M.Sc. (Tech.) Geophysics
Department of Geophysics, Institute of Science, Banaras Hindu University
DISTRIBUTION OF DIFFERENT COURSES AND CREDITS IN VARIOUS SEMESTERS
EFFECTIVE FROM SESSION 2019-20

Semester- I		
Course Code	**Title**	**Credits**
GPM 101	Elements of Geology	3
GPM 102	Geoexploration & Surveying	4
GPM 103	General Meteorology	4
GPM 104	Advanced Computer Programming	3
GPM 105	Practical based on course GPM101	2
GPM 106	Practical based on course GPM102	2
GPM 107	Practical based on course GPM103	2
GPM 108	Practical based on course GPM104	2
	Total	**22**

Semester- II		
Course Code	**Title**	**Credits**
GPM 201	Geohydrology	4
GPM 202	Seismology	4
GPM 203	Geodynamics	4
GPM 204	Practical based on course GPM201	2
GPM 205	Practical based on course GPM202	2
GPM 206	Educational Tour & Excursion*	2
GPM 207M	Minor Elective: To be selected from Swayam Portal	2
	Total	**20**

Semester- III		
Course Code	**Title**	**Credits**
GPM 301	Mathematical & Numerical Methods in Geophysics	4
Any one of the corresponding combinations of five courses of Group A (*Exploration Geophysics): (GPM 302A-GPM 306A) or Group B (Meteorology):(GPM 302B – GPM 306B)*		
GPM 302A GPM 302B	Geoelectrical Methods Agro-meteorology	4
GPM 303A GPM 303B	Seismic Methods Physical Meteorology	4
GPM 304A GPM 304B	Practical based on course GPM302A Practical based on course GPM302B	2
GPM 305A GPM 305B	Practical based on course GPM303A Practical based on course GPM303B	2
GPM 306A GPM 306B	Geophysical (Exploration) Field Training* Geophysical (Meteorology) Field Training*	2
GPM 307M	Minor Elective: To be selected from Swayam Portal	2
	Total	**20**

Semester- IV		
Course Code	**Title**	**Credits**
GPM 401	Stratigraphy, Economic and Petroleum Geology	3
Any one of the corresponding combination of four courses of Group A *(GPM 402A-GPM 405A) or Group B (GPM 402B-GPM 405B)*		
GPM 402A GPM 402B	Geo-electromagnetic Methods Climate Dynamics I	4
GPM 403A GPM 403B	Borehole & Reservoir Geophysics Climatology & Climate change	4
GPM 404A GPM 404B	Practical based on course GPM 402A Practical based on course GPM 402B	2
GPM 405A GPM 405B	Practical based on course GPM 403A Practical based on course GPM 403B	2
GPM 406	Practical based on course GPM 401	2
GPM 407M	Minor Elective: To be selected from Swayam Portal	2
	Total	**19**

Semester- V		
Course Code	**Title**	**Credits**
GPM 501	Communication Theory and Signal Processing	4
Any one of the corresponding combination of four courses of Group A *(GPM 502A-GPM506A) or Group B (GPM502B-GPM506B)*		
GPM 502A GPM 502B	Inversion Theory Synoptic and Tropical Meteorology	4
GPM 503A GPM 503B	Gravity and Magnetic Methods Climate Dynamics II	4
GPM 504A GPM 504B	Petroleum Geophysics and Seismic Stratigraphy Aerosol and Atmospheric Chemistry	3
GPM 505A GPM 505B	Practical based on course GPM502A Practical based on course GPM502B	2
GPM 506A GPM 506B	Practical based on course GPM503A Practical based on course GPM503B	2
GPM 507	Practical based on course GPM501	2
	Total	**21**

Semester- VI		
Course Code	**Title**	**Credits**
GPM 601	Physical Oceanography and Marine Geophysics	4
GPM 602 (O-Z)	One of the Elective courses (GPM 602O to GPM 602Z): (O) Advanced Hydrology; (P) Advanced Seismology; (Q) Digital Electronics & Microprocessor; (R) Remote Sensing and GIS; (S) Environmental Geophysics; (T) Geomagnetism; (U) Non-linear System in Geophysics; (V) Geo-tomography and Computer modeling; (W) Advanced Physical Meteorology; (X) Applied Meteorology; (Y) Advanced Climatology; (Z) Modern Techniques in Seismic Interpretation.	4
GPM 603	Seminar (in the respective specialization Groups)	2
GPM 604A GPM 604B	Comprehensive viva-voce (Exploration Geophysics) Comprehensive viva-voce (Meteorology)	2
GPM 605A GPM 605B	Project work/ Dissertation (Exploration Geophysics) Project work/ Dissertation (Meteorology)	6
	Total	**18**
	Grand Total	**120**

*** Educational Tour & Excursion; Geophysical Field Training shall be conducted during the respective Semester break after the end semester examination.**

Course Contents of M. Sc. (Tech.) Geophysics Syllabus
(Semester System)

The M.Sc. (Tech.) Geophysics course will have the following academic structure of the syllabus with regard to the paper distribution over the entire three year courses (six semesters).

SEMESTER-I (Credit: 22)

GPM 101: ELEMENTS OF GEOLOGY **Credits: 3**

1. Physical and Structural Geology: Introduction to geology, scope, sub-disciplines and relationships with other branches of science, weathering agents, landslides and volcanic activity, Representation of altitude, Dip and strike, outcrops, outlier and inlier, Folds, faults, unconformities, joints and their classification, criteria of their recognition, clinometer compass and its use.
2. Mineralogy: Mineral- its definition and mode of occurrence, physical properties of minerals like form, colour, lustre, streak, cleavage, fracture, hardness and specific gravity, Physical characters and chemical composition of the following rock forming minerals : Quartz, Orthoclase, Microcline, Plagioclase, Nepheline, Muscovite, Biotite, Augite, Hornblende, Olivine, Garnet, Epidote, Calcite and Beryl, graphite, tourmalilne, talc, Kaolinite, Kyanite and Corundum.
3. Petrology: Rock- its definition, classification and distinguishing characteristics of Igneous, Sedimentary and Metamorphic rocks forms of Igneous rocks, elementary ideas regarding formation, texture and structure of Igneous, Sedimentary and Metamorphic rocks, brief petrographic description and occurrences of the following rocks: Granite, Syenite, Gabbro, Rhyolite, Dolerite, Basalt, Conglomerate, Breccia, Sandstone, Limestone, Shale, Gneiss, Schist, Quartzite and Marble, Formation of rocks in plate tectonic settings.

Suggested Readings:

1. Berry & Mason: Mineralogy
2. Billings: Structural Geology
3. Mukherjee: A Text Book of Geology
4. Read & Rutley's: Elements of Mineralogy
5. Singh: Stuctural Geology: A Practical Approach
6. Smith: Minerals and Microscope
7. Tyrrell: Principles of Petrology

GPM 102: GEOEXPLORATION AND SURVEYING **Credits: 4**

1. Basic principles of geophysical exploration.
2. Physical properties of minerals and rocks.
3. Gravity Method: Stable and unstable gravimeters, Worden, Lacoste and Romberg, Hartley Askania and Gulf gravimeters, field procedure and reduction of gravity data.
4. Magnetic Method: Fluxgate and Proton Precession magnetometers. Anomalies due to point pole and dipole, field practices and corrections.

5. Electrical Method: Elements of SP, IP and resistivity methods, Wenner and Schlumberger configurations. Methods of resistivity profiling and sounding, theory of images, Tagg's method of interpretation.
6. Seismic Method: Elementary principle of reflection and refraction methods, two layered reflection and refraction problems including inclined layer, fundamentals of conventional seismic instruments, fan shooting, profile shooting, continuous profiling and correlation methods of surveying.
7. Radiometric Method: Physical and geological principles of radiometric method, successive disintegrations equilibrium conditions, GM counter, scintillation counter and gamma ray spectrometer, radon measurements.
8. Basic principles of electromagnetic and GPR methods.

Suggested Readings:

1. Dobrin & Savit: Introduction to Geophysical Prospecting
2. Parasnis: Principle of Applied Geophysics
3. Telford et al: Applied Geophysics
4. Sharma: Geophysical Prospecting for Geologists and Engineers
5. Israel & Krebs: Nuclear Radiation in Geophysics

GPM 103: GENERAL METEOROLOGY **Credits: 4**

1. Instrumentation: Surface, self recording and upper air meteorological instruments (mercury and aneroid barometer, barograph, air thermometers, bimetallic thermograph, psychrometer, hair hygrograph, cup anemometer, Dines pressure tube anemograph, ordinary and recording rain gauges, nephoscope, sunshine recorder, AWS.
2. Composition and structure of the atmosphere.
3. Evaporation, condensation, fog, cloud and precipitation, thunderstorm, supercell and multi cell structure, tornado.
4. Thermodynamics: Thermodynamic principles, properties of dry and moist air, adiabatic processes, hydrostatic stability and instability, parcel method, tephigram.
5. Radiation: Solar and terrestrial radiation, laws of radiation, green house effect, Simpson's method of computing long wave radiation flux, heat balance of the earth and its atmosphere.
6. Wind System: Geostrophic wind, gradient wind, thermal wind, cyclostrophic wind and inertial wind, land and sea breezes, mountain and valley winds.
7. Air masses, front, jet stream. Extra tropical and tropical cyclones and anticyclones, western disturbances.
8. General Circulation of the Atmosphere: N.E. And S.W. Monsoon, seasons.
9. Principles of weather forecasting.

Suggested Readings:

1. Byers: General Meteorology IV edition
2. Cole : Introduction to Meteorology
3. Pettersen: Introduction to Meteorology
4. Banerjee & Upadhyay: Mausam Vigyan
5. Lutgens & Tarbuck: the atmosphere: An Introduction to Meteorology
6. Rama Sastry: Weather and Weather Forecasting
7. Das: the Monsoons
8. Wallace and Hobbs: Meteorology and Introductory Survey

GPM 104: ADVANCED COMPUTER PROGRAMMING Credits: 3

1. Introduction to computer architecture, Operating System, UNIX/LINUX operating System: system organization, commands and file systems, AWK-An advanced filter, shell programming.
2. Types of Programming Language, Introduction of FORTRAN: preliminaries, data types, expression and statements, iterative statements, input/output statements, subroutine and functions, file handeling.
3. Object Oriented Programming: Procedure oriented programming (POP); Object Oriented programming (OOP); paradigm concept of object and class, reusability, encapsulation and polymorphism.
4. C++An object Oriented language: Class, object, constructor, destructor, operator over loading, function overloading, inheritance virtual function, multiple inheritance, generic classes.

