Department of Geophysics
Kurukshetra University Kurukshetra

Syllabus for Ph.D. entrance test 2019-20

Mathematical Methods in Geophysics

UNIT-I: Special Functions
Power series method to solve partial differential equations Legendre Function: Legendre differential equation and its solution, recurrence relation, Legendre functions, Rodrigue's formula, Associated Legendre functions and its recurrence relations and orthogonality property Bessel Functions: Bessel differential equation and its first and second solutions, Bessel functions, Recurrence relations, Orthogonality, Modified Bessel function, Spherical Bessel functions Applications of Legendre and Bessel functions in Geophysics

UNIT-II: Complex Variables
Complex variable, limit, continuity and differentiability of function of complex variables, analytic functions, Cauchy Reimann's equations, Cauchy's integral theorem, Morera's theorem, Cauchy integral formula, Expansion by Taylors and Laurents series, singularities, Residue theorem, contour integration Applications in Geophysics

Unit-III: Integral Transforms
Fourier series, evaluation of coefficients of Fourier series, sine and cosine series, complex form of Fourier series, Dirichlet condition, integration and differentiation of Fourier series, Parseval theorem for Fourier series, Fourier sine and cosine integral Concept of integral transform, Laplace Transform (L.T): definition, properties, L.T. of periodic function, multiplication and division with L.T., L.T. of error function, L.T. of Bessel function, Inverse Laplace Transform. Fourier transform (F.T.): Definition, properties, Parseval theorem for F.T., Modulation, Conjugate and Convolution Theorem, Derivative of F.T., Inverse Fourier transform, application of Fourier transform in solving differential equations. Applications in Geophysics

Unit-IV: Partial Differential Equations (P.D.E.)
Solution by separation of variables of
(a) Wave equation: Transverse vibrations of a stretched string; Oscillations of a hanging chain, vibrations of rectangular and circular membrances, tidal waves in a canal.
(b) Laplace's equation: Laplace equation in Cartesian, Cylindrical and spherical coordinate systems, two dimensional steady flow of heat, General cylindrical and spherical harmonics.
(c) Diffusion equation: Variable linear heat flow, periodic heat flow in one dimension, two dimensional heat conduction.

Solid Earth Geophysics

UNIT-I
A brief history of the development of Earth Sciences and of Geophysics in particular, an overview of Geophysical methods and their essential features, Problems of inversion and non-uniqueness in Geophysics, Origin & evolution of Solar system, Earth and Moon structure, Kepler's law of planetary motion, A review of the Earth's structure and composition

UNIT-II
Chemical composition of Earth, Rheological behaviour of crust and upper mantle, viscoelasticity and rock failure criteria, Geochronology: Radiometric dating and their advantages, meaning of radiometric ages, Major features of the Earth's gravitational field and relationship with tectonic processes in the crust and upper mantle, concept of isostasy, mathematical concept of Airy and Pratt hypotheses of isostasy.

UNIT-III

Origin of geomagnetic field, polar wandering, secular variations and westward drift, reversals of geomagnetic field, sun spot, solar flares, geomagnetic storms, sea-floor spreading, Paleomagnetism and its uses, Thermal history of the Earth, sources of heat generation and temperature distribution inside the earth, convection in the mantle.

UNIT-IV

Earthquake seismology, Earthquakes and its classifications, Global seismicity and tectonics, Earth's internal structure derived from seismology, Earthquake mechanism and Anderson's theory of faulting, Continental drift and plate tectonics: its historical perspective and essential features, present day plate motions, Triple junctions, oceanic ridges, Benioff zones, trenches and island arcs, hot spots, Mantle Plume, Mountain building, origin of Himalaya, Geodynamics of Indian subcontinent.

NUMERICAL METHODS AND COMPUTER PROGRAMMING

UNIT-I

Introduction- Computer organization, Functional Units, basic I/O devices and storage media, computer software, computer languages, Problem Solving Approaches: Notion of an algorithm, stepwise methodology of developing algorithm, flowchart and computer program, introduction to computer operating systems: DOS, WINDOWS, UNIX/LINUX, brief introduction about MATLAB.

