluvial and Pluvial Flooding; Forest Fire, Man Made disasters, Space Based Inputs for Disaster Mitigation and Management and field works related to disaster management.

Unit V: **(2 Hours)**

Role of GIS and Information Technology Components in Preparedness, Risk Assessment, Response, Recovery and Rehabilitation Phases of Disaster – Disaster Damage Assessment.

Essential Reading:

1. Singhal J.P. "Disaster Management", Laxmi Publications, 2010. ISBN-10: 9380386427 ISBN-13: 978-9380386423
2. Tushar Bhattacharya, "Disaster Science and Management", McGraw Hill India Education Pvt. Ltd., 2012.
3. ISRO publications on "Effective use of Space Technology in Disaster Mitigation and Management", 2000-2018.

Supplementary Reading:

1. Gupta Anil K, Sreeja S. Nair. Environmental Knowledge for Disaster Risk Management, NIDM, New Delhi, 2011
2. Kapur Anu Vulnerable India: A Geographical Study of Disasters, IIAS and Sage Publishers, New Delhi, 2010.

ES2102	IGNEOUS PETROLOGY		L	T	S	C
			2	**0**	**0**	**2**
Designation	**Compulsory**	Course type	**Theory**			
Pre-requisites	--	Contact hours:	**25**			
Department	**Earth and Environmental Studies**					

Course Content

Unit I: (**12 Hours**)

Phase rule, Selected Binary and Ternary phase diagrams; Chemical Petrology, its application to igneous petrogenesis: Major and minor elements and trace elements and isotopes, trace element modelling; Generation of basaltic magmas: Petrology of the mantle and mantle heterogeneity. Melting of the mantle and generation of primary magmas.

Unit II: (**13 Hours**)

Controls on magma segregation. Diversification of magmas – physical and chemical attributes of partial melting, magmatic differentiation, magma mixing, assimilation and mixed processes. Large Igneous Provinces. Magma generation with respect to Plate Tectonic setting.

Essential Reading:

1. Myron G. Best, *Igneous and Metamorphic Petrology,* Wiley-Blackwell; 2nd edition, 2002.
2. John D. Winter, *Principles of Igneous and Metamorphic Petrology,* Prentice Hall; 2nd edition, 2009.
3. Anthony Philpotts, Jay Ague, *Principles of Igneous and Metamorphic Petrology,* Cambridge University Press; 2nd edition, 2009.

Supplementary Reading:

1. Powell, R., *Equilibrium thermodynamics in Petrology: An Introduction,* Harper and Row Publ., London, 1978.

ES2103	METAMORPHIC PETROLOGY		L	T	S	C
			2	**0**	**0**	**2**
Designation	**Compulsory**	Course type	**Theory**			
Pre-requisites	--	Contact hours:	**26**			
Department	**Earth and Environmental Studies**					

Unit I: (**10 Hours**)

Metamorphism: A plate tectonic overview. Heat flow, geotherms and thermal models. Variance of metamorphic paragenesis. Thermodynamics of homogeneous and heterogeneous systems. Characterization of intensive and extensive variables through modeling of metamorphic reactions. Metamorphic mineral nucleation and crystal growth.

Unit II: **(16 Hours**)

Construction of petrogenetic grids. Progressive metamorphism of calcareous, pelitic and mafic rocks. Compositional zoning, Geothermobarometry and metamorphic P-T-t paths.

Essential Reading:

1. Myron G. Best, *Igneous and Metamorphic Petrology*, Wiley-Blackwell; 2nd edition, 2002.
2. John D. Winter, *Principles of Igneous and Metamorphic Petrology*, Prentice Hall; 2nd edition, 2009.
3. Anthony Philpotts, Jay Ague, *Principles of Igneous and Metamorphic Petrology,* Cambridge University Press; 2nd edition, 2009.

Supplementary Reading:

1. Anthony Hall, *Igneous Petrology*, Longman Sci. & Tech, 1987.
2. Powell, R., *Equilibrium thermodynamics in Petrology: An Introduction,* Harper and Row Publ., London, 1978.

ES2104	GEOINFORMATICS IN GEOSCIENCES		L	T	S	C
			3	**0**	**0**	**3**
Designation	**Compulsory**	Course type	**Theory**			
Pre-requisites	--	Contact hours:	**42**			
Department	**Earth and Environmental Studies**					

Course Content

Unit I: **(9 Hours)**

Digital Image Processing (DIP) for Geological Applications: Geometric and basic atmospheric correction, Digital enhancement and visualization, image transformation (band arithmetic, indices, Principal Component Analysis, De-Correlation stretching), Spatial filtering, Image classification and information extraction for geological applications.
Image segmentation, textural analysis, Morphological image processing, FFT, and wavelength transformation for geological applications.

Unit II: **(9 Hours)**

Geo-database creation, Geospatial analysis and output generation: Creation of geological database in GIS, data structure and data organization, data conversion, logical and mathematical operations, basic data integration, spatial analysis and map composition/layout preparation.

Digital Terrain Modelling (DEM): Generation of DEM, integration and composition of DEM from different sources, derivation of terrain components for geological applications, preparation of shaded relief and anaglyph images.

Unit III: **(7 Hours)**

RS for Geo-Scientific applications: Principles of RS data interpretation in Geology, RS image interpretation for Lithological Mapping, Structural Feature Identification and Analysis; Thermal RS for geological applications and earthquakes studies; volcano monitoring; microwave RS for Geological applications.

Unit IV: **(6 Hours)**

RS for Mineral Exploration: Surface indicators of Mineral Exploration; Spectroscopy of rocks and Minerals; Multi-spectral and Hyper-spectral RS for Mineral Exploration; Geochemical Anomaly mapping; Geophysical methods of exploration and integration with S; Minerals exploration modelling and Data integration, Exploration of radioactive minerals.

Unit V: **(5 Hours)**

RS for Hydrocarbon Exploration: Types of hydrocarbon resources; Mode of occurrence and surface indicators; RS for mapping geological & geo-morphological anomalies related to petroleum occurrence's; Exploration of shallow Gas, Gas Hydrates, ad Coal Bed Methane (CBM).