Suggested Readings:

1. M.G. Venkateshmurthy: Introduction to UNIX and Shell programming
2. John Hubbard: Programming in C^{++}
3. Yashwant Kanetkar: C^{++} programming
4. I.D. Chivers: Introduction to programming with Fortran
5. V.Rajaraman: Computer programming in Fortran90 and 95
6. Robert Lafore: Object Oriented Programming C^{++}
7. Stephen Prata: Advanced UNIX-A Programming Guide
8. Herbert Schield: Object Oriented Programming

GPM105: PRACTICAL BASED ON COURSE GPM101 Credits: 2

1. Clinometer compass and its use for determination of dip and strike of different beds.
2. Geological problems on slope, dip and thickness of the beds.
3. Drawing of geological sections of the given maps.
4. Study of the physical properties pf rock forming minerals (given in theory syllabus).
5. Megascopic study of rocks given in theory syllabus.

GPM106: PRACTICAL BASED ON COURSE GPM102 **Credits: 2**

1. Handling of gravimeter and magnetometer.
2. Interpretation of resistivity sounding data by Tagg's method.
3. Determination of velocities and depth of the interface by refraction method.
4. Handling of surveying instruments like GPS

GPM107: PRACTICAL BASED ON COURSE GPM103 **Credits: 2**

1. Familiarization with meteorological instruments and record surface meteorological observations.
2. Study of surface weather and upper air codes.
3. Exercises in coding and decoding.
4. Exercises in plotting station models.

GPM 108: PRACTICAL BASED ON COURSE GPM104 **Credits: 2**

1. Development and execution of programming to solve non-linear equations.
2. Development of FORTRAN and C^{++} programs to find solution of some geophysical problems.
3. Convolution and correlation of seismic signals using FORTRAN and C^{++} programs.
4. Developments of programs and solution of some geophysical problems by finite element method using FORTRAN and C^{++} programs.
5. Solution of differential equation using FORTRAN and C^{++} programs.

SEMESTER-II (Credit: 20)

GPM 201: GEOHYDROLOGY **Credits: 4**

1. Hydrological cycle, origin and age of groundwater, subsurface distribution of water, springs.
2. Hydrological Properties of Water Bearing Materials: Porosity, void radio, permeability, transmissivity, storativity, specific yield, specific retention, diffusivity, laboratory methods of determination of permeability.
3. Mode of occurrence of groundwater , classification of rock with respect to their water bearing characteristics, aquifers, aquicludes, aquitards, classification of aquifers and groundwater provinces.
4. Movement of groundwater and aquifer performance tests, Darcy's law and its range of validity, theory of groundwater flow under steady and unsteady conditions, determination of permeability, transmissivity and storativity by discharging methods.
5. Precipitation, evaporation, evapo-transpiration, seepage, infiltration and runoff.
6. Groundwater exploration, surface geological and geophysical methods of exploration, and subsurface geophysical methods.
7. Hydro-geochemistry: Physical and Chemical characteristics of groundwater, classification of groundwater in respect to domestic, irrigation and industrial use, pollution of groundwater.
8. Ground Water Exploration and Management: Natural and artificial recharge of groundwater, water balance, analysis of hydrograph, conjunctive and consumptive use of groundwater.

Suggested Readings:

1. Worcester: A Text Book of Geomorphology
2. Todd: Groundwater Hydrology
3. Ward: Principles of Hydrology
4. Chow: Handbook of Applied Hydrology
5. Health & Trainer: Introduction to Groundwater Hydrology
6. Singh: Elements of Hydrology
7. Raghunath: Introduction to Hydrology
8. Tolman: Hydrology
9. Karanth: Development, Assessment and Management of Water Resources

GPM202: SEISMOLOGY **Credits: 4**

1. Introduction to earthquake phenomena, types of earthquakes and their causes,propagation and characteristics of seismic waves, Earthquake swarms, foreshocks and aftershocks, elastic rebound theory, concept of inhomogeneity and anisotropy,theory of elasticity, equilibrium equations, equation of motions
2. Earthquake source parameters, identification of seismic phases and their applications, group and phase velocities,intensity and magnitude scales, Focal mechanism solutions

and its tectonic implications, reflection of body waves, reflection of seismic waves from the free surface, site effect, attenuation studies of seismic waves.

3. Seismicity of India, Himalayas and global seismicity, induced seismicity seismic zonation, seismic zoning of India, seismic hazards and hazard analysis, seismic micro-zonation.
4. Principle of electromagnetic seismograph, seismometers, accelerometers and strain meter seismographs, WWSSN stations, seismic arrays for detection of nuclear explosions.

Suggested Books:

1. Aki and Richards: Quantitative seismology
2. Richter:Elementary Seismology
3. Bullen& Bolt: An Introduction to the Theory of Seismology
4. Lay and Wallace: Modern global seismology
5. Gutenberg: Internal Constitution of the Earth
6. Rikitake: Earthquake Prediction
7. Bath: Introduction to Seismology
8. Stein &Wysession: An Introduction to Seismology, Earthquakes and Earth structure

GPM 203: GEODYNAMICS **Credits: 4**

1. History of development and scope of geophysics, our universe and solar system, monistic and dualistic hypotheses for the origin of solar system, Kepler's law of planetary motion, planet and satellites of the system and their characteristics, shape and size of the earth, international gravity formula and rotation of the earth. Concept of isostasy, Airy, Heiskanan and Pratt-Hayford hypotheses.
2. Internal constitution of the earth, characteristics of lithosphere, and asthenosphere, causes of geodynamical process, continental drift, Ocean floor spreading, Plate tectonics and its geological implications, oceanic ridges, trenches and island arcs,triple junction, hot spots, geodynamics of Indian subcontinents and formation of Himalayas, 90^0 E ridge.
3. Origin of geomagnetic field, secular variations and westward drift, geomagnetic storms, geomagnetic time scale,Earth's current, sun spot, solar flares, lunar and solar variations, Palaeomagnetic studies of rock samples and their applications in geophysics, polar wandering, reversals of geomagnetic field.
4. Importance of heat flow, thermal history of the earth, sources of heat generation and temperature distribution inside the earth, Jacob's hypothesis for liquid nature of the outer core. Radiometric dating principles and ages of rocks and the earth.

Suggested Readings:

1. Howell : Introduction to Geophysics
2. Stacey: Physics of the Earth
3. Gubbins: Seismology and Plate Tectonics
4. Condie: Plate Tectonics and Crustal Evolution

5. Lowrie: Fundamentals of Geophysics
6. Bird & Lacks: Plate Tectonics
7. Chapman: Earth's Magnetism
8. Jacobs: Core and Geomagnetism
9. Lilly R. J.: Whole Earth Geophysics.

GPM 204: PRACTICAL BASED ON COURSE GPM201 Credits: 2

1. Determination of average rainfall.
2. Determination of evaporation and evapotranspiration.
3. Determination of storativity coefficient and transmissivity.
4. Determination of porosity and permeability.

GPM205: PRACTICAL BASED ON COURSE GPM202 Credits:2

1. Locating the epicenter of an earthquake using earthquake data.
2. To prepare the intensity map and find out the epicenter and focal depth for an earthquake.
3. Identification of different phases on a seismogram and to determine the epicentral distance of an earthquake.
4. Estimation of earthquake source parameters.
5. Study of spatio-temporal patterns using seismic data and estimation of b-value using seismicity data.
6. Determination of magnitude from a given seismic records.
7. Estimation of strong motion parameters using deterministic seismic hazard analysis.
8. Estimation of focal mechanism of earthquakes.

GPM 206: EXCURSION AND TOUR REPORT Credits: 2

During the second Semester, the students will be required to visit some geophysical establishments and laboratories in the country to acquaint themselves with various geophysical activities and submit the tour report to the tour In-charge. The visit may be arranged during the intra/inter Semester break.

GPM207M: Minor Elective Credits: 2

The course will be opted by students from SWAYAM portal.

SEMESTER-III (Credit: 20)

GPM 301: MATHEMATICAL & NUMERICAL METHODS IN GEOPHYSICS Credits: 4

1. Integral transforms: Fourier transform, Laplace transform, Hankel transform, and their applications in geophysics.
2. Orthogonal functions: Bessel's function, Hermite, Laguerre and Legendre polynomials, introduction and applications of orthogonal systems and Green's function, and their applications in solving geophysical problems.
3. Solution of simultaneous linear equations; Non-linear system of equations and their application in solving geophysical problems.
4. Numerical Methods: Solution of algebraic and transcendental equations; Bisection and Newton-Raphson methods; Euler and Runga-Kutta methods.
5. Interpolation Techniques: Newton and Lagrange formulae; Simpson rule method; Trapezoidal method; and Gaussian quadrature method.
6. Least square curve fitting; and straight line and polynomial fits.
7. Numerical solution differential equations: Ordinary differential equation; Classification of linear partial differential equations, wave and diffusion equations; and applications in geophysics.
8. Finite difference methods: discretizations; numerical solution of linear and non-linear differential equations; Stability; Application of finite difference methods in geophysics.
9. Finite element methods: Introduction to various element shapes; descritization of structures; numerical integration; applications of finite element method in geophysics.

Suggested Readings:

1. Sastry: Introductory Methods of Numerical Analysis
2. Jain, Iyengar & Jain: Numerical Methods for Scientific and Engineering Computation
3. Raja Raman: Numerical Analysis
4. Raja Raman: Fundamentals of Computers
5. Raja Raman: Fortran Programming
6. Ram Kumar: Programming with Fortran 77
7. Sastry: Introduction Methods of Numerical analysis
8. Gerald: Applied Numerical Analysis
9. Gerald et. al.: Finite Element Simulation in Surface and Subsurface Hydrology
10. Bath: Mathematical Aspects of Seismology
11. Jain, Iyengar & Jain: Numerical Methods for Scientific and Engineering Computation
12. Jain: Numerical Solution of Differential equations
13. Mitchell: Computational Methods in Partial Differential Equations

GPM 302A: GEOELECTRICAL METHODS Credits: 4

1. General: Electrical properties of rocks & minerals and their determinations, fundamentals of direct current flow, relationship between point and line pole potential distribution.