UNIT-II

Introduction to FORTRAN, constants, variables, data types, operations and intrinsic function, expression and assignments statements, Logical operators and Logical expressions, iterative statements, input/output statements, subroutine and functions, data sharing among subprograms/programs, Arrays, operations with files, programming examples to handle problems of numerical and statistical type.

UNIT-III

Programming language C: constants, variables, data types, expressions, operators, conditional statements, iterative statements, array, function, simple programming examples.

C^{++} An object oriented language: Concepts of class, object, constructors, destructors, operator overloading, inheritance, pointers, virtual functions, simple programming examples

UNIT-IV

Numerical integration by Simpson's method, Trapezoidal method, Numerical differentiation, solution of algebraic equation, Netwon Raphson method, solution of simultaneous linear equations, Gauss method, Gauss-Jordon method, Gauss-Seidel method, matrix inversion, least square curve fitting, straight line and polynomial fits, solution of ordinary differential equations.

A brief introduction of Binomial, Poisson and normal distributions, concept of mathematical expectations

BASIC GEOLOGY

UNIT – I: INTRODUCTION

Introduction to geology, scope, sub-disciplines and relationships with other branches of science, Geomorphological Processes: Exogenic processes (weathering, erosive and tectonic denudation), Geologic time and age of the Earth, Geological processes by river, wind, glacier and waves and tides. Orogeny, volcanism, earthquakes and land slides

UNIT – II: MINERALOGY

Mineral – its definition and mode of occurrence, physical properties of minerals like form, colour, lustre, streak, cleavage, fracture, hardness and specific gravity, radioactivity, isotopes and ions, Physical characters and chemical composition of the rock forming minerals, mode of occurrence and economic uses of some important rock forming minerals.

UNIT – III: PETROLOGY

Rock- its definition, classification and distinguishing characteristics of Igneous, Sedimentary and Metamorphic rocks. Igneous rocks: Magma and lava, extrusive and intrusive forms, textures; Classification and description of some common igneous rocks (Granite, Dolerite, Basalt, Rhyolite, Pegmatite). Sedimentary rocks: Sedimentation processes; Classification and description of some common sedimentary rocks (Conglomerate, Sandstone, Shale, Limestone). Metamorphic rocks: Processes of metamorphism, textures and structures of metamorphic rocks; Classification and description of some common metamorphic rocks (Slate, Schist, Gneiss, Quartzite, Marble). Indian distribution of major rock types.

UNIT – IV: STRUCTURAL GEOLOGY

Primary and secondary structures of rock, Dip, strike, bearing and azimuth, Outcrops, outliers and inliers, Folds: definition and classification scheme, mechanism of folding, recognisation of folds in the field. Fault: definition and different terminology of fault, mechanism of faulting, recognisation of fault in the field, shear zone, lineament. Joints: definition, types of joint. Unconformity: concepts, types, recognisation and significance of unconformities. Clinometer compass and its use.

Remote Sensing and GIS

Unit I

Definition, Principle and Physical basis of Remote Sensing, Electromagnetic (EM) Spectrum, Interaction of EM radiations with earth's surface and atmosphere, Atmospheric Windows, spectral signatures, remote sensing platforms, Concept of Photogrammetry, aerial photographs, types of aerial photographs, Information recorded on aerial photographs, stereoscopy, stereoscopic parallax, measurement of height difference, vertical exaggeration, elements of photo-interpretation, geotechnical elements, photo-characteristics of different rock types, photo-mosaic, image distortion and rectification.

Unit II

Remote Sensing Sensors: active and passive sensors, Satellite Imagery: Imagery vis a vis aerial photograph, MSS, LISS, CCD, Infrared and thermal scanners, IRS, SPOT and LANDSAT satellite programmes, microwave remote sensing: RADAR, LIDAR etc, remote sensing data products, resolutions in remote sensing, multispectral, super-spectral and hyper-spectral remote sensing, fundamentals of image interpretations and analysis, visual interpretation of remote sensing data; colour composites, concept of digital image and pixels, image restoration, image enhancement and information extraction, supervised and unsupervised classification; accuracy assessment in remote sensing

Unit III

Introduction to Geographical Information System (GIS), components of GIS, functions of GIS, data structures, Concept of raster and vector data, digitization, editing, attribute attachment etc, creation of thematic layers, Data Integration, vector to raster conversion and vice–versa. Introduction to Global Position System (GPS), various segments of GPS, Uses of GPS, GNSS.