Unit VI: **(6 Hours)**

Planetary Geology: Overview of Planetary Missions; RS of Planetary surfaces; Major processes affecting planetary surfaces; Lunar Geology: observations from previous recent missions; Chyandrayaan-1: Mission objectives and fulfilment of aspirations; Chandrayaan-2: Mission objectives.

Essential Reading:

1. J. George, *Fundamentals of Remote Sensing*; University Press (India) Pvt. Ltd., Hyderabad, India, 2005.
2. J. B. Campbell, *Introduction to Remote Sensing*, Guilford Press, 2002.
3. Llifffe, Jonathan and Lott, Roiger (2008): Datum and Map Projections: For Remote sensing and GIS Surveying. 2nd ed.: CRC Press, 2008
4. Sanjib K. Ghosh (2005): Fundamentals of Computation Photogrammetry. Concept Publishing, New Delhi.

Supplementary Reading:

1. Longley, Paul A, Goodchild, Michael F., Maguire, David J., and David W. Rhind. (2005) Geographic Information Systems and Science, 2nd ed., John Wiley and Sons, Toronto.
2. M. T. Lillesand, W. K. Ralph, J. Chipman, *Remote Sensing and Image Interpretation*, 6th Edition, John Wiley, 2008.

ES2151	IGNEOUS PETROLOGY PRACTICAL		L	T	S	C
			0	**0**	**3**	**2**
Designation	**Compulsory**	Course type	**Laboratory**			
Pre-requisites	--	Contact hours:	**36**			
Department	**Earth and Environmental Studies**					

Calculation of norms, Study of igneous rock textures; Petrographic study of common igneous rocks, Application of phase diagrams in determining the liquid line of descent; Numerical problems related to partial melting and Fractional crystallization.

ES2152	METAMORPHIC PETROLOGY PRACTICAL		L	T	S	C
			0	**0**	**3**	**2**
Designation	**Compulsory**	Course type	**Laboratory**			
Pre-requisites	--	Contact hours:	**36**			
Department	**Earth and Environmental Studies**					

Identification of common metamorphic minerals; interpretation of metamorphic textures in relation to fabric elements; Construction of ACF and AFM diagram from chemical and mineralogical data.

ES2153	GEOINFORMATICS IN GEOSCIENCES PRACTICAL		L	T	S	C
			0	**0**	**3**	**2**
Designation	**Compulsory**	Course type	**Laboratory**			
Pre-requisites	--	Contact hours:	**39**			
Department	**Earth and Environmental Studies**					

End to end data processing for geological and geo-morphological mapping and terrain analysis; DEM generation using DGPS survey and satellite stereo pair, DEM integration and comparison. Identification and interpretation of Igneous, metamorphic and sedimentary rocks types; Detection, identification and analysis of structural elements (viz., bedding, folds, faults, joints, faults, unconformities); Interpretation of thermal imagery for lithological and geo-environmental applications; Interpretation of microwave data and its comparison with optical RS data; Spectral analysis of rocks and minerals; GIS and RS based case examples for minerals and oil exploration.

Tectonic landform mapping and analysis using aerial RS and high resolution multi-spectral images; Morphometric and geomorphic indices of active tectonics using DEM; Applied geo-morphological mapping using moderate resolution satellite data.

ES3101	**HYDROGEOLOGY**		L	T	S	C
			3	**0**	**0**	**3**
Designation	**Compulsory**	Course type	**Theory**			
Pre-requisites	--	Contact hours:	**42**			
Department	**Earth and Environmental Studies**					

Course Content

Unit I: **(10 Hours)**

Hydro geochemical principles and Chemical evolution of natural ground water; Chemical Constituents of groundwater; Chemical equilibrium; mineral dissolution and solubility; REDOX process; Ion exchange and adsorption; Hydrochemical sequence and facies; groundwater in crystalline rocks, carbonate rocks and in sedimentary systems.

Unit II: **(10 Hours)**

Quantitative Assessment of groundwater resources; Exploration techniques surface and subsurface geological and geo physical method; well hydraulics; measurement of parameters; basin yield ;land subsidence; seawater intrusion . Rainwater Harvesting and Groundwater recharge

Unit III: **(10 Hours)**

Groundwater Flow transport and contamination; Flow in saturated and vadose zone, dating of groundwater retardation, diffusion, dispersion, sources of Contamination Hydrochemical behaviour of contaminants groundwater modelling.

Unit IV: **(10 Hours)**

Application of RS & GIS in hydrogeology: Hydrological properties of different rocks, structure, land forms palaeochannels and their detection from remotely sensed data, hydrogeological provinces in India groundwater targeting in different geologic terrains using RS data and GIS techniques, run off estimation , quantification of groundwater resources; groundwater quality and pollution assessment, sea-water intrusion and land subsidence due to groundwater withdrawal.

Essential Reading:

1. D. K. Todd, L. W. Mays, *Groundwater Hydrogeology*, John Wiley & Sons, 3rd Edition, 2005
2. O. M. Phillips, *Geological Fluid Dynamics Su-surface Flow and Reactions*, Cambridge University Press, 2009

3. K. R. Karanth, *Ground Water Assessment, Development and Management,* Tata Mc Graw Hill,1987.
4. G. de Marsily, *Quantitative Hydrogeology: Groundwater Hydrology for Engineers,* Academic Press, 1986.
5. A.M.J.Meijerink et.al. (1994): *Introduction to the use of Geographic Information Systems for Practical Hydrology*. International Institute of Aerospace Survey and Earth Sciences (ITC), The Netherlands. Pub. No.23. p.243.

Supplementary Reading:

1. C. A. J. Appelo, D. Postma, *Geochemistry, Groundwater and Pollution*, A. A. Balkema, 2005.
2. F. H. Chapelle, F. Chapelle, *Ground-water Microbiology and Geochemistry*, John Wiley & Sons, 2001.
3. K. Subramanya, *Engineering Hydrology*, 3rd Edition, Tata Mc Graw Hill Pvt Limited, 2008

ES3102	FUEL GEOLOGY		L	T	S	C
			3	**0**	**0**	**3**
Designation	**Compulsory**	Course type	**Theory**			
Pre-requisites	--	Contact hours:	**42**			
Department	**Earth and Environmental Studies**					

Course Content

Unit I: **(14 Hours)**

Coal Geology: Origin of coal; macroscopic and microscopic constituents Concept and classification of 'Lithotype', 'Maceral' and 'Microlithotype; Classification of coal in terms of Rank, Grade and Type; Classification for coking and non-coking coals;

Definition and origin of coal; Sedimentology of coal bearing strata types of seam discontinuities and structures associated with coal seams; Physical and Chemical characteristics of coal; Biochemical and dynamochemical changes in coal formation; distribution of coal in space and time with special reference to India; clean coal technology.