2. Measuring System: Quantities measured in various electrical methods and description of the instruments used, discussion of various configurations used in electrical method and field procedure adopted.
3. D.C. Resistivity Methods: Potential distribution at the surface of horizontally stratified earth, Kernel function and its relation to the subsurface parameters, apparent resistivity function, computation of apparent resistivity model curves, principle of digital linear filtering.
4. Vertical Electrical Sounding: Interpretation of resistivity VES data, empirical methods for interpretation of resistivity sounding data, indirect interpretation techniques, auxiliary point method, partial curve matching, complete curve matching, direct interpretation techniques, automatic direct interpretation method, Dar Zarrouk parameters, inversion techniques in resistivity method of interpretation, computer-aided resistivity data interpretation (softwares), principles of equivalence, suppression and detectibility problems, effects of deviations from the fundamental assumptions, electrical resistivity imaging.
5. Electrical Profiling: Profiling near a vertical contact and thin vertical dykes and discussion of the expected apparent resistivity curves.
6. Self Potential Method: Mechanism of SP field techniques, field due to vertically polarized sphere and interpretation.
7. Induced Polarized Method: Mechanism of IP instruments and principles of measurements both in time and frequency domain, interpretation of IP.
8. Electrical Resistivity Tomography (ERT): Basic Principle, Theory and applications

Suggested Readings:

1. Bhattacharya & Patra: D.C.: Geoelectric Sounding: Principles and Interpretation
2. Kuntez: Principles of Direct Current Resistivity Prospecting
3. Keller & Frischknecht: Electrical Methods in Geophysical Prospecting
4. Nostrand & Cook: Interpretation of Resistivity Data
5. Wait: Over-voltage Research and geophysical application
6. Koefoed: Geosounding Principe-I: Resistivity Sounding Measurements
7. Patra & Nath: Schlumberger Geoelectric Sounding in Ground Water
8. Ghosh: The Application of Linear Filter theory to the Direct Interpretation of Geoelectrical Resistivity Measurements

GPM 302B: AGRO-METEOROLOGY Credits: 4

1. Meaning and scope of agricultural meteorology, Intent and extent of agricultural meteorology, plant physiology, long term and short term modifications of growth process, avoidable and unavoidable dangers, Agro-meteorological observations and microclimatic measurements.
2. Solar Radiation and Plants: Reflection, transmission and absorption, incoming, outgoing and net radiation, Spectral distribution of solar radiation and physiological response to plants, Light distribution in canopy, Phototropism and Photoperiodism: Meteorological factors in photosynthesis.

3. Environmental Temperature and Plants: Effect of low and high ambient temperature, growing degree days and other heat indices, soil temperature and factors affecting them, thermal properties of soil, Cardinal temperatures, soil moisture and its measurement, weekly water balance, water use and plant growth, evaporation and evapo-transpiration, wind effect on evapo-transpiration, wind damage to plants, transportation of pollen disease and insects by winds.
4. Climatic Requirements of Important Crops: Rice, wheat, cotton, soyabean and sugarcane, pearlmilet, groundnut and mustard.
5. Plant and Crop Diseases: The effect of weather on pathogenic agents- Insects, Fungi, Bacteria, Bacilli and Virus, combating plant diseases, natural and artificial methods, the integrated campaign, insect against insects, Bacteria and Bacilli against insect, Virus against Insects, effect of weather on the host.
6. Meteorological Hazards and Agriculture: Frost and frost fighting methods, hail damage and hail modification method, wind damage and wind breakers, Agricultural drought, its severity and management, flood damage and flood fighting.
7. Composition, structure and physical properties of soils, simple classification of soils, soil air, soil erosion, soil improvement devices and drainage.
8. Agro-meteorological forecasts systems, short, medium and long range forecasts, yield forecasts model, introduction to crop stimulation model, and a brief outline of remote sensing in agriculture.

Suggested Readings:

1. Smith: Methods in Agricultural Meteorology
2. Seemann et. al.: Agrometeorology
3. Vitchewich: Agrometeorology
4. WMO Compendium of lecture notes
5. Mavi: Introduction to Agrometeorology

GPM 303A: SEISMIC METHODS **Credits: 4**

1. Historical development and background of refraction and reflection methods. Difference between refraction and reflection surveys. System of observations for reflection and refraction surveys. Propagation of seismic waves in homogeneous/ inhomogeneous media, waveforms and their characteristics, N-layered case, continuous increase of velocity. Refraction data interpretation.
2. Amplitude and frequency response characteristics of geophone, critical and optimum damping, seismic amplifier and its frequency response, principle of maganatic tape recording, digital multiplexed recording and shot moments, principles of binary gain ranging amplifier and floating point, dynamic range, automatic gain control circuit, programmable gain control, timing system and recording formats (SEG-A, SEG-B and SEG-C).
3. Seismic data enhancement and test shooting, explosive and non-explosive sources of seismic energy for P-wave, seismic operation on land, common depth point technique, special weathering shots and noise analysis, elevation, weathering and

dynamic corrections in refraction and reflection data, random and non random noises, grouping of geophones, diffraction and its analysis, controlled source seismic sounding.

4. Inverse filtering of seismic data, hidden layer problem, sequence of seismic data processing, determination of average seismic velocities, principles of tomography, synthetic seismograms.
5. Analysis of multiples and ghost reflections, processing of seismic data, imaging of 2-D and 3-D seismic data, time and depth sections, record surface and reflection surface, presentation of seismic records, vertical and horizontal resolution.
6. Mapping of geological structures (faults, reef, pinchouts, and anticlines), migration techniques (classical and modern), wave equation migration, and pit falls of seismic interpretations.

Suggested Readings:

1. Clarbout: Fundamentals of Geophysical Prospecting
2. Telford et. al.: Applied geophysics
3. Sheriff: Seismic Stratigraphy
4. Dobrin & Savit: Introduction to Geophysical Prospecting
5. Waters: Reflection Seismology
6. Sheriff & Geldart: Exploration Seismology

GPM 303B: PHYSICAL METEOROLOGY **Credits: 4**

1. Radiation: Laws of radiation, nature of solar radiation, solar constant, geographical and seasonal distribution of solar radiation, direct beam normal flux at the earth's surface, direct beam insolation at the earth's surface, Basis of Elsasser treatment, Elsasser chart; radiative heating and cooling, radiative equilibrium and the stratosphere, mean heat balance of the earth atmospheric system, poleward transport of energy, fundamental link with general circulation.
2. Cloud Physics: Atmospheric aerosols and condensation nuclei, nucleation, physics of initial stages of condensation, curvature and solution effect, growth and evaporation of cloud droplets by diffusion, the physics of precipitation in warm clouds, collision-coalescence theory, collection efficiency, terminal velocity, precipitation from mixed clouds, Bergeron and Findeisen's theory, artificial cloud seeding of warm and cold clouds. Artificial cloud seeding.
3. Atmospheric Optics: Attenuation of light, refraction, scattering, turbidity, optical phenomena, rainbow, halo, corona, glory, mirage etc., atmospheric and terrestrial refraction, looming, towering, stooping, sinking.
4. Radar Meteorology: Basic radar equation, wavelengths used for detection of cloud, thunderstorm and cyclone, PPI and RHI scopes, meteorological applications of radar, radar echoes, estimation of precipitation, rain water content and upper winds using radar.

5. Atmospheric Ozone: Mechanism of formation and destruction, measurement of ozone, Dobson's ozone spectrometer, seasonal and latitudinal variation, Umkehr effect, vertical distribution of ozone, ozone-weather relationships, ozone hole.
6. Atmospheric Electricity: Electrical field of the earth in fair and disturbed weather, atmospheric ionization, air-earth electric current and its maintenance, supply current, theories of charge generation and separation in thunderstorm, lightning discharges.
7. Satellite Meteorology: Equation of orbital motion, types of meteorological satellites, description of important sensors on board, visible and infra red data and their interpretation, identification of typical weather systems from cloud picture, estimation of winds, vertical temperature and humidity profile and rainfall from satellite observations, tropical cyclone grading using Dvorak's technique.

Suggested Readings:

1. Johnson: Physical Meteorology
2. Mason: Physics of Cloud
3. Dobson: Exploring the Atmosphere
4. Retallack: Compendium of Meteorology v. I, Part-III, Physical Meteorology. W.M.O. 364.
5. Baton: Radar Observes the Weather
6. Kidder & Vonder Harr: Satellite Meteorology
7. Taba: Ozone Observations an Introduction and their Meteorological Applications, W.M.O. Technical Note No. 36, W.M.O. No. 108
8. Haltiner & Williams: Numerical Prediction and Dynamic Meteorology

GPM 304A: PRACTICAL BASED ON COURSE GPM302A **Credits: 2**

1. Plotting of equipotential traces and current lines for a point source.
2. Interpretation of S.P. Anomalies.
3. Interpretation of I.P. Data.
4. Interpretation of profiling data.
5. Interpretation of field resistivity sounding curves.
6. Computer-aided interpretation of sounding curve data.

GPM 304B: PRACTICAL BASED ON COURSE GPM302B **Credits: 2**

1. To study the Agro-meteorological instruments used for observations.
2. Computation of various components of weekly water balance during crop growing period and assessment of agricultural drought.
3. Computation of evaporation, evapo-transpiration and potential evapo-transpiration using various methods.
4. Forecasting of crop yield on the basis of weather parameters.
5. Crop phenol-logical changes and heat unit requirement of the crops.
6. Prediction of minimum temperature and frost under Eastern UP condition.
7. Medium range weather forecast and preparation of agro-meteorological advisory bulletins for farmers.

GPM 305A: PRACTICAL BASED ON COURSE GPM303A **Credits: 2**

1. Interpretation of seismic records and plotting section.
2. Determination of velocity.
3. Interpretation of reflection and refraction data.
4. Plotting of seismic section.
5. Testing and handling of seismic prospecting units.
6. Automatic migration and mapping techniques.
7. Preparation of structural maps.
8. Exercises on NMO calculation.
9. Seismic modeling and working at the seismic signal processing laboratory.

GPM 305B: PRACTICAL BASED ON COURSE GPM303B **Credits: 2**

1. Measurement of total amount of atmospheric ozone by Dobson's ozone spectrophotometer.
2. Numerical computation in radiation, atmospheric optics, cloud physics, satellite meteorology and radar meteorology.
3. Interpretation of Satellite Imageries.

GPM 306A: GEOPHYSICAL (Exploration) FIELD TRAINING **Credits: 2**

Field training of the Second year students will undergo field training for familiarization at specialized centers/field work for about 2 weeks after the **third semester** examination and submit the report to the field training In-charge.

GPM 306B: GEOPHYSICAL (Meteorology) FIELD TRAINING **Credits: 2**

Field training of the Second year students will undergo field training in the meteorological organizations for familiarization at specialized centers/field work for about 2 weeks after the **third semester** examination and submit the report to the field training In-charge.