Unit IV

Applications of Remote Sensing and GIS: image interpretation for identification of different rock types, structures, lineaments and preparation of geological map; recognition of landforms and preparation of

geomorphological map; drainage pattern and its significance; ground water prospects mapping, integrated ground water resources (IGWR) mapping, landslide hazard zonation, route alignment for road/ canal, Hydrocarbon and minerals exploration, Disaster management (flood and cyclones)

STRATIGRAPHY, HIMALAYAN, ECONOMIC AND PETROLEUM GEOLOGY

Unit-1 Stratigraphy: Principles of stratigraphy, elements of stratigraphic classification, physical and structural sub-disciplines of Indian subcontinent and their characteristics, An outline of the geology of India with respect to distribution, classification, lithology and economic importance of the following: Archean, Dharwar, Cuddapah, Vindhyan, Gondawana.

Unit-2: Himalayan Tectonics and Exhumation: Tectonic divisions of the Himalaya and its evolution based on plate tectonics, Topographic growth: uplift, Isostasy and flexure, Tectonic-climate interactions, Principle and application of thermochronology to orogenic belt, Mountain belt exhumation with special reference to the Himalaya.

Unit-3. Economic Geology: Definition of ore, Ore and gangue mineral, Classification of ore deposits, Elementary ideas of the following processes of formation of ore deposits: Magmatic concentration, Pegmatitic, Sedimentation, Evaporation, Residual concentration, Mechanical concentration and Metamorphism, Chemical composition, Diagnostic characters, Occurrences, Uses and Distribution in India of important metallic and non-metallic mineral deposits.

Unit-4 Petroleum Geology
Petroleum; Origin of petroleum; Sedimentary environments and facies; The sources; Migration; The reservoir rocks; Traps and Seals; Classfication of Indian basins and petroleum geology of Assam, Krishna-Godavari, Cambay and Bombay offshore basins. Unconventional Source of energy: Shale gas; Coal Bed Methane; Gas hydrates.

Geophysical Signal Processing

UNIT I: Signal and System
Signals: Various special signal and classification of signals, orthogonal function, band limited signals, sampling theorem, aliasing effect of sampling on reconstruction of continuous signal from their samples, extrapolation of band limited signals
Systems: Classification of Systems, Linear time invariant causal and stable system with continuous and discrete input, minimum phase signals, Hilbert transform

UNIT II: Discrete Transform
Z transform, properties of Z transform, and the region of convergence, Z transform of causal and non causal sequence, inverse Z transform, Transfer function, Solutions of difference equation using Z-transform, Relation between S-plane and Z-plane
Review of Fourier Transform, Introduction to wavelet transform and Walsh transform and their application in geophysics
Discrete Fourier transform (DFT), relation between DFT and Z transform, Fast Fourier Transform (FFT), Decimation in time(DIT) and Decimation in frequency (DIF) algorithms, applications of FFT in

geophysics, deconvolution, circular convolution, Importance of Windowing, Commonly used windows, cepstral analysis

UNIT III: Time series analysis
Introduction of stochastic process, autocorrelation and cross correlation, Stationarity, Wide sense stationarity, ergodicity, power spectral density function, Wiener Khinchine theorem, White Gaussian Noise, Wiener Filtering, Matched Filtering

UNIT IV: Filters and System Realization
Recursive and non-resursive filters, ideal and realizable low pass, band pass and high pass filters, Gibbs phenomenon, IIR filters: design if IIR filter by Bilinear transformation method, Design of Butterworth filters, Characteristics of Chebyshev and elliptic filters, Design of FIR filters using windows.
direct and canonical realization scheme, Cascade and paraellel realization scheme.

Geophysical Fields and Waves

UNIT – I: Potential Field Theory:
Introduction to Geophysical fields; Inverse square law of field: Gravity, Magnetostatic and electrostatic, Green's theorem and Green's functions, Potential due to an arbitrary source distribution, continuation of potential fields, Dirichlet and Neumann problems.

UNIT-II: Thermal Conduction in Earth
Heat conduction equation; effect of advection; time scale of conductive heat flow;calculation of simple geotherms in continents; Geological applications of heat conduction in semi-infinite half space: (i) penetration of external heat into the earth due to periodic variation of surface temperature, (ii) instantaneous heating or cooling of semi-infinite half space and its application to cooling of oceanic lithosphere and (iii) thermal and subsidence history of sedimentary basins, Age of Earth on the basis of cooling.