Unit II: **(14 Hours)**

Petroleum Geology: Petroleum, its composition, Origin (Formation of source rocks-kerogen, organic maturation and thermal cracking of kerogen), and migration of petroleum; Reservoir rocks-porosity and permeability; Reservoir traps: structural, stratigraphic and combination traps; Oil field fluids: water, oil and gas; Onshore and offshore petroliferous basins of India. Oil-shale and shale-oil.

Unit III: **(14 Hours)**

Coalbed methane (CBM) – a new energy resource; Present status of CBM; Elementary idea about formation, properties, and generation of CBM; coal as a reservoir and CBM exploration; Hydro-fracturing of coal seams; Overview of drilling and production systems of CBM wells.

Nature, origin and distribution of Shale Gas/Oil; characterization of shale for production of Shale Gas/Oil; extraction methods of Shale gas/Oil; development of current practices; environmental issues in shale gas exploration.

Essential Reading:

1. L. D Thomas, *Coal Geology,* Wiley-Blackwell; 2nd Edition, 2012.
2. D. Chandra, R.M. Singh, M. P. Singh, *Textbook of Coal (Indian context),* Tara Book Agency, Varanasi, 2000.
3. R.C. Selley, *Elements of Petroleum Geology,* Academic Press, USA, 1997.
4. Titayeva, *Nuclear Geochemistry,* CRC Press, 1994.

Supplementary Reading:

1. R.E Chapman, *Petroleum Geology,* Elsevier Science Publishers 1983.
2. G.D. Holson and E.N. Tiratso, *Introduction of Petroleum Geology,* Fulf Publishing, Houston, Texas, 1985.
3. K. Bjørlykke, *Petroleum Geoscience: From Sedimentary Environments to Rock Physics,* Springer, 2010.
4. A.C. Scott, *Coal and Coal-bearing strata: Recent Advances*, The geological Society of London, Publication no; 32, Blackwell scientific Publications, 1987.

ES3103	ORE GEOLOGY		L	T	S	C
			2	**0**	**0**	**2**
Designation	**Compulsory**	Course type	**Theory**			
Pre-requisites	--	Contact hours:	**26**			
Department	**Earth and Environmental Studies**					

Course Content

Unit I: (**12 Hours**)

Ore forming processes; Metallogeny and crustal evolution - spatial-temporal distribution of ore deposits; Study of ores in all possible scales of observation; phase equilibria in common ore bearing systems.

Unit II: (**14 Hours**)

Ores in mafic and ultramafic rocks: Chromite Ores, Ni-Cu-sulphide (+PGE) and Fe-Ti oxide deposits; Ores in felsic rocks: Porphyry Cu-Mo, Sn-W, skarns and near-surface epithermal Au-Ag-(Cu) deposits; Sources of ore fluid and metals through fluid inclusions and stable isotopes;

Essential Reading:

1. L. Robb, *Introduction to Ore-forming processes,* Blackwell Publishing, Oxford, 2005.
2. J. Ridley, *Ore Deposit Geology,* 1st edition, Cambridge university press, 2013.
3. A.M. Evans, *Ore Geology and Industrial Minerals: An Introduc*tion, 3rd Edition, Blackwell Publishing, Oxford, 1993.
4. A. Mookherjee, *Ore genesis–A holistic approach,* Allied Publisher, New Delhi, 1999.
5. M. Deb and S. C. Sarkar, *Minerals and Allied Natural Resources and their Sustainable Development – Principles, Perspectives with emphasis on the Indian scenario,* Springer, 2017.

Supplementary Reading:

1. J.R. Craig, D.J. Vaughan, *Ore Microscopy and Ore Petrography,* Wiley-Blackwell, 2nd Edition, 1994.
2. B. Pracejus *The Ore Minerals Under the Microscope,* Volume 3: An Optical Guide (Atlases in Geoscience) 2nd Edition 2015.
3. W. Pohl, *Economic Geology: Principles and Practice,* Wiley-Blackwell 1st Edition 2011.

ES 3104	ENGINEERING GEOLOGY		L	T	S	C
			3	**0**	**0**	**3**
Designation	**Compulsory**	Course type	**Theory**			
Pre-requisites	--	Contact hours:	**42**			
Department	**Earth and Environmental Studies**					

Course Content

Unit I: (11 Hours)

Civil Engineering Projects, geology and ground model: Project Management, Design of structures, design codes, Application of engineering geological principles; Concept of modelling, Geological reference models; Geological structures, Weathering, Geological hazards, Ground model for Engineering projects, Engineering properties of rocks, Geo-mechanical classification of rock mass, Rock Quality designation (RQD), Rock structure Rating (RSR) , Rock Mass Rating (RMR), Tunnelling Quality Index(TQI); Slope mass rating (SMR), 3D logging and drill core logging.

Unit II: (11 Hours)

Site investigation Analysis, Design and construction: Planning of ground investigation considering geological factors, environmental factors and construction related factors with reference to dam and Reservoir, Tunnel, Bridge foundation, building foundation, mass movement, slope stability problems-prediction and optimum design of slope including benches in mines and mine dumps ; seismic influence and earthquake resistive design; Criteria for selection of suitable dam, powerhouse and its appurtenant structures, Dam foundation mapping, delineation of adverse geological features, treatment and support measures; a few case studies related to geological problems.

Unit III: (7 Hours)

Roll of groundwater in engineering geology: Pore pressure, landsides and slope stability, influence of groundwater to dam and reservoir, inflow of groundwater into tunnel, inflow of groundwater into excavation.

Unit IV: (13 Hours)

Application of RS and GIS in engineering geology: RS based study of dam/ reservoir site selection in deferent geological setting, EIA of dam and reservoir, reservoir rim area, monitoring, land uses / land cover change analysis, analysis of impact of drawdown reservoir induced landslide assessment, RS application for mapping and monitoring of landslides, landslide hazard and risks modelling, mitigation and management.

