Subject: Earth Science

Existing Syllabus	Proposed Syllabus
PAPER I (PART B) 1. **The Earth and the Solar System**: Milky Way and the solar system. Modern theories on the origin of the Earth and other planetary bodies. Earth‟s orbital parameters, Kepler‟s laws of planetary motion, Geological Time Scale; Space and time scales of processes in the solid Earth, atmosphere and oceans. Radioactive isotopes and their applications. Meteorites Chemical composition and the Primary differentiation of the earth. Basic principles of stratigraphy. Theories about the origin of life and the nature of fossil record. Earth‟s gravity and magnetic fields and its thermal structure: Concept of Geoid and, spheroid; Isostasy. 2. **Earth Materials, Surface Features and Processes**: Gross composition and physical properties of important minerals and rocks; properties and processes responsible for mineral concentrations; nature and distribution of rocks and minerals in different units of the earth and	**PART B** **1. The Earth and the Solar System** The Milky Way and the solar system. Modern theories on the origin of the Earth and other planetarybodies. Earth's orbital parameters, Kepler's laws of planetary motion, Geological Time Scale, Space and time scales of processes in the solid Earth, atmosphere, and oceans. Radioactive isotopes and their applications. Chemical composition of meteorites and the Primary differentiation of the Earth. Basic principles of stratigraphy. Theories about the origin of life and the nature of the fossil record. Earth's gravity, magnetic fields, and thermal structure: Concept of Geoid and Spheroid; Isostasy. **2. Earth Materials, Surface Features, and Processes** Gross composition and physical properties of essential minerals and rocks; properties and processes responsible for mineral concentrations; nature and distribution of rocks and minerals in different units of the Earth and various parts of India. Physiography of the Earth: weathering, erosion, transportation, and deposition of Earth's material; formation of soil, sediments, and sedimentary rocks; energy balance of the Earth's surface processes; physiographic features and river basins in India **3. Interior of the Earth, Deformation and Tectonics**

different parts of India. Physiography of the Earth; weathering, erosion, transportation and deposition of Earth‟s material; formation of soil, sediments and sedimentary rocks; energy balance of the Earth‟s surface processes; physiographic features and river basins in India

3. **Interior of the Earth, Deformation and Tectonics**:

Basic concepts of seismology and internal structure of the Earth. Physico-chemical and seismic properties of Earth‟s interior. Concepts of stress and strain. Behaviour of rocks under stress; Folds, joints and faults. Earthquakes – their causes and measurement. Interplate and intraplate seismicity. Paleomagnetism, sea floor spreading and plate tectonics.

4. **Oceans and Atmosphere :**

Hypsography of the continents and ocean floor –continental shelf, slope, rise and abyssal plains. Physical and chemical properties of sea water and their spatial variations. Residence times of elements in sea water.

Basic concepts of seismology and the internal structure of the Earth. Physico-chemical and seismic properties of Earth’s interior. Concepts of stress and strain. Behaviour of rocks under stress: Folds, joints, and faults. Earthquakes – their causes and measurement. Interplate and intraplate seismicity. Paleomagnetism, seafloor spreading, and plate tectonics.

4. Oceans and Atmosphere

Hypsography of the continents and ocean floor –continental shelf, slope, rise, and abyssal plains.Physical and chemical properties of seawater and their spatial variations. Residence times of elements in seawater. Ocean currents, waves, tides, critical current systems, thermohaline circulation, and the oceanic conveyor belt. Major water masses of the world’s oceans. Biologicalproductivity in the oceans.

Motion of fluids and waves in atmospheric and oceanic systems. Atmospheric turbulence and boundary layer. Structure and chemical composition of the atmosphere, lapse rate andstability, scale height, geopotential, greenhouse gases, and global warming. Cloud formation and precipitation processes, air-sea interactions on different space and time scales. Insolation and heat budget, radiation balance, and general circulation of the atmosphere and ocean. Climatic and sea level changes on various time scales. Coupled ocean-atmosphere system, El Niño Southern Oscillation (ENSO). General weather systems of India:Monsoon systems, cyclones, jet streams, western disturbances, local convective systems, and distribution of precipitation over India.Marine and

Ocean currents, waves and tides, important current systems, thermohaline circulation and the oceanic conveyor belt. Major water masses of the world‟s oceans. Biological productivity in the oceans. Motion of fluids, waves in atmospheric and oceanic systems. Atmospheric turbulence and boundary layer. Structure and chemical composition of the atmosphere, lapse rate and stability, scale height, geopotential, greenhouse gases and global warming. Cloud formation and precipitation processes, air- sea interactions on different space and time scales. Insolation and heat budget, radiation balance, general circulation of the atmosphere and ocean. Climatic and sea level changes on different time scales. Coupled ocean-atmosphere system, El Nino Southern Oscillation (ENSO). General weather systems of India, - Monsoon system, cyclone and jet stream, Western disturbances and severe local convective systems, distribution of precipitation over India. Marine and atmospheric pollution, ozone depletion.

atmospheric pollution and ozone depletion.

5. Environmental Earth Sciences

Properties of water; hydrological cycle; water resources and management; energy resources, uses, degradation, alternatives, and management; ecology and biodiversity; impact of energy and land use on the environment; exploration and conservation of mineral and other natural resources; natural hazards.

6. Data Acquisition and Handling

Analytical Techniques: Fundamentals of quantitative analyses. Concepts of standards and calibration. Transmitted & Reflected light Microscopy, X-ray DiffractionSpectroscopy, X-ray Fluorescence Spectroscopy, Scanning Electron Microscopy, Mass Spectrometry, Geophysical Methods (Gravity-Seismic-Magnetic-Electrical-Electromagnetic),Geophysical Well-logging,CTD Ocean Profiling, Acoustic Doppler Current Profiler, Nutrient Analysis and Chlorophyll-a Measurement, Argo Floats, Thermo-Baro-Anemometers, Pyranometer, AWS, Radiosonde, LIDAR, GPR, Remote Sensing, and Geospatial Analysis.

Statistics & Error Analysis: Sampling Methods, Measures of Central tendency & analysis of Variance, Probability & Distributions, Tests of Significance, Concepts of Accuracy and Precision, Uncertainties in Measurements, Propagation of Errors, Method of Least Squares, and Analysis of Multivariate Data.

5. **Environmental Earth Sciences**:

Properties of water; hydrological cycle; water resources and management. Energy resources, uses, degradation, alternatives and management; Ecology and biodiversity. Impact of use of energy and land on the environment. Exploitation and conservation of mineral and other natural resources. Natural hazards. Elements of Remote Sensing.

PAPER I (PART C)

I. GEOLOGY

1) MINERALOGY AND PETROLOGY:

Concept of point group, space group, reciprocal lattice, diffraction and imaging. Concepts of crystal field theory and mineralogical spectroscopy. Lattice defects (point, line and planar). Electrical, magnetic and optical properties of minerals. Bonding and crystal structures of common oxides, sulphides, and silicates. Transformation of minerals – polymorphism, polytypism, and polysomatism. Solid solution and exsolution. Steady-state geotherms. Genesis, properties, emplacement and crystallization of magmas. Phase equilibrium studies of simple systems, effect of volatiles on melt equilibria. Magma -mixing, - mingling and -immiscibility. Metamorphic structures

PART C

I. GEOLOGY

1. Crystallography and Mineralogy:

Elements of crystal symmetry, external form; Translational and point symmetry; Lattice and unit cell; Crystal axes and systems; 32 Point groups; Space groups; Miller indices; Twinning and twinning laws; Stereographic projections; X-ray crystallography and Bragg’s law

Types of bonding, Crystal structure, and ionic radius; Pauling’s rules; Radius-ratio and co-ordination number; Crystal field theory; Polymorphism; Mineral solid solutions; Exsolution and ordering; Crystal defects; Classification, structure, chemistry, physical, optical properties, and paragenesis of common rock-forming Neso-, Cyclo-, Soro-, Ino-, Phyllo- and Tectosilicate minerals, and common non-silicate minerals (spinel, carbonate, phosphate).