UNIT-III: Wave Theory
Introductory remarks about seismic and electromagnetic waves, Elastic Waves: Analysis of stress and strain, properties of equilibrium and motion in terms of stresses/displacements for infinitesimal and finite deformation, Generlised Hook's Law, Isotropy, Aelotropy and Anelasticity.
Electromagnetic Waves: Maxwell's equations, constitutive relations, Plane electromagnetic waves in dielectric and conductor.
Kirchoff's integral theorem and Kirchoff's solution of diffraction at a slit.

UNIT-IV: Oceanography
Tidal Waves, driven tidal waves, seiches, geostrophic effect on tidal waves, internal tidal waves, surface waves, permanent waves, waves due to local disturbances, equilibrium theory of tides, dynamic theory of tides.

Seismology

UNIT – I: SEISMIC WAVE PROPAGATION

Review of basic concepts and relations in elasticity theory, Hook's Law, reflection and transmission of elastic waves at a plane boundary, plane waves, laws of simple reflection and refraction, head waves, total internal reflection, spherical waves, surface and interface waves, Rayleigh waves, Stoneley waves, love waves, dispersion curves, Free oscillations of the earth, toroidal and spheroidal oscillations, normal modes of a homogeneous sphere.

UNIT – II: EARTH STRUCTURE AND LOCATION

Travel time table: the ray parameter and seismic rays, time distance curves for local and teleseismic events, Inversion of travel times for earth's structure, the method of Herglotz and Wichert, Preliminary location of earthquakes, refining the locations, review of various types of field observations, salient features of seismograms with description of different seismic phases.

UNIT-III: EARTHQUAKE SOURCE PROCESS

Uniqueness and reciprocal theorems, Green's tensor for a uniform medium, mathematical models of earthquake source, radiation pattern for P & S waves from a shear fault, the fault plane solutions.

UNIT – IV: EARTHQUAKE PARAMETERS AND SEISMIC ZONING

Earthquake parameters: Intensity and magnitude scales, seismic moment, relation between parameters, scaling laws, seismic zoning, seismicity, induced seismicity, earthquake prediction, discrimination between earthquakes and explosions. Earthquake Early Warning System.

Gravity & Magnetic Prospecting

Unit – I: Basic Principles

Principles of Gravity and Magnetic methods, concept of Geoid, Spheriod, a review of magnetic field of the Earth, relation between gravity and magnetic potential, variation of gravity with elevation and depth, determination of density, isostasy and gravity, Magnetization of rocks-Dia, Para- and Ferromagnetism, Magnetic susceptibility of rocks and their ranges, Artificial versus natural source Methods.

Unit-II : Instrumentation

Gravity Prospecting Instruments: Absolute versus Relative measurements of Gravity, Pendulum apparatus, stable and unstable gravimeters, calibration of gravimeters, LaCoste-Romberg gravimeter, Worden gravimeter.

Magnetic Prospecting Instruments: Fluxgate magnetometers, Proton precession magnetometers, optical pumping instruments, Schmidt's horizontal and vertical magnetometrs.

UNIT-III: Gravity and Magnetic Surveys:

Gravity survey on land: setting up of a base station, tide and drift corrections, the reduction of gravity data: the latitude adjustment, the elevation adjustment, the excess mass adjustment, terrain correction, Gravity anomalies, Plan of conducting ground magnetic surveys, corrections applied to magnetic data, Airborne magnetic surveys and magnetic gradient surveys.

UNIT-IV: Interpretation

Separation of residual and regional anomalies: Graphical method, direct computation, second derivative method, polynomial fitting method, depth rules, gravitational and magnetic attraction of structures with various simple shapes, estimation of anomalous mass, ambiguity in gravity interpretation, model analysis, step model, ribbon model, Applications of gravity and magnetic methods in oil and mineral exploration.