SEMESTER-IV(Credit: 19)

GPM 401: STRATIGRAPHY, ECONOMIC & PETROLEUM GEOLOGY Credits: 3

1. Stratigraphy: Principles of Stratigraphy, elements of stratigraphic classification; geological time scale. Basic concepts of sequence Stratigraphy and seismic stratigraphy Geophysical methods of stratigraphic correlation. Physical and structural divisions of Indian subcontinent and their characteristics. Classification, lithology and economic importance of the following: Dharwar supergroup of Karnataka, Cuddapah supergroup of Andhra Pradesh, Vindhyan Supergroup of Son valley, Gondwana Supergroup of peninsular India and Tertiary of Assam, Siwaliks of Himalaya.
2. Economic Geology: Definition of ore, ore mineral and gangue, Classification of ore deposits, Chemical composition, diagnostic characters, usages and distribution in India of the following metallic and non-metallic minerals: Haematite, magnetite, pyrolusite, psilomalane, chromite, ilmenite, wolframite, cassiterite, chalcopyrite, boronite, galena, sphelerite, pyrite, bauxite sulphur, graphite, gypsum, fluorite, barite, magnesite, dolomite, apatite, calcite, kyanite, sillimanite, beryl, muscovite, kaolinite, halite and talc.
3. Petroleum Geology: Origin of petroleum; source rocks; reservoir rocks; reservoir pore spaces; reservoir traps. Migration and accumulation of oil and gas. Geological modelling in petroleum exploration, Brief geological account of oil and gas fields in India: Assam, Gujarat, Tamil Nadu and Bombay Offshore.

Suggested Readings:

1. Jensen and Bateman: Economic Geology
2. Krishna Swami: India's Mineral Resources
3. Sharma & Ram: Introduction to India's Economic Minerals
4. Levorsen: Geology of Petroleum
5. Evans & Mathur: Oil in India
6. Krishman: Geology of India and Burma
7. Wadia: Geology of India.
8. Ravindra Kumar: Historical geology and stratigraphy of India
9. U. Prasad: Economic Geology.

GPM 402A: GEO-ELECTROMAGNETIC METHODS Credits: 4

1. Basic Principles and Theory: Maxwell's equations, electromagnetic potential and wave equations, boundary conditions, long wavelength approximation, depth of penetration, electromagnetic field due to straight wire, rectangular and circular loops, elliptical polarizations, amplitude and phase relations, real (in phase) and imaginary (quadrature) components.
2. Methods of Prospecting: Bieler Watson method, Dip angle methods-fixed vertical loop transmitter, broadside and shoot back methods, two frame method, compensator method, Turam method, Moving source-receiver methods- horizontal loop (Slingram) method, AFMAG and VLF methods, Airborne EM systems- rotary field method, INPUT method, EM profiling and sounding.

3. Interpretation: Principles of EM similitude and modeling, response of conducting sphere to uniform alternating magnetic field and infinitely long horizontal cylinder to line source, response of sheet conductors to dip angle, Turam and horizontal loop EM systems, dip angle characteristic curves and phasor diagrams for horizontal loop EM system for sheets, effect of overburden on EM anomalies, Principles and practices of Ground Penetrating Radar.
4. Magnetotelluric (MT) method: Origin and characteristic of MT fields, MT instrumentation, field practices, MT effect over a conducting half space and two layer model.

Suggested Readings:

1. Parasnis: Mining Geophysics
2. Grant & West: Interpretation Theory in Applied Geophysics
3. Telford et. al: Applied Geophysics
4. Patra & Mallick: Geosounding Principles Vol.II
5. SEG Publication: Mining Geophysics Vol. II

GPM 402B: CLIMATE DYNAMICS I **Credits: 4**

1. Principles of thermodynamics: First law of thermodynamics, internal energy, specific heat capacity and enthalpy, adiabatic process, entropy and the second law of thermodynamics.
2. Thermodynamics of water Vapour and Moist Air. Isotherms on an □, e diagram, equation of state of moist air, Clausius Clapeyron equation, adiabatic processes of saturated air and moisture variables.
3. Thermodynamics Diagrams: General considerations, emagram, tephigram, skew T/ log P diagram, stuve diagram, choice of a diagram, CAPE and Convective Inhibition Energy (CINE).
4. Hydrostatic Equilibrium: Hydrostatic equation, geo-potential height computations for upper-air sounding, hydrostatic of homogeneous, isothermal, constant lapse rate and dry adiabatic atmosphere, standard atmosphere.
5. Hydrostatic Stability and Instability: General consideration, slice method, entrainment.
6. Fundamental forces, gravitation and gravity, geo-potential.
7. Equation of motion in different coordinate systems, cartesian, natural, isobaric and spherical polar coordinate, scale analysis of the equations of motion.
8. Continuity equation in cartesian, isobaric and spherical coordinate.
9. Balanced Motion: Inertial wind, geostrophic wind, Rossby number, gradient wind, cyclostrophic wind and thermal wind.
10. Viscosity and Turbulence: Fundamental laws of viscosity, equations of mean motion in turbulent flow, mixing length theory, planetary boundary layer, power law, Ekman layer, Richardson number, Raynold's number, Froud number.
11. Circulation and Vorticity: Kelvin's circulation theorem, Bjerknes theorem, potential vorticity, vorticity equation, divergence equation, Helmholtz theorem.
12. Tendency equation, Bjerknes Holmboe theory, isallobaric wind.
13. Vertical Motion: Kinematic and adiabatic methods.

14. Front and front genesis, sectors of frontogenesis and frontysis, effects of convergence, divergence and deformation fields on fronto-genetic and fronto-litic sectors.

Suggested Readings:

1. Hess: Introduction to Theoretical Meteorology
2. Pisharoty: Thermodynamic Diagram and some of Their Uses (IMD Tech. Note)
3. Gordon: Introduction to Dynamic Meteorology
4. Holton: An Introduction to Dynamic Meteorology
5. Haltiner: Numerical Weather Prediction
6. Haltiner & Martin : Physical and Dynamic Meteorology
7. Haltiner & William: Numerical Weather Prediction and Dynamic Meteorology
8. Askel Wiin-Nielsen: Compendium of Meteorology, Vol. I. Dynamic Meteorology, W.M.O. No. 364

GPM 403A: WELL LOGGING & RESERVOIR GEOPHYSICS Credits: 4

1. Reservoirs characteristics and objectives of well logging. Reservoir Rocks: Clastic and carbonate rocks. Reservoir Properties: Porosity, permeability, fluid saturation, need of drilling fluids and its properties, invasion process and various profiles, classification of formation evaluation methods, objective of well logging methods, logging operational field system and its procedure.
2. Electric-Logging: Spontaneous Potential (SP) logging: Spontaneous potentials in boreholes and its sources, SSP and its measurements, SP curves and its interpretation factors affecting the shape and amplitude of SP curve, Non-focussed, focused and induction logging, principles and sondes, Interpretation of electric Log Data: Determination of resistivity of interstitial water Rw, porosity □ □and water saturation Sw of clean and shaly sandstones, determination of Rw of clean sandstone from SP curve, estimation of permeability.
3. Radiation Well Logging: Gamma ray logging, details of the radiation logging, density or gamma-gamma logging, principle of the neutron-gamma logging, neutron-epithermal-neutron logging, neutron-thermal-neutron logging, interpretation and applications of radiation logging for evaluation of reservoir characteristics.
4. Other Miscellaneous Logging Techniques: Acoustic velocity (Sonic) logging, Cement Bond Log (CBL), Litho-density Tool (LDT), Thermal log, caliper or section gauge log, Casing Collar Locator's (CCL), dip and direction logging, Formation micro Image logging, nuclear magnetic resonance logging.
5. Advanced Logging Tools: Introduction of induced gamma-ray spectrometry, chlorine logging, introduction to natural Gamma-ray Spectrometry (NGS), Cased Hole Neutron Tool (Thermal Decay Time or TDT) measurements, Introduction to wire line formation testing; Repeat formation testing (RFT) and drill stem testing (DST).
6. Cross Plots: Resistivity-porosity cross plots, Porosity Cross plots: neutron-density, sonic density and sonic neutron density cross plots. Application of well logging to ground water mineral and petroleum resources.

Suggested Readings:

1. Lynch: Formation Evaluation

2. Wyllie: Fundamentals of Well Log Interpretation
3. Vaish : Geophysical Well Logging : Principles and Practices
4. Schlumberger: Schlumberger Log Interpretation Principles/ Applications
5. Schlumberger: Schlumberger Log Interpretation Charts
6. Serra: Fundamentals of Well - Log Interpretation
7. Pirson: Hand book of Well log Analysis for Oil and Gas Formation Evaluation
8. Deveton: Log analysis of subsurface Geology: Concepts and Computer Methods.

GPM 403B: CLIMATOLOGY & CLIMATE CHANGE **Credits: 4**

1. Introduction: Concept of weather and climate, climatic elements, climatic factors, earth-sun relationship, ecliptic and equatorial plane, rotation and revolution of the earth, equinox, solstice, perihelion, cause of seasons, radiation balance.
2. World distribution of isolation, air temperature, mean sea level pressure and wind, effect of land and ocean on circulation, diurnal and annual variations of surface air temperature at different latitudes and over the globe, upper air circulation over the whole world.
3. World distribution of precipitation, effects of continents, oceans and topography on rainfall, diurnal and annual variation of precipitation, world distribution of atmospheric perils.
4. Air masses, their classifications, source regions, modification and associated weather. Extra- tropical cyclones, their origin and associated weather.
5. Climatic Classification: Koppen and Thornthwait schemes applicable to India.
6. Climatic changes and cycles, elements of microclimatology, palaeoclimatology.
7. Indian Climatology: Principal seasons of India, annual and seasonal rainfall and its variability. Definition and concept of drought, aridity, drought indices and drought assessment.
8. Climatic change: climatic system- an overview, observed climate variability and change, physical climate processes and feedback, detection and projection of future climate scenario.

Suggested Readings:

1. Sellers: Physical Climatology
2. Trewartha: Introduction to Climates
3. Haurwitz & Austin: Climatology
4. I.M.D. Forecasting Manuals
5. Lockwood: World Climatology

GPM 404A: PRACTICAL BASED ON COURSE GPM402A **Credits: 2**

1. Computational of dip angle response over sheet type bodies.
2. Analysis of dip angle data and its interpretation.
3. Computation of Turam profiles over sheet type bodies.
4. Reduction of Turam data and its interpretation.
5. Interpretation of Slingram profiles over sheet conductors using phasor diagrams.

6. Interpretation of MT data

GPM 404B: PRACTICAL BASED ON COURSE GPM402B **Credits: 2**

1. Analysis of tephigram: (a) Computation of derived parameters, LCL, CCL, LFC, CAPE and CINE (b) Computation of precipitable water content, (c) Computation of heights of pressure surfaces by adiabatic and isothermal methods, (d) Study of stability and instability of various layers and forecasting of fog, thunderstorm, etc., (e) Determination of height of tropo-pause, thickness of isothermal and inversion layers etc.
2. Computation of geostrophic vorticity, geostrophic wind.
3. Computation of atmospherics parameters using computer programming.

GPM 405A: PRACTICAL BASED ON COURSE GPM403A **Credits: 2**

1. Qualitative interpretation of well logs and their correlation
2. Computation of porosity.
3. Computation of formation factor.
4. Computation of water saturation.
5. Computation of oil saturation.
6. Computation and estimation of producible oil per acre.
7. Applications of cross plots for estimation of various parameters.