2. Geochemistry andIsotope Geology:

Fundamentals: Atomic Structure, atomic mass, and properties of elements.The Periodic Table, Chemical bonding.The nucleus-binding energy-radioactivity, Isotopes-Abundance-Atomic Weight, Origin of elements-nucleosynthesis, Origin of the solar system, Cosmic and solar abundance of elements. Composition of different groups of meteorites and planets, Chemical differentiation of the Earth and terrestrial planets, Geochemical classifications,Ionic

and textures; isograds and facies. Mineral reactions with condensed phases, solid solutions, mixed volatile equilibria and thermobarometry. Metamorphism of pelites, mafic -ultra mafic rocks and siliceous dolomites. Material transport during metamorphism. P-T-t path in regional metamorphic terrains, plate tectonics and metamorphism. Petrogenetic aspects of important rock suites of India, such as the Deccan Traps, layered intrusive complexes, anorthosites, carbonatites, charnockites, alkaline rocks, Kimberlites, ophiolites and granitoids. 2) STRUCTURAL GEOLOGY AND GEOTECTONICS: Theory of stress and strain. Behaviour of rocks under stress. Mohr circle. Various states of stress and their representation by Mohr circles. Different types of failure and sliding criteria. Geometry and mechanics of fracturing and conditions for reactivation of pre-existing discontinuities. Common types of finite strain ellipsoids. L-, L-S-, and S-tectonic fabrics. Techniques of strain analysis. Particle paths and flow patterns. Progressive strain history. Introduction to deformation mechanisms. Role of fluids in deformation processes. Geometry and analyses of brittle-ductile and ductile shear zones. Sheath folds. Geometry and mechanics	potential, Chemical equilibria, Thermodynamic functions, Thermodynamics of pure phases and solutions, Mineral kinetics, Phase Rule and its Applications, Trace Elements & Henry's Law, Distribution of Trace Elements in Coexisting Phases, Trace element partitioning during Partial Melting & Crystallization. Radiometric Dating and Isotope Geochemistry: K-Ar, Rb-Sr, Sm-Nd, and U-Th-Pb dating methods. Radiogenic isotope geochemistry: petrogenesis of igneous rocks, origin, and evolution of the crust and mantle system.Light stable isotope systems (H, O, C, S); Equilibrium and kinetic isotope fractionation; Fractionation factor; Delta notation; Rayleigh fractionation, Applications: Hydrology, Petrology, Ore Geology& Paleoclimate Studies. Aqueous geochemistry: activity coefficients of dissolved species, metal ions in aqueous solutions, carbonate chemistry, and pH control, adsorption-desorption reactions, stability relationships, and silicate equilibria; mineral stability diagrams, chemical weathering, and water chemistry; redox equilibria; rates of geochemical reactions.Interaction of multiple reservoirs and geochemical cycles, Mixing: Binary, Ternary & Dilution with elements & isotopes. **3. Igneous and Metamorphic Petrology:** Igneous Petrology: field occurrences, textures & classification. Mantle

of development of folds, boudins, foliations and lineations. Interference patterns of superposed fold. Fault-related folding. Gravity induced structures. Tectonic features of extensional-, compressional-, and strike-slip-terrains and relevance to plate boundaries. Mantle plumes.

Himalayan Orogeny; concept of super continent, their assembly and breakup.

3) **PALEONTOLOGY AND ITS APPLICATIONS:** Theories on origin of life. Organic evolution – Punctuated Equilibrium and Phyletic Gradualism models. Mass extinctions and their causes. Application of fossils in age determination and correlation. Paleoecology, Life habitats and various ecosystems, Paleobiogeography. Modes of preservation of fossils and taphonomic considerations. Types of microfossils. Environmental significance of fossils and trace fossils. Use of microfossils in interpretation of sea floor tectonism. Application of micropaleontology in hydrocarbon exploration. Oxygen and Carbon isotope studies of microfossils and their use in paleoceanographic and paleoclimatic interpretation. Important invertebrate fossils,

petrology, geothermal gradient, mantle melting mechanisms, and generation of different types of magmas. Melt properties, composition, and their segregation and differentiation; Use of binary and ternary systems to understand melting and crystallization; Application of major, trace elements, and radiogenic&stable isotopes in igneous petrogenesis; Common igneous rocks and their plate tectonic associations and petrogenesis.

Metamorphic Petrology: Controls of metamorphism-pressure, temperature, bulk composition, fluid composition; Concepts of metamorphic isograd, zones, metamorphic facies, facies series; Regional and contact metamorphism; Anatexis; Steady state geotherms; Metamorphic P-T-t paths; Thermodynamics of homogeneous and heterogeneous systems; Nucleation and crystal growth in metamorphism; Graphical representation of mineral assemblages-ACF, AKF, AFM diagrams; Metamorphism of basalts, pelites, and calcareous sediments along different field gradients; Concepts of petrogenetic grid, P-T pseudo section and geothermobarometry; Time scales of metamorphism.

4. Structural Geology, Tectonics, Rock mechanics, and Engineering geology

Concepts of stress and strain; Ductility/strength of materials; Theories of rock failure; Mohr Stress circle; Strain associated with homogeneous deformation; Types of strain ellipses and ellipsoids-their properties and geological significance; Strain markers and methods of strain measurements in naturally deformed rocks; Faults-classification,

	vertebrate fossils, plant fossils and microfossils in Indian stratigraphy. 4) **SEDIMENTOLOGY AND STRATIGRAPHY:** Classification of sediments and sedimentary rocks ; elastic, volcanoclastic and chemical. Classification of elastic rocks. Flow regimes and processes of sediment transport. Sedimentary textures and structures. Sedimentary facies and environments, reconstruction of paleoenvironments. Formation and evolution of sedimentary basins. Diagenesis of siliciclastic and carbonate rocks. Recent developments in stratigraphic classification. Code of stratigraphic nomenclature – Stratotypes, Global Boundary Stratotype Sections and Points (GSSP). Lithostratigraphic, chronostratigraphic and biostratigraphic subdivisions. Methods of startigraphic correlation including Shaw‟s Graphic correlation. Concept of sequence stratigraphy. Rates of sediment accumulation, unconformities. Facies concept in Stratigraphy – Walther‟s law. Methods for paleogeographic reconstruction. Earth‟s Climatic History. Phanerozoic stratigraphy of India with reference to the type areas– their correlation with equivalent formations in other regions.	relation with principle stress axes orientation, criteria for identifying in the field; Folds-classification, mechanisms; Foliations-types, processes of development, relation with principal axes of strain ellipsoid, crenulation cleavage formation, bedding-cleavage relationship in structural geology; Lineations-classification, boudin formation, strain ellipsoid and stretching lineation; Joints-classification, conjugate joints and stress orientations; Unconformities and basement-cover relationship; Shear zones; Mylonites; porphyroblast-matrix relationship; Pseudotachylites; Superposed deformation; Interpretation of geological maps with unconformity, faults, and folds; Equal area and orthographic projections. Thermal and rheological character of the crust, mantle, lithosphere, asthenosphere; Mantle structure and convection models; Models of vertical and horizontal tectonics; Isostasy; Principles of Plate tectonics, Plates and plate boundaries-ridges, transform faults, trenches; Geometry of Plate motion; Mantle plumes; Palaeomagnetism and past plate motions, with special reference to the Indian plate; Orogenic belts; Geodynamic evolution of the Himalayas. Engineering properties of rocks; Rock failure hypotheses and criteria; Mechanical behaviour of isotropic and anisotropic rock materials; Rock physical and index properties; Shear behaviour of rock discontinuities; Rock mass classifications and geological strength index; Weathering and weathering classifications of rock materials and masses; In-situ stresses and their measurement; Soil Mechanics- soil profile

Boundary problems in Indian Phanerozoic stratigraphy.

