Syllabus for Ph.D. Entrance Test for Part-time Research Scholar in the Department of Geophysics, K.U. Kurukshetra for the Academic Session 2023-24

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 membranes, 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: Origin of the Solar System and Earth
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: Rheology, Radiometric Dating and Gravity of the Earth
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: The Earth's magnetic field
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 and Interior of the Earth
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, structure and subdivision of Himalaya, Geodynamics of Indian subcontinent.

Numerical Methods and Computer Programming

Unit-I: Introduction
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.

Unit-II: Basics of FORTRAN
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: Learning C
Introduction: Variables, Constants, Functions, Arguments, Character Arrays; Statements, Arrays, Functions; Data Types, Operators and Expressions; Control Flow: Statements, If-Else, Else-If,

Switch, Loops-While and For, Break and Continue, Goto; Functions and Program Structure: Basics, Header files, Static Variables; Pointers and Arrays; Structures: Basics, Array of Structures, Pointers to Structures; Input and Output: Scanf, Printf, Line Input and Output.

Unit-IV: Programming in FORTRAN

Numerical integration by Simpson's method, Trapezoidal method, Numerical differentiation, solution of algebraic equation, Newton 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 of Geology

Introduction to geology, Geomorphological Processes: Exogenic processes, Geologic time-scale and age of the Earth, Geological processes by river, wind, glacier and waves and tides. Principle 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, Gondwana.

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: Introduction to Remote Sensing and Aerial Photography

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: Sensor and Image Interpretation

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: GIS and GNSS

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

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)

Advanced Computing

Unit-I: Introduction to C++ programming

Brief history of C++, Basics of a C++ program; Command Line Compiler, Integrated Development Environment (IDE); Declarations and Expressions: Program Structure, Variable Storage and Declarations, Assignment statements, Characters; Programming Examples.

Unit-II: Simple Programming in C++

Arrays, Reading Data, Strings, Integers and Floats; Hexadecimal and Octal Constants; Decision and Control Statements: if, while, for, Break and continue- Statements; Makefile, Testing and Debugging; Variable: Scope and Functions: Basics of Structured Programming; Programming Examples.

Unit-III: Advanced Programming in C++

Structures and Array of Structures; File Input/Output: C++ File I/O, Binary and ASCII files, Buffering; Debugging and Optimization: Serial Debugging, Runtime Errors; Floating Point: Format, Roundoff Errors; Pointers: Pointers and Structure; Classes: Derived and Virtual Classes, Virtual Functions; Exceptions; Modular Programming.

Unit-IV MatLab and Generic Mapping Tools

Introduction to MatLab; Formats, Variables: Declaration; Characters; Strings; Functions; Control Statements; Vectors; Script file; Vector calculations, Matrix and its operations; Solving system of linear equations; m-file; Input/Output data; Graphical User Interface. Introduction to Generic Mapping Tools (GMT): Input, Job Control, Output; Projections; GMT defaults; Examples.

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-recursive filters, ideal and realizable low pass, band pass and high pass filters, IIR filters, Design of Butterworth filters, Design of FIR filters using direct and canonical realization scheme, Cascade and parallel 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, Generalised Hook's Law, Isotropy and Anelasticity.

Electromagnetic Waves: Maxwell's equations, constitutive relations, Plane electromagnetic waves in dielectric and conductor.

Unit-IV: Electromagnetic method

Principles of EM prospecting, various EM methods, passive source and active source methods, theory of EM induction; elliptical polarization, Airborne electromagnetic survey. Telluric methods: Theory of telluric method, field procedure and method of measurement, analysis of telluric field data, Magnetotelluric method, processing and interpretation of MT data.

Seismology

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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, Derivation of expressions for Bouguer correction and Terrain correction, Gravity anomalies: Bouguer anomaly, Free air anomaly and Isostatic anomaly, Gravity anomaly and isostasy, 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, wavelength filtering, downward continuation, 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

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Unit-I: Concept and Processes

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

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: Aquifers and Well Development

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: Geophysical Methods and Groundwater Characterstics

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 conductor, 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, different electrode configurations and their geometrical factors, the potential distribution at the surface of horizontally stratified earth, Kernel function and its relation to subsurface parameters, Principle of equivalence, Principle of superposition and Principle of suppression.

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. . Review of basins in India: Assam, Krishna-Godavari, Cambay and Bombay offshore basins.

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: Introduction

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, Geophysical inverse problems.

Unit-II: Finite difference and Finite Element Method

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: Non-Linear Inversion

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, Inversion of gravity profiles due to simple geometrical shape, Applications of non-linear inversion techniques in seismology.

Unit-IV: Global Optimization Techniques:

Probabilistic approach of inverse problems, maximum likelihood and stochastic inverse methods, Backus-Gilbert method, Global optimization techniques: genetic algorithm:Heat Bath algorithm,

Metropolis algorithm, simulated annealing methods, neighbourhood algorithm, examples of applying global optimization techniques.

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, microgravity 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 aquifer potential, Investigation of waste dump sites.

Unit-III: Ground-Penetrating Radar

Introduction, Electromagnetic Theory, Physical properties, EM wave properties, GPR Instrumentation, 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, point and finite fault sources, Simulation of earthquake strong ground motions at bedrock and at surface level.

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, Q estimation from different parts of seismograms, 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, Different techniques of estimating site amplification functions using microtremors and earthquake waveforms, Applications in hydrocarbon detection, 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. Unconventional energy sources: Shale gas; Coal Bed Methane; Gas Hydrates.

Artificial Intelligence & Machine Learning In Geophysics

Unit-I: Fundamentals of Machine Learning

Introduction to Artificial Intelligence and Machine Learning. Machine Learning: Supervised Learning: Classification and Regression, k-Nearest Neighbors, Neural Networks (Deep Learning). Unsupervised Learning: Dimensionality reduction, Feature extraction, Clustering: k-Means clustering.

Unit-II: Review of Seismic Methods

Seismic data analysis: Signal processing, Data processing sequence, Deconvolution, Filtering, Normal moveout correction. Reservoir geophysics: Amplitude variation with offset, Seismic attribute analysis, Full waveform inversion. Geophysical Inversion versus Machine Learning: similarity and differences.

Unit-III: Machine Learning with Python

Introduction to Python. Python 3.7, scikit-learn, Libraries and tools: NumPy, SciPy, matplotlib, pandas, Jupyter notebook. 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, Seismic deconvolution, N.M.O. correction in τ-p domain. Reservoir characterization: Direct hydrocarbon indicator, Pattern recognition, Principle component analysis, Thin bed identification for shale gas, Data driven amplitude variation with offset, Rock physics analysis.