GPM 405B: PRACTICAL BASED ON COURSE GPM403B **Credits: 2**

1. Basic analysis of global distribution of mean climatic parameters.
2. Computation of weighted and running means of a time series.
3. Computation of rainfall variabilities and coefficient of variation.
4. Seasonal wind pattern.
5. Computation of climatic types according to Koeppen and Thornthwaite.
6. Exercise in curve fitting, least square, correlation and regression.

GPM 406: PRACTICAL BASED ON COURSE GPM401 **Credits: 2**

1. Preparation of lithostratigraphic maps of India showing distribution of Dharwar, Cuddapah, Vindhyan and Gondwana Super groups.
2. Study of about 15 rock specimens from the important stratigraphic horizons of India.
3. Study of mega-scopic characters of about 25 economic minerals.
4. Distribution of important mineral deposits of India.
5. Exercises on accumulation of oil and gas in different types of traps.
6. Distribution of important petroliferous basins of India.

GPM 407M: Minor Elective **Credits: 2**

The course will be opted by students from SWAYAM portal.

SEMESTER-V(Credit: 21)

GPM 501: COMMUNICATION THEORY AND SIGNAL PROCESSING

Credits: 4

1. Introduction: Historical development of time series, classification of data, analogue and discrete signals, digitization, sampling interval and aliasing, wavelets, Z transform, linear system, Dirac delta function and impulse response of a linear system, impulse response function, minimum delay, maximum delay and mixed delay wavelets.
2. Convolution and Correlation Techniques: Convolution, method for Convolution, properties of Convolution, autocorrelation, cross-correlation, and their applications, time domain and frequency domain concepts.
3. Fourier series and Fourier transform, Hilbert transform, Walsh transform, orthogonal function and Dirichlet conditions, complex form of Fourier Series and Fourier transform, physical significance and interpretation of Fourier transform, properties of Fourier transform, Fourier transform of a symmetrical rectangular pulse, reciprocity Fourier transform (FFT), two dimensional Fourier transform and its applications.
4. Digital Filtering: Low, high and band pass filters, truncation of unit impulse response function, illustration of Gibb's phenomenon. Butterworth filters, Chebysev filter, recursive filters.
5. Weighting Functions (Windows): Hamming window, Hamming window and their comparison, triangular window, Bortlett window, practical applications of windows.
6. Techniques for Spectral Estimation: Power spectrum, method for calculation of power spectrum, three basic data models, Moving Average (MA) method, Maximum Likelihood Method (MLM), Autoregressive process (AR), comparison of MA, MLM and AR techniques.
7. Deconvolution: Introduction, white spectrum, Wiener inverse and its mathematical details, homomorphic applications of deconvolution filtering.
8. Applications of Time Series in various branches of Geophysics: Seismic method, gravity and magnetic methods, resistivity and well-logging methods, use of spectral techniques in meteorology, oceanography and groundwater hydrology.

Suggested Readings:

1. Silvia & Robinson: Deconvolution of Geophysics Time Series in the Exploration for Oil and Natural Gas
2. Robinson & Trietel: Geophysical Signal Analysis
3. Kanasevich: Time Sequence Analysis in Geophysics
4. Bath: Spectral Analysis in Geophysics
5. Oppenheim & Schafer: Digital Signal Processing
6. Papoulis: The Fourier Integral and its Applications

GPM 502A: INVERSION THEORY **Credits: 4**

1. Space in inverse theory; linear Euclidean space; norm space; vector space; metric space; Hilbert space.

2. Definition of inversion; rank of a matrix; matrix partitioning; forward and inverse problems in geophysics; Eigen values and Eigen vector; condition number; singular value decomposition.
3. Formulation of inverse problems: existence; uniqueness and stability.
4. Direct, linear and quasi-linear inverse problems; linearization of quasi and nonlinear problems; generalized inverses; Tikhonov regularization method of inversion.
5. Norms: L1 and L2 norms; ridge regression; Lagrange multiplier; minimum norm algorithm; Bachus-Gilbert inversion.
6. Stochastic inversion: a priori and a posteriori probabilities; Bayesian inversion; Occam's principle.
7. Non-linear inversion: Monte Carlo inversion method; Global optimization techniques; simulated annealing; genetic algorithm; ANN and its applications in geophysics.

Suggested Readings:

1. Aster, R.C., Brochers, B. and Thurber, C.H. Parameter estimation and inverse problems, Elsevier, London, 2005.
2. Bernardo, J.M. and Smith, A.F.M. Bayesian Theory, Wiley, Chichester, 1994.
3. Gill, P.E., Murray, W. and Wright, M.H. Practical optimization, Academic, London, 1981.
4. Haykin, S. Neural Network and Learning machines, Upper Saddler River, pearson Education, 2009.
5. Hammersley, J.M. and Handscomb, B.C. Monte Carlo method, Chapman & Hall, London, 1964.
6. Indira, N.K. and Gupta, P.K. (Ed.). Inverse methods: General Principles and Application to Earth System Sciences, Narosa, New Delhi, 1998.
7. Mallat, S. Wavelet tour of signal processing: The Sparse Way, Elsevier, Amsterdam, 2009.
8. Menke, W. Geophysical data analysis: Dicrete Inverse Theory, Academic, Orlando, 1984.
9. McCord Nelson, M. and Illingworth, W.T. A practical guide to neural nets, Addison-Wesley, Reading, 1991.
10. Poulton, M.M. Computational neural networks for geophysical data processing, Elsevier, London, Handbook of Geophysical Exploration: Seismic Exploration.
11. Rao, C.R. and Mitra, S.K. Generalized Inverse of Matrices and its Applications, Wiley, New York, 1971.
12. Sen, M.K. and Stoffa, P.L. Global Optimization Methods in Geophysical Inversion, Elsevier, Amsterdam, 1995.
13. Sen, M.K. Seismic Inversion, Society of Petroleum engineers Press, 2006.
14. Tarantola, A. Inverse Problem Theory, methods of data fitting and model parameter estimation, Elsevier, Amsterdam, 1987.
15. Tikhonov, A.N. and Arsenin, V.Y. Solution of ill-posed problems, Wiley, New York, 1977.
16. Ulrych, T.J. and Sacchi, M.D. Information based inversion and processing with applications, Elsevier, Amsterdam, 2005.
17. Michael Zhdanov (2002). Geophysical Inverse Theory and Regularization Problem, Elsevier.

GPM 502B: SYNOPTIC AND TROPICAL METEOROLOGY **Credits: 4**

1. Meaning and scope of synoptic meteorology, Plotting of synoptic observations on different
2. maps, analysis of surface and upper air charts, vertical time section and cross section analysis.
3. Scales of Atmospheric Weather Systems: Primary, secondary and tertiary circulations.
4. Kinematics of horizontal motion, characteristics of wind fields, construction of streamlines, isotach, trajectories, relation between stream line and trajectories, Blatons equation.
5. Jet streams, their classification and characteristics, PFJ, STJ, TEJ, low level jet stream of Asian monsoon, structure, formation, maintenance and associated weather, zonal index, index cycle, cutoff lows, highs, blocking.
6. Principle of Weather Prediction: Short range, medium range and long range weather prediction, limits of predictability, forecast evaluation.
7. Tropical Meteorology: Mean tropical atmosphere, equatorial trough (ITCZ), basic currents, trade wind inversion, easterly waves and their dynamical aspects, formation and forecasting of easterly waves, QBO.
8. Tropical cyclones, classification of tropical disturbances, global climatology, life cycle, surface and upper air structure, thermal structure, the eye and wall cloud, rainfall, energy aspects, theories of formation, CISK, detection, movement tracks, recurvature, Fujiwara effect, forecasting, storm surges, cyclone warning.
9. Monsoons: Monsoon regions in the tropics, causes of monsoon, the Indian summer monsoons, rainfall distribution, elements of the monsoon system, monsoon disturbances, MTC, monsoon variability, onset and advancement of monsoon, withdrawal, fluctuations in monsoon activity, active, weak and break monsoon conditions, intra seasonal and inter-annual variability of summer monsoon, biweekly and 30-50 day oscillation (MJO), southern oscillation and El Nino, , PDO, AMO, NAO, monsoon rainfall and teleconnections, long range prediction of monsoon, monsoon over China, S.E. Asia, N. Australia, east and west Africa.
10. General Circulation Features over India during other seasons: Winter seasons, western disturbances, cold waves, fog, Pre Monsoon Seasons: different convective phenomenon, Norwesters and tropical storms, Post monsoon Season: N.E. Monsoon, tropical storms and their differences with tropical storms of pre monsoon season.

Suggested Readings:

1. Riehl: Tropical Meteorology
2. Palmen & Newton: Atmospheric Circulation System
3. Reiter: Jet Stream Meteorology
4. Ramage: Monsoon Meteorology
5. Saucier: Principles of Meteorological Analysis
6. Wiin-Nielson: Compendium of Meteorology, Vol. I, Part 3, Synoptic Meteorology, Geneva, W.M.O. No. 364.
7. Asnani: Tropical Meteorology,Vol. I and II
8. Das: Monsoons, Geneva, WMO No. 613

9. Keshavamurty & Sankar Rao: The Physics of Monsoons
10. Tarakanov: Tropical Meteorology
11. Krishnamurthi: Compendium of Meteorology, Vol. II, Tropical Meteorology, Geneva, W.M.O. No,364

GPM 503A: GRAVITY AND MAGNETIC METHODS **Credits: 4**

1. Basic Theory: Magnetic elements I.G.R.F., inverse square law, concept of potential, Poisson's and Laplace's equations, magnetism on atomic scale, Dia- para- ferro magnetic materials, susceptibilities and densities of various rocks and minerals, factors affecting density and susceptibilities, and susceptibility determination.
2. Instrumentation: gravity prospecting instruments: borehole and airborne gravimeters, magnetic prospecting instruments, Rubidium vapour magnetometer.
3. Data Acquisition and Correction: Aeromagnetic surveys, plan of the field surveys, station spacing, corrections for gravity and magnetic data, Processing and interpretation.
4. Calculation of derivatives, continuation methods, polynomial fitting for regional-residual separation of gravity and magnetic anomalies, filter theory and filtering of potential field data, Gravity anomalies over spheres, cylinders, dykes, faults and sheets, Magnetic anomalies over single pole, dipole, line pole, spheres, cylinders, faults and dykes, graticules and anomalies of irregular bodies, relation between gravity and magnetic potentials, depth estimation, curve matching techniques. Forward and inverse methods of modeling. Transformation of gravity and magnetic anomalies in frequency domain, spectral representation of field data and interpretation of gravity and magnetic profiles.
5. Gravity and magnetics for the exploration of the minerals, oil/gas and groundwater, microgravity studies-crustal movement and reservoir monitoring.