5) MARINE GEOLOGY AND PALEOCEANOGRAPHY: Morphologic and tectonic domains of the ocean floor. Structure, composition and mechanism of the formation of oceanic crust. hydrothermal vents-. Ocean margins and their significance. Ocean Circulation, Coriolis effect and Ekman spiral, convergence, divergence and upwelling, El Nino. Indian Ocean Dipole Thermohaline circulation and oceanic conveyor belt. Formation of Bottom waters; major water masses of the world‟s oceans. Oceanic sediments: Factors controlling the deposition and distribution of oceanic sediments; geochronology of oceanic sediments, diagenetic changes in oxic and anoxic environments. Tectonic evolution of the ocean basins. Mineral resources. Paleoceanography – Approaches to paleoceanographic reconstructions; various proxy indicators for paleoceanographic interpretation. Reconstruction of monsoon variability by using marine proxy records Opening and closing of ocean gateways and their effect on circulation and climate during the Cenozoic. Sea level processes and Sea level changes.

and classification, engineering properties of soils and their determination, consistency limits; Geotechnical treatments including grouting and rock bolting, foundation treatment; ground investigations-boreholes and trial pits, drilling, sampling and logging; Slope stability and calculation of factor of safety; Slope stabilization methods; Geological and geotechnical Investigation of dams, reservoirs and spillways, tunnels, bridges, highways.

5. Ore Genesis and Economic Geology

Processes of formations of ore mineral deposits-magmatic concentration, hydrothermal processes, oxidation and supergene sulphide enrichment, residual and mechanical concentration; Spatial and temporal distribution of ore deposits-metallogenic provinces and epochs; ore deposits and plate tectonics; mode of occurrence of ore bodies-morphology, relation with host rocks; wall-rock alteration; texture, paragenesis, and zoning of ores; ore fluids-their source, physicochemical conditions, hydrothermal alteration, water-rock interaction and mass transfer; Structural, physiochemical and stratigraphic controls of ore localization; Significance of organic matter in ores; Use of trace elements and stable isotopes in ore genetic studies; Geothermometry and geobarometry of ore assemblages; Geologic and genetic aspects of magmatic Cu-Ni-PGE ores, carbonatite-hosted REE-Nb ores, granite-greenstone hosted lode gold deposits, VHMS and SEDEX deposits, BIF and sedimentary Mn ores; Study of ore minerals related to the following metals with special reference to their mineralogy, genesis, uses and distribution in India: Fe, Mn, Cr, Cu, Pb, Zn, Al, Mg, Sn, W, Au; Introduction to ore

Methods of paleo Sea Surface temperature. Quantifications.

6**) GEOCHEMISTRY**:

Atomic Structure and properties of elements, the Periodic Table; ionic substitution in minerals; Phase rule and its applications in petrology, thermodynamics of reactions involving pure phases, ideal and non-ideal solutions, and fluids; equilibrium and distribution coefficients. Nucleation and diffusion processes in igneous, metamorphic and sedimentary environments, redox reactions and Eh- pH diagrams and their applications. Mineral/mineral assemblages as „sensors" of ambient environments. Geochemical studies of aerosols, surface-, marine-, and ground waters. Radioactive decay schemes and their application to geochronology and petrogenesis. Stable isotopes and their application to earth system processes; geochemical differentiation of the earth; geochemical cycles.

7**) ECONOMIC GEOLOGY:**

Magmatic, hydrothermal and surface processes of ore formation. Metallogeny and its relation to crustal evolution; Active ore-forming systems, methods of mineral deposit studies including ore microscopy, fluid inclusions and isotopic systematics; ores and metamorphism- cause and microscopy-techniques, methods, textures and microstructures of ores, interpretation of ore texture and optical properties of common sulphide, oxide ore minerals; Ore grade and reserve estimation.

6. Sedimentology, Basin Analysis, and Stratigraphy

Sediment generation and classification of sedimentary rocks, Grain size, shape, and fabric analysis; Textural and compositional maturity of clastic sediments; Heavy mineral analyses, Application of geochemistry to sedimentological problems; Fluid flow, Sediment Gravity

flow and their products; Primary and Penecontemporaneous sedimentary structures, Paleoclimate and Paleoredox conditions of deposition; Flow regime concept; Reconstruction of Paleocurrent, Provenance, Paleocurrent Analysis; Facies concept and depositional

environments; Major siliciclastic and chemogenic depositional systems; Diagenesis of sediments.

Definition, classification, and mechanism of sedimentary basin formation. Factors controlling sequence - building process and sequence stratigraphy; Basin analysis.

Principles of stratigraphy and concepts of correlation; Lithostratigraphy, Biostratigraphy, and Chronostratigraphy; Physiographic and tectonic subdivisions of India, Introduction to Archaean, Proterozoic, and Phanerozoic basins of India.; Economic importance of major

effect relationships. Geological setting, characteristics, and genesis of ferrous, base and noble metals. Origin, migration and entrapment of petroleum; properties of source and reservoir rocks; structural, stratigraphic and combination traps. Methods of petroleum exploration. Concepts of petrophysics, Petroliferous basins of India. Origin of peat, lignite, bitumen and anthracite. Classification, rank and grading of coal; coal petrography, coal resources of India. Gas hydrates and coal bed methane. Nuclear and non-conventional energy resources.

8) **PRECAMBRIAN GEOLOGY AND CRUSTAL EVOLUTION:**

Evolution of lithosphere, hydrosphere, atmosphere, biosphere, and cryosphere;, lithological, geochemical and stratigraphic characteristics of granite – greenstone and granulite belts. Stratigraphy and geochronology of the cratonic nuclei, mobile belts and Proterozoic sedimentary basins of India. Life in Precambrian. Precambrian – Cambrian boundary with special reference to India.

9) QUATERNARY GEOLOGY:

Definition of Quaternary. Quaternary Stratigraphy – Oxygen Isotope stratigraphy, biostratigraphy and stratigraphic units of India.

7. Palaeontology

Fossilization,taphonomy, quantitative assessment of paleontological sampling strategies; Ontogenetic variation, functional morphology, evolutionary morphology; Systematics, phylogenetics; Population and species, morphological and taxonomic evolution, evolutionary rates and trends; Macroevolution, quantitative assessment of global diversification and extinction; Paleoecology; Paleobiogeography; Biostratigraphy; Important fossil groups (macrofossils: Mollusca, Echinodermata, Brachiopoda; microfossils: foraminifera, ostracoda, conodonta; spores, pollens) and their application in paleoenvironmental reconstruction;

Origin of life and evidence of early life; early ecosystem (Ediacaran and Cambrian); important evolutionary transitions of clades (Vertebrata, Tetrapoda, Amniota, dinosaurian) and their impact on paleoecosystem; young fossil record and its application to conservation.