Essential Reading:

1. F.G. Bell, *Engineering Geology*, Butterworth-Heinemann; 2nd edition, 2007.
2. Tony Waltham, *Foundations of Engineering Geology*, CRC Press; 3rd edition, 2009.
3. David George Price, Michaelde Freitas, *Engineering Geology: Principles and Practice*, Springer, 2010.

Supplementary Reading:

1. J. Jaeger, N. G. Cook and R. Zimmerman, *Fundamentals of Rock Mechanics*, Wiley-Blackwell; 4th edition, 2007.
2. R. E. Goodman, *Introduction to rock mechanics*, Wiley, 2nd edition, 1989.

ES3105	SEDIMENTOLOGY		L	T	S	C
			2	**0**	**0**	**2**
Designation	**Compulsory**	Course type	**Theory**			
Pre-requisites	--	Contact hours:	**27**			
Department	**Earth and Environmental Studies**					

Course Content

Unit I: **(11 Hours)**

Sedimentary basin; Mechanics of basin formation and classification; Tectonics and sedimantation; Extrabasinal and intra basinal factors in sedimentation patterns; Terrigenous sediments; Petrography- depositional and diagenetic signatures, paleoclimatic and tectonic implications; Chemical Index of Alteration and its paleoclimatic implications. Carbonate sediments – Major controls on carbonate sedimentation, carbonate depositional systems, and carbonate geochemistry.

Unit II: **(12 Hours)**

Depositional system analysis: basic concept, architectural elements, bounding surface hierarchy, facies modelling, cyclic sedimentation: stratigraphic cycles and controlling factors

Unit III: **(4 Hours)**

Sequence stratigraphy : principles and applications

Essential Reading:

1. D.R. Prothero, F. Schwab, *Sedimentary Geology,* W.H. Freeman, 2nd Edition, 2003.
2. G. Nichols, *Sedimentology and Stratigraphy,* Wiley-Blackwell, 2nd Edition, 2012.
3. M. Tucker, *Sedimentary Petrology,* Wiley-Blckwell, 3rd edition, 2001.
4. S. M Sengupta, *Introduction to Sedimentology,* CBS Publications, 2nd Edition, 2007.
5. H.G. Reading, *Sedimentary Environments: Process, Facies and Stratigraphy,* Wiley-Blackwell, 3rd edition, 1996.
6. Allen, P A and J R L Allen : Basin analysis, Blackwel, 2nd edition 2005

Supplementary Reading:

1. S. Boggs, *Principles of Sedimentology and Stratigraphy,* Pearson Education India 5th Edition, 2016.
2. R.C. Selley, *Applied sedimentology,* Academic Press, 2nd edition, 2000.
3. J. Collinson, N. Mountney, D. Thompson, *Sedimentary Structures,* Terra Publishing, 3rd edition, 2006

ES3151	HYDROGEOLOGY AND ENGINEERING GEOLOGY PRACTICAL		L	T	S	C
			0	**0**	**3**	**2**
Designation	**Compulsory**	Course type	**Laboratory**			
Pre-requisites	--	Contact hours:	**36**			
Department	**Earth and Environmental Studies**					

Porosity and Permeability test (Falling bed); Pumping test; Analysis of groundwater quality; satellite image interpretation and analysis for groundwater prospects; groundwater prospect zonation using GIS; groundwater flow modelling using open source/proprietary software.

Liquid limit, plastic limit, density and bulk density of soil; optimum moisture content and dry density of soil; Engineering geological mapping using different type of Remote Sensing data; Exercise on rock properties and strength/failure behaviour of rocks; landslide hazard zonation and risk analysis using RS and GIS; suitable site selection of dam/reservoir, catchment and rim area analysis; route alignment between two points and discharge calculation at bridge site using RS and GIS; grain size, cohesion and friction angel (c & Ø); kinematic analysis for slope

ES3152	FUEL GEOLOGY PRACTICAL		L	T	S	C
			3	**0**	**3**	**4.5**
Designation	**Compulsory**	Course type	**Laboratory**			
Pre-requisites	--	Contact hours:	**36**			
Department	**Earth and Environmental Studies**					

Identification of different types of Coal, lithotypes, cokes and structures associated with coal seams; Proximate analysis of Coal: Determination of moisture, ash and Volatile matter; Petrography of Coal: Polished block study under microscope; Analysis and interpretation of Rock-Eval Pyrolysis Data

ES3153	ORE GEOLOGY PRACTICAL		L	T	S	C
			0	**0**	**3**	**2**
Designation	**Compulsory**	Course type	**Laboratory**			
Pre-requisites	--	Contact hours:	**36**			
Department	**Earth and Environmental Studies**					

Megascopic study of Indian metallic ores and industrial minerals in hand specimens; Study of optical properties and identification of important ore minerals under ore-microscope; Ore texture and paragenesis

ES3154	SEDIMENTOLOGY PRACTICAL		L	T	S	C
			0	**0**	**3**	**2**
Designation	**Compulsory**	Course type	**Laboratory**			
Pre-requisites	--	Contact hours:	**36**			
Department	**Earth and Environmental Studies**					

Petrographic interpretation, litholog correlation, fence diagram, preparation of isopach maps,

ES 4101	ENVIRONMENTAL GEOLOGY		L	T	S	C
			3	**0**	**0**	**3**
Designation	**Compulsory**	Course type	**Theory**			
Pre-requisites	--	Contact hours:	**42**			
Department	**Earth and Environmental Studies**					

Course Content

Unit I: **(12 Hours)**

Ecosystem and mutual interaction among environment segment (atmosphere, lithosphere, hydrosphere and biosphere); Indicators of climate change and impact of climate change in earth system with geologic time; impact of atmospheric and oceanic circulation on climate and agriculture; Cainozoic climate extremes, evolution of life, especially the impact on human evolution; CO_2 in atmosphere, ocean and geologic sequences, records of palaeotemperature in ice cores of glaciers, correction between atmosphere Co2 content and palaeotemperature. Present day Global warming mechanism natural and anthropogenic causes and effects.