Suggested Readings:

1. Grant & West: Interpretation Theory in Applied Geophysics
2. Nettleton: Gravity and Magnetics in Oil Prospecting
3. Rao & Murthy: Gravity and Magnetics
4. Dobrin & Savit: Introduction to Geophysical Prospecting
5. Telford et al.: Applied Geophysics
6. Murthy & Mishra: Interpretation of Gravity and Magnetic Anomalies in Space and Frequency Domain

GPM 503B: Climate Dynamics II **Credits: 4**

1. Numerical Methods: Finite difference, truncation error, linear computational instability, Neuman condition, implicit and semi-implicit method, relaxation method, simultaneous and sequential method.
2. Numerical Weather Prediction: Historical review, filtering of sound and gravity waves, filtered forecast equation, forecasting of stream function. Barotropic model,

equivalent barotropic model, baroclinic model-two level, multilevel quasigeostrophic model, primitive equation models, spectral and finite element model, Sigma coordinate, hydrodynamical equations in Sigma coordinate Eta coordinate, Eta model, precipitation forecasting, range of predictability.

3. Objective analysis: Cressman method, method of optimum interpolation, initialization: static initialization, dynamic initialization, normal mode initialization, Newtonian relaxation or Nudging, nonlinear stability, Aliasing, Arakawa Jacobian, Staggered grid systems.
4. Hydrodynamic Instability: Barotropic, inertial and baroclinic instability.
5. Atmospheric Waves: Perturbation theory, properties of waves, sound waves, gravity waves, vertical stability, internal gravity waves, Rossby waves, mountain waves.
6. Scale analysis of momentum, continuity, vorticity, divergence, thermodynamic and omega equation, diagnostic analysis of synoptic scale motion in middle latitude.
7. Sutcliffe's Development Theory: Thickness and vorticity advection.
8. General Circulation: Longitudinally averaged and varying flow, constraints on the theories of the general circulation, maintenance of mean zonal circulation (angular momentum consideration and kinetic energy consideration), experimental approach.
9. Energetics: Energy equation, internal and available potential energies, generation, conversion and dissipation of energies.
10. Cumulus parameterization, Kuo Method, Parameterization involving cloud models, Arakawa and Schubert model, parameterization of terrestrial radiation for clear sky and cloudy sky, solar radiation for clear sky and cloudy sky.
11. Modeling of tropical climate and weather: Global, Regional and Meso-scale modeling. Global and Regional models used in weather forecasting and climate simulations.

Suggested Readings:

1. Hess: Introduction to Theoretical Meteorology
2. Holton: An Introduction to Dynamic Meteorology
3. Haltiner: Numerical Weather Prediction
4. Haltiner & Martin: Dynamic and Physical Meteorology
5. Atkinson: Dynamic Meteorology: An Introductory Selection
6. Thompson: Numerical Weather Analysis and Weather Prediction
7. Wiin-Nielsen: Compendium of Meteorology, Vol. I Geneva, W.M.O.

GPM 504A: PETROLEUM GEOPHYSICS AND SEISMIC STRATIGRAPHY

Credits: 3

1. Shear wave prospecting, seismic source energy for S-wave, splitting of shear wave. Shear wave velocity and relationship between Vs and Vp for different materials. Application of shear wave in processing and interpretation of seismic data.
2. Data acquisition for vertical seismic profiling (VSP), 3D-VSP and its applications. Multi-component seismic data acquisition for recording of P and S waves. Relation between rock properties and AVO response, seismic inversion.

3. 4-D seismics, passive seismics. AVO/AVA analysis, splitting of P wave energy into P and S seismic reflected and refracted waves, Zoeppritz equations. Offset dependent reflectivity.
4. Seismic stratigraphy and sequence analyses, seismic facies analyses, reflection and amplitude character analyses, direct hydrocarbon indicators, bright spot.
5. Seismic lithologic modelling, Vp/Vs and lithology, gas detection using AVO.
6. Introduction to unconventional energy resources and their exploration.

Suggested Readings:

1. Clarbout: Fundamentals of Geophysical Prospecting
2. Telford et. al.: Applied Geophysics
3. sheriff: Seismic Sratigraphy
4. Dobrin & Savit: Introduction to geophysical Prospecting
5. Waters: Reflection Seismology
6. Sheriff & Geldart: Exploration Seismology
7. Fundamentals of geophysical interpretations by Laurence R. Lines and R.T. Vavrick.

GPM504B: AEROSOL AND ATMOSPHERIC CHEMISTRY **Credits: 3**

1. Atmospheric aerosols: Origin of aerosols, Physical and chemical properties of aerosols, Size distribution, characterization of aerosols.
2. Aerosols in the atmosphere: Aerosol vertical profile in the boundary layer, in the free troposphere and in the stratosphere, Dynamics of particle in the atmosphere.
3. Optical properties of aerosols: Absorption and scattering of radiation by aerosols; Various terminology, Interaction of aerosols with radiation; Direct, indirect, and semi-direct effects of aerosols.
4. Aerosols in the atmosphere: Climatology of tropospheric and stratospheric aerosols, Transport and modification of aerosols; Dry and wet removal processes of aerosols.
5. Aerosols with respect to climate, weather, and environment: Aerosols in chemical transport models; Aerosols in climate models; Dispersion of pollutants in the atmosphere, Effect of local topography on dispersion.
6. Gaseous pollutants: Introduction to green house gases and trace gases, atmospheric photochemistry; basic photochemical cycle, atmospheric chemistry dealing with various pollutant species and photochemical smog; global budgets of precursor species.
7. Effects of pollutants: Aerosols and gaseous pollutants impact on human health and air quality.
8. Present status: Current knowledgebase and research in aerosols and atmospheric chemistry, Future directions.

Suggested Readings:

1. B.J. Finlayson-Pitts, J. N. Pitts, Jr., Chemistry of the Upper and Lower Atmosphere, Academic Press, 2001.
2. Seinfeld, J. and Pandis, S. Atmospheric Chemistry and Physics: From Air Pollution to Climate Change, Wiley Interscience, New York, 1998.

3. Petty, G.W. A first course in Atmospheric Radiation. Sundog Publishing, Madison Wisconsin, 2nd edition, 2006.
4. Liou, K. N., Introduction to Atmospheric Radiation. Academic Press, San Diego, 2nd edition, 2002.
5. Hinds, W., Aerosol Technology: Properties, Behavior, and Measurement of Airborne Particles, Wiley Interscience,1999.
6. Vincent, J.H., Aerosol Sampling: Science, Standards, Instrumentation and Applications, Wiley Interscience, 2007.
7. Baron, P.A. and K. Willeke, Aerosol Measurement: Principles, Techniques, and Applications, Wiley Interscience, 2005
8. Atmospheric Chemistry and Physics: Open access peer-reviewed scientific journal published by the European Geosciences Union. ISSN: 1680-7324.

GPM 505A: PRACTICAL BASED ON COURSE GPM502A Credits: 2

1. Formulation of 2D forward linear and non-linear problems in gravity.
2. Formulation of 2D forward linear and non-linear problems in magnetics.
3. Inversion of 1D resistivity data.
4. Formulation of 1D induced polarization forward problem
5. Use of generalized (Psedo) inverse methods to invert different AVO data.
6. Comparison of performances SD, CG and Newton's method in inverting post-stack seismic reflection data.
7. To develop an algorithm for simulated annealing (SA)/ very fast SA to invert multi-parameter data.
8. To develop genetic algorithm (GA).
9. To develop neural network (NN) algorithm.
10. Formulation of 1D EM/ MT forward problem, an computation of sensitivity matrix.

GPM 505B: PRACTICAL BASED ON COURSE GPM502B Credits: 2

1. Plotting and analysis of surface weather charts for different seasons and issue of inferences.
2. Plotting and analysis of constant pressure charts.
3. Plotting and analysis of vertical time section and cross section chart.
4. Streamline and isotach analysis.
5. Analysis of synoptic systems like lows, trough etc. using different Synoptic Charts.

GPM 506A: PRACTICAL BASED ON COURSE GPM503A Credits: 2

1. Determination of density by Nettleton method.
2. Handling of gravimeter and its calibration.
3. Structure contouring from subsurface informations
4. Preparation of a residual map by (a) Graphical method and (b) Grid method.
5. Upward and downward continuation of gravity and magnetic fields.

6. Computation of gravity effect of a sphere, horizontal cylinder and fault.
7. Computation of effect of a magnetic dipole of finite length, sphere and horizontal cylinder.

GPM 506B: PRACTICAL BASED ON COURSE GPM503B **Credits: 2**

1. Preparation of Bellamy grid and computation of divergence, vortices and deformation field by Bellamy grid.
2. Preparation of curvature circle nomogram and computation of divergence and vorticity by curvature circle.
3. Computation of divergence and vortices by finite difference method.
4. Problems in dynamic meteorology.
5. Simulations using numerical model.

GPM 507: PRACTICAL BASED ON COURSE GPM501 **Credits: 2**

1. To digitize analogue signal by graphical method choosing different sampling intervals, plotting the digitized record and examining the aliasing phenomenon.
2. To convolve the two signals (wavelets), plot and examine the results.
3. To compute the autocorrelation and cross-correlation functions for a given data set, plot and examine the results.
4. To perform digital filtering after designing a low, high and band pass filters and to examine the effects of truncation.
5. To apply Hanning and Hamming windows on a given set of data points.
6. To compute the amplitude, phase and power spectra of a given time series.
7. To apply Wiener inverse filtering to seismic data, comment on wavelet extraction problems.
8. To perform the spectral analysis of gravity, magnetic and meteorological data.
9. Computer modeling of some geophysical problems.
10. Compute MLM of different data distribution.

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SEMESTER-VI (Credit: 18)

GPM 601: PHYSICAL OCEANOGRAPHY AND MARINE GEOPHYSICS Credits: 4

Section I: PHYSICAL OCEANOGRAPHY Credits: 2

1. Physical properties of Sea Water: Chlorinity, salinity, thermal properties, density, pressure, optical properties, transmission of sound, water masses, T-S diagram, variation of salinity, heat budget of the ocean, Bowen ratio.
2. Acquisition of Ocean Data: Salinity measurements, Nansen bottle, light in sea, measurement of SST, reversing thermometers, Bathy thermograph, current meters.
3. Ocean Currents: Hydrodynamic equations of motion, inertia currents, geostrophic currents in homogeneous and stratified ocean; relative and slope currents, thermohaline currents, drift current in homogeneous water, Ekman theory, the major surface current systems of the ocean, upwelling and sinking with special reference to Indian ocean and their effects.
4. Waves: Wave velocity, group velocity, theory of surface gravity waves, short and long waves, generation and growth of wind waves, long waves in canals, standing waves in closed basins, seiches, swell, breakers and surf, internal waves, storm surges, tsunami.
5. Tides: Tide generating forces, principal harmonic components, theories of tides, description and types of tides, prediction of tides, tidal gauges.
6. Air Sea Interaction: Structure of the boundary layer, exchange coefficients and profiles, transfer of heat and water vapour.