8. Geomorphology, Quaternary Geology, and Remote Sensing

Basic concepts and significance of geomorphology; Weathering, erosion, deposition and genetic classification of landforms; Role of lithology, peneplaination, endogenous and exogenous forces, climatic and tectonic factors in landform generation and rejuvenation; Weathering products and soils; River and drainage basin-drainage pattern, network characteristics, valleys and their development, processes of river erosion, transportation, and

magnetostratigraphy. Quaternary climates – glacial-interglacial cycles, eustatic changes, proxy indicators of paleoenvironmental/ paleoclimatic changes, - land, ocean and cryosphere (ice core studies). Responses of geomorphic systems to climate, sea level and tectonics on variable time scales in the Quaternary, Quaternary dating methods, – radiocarbon, Uranium series, Luminescence, Amino- acid. Quaternary stratigraphy of India– continental records (fluvial, glacial, aeolian, palaeosols and duricrust); marine records; continental-marine correlation of Quaternary record. Evolution of man and Stone Age cultures. Plant and animal life in relation to glacial and interglacial cycles during Quaternary. Tectonic geomorphology, neotectonics, active tectonics and their applications to natural hazard assessment. 10) (I)APPLIED GEOLOGY: (i) **Remote Sensing and GIS**: Elements of photogrammetry, elements of photo-interpretation, electromagnetic spectrum, emission range, film and imagery, sensors, geological interpretations of air photos and imageries. Global positioning systems. GIS-data structure, attribute data, thematic layers and	deposition; Evolution of landforms in fluvial, aeolian, marine, glacial and karst landscapes; Geomorphic indicators of neotectonic movements; Elementary idea about morphogenesis and morphography, morphometric analysis; Societal implication of geomorphology Quaternary stratigraphy: oxygen isotope stratigraphy, biostratigraphy, magnetostratigraphy. Quaternary climates-glacial/interglacial cycles, eustatic changes, proxy indicators of paleoenvironmental/paleoclimatic changes, - land, ocean and cryosphere; Responses of geomorphic systems to climate, sea level and tectonics on variable time scales in the Quaternary; Quaternary dating methods-radiocarbon, uranium series, luminescence, amino-acid; Quaternary stratigraphy of India-continental records (fluvial, glacial, aeolian, palaeosols and duricrust); Marine records; Continental-marine correlation of Quaternary record. Basic principles of remote sensing; Electromagnetic radiation-its characteristics and interactions with earth’s surface and atmosphere, remote sensing regions, bands, sensors; Aerial-photo interpretation; Multispectral remote sensing in visible, infrared, thermal IR, and microwave regions; Different satellite programs, Digital processing of satellite images; GIS–basic concepts, raster, and vector mode operations; Application of remote sensing in natural hazard study, groundwater, mineral exploration, structural geology, land use, and regional planning.Mineral absorption/reflectance spectra and planetary mineral mapping.

query analysis.

(ii) **Engineering Geology**: Engineering properties of rocks and physical characteristics of building stones, concretes and other aggregates. Geological investigations for construction of dams, bridges, highways and tunnels. Remedial measures. Mass movements with special emphasis on landslides and causes of hillslope instability. Seismic design of buildings.

(iii) **Mineral Exploration**: Geological, geophysical, geochemical and geobotanical methods of surface and sub-surface exploration on different scales. Sampling, assaying and evaluation of mineral deposits.

(iv) **Hydrogeology:** Groundwater, Darcy‟s law, hydrological characteristics of aquifers, hydrological cycle. Precipitation, evapotranspiration and infiltration processes. Hydrological classification of water-bearing formations. Fresh and salt-water relationships in coastal and inland areas. Groundwater exploration and water pollution. Groundwater regimes in India.

(II**) PHYSICAL GEOGRAPHY**

1) Geomorphology: Concepts in geomorphology. Historical and process Geomorphology. Landforms

9. Hydrogeology

Groundwater as a part of the hydrosphere; Hydrologic cycle; Hydrological equations; Hydrologic properties of rocks-porosity, permeability, specific yield, specific retention, hydraulic conductivity, transmissivity, storage coefficient; Surface-groundwater interactions, recharge, and discharge processes; Hydraulic parameters and their influence on hydro dynamics of groundwater flow; Groundwater quality and pollution.

10. Coal and Petroleum Geology

Definition and origin of kerogen and coal mode of occurrence; Coal petrography-macerals, microlith, rank, grade, and type of coal; Indian coals-origin, geology, mineral association, and geochemistry.

Petroleum-its composition and different fractions, origin, nature, and migration; Source rocks and reservoir, rocks-their physical characteristics and types, cap rocks and mechanics of sealing, the effect of hydrodynamics and overpressure; Classification of hydrocarbon traps-structural - structural, stratigraphic, and combination; Sedimentary basins, thermal history, and petroleum accumulation; Onshore and offshore distribution of petroliferous basins of India.

II. PHYSICAL GEOGRAPHY

1. Geomorphology

Key concepts in geomorphology: evolutionary concepts, geomorphic

in relation to climate, rock type, structure and tectonics. Processes – weathering, pedogenesis, mass movement, erosion, transportation and deposition. Geomorphic processes and landforms – fluvial, glacial, eolian, coastal and karst. River forms and processes – stream flow, stage-discharge relationship; hydrographs and flood frequency analysis. Submarine relief. Geomorphology and topographic analysis including DEM, Environmental change– causes, effects on processes and landforms. Extra-terrestrial geomorphology. 2) **Climatology:** Fundamental principles of climatology. Earth‟s radiation balance; latitudinal and seasonal variation of insolation, temperature, pressure, wind belts, humidity, cloud formation and precipitation, water balance. Air masses, monsoon, Jet streams, tropical cyclones, and ENSO. Classification of climates – Koppen‟s and Thornthwaite‟s scheme of classification. Climate change. 3) **Bio-geography**: Elements of biogeography with special reference to India; environment, habitat, plant-animal association; zoo-geography of India; Biomes, elements of plant geography, distribution of	systems, equilibrium, geomorphic thresholds, geomorphic scales, magnitude-frequency. Lithology, structure, and landforms. Tectonic geomorphology. Global and Planetary Geomorphology. Tropical geomorphology: humid, arid, and Savanna landscapes. Drainage basin hydrology. Channel geometry, hydraulics, and sediment transport. Geomorphic processes, sediments, and landforms: weathering, mass movement, hillslopes, fluvial, coastal, aeolian, glacial, and karst. Geomorphometry. Terrain analysis, drainage basin,network morphometry, and tectonic activity indices. Quaternary geomorphology. Geoheritage. Applied geomorphology: geomorphic hazards, anthropogenic changes, and management. Anthropogenic impacts on geomorphic systems. **2. Climatology** Climatological observations - measurements and networks. Climate controls. Planetary energy budget, greenhouse effects, surface energy balance. Global hydrologic cycle, surface water balance, potential evapotranspiration, soil moisture storage, deficit, surplus, and runoff, drought. Condensation, precipitation. Circulations and climates in tropics, mid-latitudes, and polar regions; Mountain climates. Climate classifications. Paleoclimates and their reconstruction. Climate change and global warming: processes, evidence, human and societal responses. Urban climates. Future climate – predictions, frameworks, governance, negotiations, and controversies. Climatological diagrams and analysis of climatological time series.

forests and major plant communities. Distribution of major animal communities. Conservation of forests. Wildlife sanctuaries and parks.

4) Environmental Geography: Man-land relationship. Resources – renewable and non-renewable. Natural and man-made hazards – droughts, floods, cyclones, earthquakes, landslides, tsunamis. Ecological balance, environmental pollution and deterioration.

5) Geography of India: Physiography, drainage, climate, soils and natural resources – the Himalaya, Ganga-Brahmaputra Plains, and peninsular India Precambrian shield, the Gondwana rift basins, Deccan Plateau. Indian climatology with special reference to seasonal distribution and variation of temperature, humidity, wind and precipitation; Climate zones of India. Agricultural geography of India. Population – its distribution and characteristics. Urbanization and migration. Environmental problems and issues.

