DEPARTMENT OF APPLIED GEOLOGY
DIBRUGARH UNIVERSITY

RATIONALE, COURSE STRUCTURE, & SYLLABUS
M.TECH. IN EXPLORATION GEOPHYSICS (EG) PROGRAMME

(Proposed New Syllabus to be discussed in the BOS Meeting to be held on 19th July, 2018 to be implemented for the August, 2018 session)

2018

RATIONALE

The department of Applied Geology is located within the triple junction of the Eurasian, Indian and the Burmese plates which is structurally dynamic, rich in natural resources, (Some of these resources are already proven and some are prognosticated) diverse in its demographic content, highly promising for further exploration and utterly vulnerable for unmindful exploitation and plunder. Unless high quality knowledge is cultivated by the indigenous institutions and the people with a faster pace, programmes of developments cannot touch the projected heights. Geophysics forms the backbone of the tools for exploration in the subsurface. Keeping a watchful eye on the fast changing scenario of the world economy and the importance of the states of the NE India in this overall perspective, the presence of earth science in general and Exploration geophysics in particular needs a strong footing and steady growth in the institutes of higher education so that the frontier problems of the earth science related research works may attract curious and intelligent students and they are encouraged to take up Geophysics as their passion and profession in more numbers.

From its very inception, the Department of Applied Geology, Dibrugarh University had put its effort to groom good geoscientists having expertise in oil, water and mineral resource exploration. This was done for a considerable length of time by offering a three years' M.Tech Course in Applied Geology that was subsequently modified to a two years' M.Sc. Course in Applied Geology. Introducing a post-M.Sc. two years' M.Tech. Course in Petroleum Geology in 2003, the department could extend its vision towards the needs to focused studies and research in the field of oil exploration. Interestingly, the effort could draw national attention from the students from Kashmir to Kerala. In extension to the same vision, the department introduced Advanced Post Graduate Diploma in Petroleum Exploration Geophysics (APGDPEG) of one (1) year duration in 2009. The response was good. Subsequently, the department took a decision to upgrade and broad-base the existing Diploma course to a Two Year M.Tech. (Exploration Geophysics) Programme from 2012-13 academic session onward with active collaboration from the OIL and the ONGCL. A drive was given to modernize the syllabus in 2018 based on the counseling from the Stanford University, USA.

The basic objective behind offering Exploration Geophysics as an M.Tech Course is three fold. First, to generate quality human resources in the 'high skill' segment of workers belonging to Exploration Geophysics and increasing thereby the practical importance of higher education in nation building. Secondly, introduction of more down-to-earth steps so that the academia-industry symbiosis becomes more meaningful as well as useful. Developing the software based learning skill has been given additional weightage. Initiation of building up a good infrastructure to conduct research in basin analysis of the Assam & Assam Arakan area as a part of the principal thrust area of the department in the field of 'Tectonics and basin Evolution' studies is the third objective. In conformity with these objectives, the first semester of the Programme is devoted to introduce the philosophy of scientific exploration in general and exploration geophysics in particular. As the students joining this programme are broadly having either Physics or Earth Science background; an elective bridge course has been introduced depending upon the needs of the students. Earth System Science approach with emphasis on climate change has been included which is supposed to act as a broader perspective. To develop the computational skill besides 'Numerical Analysis and Computer programming', a new course 'Geoscientific data analysis with MATLAB' has been introduced. The second semester is principally devoted to Inversion theories, Seismology and Seismic methods of data acquisition & processing. Besides this, there is in-depth coverage of Gravity and Magnetic Methods. Elective papers include Hydrogeology and ground water investigations, Practical aspects of the GIS and Principles of Stratigraphy. Moreover, there is a 'Field Visit' component which is planned as per convenience. The third semester is devoted principally to core issues of exploration like seismic data interpretation, well logging and Reservoir Geophysics. Options were given to choose from latest fields of concern like 'Decision Analysis and Value of Information' and 'Simulation modeling in environmental science' etc. Besides the regular field work, serious project works of six months' duration having strictly monitored periodic submission of progress reports related to exploration under the joint supervision of the Department of Applied geology, Dibrugarh University and reputed organizations (OIL, ONGCL, CSIR-NEIST etc.) are conducted to promote research aptitude of the candidate.