Section II: MARINE GEOPHYSICS Credits: 2

1. Ocean and Seas: classification, growth and decline of ocean basins, turbidity currents, submarine sedimentation and stratigraphy, physiography and divisions of the sea floor, continental shelves, slopes, aprons and abyssal planes, occurrence of mineral deposits and hydrocarbon in offshore.
2. Radio Positioning System: Short range and long range Doppler Sonar, satellite navigation, GPS & GIS.
3. Gravity and magnetic Surveys: Types of magnetometer used in a survey ship, towing cable and fish, data collection their reduction and interpretation, underwater gravity measurements, ship borne gravimeters, Graf sea gravimeter, vibrating string accelerometer, Lacoste Romberg gravimeter, problems with shipborne gravity measurements, survey procedure, data reduction and interpretation.
4. Seismic Surveys: Marine energy sources, Finger, Boomer, Sparker, explodor, airgun, vapour cook etc. hydrophones active section and streamer towing gear, shooting methods near offshore and offshore exploration techniques, analysis of seismic data

their processing and interpretation, refraction survey with Sonobuoy's and interpretation.

Suggested Readings:

1. Duxbury: The Earth and its Oceans
2. WMO No.364: Marine Meteorology
3. Sverdrup, Johnson & Fleming: The Oceans
4. Defant: Physical Oceanography, Vols. I and II
5. McLellen: Elements of Physical Oceanography
6. Jacob, Russel & Willson: Physics and Geology
7. Dobrin & Savit: Introduction to Geophysical prospecting
8. Telford et.al.: Applied Geophysics

GPM 602 (O-Y): ELECTIVE PAPER **Credits: 4**

GPM 602O: ADVANCED HYDROLOGY

1. Surface water losses: evaporation and evapo-transpiration formulae; infiltration theories; and theories of surface flows (run-off).
2. Surface water hydrograph: method of unit hydrograph; synthetic hydrographs and their application; floods, estimation of flood flows; flood routing through rivers and reservoirs;
3. Application of statistical methods in hydrology.
4. Water resources: Partially saturated soils; Darcy's law in unsaturated medium; derivation of Darcy's law from Navier-Stokes theorem; different forms of unsaturated flow equations; nature of the physical parameters in unsaturated flow; concept of mass transfer; groundwater hydrographs.
5. Application of finite difference and finite element techniques in hydrology; simulation and digital modelling; tracer techniques.
6. Practical aspects of flow of ground waters to wells; analyses of pumping test.
7. Water Management: conservation and utilization of water and its management; safe yield; and urban hydrology.

Suggested Readings:

1. Ward: Principles of Hydrology
2. Todd: Groundwater Hydrology
3. Heath & Trainer: Introduction to Groundwater Hydrology
4. Guide Book on Nuclear Techniques in Hydrology
5. Dury: Face of the Earth
6. Chow: Handbook of Applied Hydrology

7. Childs: Introduction to Soil Water Physics
8. Walton: groundwater Evaluation
9. Tolman: Groundwater.
10. Jacob Bear: Groundwater hydraulics.

GPM 602P: ADVANCED SEISMOLOGY

1. Measurement and characteristics of strong ground motion, dispersion of surface waves, ray theory, travel-time curves for body waves and inversion techniques, tomography, 3-D earth structure, attenuation, diffraction and scattering of seismic waves, fault asperities inferred from seismic waves, crust and mantle structures inferred from surface waves, broad band seismometry, and recent Indian earthquakes.
2. Seismic arrays, tectonic and volcanic earthquakes and their characteristics, seismic hazard, risk analysis, seismic gaps and regions of high seismic potential, earthquake source studies, earthquake processes and source modeling, earthquake prediction problem, application of fractals and chaotic dynamics in seismology, non-linear propagation and geodynamics.

Suggested Readings:

1. Kanamori & Baschi: Earthquakes: Observation, theory and Interpretations
2. Ewing: Elastic Waves in Layered Media
3. Bath: Mathematical Aspects of Seismology
4. Bullen: Introduction to Seismology
5. Aki & Richard: Quantitative Seismology, Vol. I and II
6. Slawomir & Andrezej: An Introduction to Mining Seismology.

GPM 602Q: DIGITAL ELECTRONICS & MICROPROCESSOR

1. Number Systems: Decimal, binary, octal and hexadecimal number systems, Interconversion of decimal, binary and hexadecimal numbers, BCD numbers, BCD addition and subtraction.
2. Logic gates: AND, OR, NOT, NAND, NOR, and exclusive OR gates, NAND and NOR gates as universal gates.
3. Logic Families: TTL logic circuits (NAND and NOR gates), comparison of TTL, ECL and CMOS.
4. Boolean Algebra: De Moegan's theorems, standard POS and SOP forms, min-term and max-term representation of Boolean functions, simplification of Boolean functions using K-maps (up to 4 variables).
5. Combinational Circuits: Half and full adders, half and full subtractors, multiplexer, demultiplexer, encoder, decoder, BCD to seven segment decoder.
6. Flip-flops: R-S, J-K, master-slave and edge triggered J-K, T and D Flip-flops.
7. Sequential Circuits: Shift registers, ring counters, ripple and synchronous counter, modulo-N counter, decade counter, digital-to analog converter (binary weighted

register and ladder types), and analog -to- digital converter (using D/A converter and comparator).

8. Digital Wave form Generator: Concept of timer IC 555 and its use for waveform generation (astable and monostable).
9. OP-AMP: Concept and characteristics of OP-AMP and its use as: Adder, subtractor, differentiator, integrator, logarithmic and exponential operator, inverting and non-inverting amplifier, differential amplifier, CMRR, analog computer (for 2nd order differential equations).
10. Memories: Concept of Random Access Memory (RAM) , static and dynamic RAM, Read Only Memory (ROM), PROM and EPROM.
11. Introduction to Microprocessors: Evolution of microprocessors, organization, architecture and pin description of 8085 microprocessor, addressing modes and instruction set, input/ output interfacing devices (8255, 8251), simple programs for addition/ subtraction, developmental trends in microprocessors technology (8086, 80186, 80286, 80386, 80486 and Pentium).
12. Application of Microprocessors: Application of Microprocessors in Geophysical Instrumentation: Microprocessors based data acquisition, frequency, temperature and voltage measurements using microprocessors.

Suggested Readings:

1. Jain: Modern Digital Electronics
2. Malvino: Digital Computer Electronics
3. Puri: Digital Electronics
4. Mathur: Introduction to Microprocessors
5. Sheth & Hebber: Microprocessors
6. Gaonkar: Microprocessors Architecture, Programming and Applications
7. Ram: Microprocessors and Microcomputers
8. Gaikwad: Operational Amplifier.

GPM 602R: REMOTE SENSING AND GIS

1. Fundamentals of Remote Sensing: Energy sources, principles of solar and terrestrial radiation, laws of radiation, energy interactions, spectral patterns and signatures.
2. Characteristics of aerial photographic imagery, photogrammetry, airphoto interpretation for terrain evaluation.
3. Application in geological mapping and mineral resource evaluation, concepts of GIS and applications, theory and principles, structural concepts, geological interpretation and its ambiguity, geological guides, characteristics for mineral resource.
4. Application to water resources evaluation and soil moisture determination; watershed parameters, physiographic measurements, surface water, flood plain delineation, precipitation, ice and snow monitoring, evaporation and evapotranspiration, subsurface water information system and analysis.
5. Developments of satellites and remote sensing developments in India.

6. Development in remote sensing platforms, constant level and tethered balloons, aircrafts, rockets and satellites.
7. Kepler's laws of planetary motion, circular and elliptical orbits of satellites, polar, geosynchronous and geostationary satellites.
8. Types of sensors, photographic and TV cameras, visible and infrared sensing, radiometer, side looking radar.
9. Remote sensing application in meteorology, visible and infrared pictures of clouds, recognition of various clouds and weather systems, estimation of surface temperature and cloud tops, vertical profiles of temperature and water vapour, wind estimation.

Suggested Readings:

1. Barret & Curtis: Introduction to Environmental Remote Sensing.
2. Lillesand & Kiefer: Remote Sensing and Image Interpretation.
3. Reeves (Ed.): Manual of Remote Sensing, Vols. I and II, American Soc. Photogrammetry.
4. Siegal & Gellospie: Remote Sensing in Geology.
5. Teekshadulu & Rajan: Remote Sensing , Indian Academy of Sciences.
6. Kidder & Vonder Haar: Satellite Meteorology an Introduction.

GPM 602S: ENVIRONMENTAL GEOPHYSICS

1. Earth and environment, elements of environment, man and environment.
2. Atmosphere : Origin, composition and structure, the troposphere as an Environmental layer, air pollution, pollutants and its impact on weather, the ozone shield, green house effects and role of trace gases, global warming, acid rains.
3. Hydrosphere: Ocean and environment, the hydrologic cycle and global water balance, surface water hydrology, water pollutants and their effects on surface and ground water, heavy mentals (Hg, Cd and As) in ground water, their detection and abatements.
4. Mineral resources and environment, impact of mining and mineral resources.
5. Energy and Environment: Coal, oil and gas, geothermal energy, nuclear energy, solar energy.
6. Role of geophysics in Environmental protection.

Suggested Readings:

1. Jorgensen: Principles of Environmental Sciences and Technology
2. Keller: environmental geology
3. Ramade & Strahler: Environmental Geoscience-Interaction Between Natural System and Man.
4. Tyler & Mitter: Jr. Environmental Science
5. Sharma: Environmental Geophysics

GPM 602T: GEOMAGNETISM

1. Earth's Magnetic Field: Internal and external fields, main field and variational field, components of the main field, magnetic and geomagnetic coordinates, measurement and recording of the main field: measurements of horizontal, vertical, declination, inclination and total field, magnetometers and variographs, Theories of the earth's main magnetic field: A brief introduction of the various of the main field and its secular variation, dynamo theory of the main field, Geomagnetic indices: Ci, CR, Ks, Kp indices, concepts of quiet and disturbed days.
2. Transient Variations: Definition, computation, morphological features, current systems and causes of solar quiet day variation (Sq), disturbance daily variation SD, storm time variation Dst and lunar variation L, Morphology of the equatorial electrojet, geomagnetic storms: morphological features of geomagnetic storms, gradual and sudden commencement storms, DS and Dst fields, ring current, Van Allen belts theories of the geomagnetic storms.
3. The Sun, Sunspots and Solar Flares: A brief introduction of the structure of the sun, morphological features and classification of sun sport indices, morphological features of solar flares, classification of solar flares, Morphological feature, classification and causes of auroras, Morphological features, classification, observation and causes of geomagnetic micropulsation, morphological features, composition, structure and production of various layers of the ionosphere, sudden ionospheric disturbances, Earth currents, its measurements, morphological features and interrelation with geomagnetism.