(III) GEOPHYSICS

1) Signal Processing: Continuous and discrete signals; Fourier series; auto and cross correlations, linear time invariant systems with deterministic and random inputs; band limited signal and sampling theorem; Fourier and Fast

3. Oceanography

Relief of the ocean floors with special reference to the Indian Ocean. Physical and chemical properties of ocean water. Water mass: distribution of temperature, salinity, and pressure. Shallow and deep-water circulation. Formation and propagation of waves and tides. Air-sea interaction. Coral reefs. Impacts of global warming. Sea level change. Ocean sediments. Anthropogenic utilization of oceans: Marine resources with special reference to India. Laws of the Sea – India's Exclusive Economic Zone, Coastal Regulation Zones and their significance.

4. Biogeography

Species distribution – Habitat factors, geographical range, niche, barriers, species interaction, competition, migration, invasion. Historical biogeography. Plate tectonics and biogeography. Biogeographical responses to Pleistocene glaciation. Historical patterns: speciation, diversification, extinction. Plant and animal dispersal: movements, barriers, biotic exchange. Endemism, provincialism, and disjunction. Ecosystems: types, structure, and functions. Ecosystem services. Biomes, phytogeographical, and zoogeographical zones. Biodiversity: Patterns, hotspots, crisis, conservation. Conservation Biogeography: National parks, biosphere reserves, wildlife sanctuaries, eco-sensitive zones, Ramsar sites. Ecological survey and assessment.

5. Paedology

Soil and soil profile. Factors and

Fourier transforms; Z-transform; convolution; Filters: discrete and continuous, recursive, non-recursive, optimal and inverse filters; deconvolution; fractal analysis.

2**) Field theory: Newtonian potential**; Laplace and Poisson‟s equations; Green‟s Theorem; Gauss‟ law; Continuation integral; equivalent stratum; Maxwell‟s equations and electromagnetic theory; Displacement potential, Helmhotz‟s theorem and seismic wave propagation.

3) Numerical analysis and inversion: Numerical differentiation and integration, finite element, and finite difference techniques; Simpson‟s rules; Gauss‟ quadrature formula; initial value problems; pattern recognition in Geophysics. Well posed and ill-posed problems; method of least squares; direct search and gradient methods; generalized inversion techniques; singular value decomposition; global optimization.

4) Gravity and Magnetic fields of the earth: Normal gravity field; Clairaut‟s theorem; Shape of the earth; deflection of the vertical, geoid, free-air, Bouguer and isostatic anomalies, isostatic models for local and regional compensation.

Geomagnetic field, secular processes of soil formation. Soil morphological and chemical properties. Soil water retention and movement, moisture conditions. Major soil types: podzol, chernozem, laterites, saline and alkaline soils. Soil classification systems. Soil degradation, accelerated erosion, and restoration.Soil organic matter content and factors influencing it. Cation exchange capacity.

6. Environmental Management

Classification of environmental pollution and deterioration. Integrated watershed and coastal management: Issues, components, and principles. Water harvesting techniques. Risk assessment and management of soil erosion, coastal erosion, riverbank erosion, landslides, land subsidence, salinification, and groundwater depletion. Terrain evaluation and hazard zone mapping. Environmental Impact Assessment (EIA) and Environmental Management Planning (EMP): Legal and policy framework in India. Stages and components of conducting EIA and EMP.

7. Geoinformatics

Datums, coordinate systems, and map projection systems. Survey of India maps and National Hydrographic Office charts. Principles of surveying with special reference to theodolite, total station, and echosounder. Global Navigation Satellite Systems: Principles of satellite- and Unmanned Aerial Vehicle-based remote sensing. Platforms and sensors. Image processing: classification, change detection. Source and analysis of Digital Elevation Models and Digital Terrain Models. Satellite-based collection of Earth data. Photogrammetry: Principles and products. Geographical Information

and transient variations and their theories; palaeomagnetism, construction of polar wandering curves.

5) **Plate Tectonics and Geodynamics**: Marine magnetic anomalies, sea floor spreading; mid-oceanic ridges and geodynamics; plate tectonics hypothesis; plate boundaries and seismicity. Heat flow mechanisms, thermal moddling of earth, core-mantle convection and mantle plumes.

6)Seismology Elastic theory: Seismometry: short period, long period, broad band and strong motion; elements of earthquake seismology; seismic sources: faulting source, double couple hypothesis, seismic moment tensor, focal mechanism and fault plane solutions; seismic gaps; seismotectonics and structure of the earth; Himalayan and stable continental region earthquakes, reservoir induced seismicity; seismic hazards; earthquake prediction, travel time residuals, velocity anomalies, seismic tomography.

7) Gravity and Magnetic Methods: Gravimeters and magnetometers; data acquisition from land, air and ship; corrections and reduction of anomalies; ambiguity; regional and residual separation; continuation and derivative calculations; interpretation system, Data structure. Spatial analysis.

8. Physical Geography of India

Classification and characteristics of India's physiography, drainage, climate, soil, vegetation, and mineral resources. Principal physiographic regions: Himalaya, Peninsular Plateaus and Ranges, Northeastern Fold Belt, Great Plains, Thar Desert, Coastal Lowlands, Islands. Agro-climatic zones. Water resources and river valley projects. Management and conservation of natural resources. Climate change scenarios and impacts. Environmental quality and pollution. Natural hazards: earthquake, subsidence, drought, forest fire, smog, flood (rain and outburst floods), cyclones, tsunamis, landslides, coastal and riverbank erosion.

III. GEOPHYSICS

1. Signal Processing

Continuous and discrete signals; Fourier series; auto and cross-correlations, linear time-invariant systems with deterministic and random inputs; band-limited signal and sampling theorem; Fourier and Fast Fourier transform; Z-transform; convolution; Filters: discrete and continuous, recursive, non-recursive, optimal and inverse filters; deconvolution.

2. Field theory

Newtonian potential; Laplace and Poisson's equations; Green's Theorem;

of anomalies of simple geometric bodies, single pole, sphere, horizontal cylinder, sheet, dyke and fault. Forward modelling and inversion of arbitrary shaped bodies and 2-D, 3-D interfaces. Interpretations in frequency domain.

8) Electrical and Electromagnetic Methods: Electrical profiling and sounding, typical sounding curves, pseudo-sections; resistivity transform and direct interpretation; induced polarization methods. Electromagnetic field techniques; elliptic polarization, in-phase and out of phase components, horizontal and vertical loop methods; interpretation; VLF (very low frequency); AFMAG (Audio frequency magnetic) methods; and central frequency sounding; transient electromagnetic methods; magneto-telluric method; geomagnetic depth sounding.

9) Seismic Methods: Generalized Snell‟s Law; Ray theory; reflection, refraction, diffraction; Zoeppritz‟s equation; seismic energy sources; detectors; seismic noises and noise profile analysis; seismic data recording, reduction to a datum and weathering corrections; Interpretation of refraction and reflection data; CDP/CMP; velocity analysis, F-K filtering, stacking, deconvolution, migration

Gauss' law; Continuation integral; equivalent stratum; Current and potential distributions, Image theory, Maxwell's equations and electromagnetic theory; Displacement potential, Helmholtz's theorem and seismic wave propagation.

3. Numerical analysis and inversion

Numerical differentiation and integration, finite element, finite difference techniques; Simpson's rules; Gauss' quadrature formula; initial value problems. Well-posed and ill-posed problems; method of least squares; direct search and gradient methods; generalized inversion techniques; singular value decomposition; local and global optimization.