Groundwater Geophysics

Unit I

Concept of geohydrology and hydrogeophysics, hydrology in relation to other sciences, hydrosphere, hydrologic cycle, surface and subsurface distribution of water, origin of ground water, springs, hydrometeorology, precipitation, evaporation, evapotranspiration, seepage, infiltration and runoff and methods of measurement

Unit II

Hydrological properties of water bearing materials: porosity, void ratio, permeability, transmissivity, storativity, specific yield, specific retention, diffusivity, field and laboratory method for determining permeability, movement of ground water and aquifer performance tests, Darcy's Law and its range of validity, theory of groundwater flow under steady and unsteady conditions, determination of transmissivity and storativity by discharge methods.

Unit III

Mode of occurrence of ground water, classification of rocks with respect to their water bearing characteristics, aquifers, Aquiclude, aquitards, classification of aquifers, remote sensing studies for water resources evaluation. groundwater exploration and management, water balance studies, hydrograph analysis, conjunctive and consumptive use of ground water, water well drilling, development of wells, concept of artificial recharge, Watershed characterization and management,

Unit IV

Monitoring the health of groundwater reservoir, Use of IP for groundwater contamination, Groundwater exploration: surface geological and geophysical methods of exploration and subsurface geophysical methods; Hydro-geochemistry: Physical and Chemical characteristics of groundwater, classification of groundwater in respect to domestic, irrigation and industrial use, pollution of groundwater.

Electrical Prospecting

Unit I Introduction to electrical methods

A rapid review of the method and techniques of electrical prospecting and their classifications. Electrical properties of rocks, electrical properties of rock and their measurement, anisotrophy and its effect on electrical fields. The geoelectric section and geological section. Basic concept on natural electric field.

Unit II Induced Polarization and Self Potential method

Electrode configuration, the choice of method and choice of site measurement, presentation of measured data.

S.P. Method: Origin of self potential, theoretical and experimental basis of S.P. method, field of polarized conducter, sphere and cylinder, determination of ore body parameter, downward continuation of S.P. data

I.P method: Sources of I.P, Membrane and electrode potential, time domain and frequency domain measurement of IP, chargeability, percent frequency effect and metal factor, dipole theory of I.P., transformation of time domain to frequency domain data

Unit III Resistivity Methods

D.C. resistivity method, fundamental laws, the potential distribution at the surface of horizontally stratified earth, Stefanescu's expression: Kernel function and its relation to subsurface parameters, Flathe

and Pekeris recurrence relation: principle of equivalence, principle of superposition and principle of suppression. Apparent resistivity function, computation of apparent resistivity model curves, vertical electrical sounding
Resistivity Transform, Method of determination of resistivity transform, Asymptotic method, Complete curve matching, auxillary point method, equivalent curve matching using maxima and minima, Dar Zurruck curve, Direct interpretation method, application of linear filter theory for resistivity interpretation.

Unit IV: Interpretation of Electrical resistivity Data
Apparent resistivity function, computation of apparent resistivity model curves, vertical electrical sounding and horizontal profiling techniques, Interpretation of resistivity sounding data, Asymptotic method, Complete curve matching, auxillary point method, equivalent curve matching using maxima and minima, Dar Zurruck curve, Direct interpretation method, electrical profiling near a vertical contact, dyke, sphere, application of linear filter theory for resistivity interpretation.

PETROPHYSICS AND WELL LOGGING

UNIT-I: Basics of Petrophysics and Formation Evaluation
Well logging - objectives and its place in geoexploration Formation evaluation: Hydrocarbon volume calculation; Porosity: controls on porosity, porosity determination from core; Permeability: controls on permeability and ranges, determination of permeability, permeability porosity relationship; Coring: Preservation and Handling; Electrical properties of rocks: Formation resistivity factor (FR); correlations of FR with porosity, cementation, water saturation and permeability. Wire-line logging: representation of log, tools characteristics; borehole environment, invasion and drilling mud

UNIT-II: Spontaneous Potential (SP) and Natural Gamma Ray Logs
Introduction about SP logging, Principle, measurement tool, log presentation, factors affecting amplitude of SP, calculation of shale volume and other uses Fundamentals of radioactivity, scattering and attenuation, Gamma ray logging: principle, tool calibration, log representation, depth of investigation, bed resolution, calculation of shale volume, lithology identification and other uses