Suggested Readings:

1. Chapman & Bartels: Geomagnetism
2. Matsushita & Campbel: Physics of the Geomagnetic Phenomena
3. Jacob: Earth's Core and Geomagnetism
4. Mitra: Upper Atmosphere

GPM602U: NON-LINER SYSTEMS IN GEOPHYSICS

1. Kinematics of deformation - the deformation gradient tensor, the strain tensor, homogeneous deformations, deformation of surface and volume elements, material and spatial coordinates, analysis of stress, Cauchy's equation of motion, balance laws, constitutive equations for elastic and thermoelasticity.
2. Introduction to constructive aspects of bifurcation and implicit function theorem, imperfect bifurcation, bifurcation and non-linear eigen value problems.
3. Non-Linear stability and folding of rock strata, convection in magma chambers and mantle, core convection and dynamo theory, earthquakes and chaos.
4. Non-linear elastic waves and solutions, group velocity, dynamical treatment, fractals and multifractals measures in geophysics.

Suggested Readings:

1. Alkin & Fex: An Introduction to the theory of Elasticity
2. Fang: Foundation of Solid Mechanics
3. Mal & Singh: Deformation of Elastic soils
4. Spencer: Continuum Mechanics
5. Robinowitz: Application of Bifurcation Theory
6. Atherton: Stability of Non-Linear System
7. Bhatnagar: Non-Linear Waves in One-Dimensional Dispersive Systems

GPM 603V: GEOTOMOGRAPHY AND COMPUTER MODELLING

1. Concept of Tomography: Inversion, linear and non-linear inversion, inversion technique-traditional, Monte-Carlo, Backus-Gilbert, Tau method, non-linear least square, ray tomography, diffraction tomography, borehole tomography, 2D and 3D imaging, applications in various branches of geophysics.
2. Finite element and finite difference methods and their formulations, numerical modelling, super computers, Lax- Wondroff second order scheme, MacDormack fourth order scheme, stability conditions, computer simulation of P-SV, SH and acoustic cases and other geophysical problems.

Suggested Readings:

1. Mitchell: Computational Methods in Partial Differential Equations
2. Noye: Numerical Simulation fluid Motion
3. Krishnamurthy & Sen: Computer Based Numerical Algorithms
4. Gold & Rader: Digital Processing of Signals
5. Boarding er. al.: Application of Seismic Travel Time tomogrphy
6. Dines& Lytle: Computerized Geophysical Tomography
7. Wu et. al.: Diffraction Tomography and Multisource Holography Applied to Seismic Imaging.
8. Aiyer et. al.: Geotomography.

GPM 602W: ADVANCED PHYSICAL METEOROLOGY

1. Physics of tropical monsoon clouds, precipitation mechanism from convective, stratiform and orographic clouds, artificial modification of the precipitation, artificial dissipation of fog and low cloud, atmospheric electoral and boundary layer processes.
2. Precipitation chemistry, aid rain, atmospheric aerosols and trace gases, tropospheric chemistry.
3. Atmospheric chemistry, dynamics of the middle atmosphere and troposphere-stratosphere coupling, monsoon activity, climatic change, measurement of atmospheric minor constituents and climatic effects.
4. Physics of the Upper Atmosphere: Composition and structure, energy exchanges by collisions, transport processes, mean circulation and eddy transport, the ionosphere,

composition and general properties, observational methods, aurora and air glow, noctilucent clouds, nacreous clouds.

5. Atmospheric Visibility: Attenuation of light by the atmosphere, the air-light and visual range in daytime, visibility of point light sources at night, objective measurement of visual range, oblique visual range.
6. Meteorological Acoustics: Doppler effect, effect of temperature and humidity on sound velocity, sound path in a calm atmosphere, effect of wind on sound propagation, attenuation of sound, propagation of sound through stratosphere, sound origination from meteorological elements.
7. Meteorological Physics: Coronas and related phenomenon, twilight phenomenon, colour and polarisation of sky light.

Suggested Readings:

1. Johnson: Physical Meteorology
2. Mason: Physics of Cloud
3. Dobson: Exploring the Atmosphere
4. Retallack: Compendium of Meteorology Vol. I, Part-III, Meteorology. W.M.O. 364
5. Baton: Radar Observes the Weather
6. Kidder & Vonder Harr: Satellite Meteorology
7. Mitra: The Upper Atmosphere.

GPM 602X: APPLIED METEOROLOGY

1. Aviation meteorology: Requirements of climatological data for sitting of runways, meteorological observations and forecasts required for aircraft operations, organization of KAO, DGCA and air traffic control, coordination between MFT and ATC, special observations for aviation, METAR, SPECT, TREND, SIGMENT, aviation forecasts and warnings, documentation and briefing for national and international flights, aviation climatology.
2. Maritime Meteorology: Voluntary observing flight routine and special observations from ship at sea weather bulletins for shipping, storm warning bulletins, storm signals at ports, weather routing of ships, climatological atlas for oceanic regions, atlas of storm tracks.
3. Biometeorology: Thermal balance between heat production and heat loss effect of climatic factors, influence of weather and diseases caused by viruses, bacteria and metabolic disorders, acclimatization, climate and insect pests, thermal comfort and comfort indices, urban and building climatology.
4. Environmental Pollution: Extent of pollution, atmospheric ventilation, meteorological factors affecting the concentration of pollutants, monitoring for prevention control of pollution UNEP.
5. Atmospheric Transport and Diffusion: Classical diffusing theory (K-theory), similarity theory, theory of turbulence, Plum rise, short term modelling and prediction technique for pollutants.
6. Effects of air pollution on climate, human health.

Suggested Readings:

1. Stern: Air pollution
2. HMSO, London: Handbook of Aviation Meteorology
3. Munn: Biometeorology
4. WMO Note: Urban Climatology
5. WMO Technical Note: Air Pollutants, Meteorology and Plant Injury.

GPM 602Y: ADVANCED CLIMATOLOGY

1. Climatic classification based on atmospheric circulation and geographical conditions. Genetic classification, classification based on the effect originated at the surface. Types of climate, Various classifications of climate, Koepen, thornthwaite, Handdel etc.
2. Function and physical description of the climates of the different continents and ocean.
3. Radiation properties of natural surfaces, radiation in crops forest canopies, cities, vertical variation and distribution of various climatic elements, heat exchange and conduction near soil surface, atmospheric pollution.
4. Elements of bioclimatology, urban building climatology, climatic change, fundamental meteorological factors affecting the climate, past climate revealed by meteorological observation, methods of palaeoclimatology, possible causes of climatic change, influence of man on climatic changes, climatological statistics.
5. Introduction to climate system, role of green house gases, global warming, climatic change and its impacts on agriculture.
6. Asian Summer Monsoon: Global teleconnections, basic concepts of climatic modelling, energy cycle, Tropical Ocean and their role in climate control.
7. Physical processes in general circulation.

Suggested Readings:

1. Miller: Climatology
2. Lamb: Climate Present, Past and Future
3. Barry & Parry: Synoptic Climatology
4. Stringer: Fundamentals of Climatology
5. Winter School on Climate Change and its Impacts, IIT- Delhi.

GPM 602Z: MODERN TECHNIQUES IN SEISMIC INTERPRETATION AND MIGRATION

1. Seismic Sources: Explosive and non-explosive sources.
2. Seismic Refraction Method: Travel time equations for simple one layer case and for variable velocity case, expressions for dipping layer and faulted bed cases, Gardener

delay time method, hidden layer problems, field techniques for refraction survey, fan shooting.

3. Seismic Reflection Method: The travel time equations for horizontally layered medium, expressions for dipping interfaces, field techniques for reflection survey, split spread, end on spread, broad side configurations, 2D, 3D and 4D configurations, common depth point technique, presentation formats of seismograms, selection of field survey parameters.
4. Data processing sequence, static and dynamic correction, weathering and datum corrections, CDP stacking, migration and depth section preparation.
5. Velocity Depth Determination: Velocity-depth relation from measurements in boreholes, velocity depth relation from surface observations, T^2-X^2, T-ΔT and hyperbola method.
6. Noise Elimination Method: The structure of noise and its classification using frequency and spatial filters (arrays), multiples identification, suppression of multiples VSP.
7. Mapping of hydrocarbon bearing and water bearing structures, gas hydrates, pattern recognition, thin bed modeling, seismic lithologic modeling, geological interpretation, location of stratigraphic traps, direct detection of hydrocarbons, wave equation migration and its various forms, artificial intelligence, artificial neural network (ANN) and gas detection using AVO analysis.

Suggested Readings:

1. Dobrin & Savit: Introduction to geophysical Prospecting
2. Telford et.al.: Applied Geophysical
3. Keary & Brooks: Introduction to Geophysical Exploration
4. Waters: Reflection Seismology
5. Robinson: Basic Exploration Geophysics
6. Scheriff: Seismic Stratigraphy
7. Lavergne: Seismic Methods.

GPM 603: SEMINAR **Credits: 2**

Each student is required to prepare a seminar note (about 1500 words) in the form of a report and give oral presentation (of 30 minutes) on the topic assigned by the Head of the Department in consultation with respective mentors.

GPM 604A/ GPM 604B: COMPREHENSIVE VIVA- VOCE **Credits: 2**

In the end of sixth Semester, each student will be examined in this paper on the entire M.Sc. (Tech.) Geophysics courses by a Board consisting of three internal and one external examiner in each specialization.

GPM 605A/ GPM 605B: PROJECT WORK/ DISSERTATION Credits: 6

During the sixth semester, students have to work for about 2-4 weeks for their Project work/ dissertation at the laboratories of their field of specialization or with field parties depending upon the facilities available. The co-supervisor(s) for thesis on project/ dissertation work of M.Sc. (Tech.) VI Semester students is/are allowed from the outside organization. The topic of their project work/ dissertation will be decided towards the end of the fourth Semester by the Head of the Department in consultation with the supervisors, so that students may avail facilities for thesis work during summer vacation.

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NOTE:

1. **Students of Semester IV will initiate dissertation/ project work during summer vacation in laboratories in or outside Varanasi (if required).**
2. **Students of Semester II & III will carry out their 'Excursion & Tour' and 'Field Training', respectively, after the semester end examination.**
3. **The co-supervisor(s) for thesis on project/ dissertation work of M.Sc. (Tech.) VI Semester students is/are allowed from the outside organization.**