Unit II: **(12 Hours)**

Impact assessment of depletion and contamination of surface water and groundwater due to industrialisation, urbanisation mining and agriculture, soil profile and soil quality degradation due to industrialisation, urbanisation, agriculture and mining ;Role of geological in waste disposal, basic of Environmental law, EIA and EMP.

UNIT III: **(10 Hours)**

Distribution, magnitude and intensity of earthquake, Influence of neotectonics in seismic hazard assessment; Environmental effect of volcano; landslides, cyclone and major floods; deforestation and desertification.

Unit IV: **(5 Hours)**

RS & GIS: Thermal Remote Sensing for Geological application viz. Volcano monitoring, coal fire hazard; Mining and environment, Land degradation and desertification, Integrated coastal zone management

Essential Reading:

1. Carla Montgomery, *Environmental Geology,* McGraw-Hill Science/Engineering/ Math; 9th edition, 2010.
2. Edward A. Keller, *Environmental Geology*, Prentice Hall; 9th edition, 2010.

Supplementary Reading:

1. Daniel B. Botkin, *Environmental Science Earth as a Living Planet*, Wiley; 8th edition. 2009.

ELECTIVE COURSES

ES 9101	GEODYNAMICS		L	T	S	C
			3	**0**	**0**	**3**
Designation	**Elective I**	Course type	**Theory**			
Pre-requisites	--	Contact hours:	**42**			
Department	**Earth and Environmental Studies**					

Course Content

Unit I: (20 Hours)

Concept of Tectonics. Continental drift and the origin of Plate Tectonic theory. Tectonics on a sphere. Palaeomagnetism and past plate motions, with emphasis on the history of modern oceans. Components of the oceanic lithosphere - ridges, transform faults, trenches and oceanic islands. The continental lithosphere – cratons, sedimentary basins, continental margins and rift zones. Collisions – characteristics of arc-arc, arc-continent and continent-continent collision zones. Anatomy of orogenic belts – foreland basins, foreland fold-and-thrust belts and Crystalline Core Zones. Origin of mantle discontinuities and implications for mantle convection models. Evidence for single and double-layered mantle convection. Granite tectonics – emplacement mechanisms of granitic plutons, regional tectonics and its influence on fabric development in granites, concept of percolation theory, rheological properties of granite with changing crystal-melt fraction and evolution of fabrics.

Unit II: (20 Hours)

Geodynamics - application of basic geophysical theory to interpretation of geologic phenomena. Heat flow and geothermics – calculation of equilibrium and evolving geotherms. Plate cooling models - relationship between surface heat flow and bathymetric depth. Driving forces for plate motions. Mantle geotherms and adiabats. Elasticity and flexure, and application to the earth's lithosphere. Origin and models of various types of sedimentary basins – basins of thermal origin, flexural basins, extensional basins and compressional basins.

Essential Reading:

1. Kent C. Condie**,** *Earth as an Evolving Planetary System,* Academic Press; 2nd edition, Second Edition, 2010.
2. J. S. Brian, W.M. Barbara, *The Blue Planet: An Introduction to Earth System Science,* 3rd Edition, Wiley, 2010.
3. Edward J. Tarbuck, Frederick K. Lutgens, Dennis G. Tasa, *Earth: An Introduction to Physical Geology,* Pearson 12th edition, 2016.

Supplementary Reading:

1. William Lowrie, *Fundamental of Geophysics,* Cambridge University Press, 2nd edition, 2007.

2. Charles Fletcher, *Physical Geology: The Science of Earth*, John Wiley & Sons, 2nd Edition, 2010.

ES 9102	**APPLIED GEOCHEMISTRY**		L	T	S	C
			3	**0**	**0**	**3**
Designation	**Elective I**	Course type	**Theory**			
Pre-requisites	--	Contact hours:	**42**			
Department	**Earth and Environmental Studies**					

Course Content

Stellar evolution and the origin of elements; the origin and evolution of meteorites with implications for homogeneous versus heterogeneous accretionary models of planet formation. Structure and composition of earth and distribution of elements. Element fractionation in magmatic and metamorphic systems. Introduction to isotope geochemistry with implications for the crust-mantle couple. Geochemistry of natural waters, and low temperature aqueous geochemistry. Chemistry of the oceans.

Essential Reading:

1. K. B. Krauskopf, D. K. Bird, *Introduction to Geochemistry*, McGraw-Hill, 1995.
2. C.A.J. Appelo, D. Postma, *Geochemistry, Groundwater and Pollution*, Taylor & Francis; 2nd edition, 2005.
3. J. V. Walther, *Essentials of Geochemistry*, Jones and Bartlett, 2010
4. P. Henderson, *Inorganic Geochemistry*, Oxford Pergamon Press, 1982.

Supplementary Reading:

1. J. I. Drever, *The Geochemistry of Natural Waters*, Prentice Hall, 1997
2. H. McSween, S. M. Richardson and M. E. Uhle, *Geochemistry: Pathways and Processes*, Overseas Press, 2006.

ES 9103	ISOTOPE GEOLOGY AND GEOCHRONOLOGY		L	T	S	C
			3	**0**	**0**	**3**
Designation	**Elective I**	Course type	**Theory**			
Pre-requisites	--	Contact hours:	**42**			
Department	**Earth and Environmental Studies**					

Course Content

Unit I: (20 Hours)

Mass spectrometerty: principles and applications; Fission track dating; Stable isotopes of oxygen, hydrogen, carbon and sulphur; Fractionation of stable isotopes; Stable isotope geothermometry; Analytical methods in stable isotopes; Applications of isotopes in petrogenesis, mineral-petroleum exploration, paleo-climate and environmental studies.

Unit II: (20 Hours)

Nuclear systematics; Decay mechanisms of radionuclides atoms; Radioactive Decay and radiogenic growth, Geochronometry; Isotope systematics of Rb-Sr, K-Ar Sm-Nd, U-Th-Pb Re-Os in igneous, metamorphic, sedimentary and ores and in evolution of ocean crust and mantle.

Essential Reading:

1. G. Faure, T. M. Mensing, *Isotopes: Principles and Applications,* Wiley; 3rd Edition, 2009.
2. A. Dickin, *Radiogenic Isotope Geology*, Cambridge University Press. 2nd Edition 2005.
3. C. J. Allègre, *Isotope Geology,* Cambridge University Press, 2008.
4. Z. Sharp, *Principles of Stable Isotope Geochemistry,* Prentice Hall; 1st Edition, 2006.