UNIT-III: Porosity Logs
Acoustic Log: Principles; acoustic logging tools; log representation, depth of investigation and vertical resolution, logging problems, uses of acoustic logging, Formation Density Log: principle; measurement tools and operation; calibration of tool, log characteristics- depth of investigation and bed resolution; uses of formation density logging; Neutron Log: Theory: neutron emission, scattering and absorption, Hydrogen Index, neutron logging tools, Log representation, Calibration, depth of investigation and vertical resolution; Uses of Neutron logging

UNIT-IV: Electrical Resistivity Logs and other logs
Concept of resistivity, resistivity of rocks, variation of formation fluid resistivity with temperature, Archie's first and second law, Hingle and Pickett plots, Saturation of Moveable Hydrocarbons. Resistivity logging: response of tool, resistivity tools: old and modern, spherically focused log, micro-resistivity logs, proximity log, induction log, depth of investigation and bed resolution, log representation, uses of resistivity log Nuclear Magnetic Resonance (NMR) Logging: background, need of NMR logging, log representation and interpretation; Caliper logging, temperature logging, dipmeter logging, LWD

Physical Oceanography and Marine Geophysics

Unit I Physical Oceanography
Physical properties of seawater and methods of determination, distribution of salinity in the oceans, factors affecting salinity, water masses and water type, TS Diagram, Circulation of currents in major ocean waves. Tides: Dynamical and equilibrium theory of tides. Marine pollution, steps to control marine pollution, Laws of seas, Coastal zone management

Unit II Dynamical Oceanography
Equation of motion in a rotating and translating coordinate system, Coriollis force term and other terms, Nonlinear term in equation of motion, Brunt Viasala frequency, Geopotential surface and isobaric surface, wind driven ocean circulation, Ekman Solution, Sverdrup's Solution, Vorticity.

Unit III Marine exploration
Resource potential for offshore areas, Geophysical continental margins, type of continental margins, geophysical evidences for evolution of Atlantic type continental margins, Characteristic geophysical signatures for transitional crust, isostatic 2D gravity anomalies, sea floor magnetic anomalies and their interpretation.

Unit IV
Geophysical studies for active continental margins, Seismicity, volcanism, heat flow studies, seismic surveys along island arc-trench areas, seismic expression for subduction and crustal deformation, paired gravity anomalies over island arc trench areas and their interpretation. Geophysical exploration for continental Margins of India and Andman shelves, brief review on the hydrocarbon exploration for the Indian continental margin.

SEISMIC PROSPECTING

UNIT-I: FUNDAMENTAL OF PROSPECTING
Motivation for Seismic Prospecting, Oil Exploration, Mining and Engineering Application, Principles and Physical Basis of Seismic prospecting: Types of Elastic Waves, Reflection, Refraction and Transmission Coefficients, Expression for wave velocities, Factors affecting wave velocities in Rocks.

UNIT-II: DATA ACQUISITION
Seismic Sources: Explosive and Non-Explosive Sources, Seismic Refraction Method: Travel Time Equation 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.
Seismic Reflection Method: The travel time equations for horizontally layered medium, Expression for dipping interfaces, Field techniques for reflection survey: Split Spread, End on Spread, Broad side configurations. 2D/3D configurations, Common depth point technique, Presentation formats for Seismograms, Selection of field survey parameters.

UNIT-III: SEISMIC DATA PROCESSING
Data processing sequence, Static and Dynamic Correction, weathering and datum corrections, CDP stacking, Migration and depth section preparation.

Velocity depth determination: Velocity-depth relation for measurements in boreholes, velocity depth relation from surface observations, the T^2-X^2 method, the T-ΔT method, the hyperbola method.
Noise Elimination method: The structure of noise and its classification using frequency and spatial filters(arrays), Multiples identification, Suppression of multiples, VSP.

UNIT-IV: SEISMIC DATA INTERPRETATION
Mapping of Hydrocarbon bearing and water bearing structures, geological interpretation, Structural and Stratigraphic traps, direct detection of hydrocarbons, pattern recognition, Seismic attribute analysis.

Geophysical Inversion

Unit-I:
Forward problems versus Inverse problems, continuous inverse problem, discrete inverse problem, formulation of inverse problems and their reduction to a matrix problem, linear inverse problems, classification of inverse problems, L1 norm inversion, least squares solution and minimum norm solution, concept of norms, concept of 'a priori' information, constrained linear least squares inversion, review of matrix theory.