4. Gravity and Magnetic fields of the Earth

Normal gravity field; Clairaut's theorem; the shape of the earth; deflection of the vertical, geoid, free-air, Bouguer, and isostatic anomalies; isostatic models for local and regional compensation; geomagnetic field, secular and transient variations, and their theories; paleomagnetism; construction of polar wandering curves.

5. Plate Tectonics and Geodynamics

Marine magnetic anomalies, seafloor spreading, mid-oceanic ridges and geodynamics, plate tectonics hypothesis, plate boundaries and seismicity. Heat flow mechanisms, thermal modeling of the Earth. Core-mantle convection and mantle plumes.

before and after stack; bright spot analysis; wavelet processing; attenuation studies, shear waves, AVO; VSP; introduction to 3D seismics; seismic stratigraphy.

10) Well logging: Open hole, cased hole and production logging; Electrical logs; lateral, latero, induction, temperature, S.P; porosity logs; sonic, density, neutron; natural gamma; determination of formation factor, porosity, permeability, density, water saturation, lithology; logging while drilling.

(IV) METEOROLOGY

1) Climatology: Same as under Geography

2**) Physical Meteorology**: Thermal structure of the atmosphere and its composition. Radiation: basic Laws - Rayleigh and Mie scattering, multiple scattering, radiation from the sun, solar constant, effect of clouds, surface and planetary albedo. Emission and absorption of terrestrial radiation, radiation windows, radiative transfer, Greenhouse effect, net radiation budget; Thermodynamics of dry and moist air: specific gas constant, Adiabatic and isoentropic processes, entropy and enthalpy, Moisture variables, virtual temperature; Clausius – Clapeyron equation, adiabatic process of moist

6. Seismology

Theory of elasticity: stress, strain, elastic moduli, Hooke's law, wave equation; Types of seismic waves, Ray theory and geometry: Snell's law, nomenclature of seismic waves – crustal and whole Earth phases;Surface wave dispersion and free oscillations; Internal structure and composition of the Earth; Seismic anisotropy, Inversion of travel time data; Seismic Tomography - local earthquake, teleseismic, surface wave, and ambient noise tomographic techniques; Waveform modelling; Earthquake location, magnitude, and intensity scales;Kinematics and dynamics of source:faulting sources, seismic moment tensor, focal mechanism; Seismotectonics, seismic hazard, and earthquake prediction.

7. Gravity and Magnetic Methods

Gravimeters and magnetometers; data acquisition from land, air, and ship; corrections and reduction of anomalies; ambiguity; regional and residual separation; continuation and derivative calculations; interpretation of anomalies of simple geometric bodies, single pole, sphere, horizontal cylinder, sheet, dyke, and fault. Forward modeling and inversion of arbitrarily shaped bodies and 2-D and 3-D interfaces. Interpretations in the frequency domain.

8. Electrical and Electromagnetic Methods

air; thermodynamic diagrams: Hydrostatic equilibrium: Hydrostatic equation, variation of pressure with height, geopotential, standard atmosphere, altimetry. Vertical stability of the atmosphere: Dry and moist air parcel and slice methods. Tropical convection. Atmospheric optics - visibility - optical phenomenon - rainbows, haloes, corona, glarg, mirage.

3) Atmospheric Electricity: Fair weather electric field in the atmosphere and potential gradients, ionization in the atmosphere. Electrical fields in thunderstorms, theories of thunderstorm electrification - Structure of lightening flash-mechanism of earth-atmospheric change balance-role of thunderstroms.

4) Cloud Physics: Cloud classification, condensation nuclei, growth of cloud drops and ice-crystals, precipitation mechanisms: Bergeron, Findeisen process, coalescence process – Precipitation of warm and mixed clouds, artificial precipitation, hail suppression, fog and cloud – dissipation, radar observation of clouds and precipitation, radar equation, rain drop spectra, radar echoes of hail storm and tornadoes, radar observation of hurricanes, measurements of rainfall by radar.

Various electrode configurations and their geometrical factors, Electrical profiling and sounding, typical sounding curves, pseudo-sections, resistivity transform and direct interpretation, Reductions of layers, Dar Zarrouk parameters, and Self-Potential & induced polarization methods. Electromagnetic field techniques; elliptic polarization, Skin depth, in-phase and out-of-phase components, horizontal and vertical loop methods; interpretation; VLF (very low frequency); AFMAG (Audio frequency magnetic) methods; and central frequency sounding; Electromagnetic scale modeling, transient electromagnetic method; magneto-telluric method; geomagnetic depth sounding.

9. Seismic Methods

Generalized Snell’s Law; Ray theory; reflection, refraction, diffraction; Zoeppritz’s equation; seismic energy sources; detectors; seismic noises and noise profile analysis; seismic data recording, reduction to a datum and weathering corrections; Interpretation of refraction and reflection data;CDP/CMP; velocity analysis, F-K filtering, stacking, deconvolution, migration before and after stack; bright spot analysis; wavelet processing; attenuation studies, shear waves, AVO; VSP; introduction to 3D seismics: 3D acquisition geometry in land and marine settings, concept of bin; seismic stratigraphy.

10. Well logging

Formation evaluation; Archies’s law; Estimation of petrophysical properties; Borehole environment; Drilling fluids and invasion; Principles and applications of wireline logging tools including

5) Dynamic Meteorology: Basic equations and fundamental forces: Pressure, gravity, centripetal and Corolis forces, continuity equation in Cartesian and isobaric coordinates. Momentum equation Cartesian and spherical coordinates; scale analysis, inertial flow, geostrophic and gradient winds, thermal wind. Divergence and vertical motion Rossby, Richardson, Reynolds and Froude numbers. Circulation, vorticity and divergence; Bjerknese circulation theorem and applications, vorticity and divergence equations, scale analysis, potential vorticity, stream function and velocity potential. Atmospheric turbulence: Mixing length theory, planetary boundary layer equations, surface layer, Ekman layer, eddy transport of heat, moisture and momentum, Richardson criterion; Linear Perturbation Theory: Internal and external gravity waves, inertia waves, gravity waves, Rossby waves, wave motion in the tropics, barotropic and baroclinic instabilities. Atmospheric Energetics: Kinetic, potential and internal energies – conversion of potential and internal energies into kinetic energy, available potential energy.

6) Numerical Weather Prediction: computational

Spontaneous Polarization, Resistivity, Induction, Density, Sonic, Neutron, Natural Gamma Ray, Gamma Ray Spectroscopy, Nuclear Magnetic Resonance, Formation Microscanner and Imager; Quick look techniques; Cross plots; Well log interpretation.

IV. METEOROLOGY

1. Atmospheric Thermodynamics

Thermal structure of the atmosphere and its composition, Thermodynamics of dry and moist air: specific gas constant, Adiabatic and isentropic processes, entropy and enthalpy, potential temperature, Moisture variables, virtual temperature; Clausius – Clapeyron equation, adiabatic process of moist air; wet bulb processes, dew point processes, thermodynamic diagrams: Hydrostatic equilibrium: Hydrostatic equation, variation of pressure with height, geopotential, standard atmosphere, altimetry. Vertical atmosphere stability: Dry and moist air parcel and slice methods. Tropical convection.

2. Atmospheric Radiation and Radiative Transfer

Radiation: basic Laws - Rayleigh and Mie scattering, multiple scattering, radiation from the sun, solar constant, effect of clouds, surface and planetary albedo. Emission and absorption of terrestrial radiation, radiation windows, radiative transfer, Greenhouse effect, net radiation budget; Radiation transfer in planetary atmospheres, Beer’s law, Reflection and absorption by a layer of the atmosphere; Absorption and emission of radiation in Cloud-free air, Vertical profiles of radiative heating rate, General equation of radiation transfer, different methods to solve radiation transfer equation and

instability, filtering of sound and gravity waves, filtered forecast equations, barotropic and equivalent barotropic models, two parameter baroclinic model, relaxation method. Multi-layer primitive equation models. Short, medium and long range weather prediction. Objective analysis; Initialization of the data for use in weather prediction models; data assimilation techniques, application of satellite in NWP (Numerical Weather Prediction) and remotely sensed data.