PROGRAMME STRUCTURE-M.Tech (Exploration Geophysics)-Proposed before the Board of Studies (BOS) on 19th July, 2018 (To be implemented from August, 2018 session)

SEMESTER-I

Course No.	Course	L	P	Marks Se.	Th.	Pr.	Total
EG-101	Foundation for Geophysics	4	-	40	60	-	100
EG-102	Elective-I A) Physics Essential B) Geology Essential	4	-	40	60	-	100
EG-103	Earth System Science	4	-	40	60	-	100
EG-104	Numerical Analysis and Computer programming	4	2	40	60	50	150
EG-105	Geoscientific Data Analysis with Matlab	4	2	40	60	50	150

Total Marks for Semester-I= 600

SEMESTER-II

Course No.	Course	L	P	Marks Se.	Th.	Pr.	Total
EG-201	Geophysical Inversion	4	-	40	60	-	100
EG-202	Geophysical Tools I: Seismology & Seismic methods	4	2	40	60	50	150
EG-203	Geophysical signal theory & Data processing	4	2	40	60	50	150
EG-204	Geophysical Tools II: Gravity & Magnetic Methods	4	2	40	60	50	150
EG-205	Elective II A)Hydrogeology & Ground water investigations B)Image Processing and elements of GIS C)Principles of Stratigraphy	2 - 2	- 2 -	20	30		50
EG-206	Field visit						50

Total Marks for Semester-II= 650

SEMESTER-III

Course No.	Course	L	P	Marks Se.	Th.	Pr.	Total
EG-301	Geophysical Tools III: Electrical and EM Techniques	4	2	40	60	50	150
EG-302	Geophysical Tools IV: Well logging & its applications	4	2	40	60	50	150
EG-303	Seismic stratigraphy and Basin Analysis	4	2	40	60	50	150
EG-304	Reservoir Geophysics	4	2	40	60	50	150
EG-305	Elective III A) Decision Analysis and Value of Information B)Simulation modeling in environmental science	2		20	30		50

Total Marks for Semester-III= 650

SEMESTER- IV
Project Work
Total Marks=600
Cumulative Total Marks=2500

PROPOSED SYLLABUS FOR M.TECH IN EXPLORATION GEOPHYSICS

Semester I

EG-101: Foundation for Geophysics

L	IS	ES	TM
4	40	60	100

Unit 1: *Philosophy of exploration in science*
The concerns of science, The objectives of scientific research, The problem of the 'Empirical basis', Scientific objectivity and subjective conviction, Causality, Explanation and the deduction of predictions, Theoretical systems, Inductive logic and probability logic, Verification and falsification, Discovery and justification, The Path of science

Unit 2: *An introduction to Applied Mathematics*
Summaries of basic concepts like Determinants, Vector analysis, Matrix analysis, Complex numbers, Method of least squares, Finite differences and Partial fractions. Fourier series and Fourier integral, Fourier Transforms, Laplace transforms, Linear systems, Digital systems and z-transforms,

Unit 3: *Geophysical properties of sediments, rocks and minerals*
Pore space properties, Densities, Magnetic susceptibilities, electrical potential differences having different origins, electrical resistivities, dielectric constants, velocities of seismic waves, reflection coefficients, Radioactive properties, Thermal Properties, contrasts and anomalies, Geophysical anomalies for different geological situations.

Unit 4: *An introduction to Exploration Geophysics*
The questions frequently faced by the geophysicists, the nature of geophysical problems, Fields of Exploration Geophysics: Regional geophysics, Oil and gas geophysics, Ore geophysics, Ground water geophysics, Engineering geophysics, Borehole Geophysics and Reservoir geophysics

Unit 5: *Elements of Surveying*
Objective of surveying and its importance, Classification, principles of surveying, Application of surveying in geophysical exploration, mapping techniques, contouring, Different types of contouring, Theory, principles and applications of Global Positioning System (GPS), Simple uses of a GPS tool.

References:

1) Popper, K.R., 1959. The logic of scientific discovery, Hutchinson, London.
2) Kuhn, Thomas S., 1962. The Structure of Scientific Revolutions, The University of Chicago Press.
3) Cahn, Steven M. (Edited by), 2000. Exploring philosophy: an introductory anthology, Oxford University Press.
4) Silver, Brian L.,1998. The ascent of science, Oxford University Press.
5) Dobrin, M.B., Savit, C.H., 1988. Introduction to Geophysical Prospecting, 4th Ed. McGraw Hill.
6) Telford, M., Geldart, L.P., and Sheriff R.E., 1990 Applied Geophysics, 2nd Edition, Cambridge University press.
7) Lowrie, W., 2007. Fundamentals of Geophysics, 2nd edition, Cambridge University Press.
8) Lowrie, W., 2011. A Student's Guide to Geophysical Equations, Cambridge University Press.
9) Barnes, John W., 2004. Basic Geological Mapping, 4th Edition, John Wiley & Sons, Ltd.