Unit-II
Introduction to finite difference method, forward, backward and central difference method, Application of finite difference method for solving Helmholtz equation.
Introduction to finite element method, various steps, simple examples showing application of finite element method.

Unit-III
Model and Data spaces, householder transformation, data resolution matrix, model resolution matrix, checkerboard resolution test, eigen values and eigen vectors, singular value decomposition (SVD), generalised inverses, Non-linear inverse problems, Gauss Newton method,, steepest descent (gradient) method, Marquardt-Levenberg method, Earthquake location problem, tomography problem.

Unit-IV
Probabilistic approach of inverse problems, maximum likelihood and stochastic inverse methods, Backus-Gilbert method, Global optimization techniques: genetic algorithm, simulated annealing methods, neighbourhood algorithm, examples of inverting geophysical data.

Near Surface Geophysics

Unit-I: Introduction
Man and Environment, Near Surface Geophysics: Introduction, Practitioners and Users, Traditional and Emerging views of Near Surface- Geophysics, Concepts and Fundamentals, Special Challenges associated with near Surface Geophysics. Rock Physics Principles for Near-Surface Geophysics: Description of the Geological Material, Conditions in the Near Surface of the Earth, Density, Electrical Properties, Elastic Wave Velocities.

Unit-II: Geophysical Techniques in Near Surface studies
Review of Seismic, Gravity, Magnetic and Electrical methods, Applications of these methods to Environmental and Engineering studies: Delineation of structural trends, contacts and faults, microgragravity detection of subsurface voids and cavities, detection of Archaeological objects, Mapping of fracture zones, reflection profiling in ground water studies, dam site investigations, evaluation of acquifer potentional, Investigation of waste dump sites.

Unit-III: Ground-Penetrating Radar
Introduction, Electromagnetic Theory, Physical properties, EM wave properties, GPR Instrumentation, Modeling of GPR Responses, Survey Design, Data processing, Interpretation, Case Studies and Pit falls.

Unit-IV:GIS Applications in Near surface Geophysics
Concept of Digital Image in Remote Sensing, Image preprocessing, rectification, enhancements and analysis, Digital Image processing procedures, Band ratioing and NDVI, GIS applications in integrated ground water resources mapping, site suitability studies and utilities management, GIS applications for engineering, environmental problems, landfill sites and solid waste management,

Electromagnetic and Magnetotelluric Methods

Unit-I
EM Principle: Maxwell's equations, electromagnetic potential and wave equations, attenuation of EM field, depth of penetration, dip and tilt angles, electromagnetic field due to straight wire, rectangular and circular loops, elliptical polarizations, amplitude and phase relations, real and imaginary (quadrature) components.
Transient electromagnetic methods (TEM), transient emf and magnetic field behaviour due to various conductors; current density in half space by rectangular loop with time, toroidal and poloidal induction in a conductive zone, various time domain systems frequency sounding and geometric sounding, advantage of time domain methods over frequency domain methods.
Electromagnetic properties of rocks and minerals

Unit-II
EM Prospecting and Interpretation: various EM methods: Dip angle methods-fixed vertical loop transmitter, two frame method, Turam method, Moving source-receiver methods- horizontal loop (Slingram) method, AFMAG and VLF methods, Airborne EM systems- rotary field method, EM profiling and sounding. Marine Electromagnetic Methods, EM modelling.

Unit-III
MT Principle: Origin and sources of MT signal, interaction with the earth -uniform earth, horizontal layers, anisotropy, inhomogeneity, impedance tensor and tipper, topographic and regional effects, static shift. Data processing and analysis: auto and cross spectra, solution to the impedance and tipper equations, local and remote references, errors and noise. Robust and hybrid processing.

Unit-IV
MT Interpretation and uses: interpretation of MT data over a two layered earth, strike, rotation swift strike, polar diagram, tipper, skew, ellipticity, TE and TM modes, 1D and 2D interpretation, imaging continental lower crust, MT study over cratons. Mapping structures for petroleum exploration, geothermal mapping, exploration for sulphides, gold, uranium. Detecting water and subsurface structures.