7) General Circulation and Climate Modelling: Observed zonally symmetric circulations, meridional circulation models, mean meridional and eddy transport of momentum and energy, angular momentum and energy budgets; zonally asymmetric features of general circulation; standing eddies; east-west circulations in tropics: climate variability and forcings; feedback processes, low frequency variability, MJO Madden-Julian oscillation), ENSO, QBO (quasi-biennial oscillation) and sunspot cycles. Basic principles of general circulation modelling; grid-point and spectral GCMs; role of the ocean in climate modelling; interannual variability of ocean fields (SST, winds, circulation, etc.) and its relationship with monsoon,

approximations, Radiation transfer in aerosols and clouds, Concept of radiative forcing.

3. Synoptic Meteorology

Weather observations and transmission; synoptic charts; analysis of surface, upper air, and other derivative charts; streamlines, isotachs, and contour analysis; tilt and slope of pressure/weather systems with height. Synoptic weather forecasting, prediction of weather elements such as rain, maximum and minimum temperature, and fog; hazardous weather elements like thunderstorms, dust storms, and tornadoes. Tropical meteorology: Trade wind inversion, ITCZ; monsoon trough tropical cyclones, their structure and development theory; monsoon depressions; tropical easterly jet stream; low-level jets, Somali jet, waves in easterlies; western disturbances; SW and NE monsoons; synoptic features associated with onset, withdrawal, break active and weak monsoons and their prediction. Air masses and fronts: sources, origin, and classification of air masses; fronts, frontogenesis, and frontolysis; structure of cold and warm fronts; weather systems associated with fronts. Extra-tropical synoptic scale features - jet streams, extratropical cyclones, and anticyclones.

4.Atmospheric Electricity

Fairweather electric field in the atmosphere, potential gradients, and ionization in the atmosphere. Electrical fields in thunderstorms: theories of thunderstorm electrification,the structure of lightning flash, the mechanism of earth-atmospheric change balance, and the role of thunderstorms.

concepts of ocean – atmosphere coupled models.

8) Synoptic Meteorology: Weather observations and transmission, synoptic charts, analysis of surface, upper air another derivative chart, stream-lines, isotachs and contour analysis; tilt and slope of pressure/weather systems with height. Synoptic weather forecasting, prediction of weather elements such as rain, maximum and minimum temperature and fog; hazardous weather elements like thunderstorms, duststorms, tornadoes. Tropical meteorology: Trade wind inversion, ITCZ; monsoon trough tropical cyclones, their structure and development theory; monsoon depressions; tropical easterly jet stream; low level jets, Somali jet, waves in easterlies; western disturbances; SW and NE monsoons; synoptic features associated with onset, withdrawal, break active and weak monsoons and their prediction. Air masses and fronts: sources, origin and classification of air masses; and fronts, frontogenesis and frontolysis; structure of cold and warm fronts; weather systems associated with fronts. Extra-tropical synoptic scale features: jet streams, extratropical cyclones and

5.Atmospheric Chemistry and Cloud Physics

Atmospheric composition, Major and minor constituents, aerosols, physical, chemical, and optical properties of aerosols, trace gases, Greenhouse gases, Atmospheric ozone, its distribution and ozone chemistry, Ozone hole, sulfur-containing compounds, nitrogen-containing compounds, carbon-containing compounds, halogen-containing compounds, emission inventories.

Formation of clouds, Condensation nuclei, Curvature Effect-Solute effect and Kohler theory, Cloud classification, condensation nuclei, growth of cloud drops and ice-crystals, precipitation mechanisms: Bergeron, Findeisen process, coalescence process – Precipitation of warm and mixed clouds, artificial precipitation, hail suppression, fog and cloud – dissipation, Microphysics of clouds, Cloud phase, Liquid and ice water content, Aerosol – cloud interaction, radar observation of clouds and precipitation, radar equation, raindrop spectra, radar echoes of hail storm and tornadoes, radar observation of hurricanes, measurements of rainfall by radar.

6.Atmospheric Dynamics

Basic equations and fundamental forces: Pressure, gravity, centripetal and Coriolis forces, continuity equation in Cartesian and isobaric coordinates. Momentum equation, Cartesian and spherical coordinates; scale analysis, inertial flow, geostrophic and gradient winds, thermal wind. Divergence and vertical motion

anticyclones.

9) Aviation Meteorology: Role of meteorology in aviation, weather hazards associated with take off cruising and landing, inflight – icing, turbulence, visibility, fog, clouds, rain, gusts, wind shear and thunderstorms, now casting and very short range forecasting.

10) Satellite Meteorology: Meteorological satellites – Polar orbiting and geostationary satellites, visible and infrared radiometers, multiscanner radiometers; identification of synoptic systems, fog and sandstorms, detection of cyclones, estimation of SST, cloud top temperatures, winds and rainfall: temperature and humidity soundings.

(V) OCEAN SCIENCES

1) Physical Oceanography: T-S diagrams; mixing processes in the oceans; characteristics of important water masses. Wind generated waves in the oceans; their characteristics; shallow and deep water waves. Propagation, refraction, and reflection of waves. Wave spectrum, principles of wave forecasting. Tide-producing forces and their magnitudes; prediction of tides by the harmonic method; tides and tidal currents in shallow seas, estuaries and rivers. Factors influencing coastal

Rossby, Richardson, Reynolds, and Froude numbers. Circulation, vorticity, and divergence; Bjerknes circulation theorem and applications, vorticity and divergence equations, scale analysis, potential vorticity, stream function, and velocity potential. Atmospheric turbulence: Mixing length theory, planetary boundary layer equations, surface layer, Ekman layer, eddy transport of heat, moisture, and momentum, Richardson criterion; Linear Perturbation Theory: Internal and external gravity waves, inertia waves, gravity waves, Rossby waves, wave motion in the tropics, barotropic and baroclinic instabilities. Atmospheric Energetics: Kinetic, potential, and internal energies – conversion of potential and internal energies into kinetic energy, available potential energy.

7.Numerical Weather Prediction

Computational instability, filtering of sound and gravity waves, filtered forecast equations, barotropic and equivalent barotropic models, two-parameter baroclinic model, relaxation method. Multi-layer primitive equation models. Short, medium, and long-range weather prediction. Objective analysis, Initialization of the data for use in weather prediction models, and data assimilation techniques. Application of satellite in NWP (Numerical Weather Prediction) and remotely sensed data.

8.General Circulation and Climate Modelling

Observed zonally symmetric circulations, meridional circulation models, mean meridional and eddy transport of momentum and energy, angular

processes; transformation of waves in shallow water; effects of stratification; effect of bottom friction, phenomena of wave reflection, refraction and diffraction; breakers and surf; littoral currents; wave action on sediments – movement to beach material; rip currents; beach stability, ocean beach nourishment; harbour resonance; seiches; tsunami; interaction of waves and structure.

Estuaries: classification and nomenclature; tides in estuaries; estuarine circulation and mixing; depth – averaged and breadth – averaged models; sedimentation in estuaries; salinity intrusion in estuaries; effect of stratification; coastal pollution; mixing and dispersal of pollutants in estuaries and near- shore areas; coastal zone management.