EG-102: Elective I (Bridge Course)
EG-102A: Physics Essential
EG-102B: Geology Essential

EG-102A: Physics Essential

L	IS	ES	TM
4	40	60	100

Unit 1: *Introduction*
Field concept, The coordinate systems, Scalar and Vector fields, Differential elements of length, surface and volume, Line , surface and volume integrals, The gradient of a scalar function, Divergence of a vector field, The Laplacian operator, Some fundamental theorems and field classifications, Vector identities

Unit 2: *Static fields*
Laws and concepts associated with electrostatics (Coulomb's law, Electric field intensity, Electric flux and electric flux density, The electrical potential, Electric dipole, materials in an electric field, Energy stored in an electric field, Boundary conditions, Capacitors and capacitance, Poisson's and Laplace's equations, Method of images), Laws and concepts associated with magnetostatics (Biot-Savart law, Ampere's force law, Magnetic torque, Magnetic flux and Gauss's law for magnetic fields, Magnetic vector potential, magnetic field intensity and Ampere's circuital law, Boundary conditions for magnetic fields, Magnetic circuits)

Unit 3: *Steady electric currents and time varying electromagnetic fields*
Nature of current and current density, the equation of continuity, Boundary conditions for current density, the electromotive force, Faraday's law of induction, self-inductance, mutual inductance, inductance of coupled coils, energy in a magnetic field, Maxwell's equations and boundary conditions, time harmonic fields, applications of electromagnetic fields

Unit 4: *Plane wave propagation*
General wave equations, Plane wave in a dielectric medium, plane wave in free space, plane wave in a conducting medium, plane wave in a good conductor, plane wave in a good dielectric, polarization of a wave, normal incidence of uniform plane waves, oblique incidence on a plane boundary

Unit 5: *Interaction of fields and matter*
Plasma Oscillations, Wave Propagation in Plasma, Polarization of Dielectric Materials,
Equivalent Volume and Surface Charges, The Permittivity Concept, Magnetic Polarization, Equivalent Volume and Surface Currents, The permeability Concept, Frequency Responses of Dielectric Materials

References:

1) Guru, Bhag and Hüseyin Hiziroğlu, Electromagnetic Field Theory Fundamentals, 2nd Edition, Cambridge University Press, 2004.
2) Jordan, Edward C., Balmain, Keith G. Electromagnetic waves & Radiating Systems, 2nd Edition, Prentice Hall of India Pvt. Ltd, New Delhi, 1990.
3) Roy, K.K., Potential Theory in Applied geophysics, Springer, 2008.

EG-102B: Geology Essential

Unit 1: *Earth Materials: Mineralogy, Rocks and the Rock Cycle*
Mineral definition, types and examples, Rocks and the rock cycle, Vulcanicity and igneous rocks, Sedimentary rocks, fossils and sedimentary structures, Metamorphic rocks.

Unit 2: *Earth Surface Processes*
Overview of the Earth, Production of sediment at the Earth's surface, Fundamentals of fluid flow, sediment transport, erosion and deposition, Environments of erosion and deposition, Diagenesis, Long-term large-scale processes: mountains and sedimentary basins.

Unit 3: *Mesoscopic structures and methods of their analysis*
Description of folds, shear zones, faults and fault zones, foliations, lineations, & Veins. Characteristics, style, age analysis and interpretation of Joints. Fault and lineament –array analysis. Fold styles and section lines, construction of profiles for plunging and non plunging folds.

Unit 4:*Quantitative surface and subsurface map interpretation*
Building structure contour maps from profiles fold trend and recognition of cylindrical and conical folds on a tangent diagram, faults- calculations of heave and throw from stratigraphic separation, basic concepts required to build 3-D structural interpretation, fault cutoff maps & Allan diagrams.

Unit 5: *Sedimentary Basins*
Types of Sedimentary basins, Depositional Systems and facies Models, Subsidence, Denudation and Sediment Budget, Basin evolution

Reference:

1. Ruddiman, W.F., Earth's Climate: Past and Future, Freeman and Company, 2013.

EG-103: Earth System Science

L	IS	ES	TM
4	40	60	100

Unit 1: *Framework of Earth System Science.*
A brief introduction to different spheres; primary causal mechanisms located in individual spheres and their influence on different spheres, Climate forcing, Climate system responses, Feedbacks in the climate system, Climate archives, Data, and models.