Supplementary Reading:

1. Hoefs, J., *Stable Isotope Geochemistry,* 3rd Edn. Springer-Verlag, 1987.
2. Geyh, M. A. and Schleicher, H., *Absolute age determination,* Springer, 1990.
3. JW Valley, D.R. Cole, *Stable Isotope Geochemistry* (Reviews in Mineralogy and Geochemistry, Volume 43)-Mineralogical Society of America, 2001.

ES 9104	PALEOCLIMATOLOGY		L	T	S	C
			3	**0**	**0**	**3**
Designation	**Elective I**	Course type	**Theory**			
Pre-requisites	--	Contact hours:	**42**			
Department	**Earth and Environmental Studies**					

Course Content

Introduction to changing climate with respect to stratigraphy; Global climate pattern; Climate controlling factors; Global energy budget; Plate tectonics and climate change; Milankovitch cycles; Atmosphere and Ocean interaction and its effect on climate; An Overview of Paleoclimatic reconstruction; Major events in earth's climatic history - Snowball earth, Cretaceous hothouse, Cenozoic climate, Pleistocene glaciations, Last Glacial Maximum and the Holocene; Pleistocene Glacial-Interglacial cycles; Geological records of climate change - Sedimentology, stable isotopes, geochemistry, geochronology – relative and numerical methods; Pre-Quaternary climates, evolution of climate through geological time; Future Climate- Anthropogenic activity and its effect on Global climate.

Essential Readings:

1. Bradley, F., *Paleoclimatology: Reconstructing Climates of the Quaternary,* Springer. Verlag 2000.
2. T.J. Crowley and G.R. North, *Paleoclimatology,* Oxford University Press, 1991.

Supplementary Readings

1. William F. Ruddiman*, Earth's Climate: Past and future,* W. H. Freeman & Co Ltd., 1st edition, 2001.

ES 9105	EXPLORATION GEOPHYSICS		L	T	S	C
			3	**0**	**0**	**3**
Designation	**Elective II**	Course type	**Theory**			
Pre-requisites	--	Contact hours:	**42**			
Department	**Earth and Environmental Studies**					

Course Content

Fundamental concepts of Geophysics, Principle, interpretation and instrumentation of various geophysical methods; Gravity Method, Gravity corrections and anomalies, Magnetic and Electromagnetic Methods, Passive and exploration Seismology; Electrical Methods – Telluric current, Resistivity, Induced Polarization, Self-Potential method; Radioactive survey; Introduction to well logging.

Essential Reading:

1. W.M. Telford, L.P. Geldart, R.E. Sheriff, *Applied Geophysics*, Cambridge University Press, Second Edition.
2. Milton B. Dobrin and Carl H. Savit, *Introduction to Geophysical Prospecting,* 4th Edition, Mcgraw-Hill College; 4th sub-edition, 1998.
3. Philip Kearey, Michael Brooks, Ian Hill, *An Introduction to Geophysical Exploration (2002)*, Wiley-Blackwell; 3rd edition, 2003.
4. James K. Hallenburg, *Standard Methods of Geophysical Formation Evaluation*, CRC Press; 1st edition, 1997.

Supplementary Reading:

1. William Lowrie, *Fundamental of Geophysics,* Cambridge University Press, 2nd edition, 2007.

ES9106	APPLIED MICROPALAEONTOLOGY		L	T	S	C
			2	**0**	**2**	**3**
Designation	**Elective II**	Course type	**Theory**			
Pre-requisites	--	Contact hours:	**60**			
Department	**Earth and Environmental Studies**					

Course Content

Unit I: (**26 Hours**)

Micropalaeontology:
Definition and scope of Micropalaeontology; Relationship of Micro palaeontology with Ocean Science Surface and Subsurface sampling methods including deep sea drilling (ODP, DSDP, IODP); Sampling Modern Ocean Biogenic Flux including Joint Global Ocean Flux Studies (JGOFS). Sample processing techniques. Equipments for micropalaeontological studies, Study of following groups of microfossils with reference to their outline of morphology, modern biogeography, application in paleoceanographic and paleoclimatic reconstruction and oceanic biostratigraphy with special reference to India. Calcareous microfossils including Foraminifera, Calcareous nannofossils. Ostracoda, pteropods, calpionellids and calcareous algae. Siliceous microfossils including Radiolaria, Diatoms, Silicoflagellates. Phosphatic microfossils including Conodonts. Organic Walled Microfossils including Acritarchs and Dianoflagellates, Pollens and Spores Applications of stable isotopic and elemental composition of various microfossils in paleoclimatic/paleoceanographic reconstruction. Organo-geochernical proxies for paleoclimatic /paleoceanographic studies Application of Micro pale ontology in Hydrocarbon Exploration.

LABORATORY (**30 Hours**)

Techniques of separation of microfossils from matrix; Types of microfossils - calcareous, siliceous, phosphatic and organic walled microfossils; SEM applications in micropaleontology; Study of surface ultrastructures of foraminifera.

Essential Reading:

1. Anis Kumar Ray, *Fossils in Earth Sciences*, PHI Learning Private Limited, February 2014
2. Howard A. Armstrong & Martin D. Brasier, *Microfossils*, Blackwell Publishing, Second Edition 2005

Supplementary Reading:

1. Bilal-Ul-Haq, Anne Boersoma, *Introduction to Marine Micropaleontology*, Elsevier Science, 1998.
2. Amal Dasgupta, *An Introduction to Palaeontology*, The World Press Private Limited Kolkata, 2012.

ES9107	MINERAL EXPLORATION		L	T	S	C
			3	**0**	**0**	**3**
Designation	**Elective II**	Course type	**Theory**			
Pre-requisites	--	Contact hours:	**42**			
Department	**Earth and Environmental Studies**					

Course Content

Importance of minerals to mankind; Value of minerals and their contribution to GNP; Minerals in times of peace and war; Intelligent use of minerals vis a vis industrial /economic growth; World production of minerals and International trade; Dwindling mineral resources and their impact on society; Mineral inventory; Planning for mineral prospecting and exploration; Infrastructure requirement for prospecting and exploration work; Work schedule for geological, geochemical and geophysical prospecting and exploration and their tentative costing; Case histories; Sampling techniques; Modern approaches ? genetic models and formulation of exploration criteria, empirical tools and target fixation; Application of Remote Sensing and GIS in mineral exploration; Mineral potential mapping using mathematical tools; Ore reserve calculations; Introduction to mining and beneficiation methods; Oil Exploration and Economics.

