Subject: EARTH, ATMOSPHERIC, OCEAN AND PLANETARY SCIENCES
SYLLABUS
PAPER-II & III
PAPER – II

1. The Earth and the Solar System:

2 A. 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 different parts of India

2 B. Surface features and Processes
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

4. Oceans and Atmosphere

5. Environmental Earth Sciences
PAPER - III
I. GEOLOGY

1) MINERALOGY AND PETROLOGY:

2) STRUCTURAL GEOLOGY AND GEOTECTONICS:

3) PALEONTOLOGY AND ITS APPLICATIONS:

4) SEDIMENTOLOGY AND STRATIGRAPHY:
paleogeographic reconstruction. Earth’s Climatic History. Phanerozoic stratigraphy of India with reference to the type areas—their correlation with equivalent formations in other regions. Boundary problems in Indian Phanerozoic stratigraphy.

5) MARINE GEOLOGY AND PALEOCEANOGRAPHY:

6) GEOCHEMISTRY:
Structure and atomic 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 cycles.

7) ECONOMIC GEOLOGY:

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 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, relative dating methods.
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) APPLIED GEOLOGY:
   (i) Remote Sensing and GIS: Elements of photogrammetry, elements of photointerpretation, electromagnetic spectrum, emission range, film and imagery, sensors, geological interpretations air photos and imageries. Global positioning systems. GIS- data structure, attribute data, thematic layers and query analysis.
   (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.

II: PHYSICAL GEOGRAPHY
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 forests and major plant communities. Distribution of major animal communities. Conservation of forests. Wildlife sanctuaries and parks.
III: GEOPHYSICS

1) Signal Processing: Continuous and discrete signals; Fourier series; linear time invariant systems with deterministic and random inputs; band limited signal and sampling theorem; discrete 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; 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 and transient variations and their theories; palaeomagnetism, construction of polar wandering curves.

5) Plate Tectonics and Geodynamics: Vine-Mathews hypothesis, marine magnetic anomalies, sea floor spreading; mid-oceanic ridges and geodynamics; plate tectonics hypothesis; plate boundaries and seismicity. Heat flow mechanisms, core-mantle convection and mantle plumes.

6) Seismology & Tomography: Seismometry: short period, long period, broad band and strong motion; elements of earthquake seismology; seismic sources: faulting source, double couple hypothesis, elastodynamics, Haskell’s function, 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.

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 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 and telemetry devices; reduction to a datum and weathering corrections; Interpretation of a refraction seismic data by graphical and analytical techniques; CDP/CMP; seismic reflection data processing, 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; seismic stratigraphy.
10) **Well logging and other methods:** Open hole, cased hole and production logging; Electrical logs; lateral, latero, induction, S.P; porosity logs; sonic, density, neutron; natural gamma; determination of formation factor, porosity, permeability, density, water saturation, lithology; logging while drilling. Radioactive and geothermal methods.

**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 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.
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.
4) **Cloud Physics:** Cloud classification, condensation nuclei, growth of cloud drops and icecrystals, 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.
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:
     - Mixinglength 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 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
(quasibiennial oscillation) and sunspot cycles. Basic principles of general circulation modelling; gridpoint and spectral GCMs; role of the ocean in climate modelling; interannual variability of ocean fields (SST, winds, circulation, etc.) and its relationship with monsoon, 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. Extratropical synoptic scale features: jet streams, extratropical cyclones and anticyclones.

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

10) **Satellite Meteorology**: Meteorological satellites – Polar orbiting and geostationary satellites, visible and infrared radiometers, multisensor 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 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 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 constituents; behavior of elements; chemical exchanges
across interfaces and residence times in seawater. Chemical and biological interactions – Ionic interactions; cycling and air-sea exchange of important biogenic dissolved gases; carbon dioxide-carbonate system; alkalinity and control of pH; abiotic and biotic controls of trace elements in the ocean; biological pump and controls on atmospheric composition.

3) Geological Oceanography: Same topics as under subhead “Marine Geology & paleooceanography

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.