Unit 2: *Scales of climate change.*
Gaia hypothesis; Greenhouse earth, Icehouse earth, BLAG hypothesis, Monsoon circulation, Insolation control of ice sheets, Milankovitch Theory, Orbital scale changes in Carbon dioxide and Methane, The Last Glacial Maximum, Millenial oscillations in climate.

Unit 3: *Global Tectonics*
The framework of plate tectonics (Plates and plate margins, Distribution of earthquakes, Direct measurement of relative plate motions, Triple junctions), measurement of relative plate motion, Plate tectonics and economic geology (Autochthonous and allochthonous deposits, Deposits of sedimentary basins, Deposits related to climates).

Unit 4: *Tectonic Geomorphology*
Geomorphic indices of active tectonics, Active tectonics and rivers, Short-term deformation and geodesy, Paleoseismology, rates of erosion and uplift, tectonic activities and mountain fronts, Fault scarps, Holocene deformation and landscape responses

Unit 5: *Historical and future climate change*
Climatic changes during the last 1000 years; Pre and post-industrial revolution climatic changes; Anthropogenic factors contributing to global warming; Future climatic change.

EG-104: Numerical Analysis & Computer Programming

L	Pr	IS	ES	PrM	T
3	2	40	60	50	150

Unit 1: *Solution of algebraic and transcendental equations*
Different methods like Bisection, Iteration, False Position. Newton-Raphson Method, Muller's Method, The Quotient-Difference Method, Solution of Systems of Nonlinear Equations.

Unit 2: *Interpolation*
Forward differences, Backward differences, Central differences; Detection of errors by use of Difference tables; Differences of a polynomial; Gauss's Central Difference formulae, Stirling's, Bessel's, Everett's formula; Lagrange's Interpolation Formula, Hermite's Interpolation Formula; Newton's General interpolation formula; Interpolation by iteration; Method of successive approximations

Unit 3: *Numerical solution of differential and integral equations*
Numerical solution of ordinary differential equations (Solution by Taylor's Series, Picard's Method of Successive Approximations, Euler's Method, Runge-Kutta Methods, Adams-Moulton Method, Milne's Method), Numerical solution of partial differential equations (Laplace's equation, Jacobi's Method, Gauss-Seidel Method, Iterative methods for the solution of equations) , Numerical Solution of Integral equations (Finite difference methods, A method of degenerate Kernels, Method of Invariant Imbedding, Method using generalized quadrature)

Unit 4: *Fundamental concepts related to Computer Programming*
Architecture of digital computers, number systems, data representation, binary arithmetic, Classification and overview of operating system modules; Introduction to UNIX and LINUX operating systems, Window environment, algorithm and flowcharts

Unit 5: *FORTRAN and C languages*
FORTRAN: Control structures- selective and repetitive,, arrays, format statements; subprogram functions, subroutines, DATA, SAVE, COMMON and EQUIVALENCE statements; file processing; additional data types, logical, double precision and complex types.
C: Introduction, constants, variables and data types, operators and expressions, I/O operations, decision making and branching; decision making and looping; arrays, structures and unions, user defined functions, pointers, file management, dynamic allocations and linked lists, the preprocessors.

EG-105: Geoscientific Data Analysis with Matlab

L	Pr	IS	ES	PrM	T
3	2	40	60	50	150

Unit 1: *Introduction to Matlab*
Common functions and operations; Arrays: vectors and matrices; Array indexing: subscript indexing, linear indexing and logical indexing; Visualizing data: line plots, scatter plots, polar plots, rose plots, compass plots, contour plots, surface plots, histograms and images; Matrix operations and manipulations; Vectorization; Scripts and Functions.

Unit 2: *Image processing using Matlab*
Transforms: Fourier transform, discrete cosine transform, radon transform, wavelet transform; Filters: Gaussian filter, Laplacian filter, moving average filter, median filter; Frequency responses; Speckle noise removal; Image reconstruction; Edge detection; Image thresholding; Properties of image regions.

Unit 3: *Signal processing using Matlab*
Fast Fourier transform; Sampling and aliasing; Spectral analysis; Power spectral density; Cross correlation and auto correlation; Time-frequency spectrogram; High-pass and low-pass filters; Downsampling and removing trends in data; Principal component analysis.

Unit 4: *Simulation*
2D random walk; Monte Carlo simulation; Bootstrapping; Kernel density estimate; Probability density functions; Empirical cumulative distribution.