The global wind system; action of wind on ocean surface; Ekman‟s theory; Sverdrup, Stommel and Munk‟s theories; upwelling and sinking with special reference to the Indian ocean. Inertial currents; divergences and convergences; geostrophic motion; barotropic and baroclinic conditions; oceanic eddies, relationship between density, pressure and dynamic topography; relative and slope currents. Wind driven coastal momentum and energy budgets; zonally asymmetric features of general circulation; standing eddies; east-west circulations in tropics: climate variability and forcings; feedback processes, low-frequency variability, MJO Madden-Julian oscillation, ENSO, QBO (quasi-biennial oscillation), and sunspot cycles. Basic principles of general circulation modelling; grid-point and spectral GCMs; the role of the ocean in climate modelling; interannual variability of ocean fields (SST, winds, circulation, etc.) and its relationship with the monsoon; concepts of ocean-atmosphere coupled models.

9.Climate system

Factors controlling climate change, Climate monitoring, past and present climate of Earth, Climate variability, internally generated climate variability, externally forced climate variability, Milankovitch cycle, Role of the increase in CO_2 emissions and other Greenhouse gases, Global warming potential, Assessment of global and regional climate change and prediction.

10.Atmospheric Observations and Remote Sensing

Automatic weather stations for in situ temperature, pressure, humidity, and wind measurements, Principles of Atmospheric Radar, Lidar, and Solar Radiometer.

Active and passive remote sensing, types of satellite orbits, Radiometric quantities and measurements, Observation geometry in remote sensing, geo-referencing, Surface reflectance,

currents; typical scales of motion in the ocean. Characteristics of the global conveyor belt circulation and its causes. Formation of subtropical gyres; western boundary currents; equatorial current systems; El Nino; monsoonal winds and currents over the North Indian Ocean; Somali current; southern ocean. Upwelling process in the Arabian Sea.

2) Chemical Oceanography: Composition of seawater – Classification of elements based on their distribution; major and minor elements, their behavior and chemical exchanges across interfaces and residence times in seawater. Element chemistry in atypical conditions-estuaries, hydrothermal vents, anoxic basins, HNLC waters, sediment pore fluid and anthropogenic inputs. Chemical and biological interactions – Ionic interactions; biochemical cycling of nutrients, trace metals and organic matter. Air-sea exchange of important biogenic dissolved gases; carbon dioxide- carbonate system; alkalinity and control of pH; biological pump. Factors affecting sedimentary deposits-$CaCO_3$, Silicate, Manganese nodules, phosphorites and massive single deposits.

3) Geological Oceanography: Same

Bidirectional reflectance function, Optical, infrared and microwave sensors for atmospheric observations, spaceborne radiometers, radar, and lidar, Basics of inversion of satellite remote sensing data to derive geophysical parameters, detection of cyclones, estimation of SST, cloud top temperatures, winds and rainfall, temperature and humidity soundings.

V. OCEAN SCIENCES

1. Physical Oceanography

T-S diagrams; mixing processes in the oceans; ocean circulation and currents, characteristics of important water masses; Wind generated waves in the oceans and their characteristics; shallow and deep water waves; Propagation, refraction, and reflection of waves; Wave spectrum, principles of wave forecasting; Tide-producing forces and their magnitudes; prediction of tides by the harmonic method; tides and tidal currents in shallow seas, estuaries and rivers; Factors influencing coastal processes; transformation of waves in shallow water; effects of stratification; effect of bottom friction, phenomena of wave reflection, refraction and diffraction; breakers and surf; littoral currents; wave action on sediments – movement to beach material; rip currents; beach stability, ocean beach nourishment; tsunami; interaction of waves and structure; tides in estuaries; estuarine circulation and mixing; sedimentation in estuaries; salinity intrusion in estuaries; effect of stratification; action of wind on ocean surface; Ekman theory; Sverdrup, Stommel and Munk’s theories; Vertical structure of water column; upwelling; Inertial currents; divergences and

topics as under subhead "Marine Geology & paleo oc e anogra ph y"

4) Biological Oceanography:

Classification of the marine environment and marine organisms. Physio-chemical factors affecting marine life – light, temperature, salinity, pressure, nutrients, dissolved gases; adaptation and biological processes. Primary and secondary production; factors controlling phytoplankton and zooplankton abundance and diversity; nekton and fisheries oceanography; benthic organisms; coastal marine communities and community ecology – estuaries, coral reefs and mangrove communities, deep-sea ecology including hydrothermal vent communities. Energy flow and mineral cycling – energy transfer and transfer efficiencies through different trophic levels; food webs including the microbial loop. Human impacts on marine communities; impacts of climate change on marine biodiversity. Impact of pollution on marine environments including fisheries.

convergences; geostrophic motion; barotropic and baroclinic conditions; oceanic cyclonic and anticyclonic eddies, relationship between density, pressure and dynamic topography; relative and slope currents; Wind driven coastal currents; typical scales of motion in the ocean; Characteristics of the global conveyor belt circulation and its causes; Formation of subtropical gyres; western boundary currents; equatorial current systems; El Nino; monsoonal winds and currents over the Indian Ocean

2. Chemical Oceanography

Composition of seawater: classification of elements based on their distribution; major and minor elements, their behaviour and chemical exchanges across interfaces and residence times in seawater; biogeochemical cycling of carbon, nitrogen, phosphorous and silica; elemental chemistry in estuaries;hydrothermal vents, anoxic basins, HNLC waters; anthropogenic inputs into the ocean; chemical and biological interactions – Ionic interactions; biochemical cycling of nutrients, trace metals and organic matter; air-sea exchange of important biogenic dissolved gases; seawater carbonate system; silicate andmanganese nodules, phosphorites, ocean warming, acidification and deoxygenation.

3. Biological Oceanography

Classification of the marine environment and marine organisms; physio-chemical factors affecting marine life; adaptation and biological processes; primary and secondary production and their

		measurement techniques; factors (e.g., eddies, circulation, warming) controlling phytoplankton and zooplankton abundance and diversity; biological carbon pump; phytoplankton and production of gases (e.g., DMS); chemical composition of marine organic matter (Redfield Ratio), benthic organisms; coastal marine communities, coral reefs and mangrove communities, deep-sea ecology including hydrothermal vent communities; energy flow and mineral cycling – energy transfer and transfer efficiencies through different trophic levels; food webs including the microbial loop. Human impacts on marine communities; impacts of climate change on marine life and biodiversity. **4. Geological Oceanography** Morphologic and tectonic domains of the ocean floor; structure, composition, and mechanism of the formation of oceanic crust; hydrothermal vents; ocean margins and their significance.Mid-ocean ridges, mantle plumes &ocean islands, aseismic ridges, subduction zones, volcanic arcs, and fracture zones.Tectonic evolution of the ocean basins. Mineral resources. The Sediment Factory: From Source to Sink,Sediment Transport, Diagenetic changes in oxic and anoxic environments.Continental Margins: Sedimentology and Sequence Stratigraphy, The Coast: Landscapes and Seascapes, Waves and Coastal Morphodynamics, Submarine Groundwater Discharge. **5. Palaeoceanography**

	CO_2-weathering Climate regulation; Last Glacial Maximum: Ice Sheets, Sea Level, Dust, Dating; Climatic evolution in the geologic past: early Earth climate states and climate evolution; climate variations and Milankovitch cycles; millennial, centennial and decadal-scale variability in the climate; Paleoceanographic applications; climate and sea level; paleo circulation and paleoproductivity; global anoxic and oxygenation events; ocean acidification in the paleo-record; Geochronology of oceanic sediments; approaches to paleoceanographic reconstructions; various proxy indicators for paleoceanographic interpretation; reconstruction of monsoon variability by using marine proxy records; Opening and closing of ocean gateways and their effect on circulation and climate in the past; Sea level changes; Methods to reconstruct Paleo sea surface temperature (SST).