Essential Reading:

1. W.M. Telford, L.P. Geldart, R.E. Sheriff, *Applied Geophysics*, Cambridge University Press, Second Edition.
2. Milton B. Dobrin and Carl H. Savit, *Introduction to Geophysical Prospecting,* 4th Edition, Mcgraw-Hill College; 4th sub-edition, 1998.
3. Philip Kearey, Michael Brooks, Ian Hill, *An Introduction to Geophysical Exploration (2002),* Wiley-Blackwell; 3rd edition, 2003.
4. James K. Hallenburg, *Standard Methods of Geophysical Formation Evaluation,* CRC Press; 1st edition, 1997.

Supplementary Reading:

1. William Lowrie, *Fundamental of Geophysics*, Cambridge University Press, 2nd edition, 2007.

ES 9108	GEOSTATISTICS		L	T	S	C
			3	**0**	**0**	**3**
Designation	**Elective II**	Course type	**Theory**			
Pre-requisites	--	Contact hours:	**42**			
Department	**Earth and Environmental Studies**					

Course Content

Unit I: **(42 Hours)**

Elements of probability and different types of probability distribution functions, inductive statistics and hypothesis testing, sampling theory: application to Geological data analysis; Techniques of multivariate data analysis and reduction, factor analysis, principal component analysis and discriminate analysis and applications to Geological problems; Analysis of data in sequence: time series analysis. Pattern recognition techniques: statistical, structural and Fractal, Neural Network approaches and application to geological problems. Principles of optimization: classical techniques, linear and quadratic programming and stochastic programming. Time series analysis and modeling, convolution, correlation, filtering. Finite element and finite difference techniques.

Essential Reading:

1. Schabenberger, O. and Gotway, C. (2005) Statistical Methods for Spatial Data Analysis Chapman &Hall/CRC.
2. Peter J. Diggle, Paulo J. Ribeiro, Jr (2007) Model-based geostatistics, Springer.
3. Cressie, N. (1993). Statistics for Spatial Data (Revised Ed.). John Wiley & Sons, Inc.
4. Chiles, J. P. and Delfiner, P. (1999) Geostatistics: Modeling Spatial Uncertainty. Wiley.
5. Davis, J.C., Statistics and Data Analysis in Geology, 3rd Edition, John Wiley & Sons, Inc.

Supplementary Reading:

1. Stein, M. L. (1999) Interpolation of Spatial Data: Some Theory for Kriging. Springer.
2. Banerjee, S, Carlin, B., and Gelfand, A. E. (2004) Hierarchical modeling and analysis for spatial data. Chapman & Hall
3. Wackernagel, Hans (1998) Multivariate Geostatistics (2nd ed.) Springer.

ES 9109	HYDROCARBON EXPLORATION		L	T	S	C
			3	**0**	**0**	**3**
Designation	**Elective III**	Course type	**Theory**			
Pre-requisites	--	Contact hours:	**42**			
Department	**Earth and Environmental Studies**					

Course Content

Unit I: **(6 Hours)**

Introduction to oil fields, flow of fluid through rocks, Petroleum reservoir types, characteristics, Performances and calculations. Genesis of hydrocarbon and migration into reservoir rock, reservoir rock properties (porosity and permeability), Hydrocarbon traps and seals, estimation of oil and gas reserves, oil field water, formation evaluation, well logging, sedimentary environment and well log interpretation. Drilling for oil and gas exploratory and production drilling m mud technology, drill bits. Drill rigs and structure, Off shoe drilling, directional drilling, Casing and cementation, well completion and stimulation. Petroleum production methods, traditional and artificial lift, sucker rod pumping systems and gas lifting, secondary and enhanced recovery, Crude transportation, pumping and pipeline components-operation and maintenance, International oil market and oil economics

Essential Reading:

1. Hydrocarbon Exploration and Production, 2nd Edition (2008): by Frank Jahn and Mark Cook.
2. Hydrocarbon: Exploration and Production (2015): by Allegra Smith.

Supplementary Reading:

1. S. A. Tedesco (1994): Surface Geochemistry in Petroleum Exploration, Springer-Verlag.
2. Hyne, N.J. (2001): Nontechnical Guide to Petroleum Geology, Exploration, Drilling and Production (2nd Ed.), Pennwell Co., Oklahoma.
3. Ian Lerche and James A. Mackay (1999): Economics Risks in Hydrocarbon Exploration, Pennwell Co.

ES 9110	OCEANOGRAPHY		L	T	S	C
			3	**0**	**0**	**3**
Designation	**Elective III**	Course type	**Theory**			
Pre-requisites	--	Contact hours:	**42**			
Department	**Earth and Environmental Studies**					

Course Content

Unit I: **(10 Hours)**

General introduction, major expeditions-Dimensions of the ocean, Geographical features of ocean – Physical properties of sea water-distribution of temperature, salinity, density and oxygen in space and time, mixed layer and barrier layer, Acoustic properties of sea water-sound velocity profile- SOFAR channel and shadow zone-Optical characteristics of sea water- Color of the sea. Heat budget of ocean: Radiation laws, insolation-long wave radiation-factors controlling short wave and long wave radiation- sensible and latent heat transfer, bulk formula for heat fluxes- Bowen's ratio- ocean heat transport- spatio-temporal variability of heat budget terms and net heat balance.

Unit II: **(10 Hours)**

Circulation and Water masses: General circulation of the atmosphere – wind driven currents in the world ocean – Equatorial current systems – Wyrtki Jet Under currents- Circulation in the Arabian Sea and Bay of Bengal- Somali current – wind stress Ekman spiral- Upwelling – Indian Ocean Dipole (IOD)- El Nino and La Nina. Formation and classification of water masses- T-S diagram-water masses of the world ocean- thermohaline circulation – Identification of water masses. Waves and Tides: General aspects of ocean waves, wave characteristics, sea and swell, deep and shallow water waves, storm surges and tsunamis-Tides and tide generating forces; their causes, variation and types, Tidal currents.