Unit 5: *Regression, classification and optimization*
Linear least squares regression; Eigenvectors and eigen values; Polynomial fitting; Non-linear least squares regression; Classification: Logistic regression, Classification trees, Neural networks, Support vector machines; Optimization; Objective functions; Numerical solution of ODEs; Numerical integration and discretization.

References :

1) Menke, W. and Menke, J. (2016). *Environmental Data Analysis with Matlab*. Academic Press.
2) Hanselman, D. and Littlefield, B. (2011). *Mastering Matlab*. Prentice Hall.
3) Moler, C. (2004). *Numerical Computing with Matlab*. SIAM.
4) Van Loan, C.F. and Fan, K.Y.D. (2010). *Insight Through Computing: A Matlab Introduction to Computational Science & Engineering*. SIAM.
5) Middleton, G.V. (2000). *Data Analysis in the Earth Sciences using Matlab*. Prentice-Hall.
6) Johnson, R.K. (2011). *The Elements of Matlab Style*. Cambridge University Press.
7) Online resources at http://www.mathworks.com.

Semester-II

EG-201: Geophysical Inversion

L	IS	ES	T
4	40	60	100

Unit 1: *Introduction to inverse theory*
Model space and data space; Definition of the forward and inverse problems; Continuous and discrete inverse problems; Mathematical background; Rank of a matrix; Eigen values and eigen vectors; Inverse of a matrix; Singular Value Decomposition (SVD); Probability; A priori information.

Unit 2: *Linear inversion*
Formulation of linear inverse problems; Least squares method: steepest descent and conjugate gradient; Norms; Misfit; Gradient and Hessian; Overdetermined and underdetermined; Existence, uniqueness and stability; Tikhonov regularization; Variance and prediction error; Generalized inverses; Maximum likelihood solution; Examples.

Unit 3: *Non-linear inversion*
Newton's method; Gauss-Newton (GN) and Levenberg-Marquardt (LM) methods; Occam's inversion; Parameterizations; Linearizing parameterizations; Convergence and nonuniqueness; Examples.

Unit 4: *Probabilistic inversion*
Bayesian approach; Prior and posterior distributions; Sampling methods: Rejection sampling, Markov chain Monte Carlo.

Unit 5: *Global optimization*
Particle Swarm Optimization (PSO); Simulated annealing; Genetic algorithm; Neighbourhood algorithm.

References:

1) Menke, W. (2018). *Geophysical Data Analysis: Discrete Inverse Theory*. Academic Press.
2) Aster, R.C., Borchers, B., and Thurber, C.H. (2013). *Parameter Estimation and Inverse Problems*. Academic Press.
3) Tarantola, A. (2005). *Inverse Problem Theory and Methods for Model Parameter Estimation*. SIAM.
4) Scales, J.A., Smith, M.L. and Treitel, S. (2001). *Introductory Geophysical Inverse Theory*. Samizdat Press.
5) Gubbins, D. (2004). *Time Series Analysis and Inverse Theory for Geophysicists*. Cambridge University Press.
6) Wunsch, C. (2006). *Discrete Inverse and State Estimation Problems*. Cambridge University Press.

EG-202: Geophysical Tools-I
Seismology & Seismic Methods

L	Pr	IS	ES	PrM	T
4	2	40	60	50	150

Unit 1: *Introduction*
Earthquake and its effects, Various magnitude scales and their limitations, Intensity scales, Earthquake frequency, Energy released in an earthquake, impacts and assessments of earthquakes, causes of intra and inter plate earthquakes, classification of earthquakes, Determination of earthquake parameters, Seismicity and seismotectonics of India and Himalayas.

Unit 2: *Elasticity theory and seismic waves*
Elastic, anelastic and plastic behavior of materials, the stress matrix, the strain matrix, the elastic constants, generalized Hooke's law, different types of elastic waves and their propagation characteristics, equations of motion of seismic body waves, Attenuation and dispersion of seismic waves, free oscillations of the earth.

Unit 3: *Seismology and earth's interior*
Ray characteristics and related parameters for horizontally and spherically stratified earth, basic principles of seismic tomography and receiver function analysis, location of the epicenter of an earthquake, global seismicity, elastic rebound theory, faultplane solutions and related interpretation, reflections and refractions in the earth's interior, models of the earth's internal structure.