Computational Seismology

Unit I Strong motion seismology

Concept of strong motion: Characteristics of earthquake strong ground motion, time domain and frequency domain parameters of strong ground motion, strong motion array and recorder, dynamics of vibration, vibration of a single degree of freedom system, earthquake response spectra, Strong motion networks in India

Modelling of strong ground motion: Stochastic modelling technique, concept of dynamic corner frequency, Empirical Greens function technique, Semi empirical technique and Composite source modelling technique, hybrid technique.

Unit II Attenuation Studies

Wave attenuation: geometrical spreading, scattering and intrinsic attenuation, Quality factor Q and its estimation using frequency domain methods, origin of coda waves, coda-Q and its estimation, estimation of frequency independent and frequency dependent Q using strong ground motion, simultaneous estimation of source parameters and Q, concept of 3-D Q and its estimation.

Unit III Engineering seismology

Concept of earthquake hazard, vulnerability and risk, probabilistic versus deterministic approach of estimating earthquake hazard, seismic quiescence/gaps, Regression analysis for estimating peak ground motion, microzonation, site amplification, concept of earthquake resistant design, Indian earthquake hazard scenario.

Unit IV: Selected Topics

Seismic tomography – Methods, regional and local tomography, 3-D velocity analysis, Receiver functions, Seismicity based studies- b-value, fractal and multifractal analysis, Dq-q analysis, self similarity, Ray tracing, Anisotropy, Time predictable model, GPS based studies in seismology.

Seismic Data Analysis and Reservoir Geophysics

Unit-I: Introduction

Objectives of Seismic Signal Processing, Seismic Resolution, Basic data processing sequence: CMP sorting, Velocity analysis, residual statics corrections, Normal-Moveout Correction, Moveout stretch, Noise and Multiple Attenuation, f-k filtering, τ-p filtering, Dip-Moveout correction, CMP stacking, post stack processing.

Unit-II: Seismic Deconvolution and Seismic Migration

The convolutional Model, Inverse Filtering, Optimum Wiener filters, Predictive deconvolution in practice, The problem of nonstationarity: Time-Variant deconvolution, gated Wiener deconvolution, Homomorphic deconvolution, Minimum and Maximum Entropy Deconvolution, Inverse Q Filtering, Fresnel Zone, Seismic Migration: Mathematical foundation of migration, Migration using wave equation, Kirchhoff's theory , Pre and Post stack time and depth migration

Unit-III: Seismic Modeling

The role of Seismic Modeling, Concept and example of Physical Models, Seismic Modeling Approaches, Forward Seismic Modeling, Inverse Seismic Modeling, Application of GLI technique, Modeling pitfalls, Ray Tracing using Snell's Law, and Ray-bending.

Unit-IV: Reservoir Geophysics

Reservoir Management, Geophysical Method for Reservoir Surveillance, Analysis of AVO, Acoustic Impedance Estimation, 4-D Seismic Method, Interpretation with SH-wave, 4-C Seismic Method.

ARTIFICIAL INTELLIGENCE & MACHINE LEARNING IN GEOPHYSICS

UNIT-I: FUNDAMENTAL OF MACHINE LEARNING

Introduction to Artificial Intelligence and Machine Learning: Machine Learning concepts, algorithms, and its applications. Techniques of Machine Learning: Supervised, Unsupervised, Overview of Linear Algebra, Eigenvalues, Eigenvectors, and Eigen-decomposition, Calculus, Probability and Statistics. Regression: Linear Regression.

UNIT-II: NEURAL NETWORKS

Neural Networks. Multi-layer Perceptions, Activation function. Restricted Boltzman Machines, Support Vector Machine, Deep Belief Networks, Deep Recurrent Neural Network, Convolution DBN, Max Pooling CDBN. Data Preprocessing: Comprehend the meaning, process, and importance of data preparation, feature engineering and scaling, datasets, dimensionality reduction.

UNIT-III: MACHINE LEARNING WITH PYTHON

Introduction to Python. Control flow tools, Data Structures, Modules, Input and Output, Errors and Exceptions, Classes, Standard Library, Virtual environment and packages. Machine Learning with Python.

UNIT-IV: APPLICATION IN GEOPHYSICS

Machine Learning Applications: First Break Picking, Sesimic Deconvolution, NMO correction in T-p domain. Reservoir characterization: Pattern recognition. Principle Component Analysis. Earthquake Prediction.