Unit III: **(10 Hours)**

Unit V: Marine geology: Continental shelf, Slope, Shelf sediments, mineral resources of the world ocean, submarine topography, mid oceanic ridge system. Manganese and other deposits and the factors controlling their distribution. Marine biology: Classification of marine environment, Bio geo chemical cycles. Influence of Physical parameters (Temperature, salinity, waves, currents, tides etc.). Mangroves

Unit IV: **(10 Hours)**

Ocean properties measurable from satellites Ocean Color Remote Sensing: optical theory for Ocean color remote sensing, recovering useful information from ocean color, estimating water parameters from spectral band ratios, identifying Potential Fishing Zones. IR measurement of Sea Surface Temperature – retrieving SST: IR Radiometer, AVHRR, ATSR, AIRS, Oceanographic application of IR SST data. Passive microwave Radiometers: Physical

principle of passive microwave radiometry, retrieval of Salinity, SST and surface wind from microwave measurements.

Essential Reading:

1. Coastal ocean observing systems, Liu, Yonggang, Kerkering, Heather, Weisberg, Robert H., Elsevier, 2015.
2. Descriptive Physical Oceanography, Reddy, M. P. M., 2000, New Delhi Oxford & IBH
3. Descriptive Physical Oceanography, Emery, William J., 1982, Pergamon Press (Oxford)

Supplementary Reading:

1. Descriptive Physical Oceanography: An Introduction: G. L. Pickard and W. J. Emery, Pergamon, 5th Edn., 1992.
2. Descriptive Physical Oceanography: An Introduction.Ed.6, Lynne D. Talley, George L. Pickard, William J. Emery and James H. Swift, Elsevier, 2011.

ES 9111	CONTAMINANT HYDROGEOLOGY		L	T	S	C
			3	**0**	**0**	**3**
Designation	**Elective III**	Course type	**Theory**			
Pre-requisites	--	Contact hours:	**42**			
Department	**Earth and Environmental Studies**					

Course Content

Unit I: **(6 Hours)**

Groundwater Quality: Water quality standards, collection of groundwater samples, Field analysis and sample conversion, Accuracy of chemical analysis; Use of mass balance to assess water presentation of water quality data, Groundwater monitoring techniques.

Unit II: **(6 Hours)**

Groundwater contamination: Septic tanks and cesspools; Landfills; Chemical spill and leaking underground tank; agricultural activities; Industrial effluent outfall, Mining, Saline – water intrusion and other sources.

Unit III: **(7 Hours)**

Concepts and principles related to the movement of solutes in groundwater systems: Continuity equation and Ficks' law, mass transfer (adsorption, desorption, absorption, decay, dissolution and volatilization); mass transfer (advection, dispersion, and diffusive flux), solute transport in double-porosity media.

Unit IV: **(8 Hours)**

Transformation, Retardation, and Attenuation of Solutes: Linear and non-linear (Frendlich and Langmuir) isotherms, equilibrium and kinetic adsorption, Determination of adsorption coefficients, Determination of flow velocity and dispersivity coefficients, Hydrodynamics dispersion, longitudinal and lateral dispersivity.

Unit V: **(6 Hours)**

Groundwater Transport Modelling: Analytical solution of classical advection-dispersion equation, Finite different and finite element approach, Discussion of boundary conditions, steady state and transient model, Modelling framework for solute transport in saturated and unsaturated media, Introduction to modelling software in groundwater and contaminant transport modelling.

Unit V: **(6 Hours)**

Remediation Techniques: Pump-and treat, Permeable reactive barriers and their design, Soil vapour extraction, Air Stripping, Bioremediation and phytoremediation processes, wetland processes.

Essential Reading:

1. Geotechnical practice for waste disposal by D.E. Daniel
2. Applied Hydrogeology by C.W. Fetter
3. Hydrology by H.M Raghunath
4. Geoenvironment Engineering: Site remediation, waste contaminant and emerging waste management technologies by H.D. Sharma and K.R. Reddy

Supplementary Reading:

1. Environmental Engineering: A Design Approach by Sincero and Sincero
2. Groundwater by Freeze and Cherry
3. Applied contaminant transport modelling by C. Zheng and G.D. Bennet.

ES 9112	PRECAMBRIUM GEOLOGY		L	T	S	C
			3	**0**	**0**	**3**
Designation	**Elective III**	Course type	**Theory**			
Pre-requisites	--	Contact hours:	**42**			
Department	**Earth and Environmental Studies**					

Course Content

Unit I: **(5 Hours)**

Origin of the Earth – theories. Age of the Earth vs the age of the oldest rocks. Classification of the Precambrian according to the IUGS classification scheme.

Unit II: **(5 Hours)**

Major components of Archean geology – the origin of cratons. Geological evolution of cratons – granite-greenstone belts and gneiss domes.

Unit III: **(10 Hours)**

The Proterozoic – mobile belts and cratonic sedimentary provinces – significance for evolution of the continental crust.

Unit IV: **(15 Hours)**

Evolving magmatism, sedimentation and metamorphism through the Precambrian. Major geological events in the Precambrian – continental crust formation, cratonization, the great oxygenation event and the evolution of life. Importance of the Ediacaran faunal assemblage. Tectonics in the Precambrian – evidence for and against Plate Tectonics.

Unit V: **(5 Hours)**

Study of few major shield areas – Kaapvaal, Yilgarn and Superior Province. Precambrian of India and evolution of the Indian shield.

Essential Reading:

1. Ramakrishnan, M. & Vaidyanadhan, R. (2008) Geology of India Volumes 1, Geological society of India, Bangalore.
2. Valdiya, K. S. (2010) The making of India, Macmillan India Pvt. Ltd.
3. Nichols, G. (2009). Sedimentology and Stratigraphy Second Edition. Wiley Blackwell
4. Code of International Stratigraphy Commission.

Supplementary Reading:

1. Krishnan, M. S. (1982) Geology of India and Burma, CBS Publishers, Delhi 2.
2. Doyle, P. & Bennett, M. R. (1996) Unlocking the Stratigraphic Record. John Wiley.