Unit 4: *Seismic Methods-Fundamental theories*
Types of seismic waves, Attenuation, Reflection, Refraction and Diffraction of elastic waves, Effects of the medium on wave propagation, Partitioning of energy at an interface, Geometry of seismic wave paths for several horizontal and dipping beds, Distinguishing features of seismic events, Events other than primary reflections, Characteristics of reflections, Types of seismic noise and their attenuation.

Unit 5: *Seismic Data Acquisition*
Refraction Methods: In-line reversed refraction profiling, Broadside refraction and fan shooting' Engineering applications of refraction methods,
Reflection methods : Field Layouts: Split-dip and common-depth-point recording, Spread types, Arrays, Noise analysis, selection of field parameters, Uphole surveys, Crooked line and 3-D methods, Multi-component seismic data acquisition, Vertical Seismic Profiling (VSP), Seismic Tomography, 4-D Seismic, Passive Seismic Techniques
Equipment for land surveys: Surface energy sources, Geophones, Amplifiers, Analog data recording, Digital recording
Marine equipment and methods: Marine operations, Bubble effect, Marine energy sources, Marine detectors, Marine positioning

EG 203: Geophysical Signal Theory & Data Processing

L	IS	ES	PrM	T
4	40	60	50	100

Unit 1: *Digital Signals*
Classification of digital signals, Wavelets, Convolution, Properties of convolution, Transfer function for a causal system, Transfer function for a non-causal system, Laplace Transform and z-transform, The inverse z-transform.

Unit 2: *Frequency Analysis*
Frequency domain representation of Digital Signals and Systems, Fourier Transform for Discrete Time Signals, Properties of the Fourier Transform, Minimum delay and Minimum phase, All-Pass Systems

Unit 3: *Deconvolution*
The Autocorrelation and the Spectrum, The cross correlation, The Convolutional Model, Signature Deconvolution, Deterministic Reverberation Deconvolution, Predictive Deconvolution, Maximum Entropy Spectral Analysis.

Unit 4: *Optimum Linear Filtering and FK techniques*
Least Squares Filtering, Linear Prediction, Spiking and Shaping Filters for Seismic Data, Adaptive Filtering. The FK Transform, Aliasing, FK Transforms related to seismic data, FK Filtering, FK Migration

Unit 5: *Data-Processing*
Processes to improve signal-to-noise ratio, Processes to reposition data, Special processing techniques, typical processing sequence and Interactive processing, Data processing of 3-D data, 3-D Migration.

EG-204: Geophysical Tools II: Gravity & Magnetic Methods

L	Pr	IS	ES	PrM	T
3	2	40	60	50	150

Unit 1: *Gravity Methods*
The Earth's gravitational field and its relation to gravity exploration , Gravitational effects over subsurface bodies having discrete shapes, Instruments for measuring gravity on land, at sea and into the boreholes, Gravity measurements on land, at sea and airborne gravity surveys.

Unit 2: *Magnetic Prospecting*
Magnetism of the earth, Magnetic susceptibility of rocks, Magnetic effects from buried magnetic bodies, Instruments used for magnetic measurements, Magnetic surveys on land, Marine and airborne magnetic data collection

Unit 3: *Gravity data processing and interpretation*
Reductions of gravity data and interpretation of Bouguer anomaly maps, analytic methods for separation of regional and residuals; ambiguity in gravity interpretation and conditions for unique interpretation; upward and downward continuations of gravity anomalies; calculation of second vertical derivatives and horizontal gravity gradients, utility of such maps; gravity effects due to 2D and 3D bodies having irregular shape; Methods for basement mapping; use of gravity survey in mineral and hydrocarbon exploration programs, search for metallic and nonmetallic ores, coal and lignite; mapping faults, exploration for salt domes, stratigraphic traps, uplifted horst and graben, use of gravity in regional geological studies including granitic plutons, thrust belts, case histories.

Unit 4: *Magnetic data processing and interpretation*
Reduction of magnetic data, preparation and interpretation of anomaly maps, Interpretation of aeromagnetic maps, Werner and Euler Deconvolution, analytical signal, Source parameter imaging, 2D and 3D modeling, spectral analysis for depth determination, utility of aeromagnetic maps in mineral and hydrocarbon exploration programs and regional studies, case histories.

Unit 5: *New Frontiers- Gravity Gradiometry*
The Gravity Tensor, Principles of gravity gradiometry, interpreting tensor components, airborne gravity gradiometry, imaging techniques for Full Tensor Gravity Gradiometry (FTGG) data, gravity gradiometer survey error, advantages of gravity gradiometry, detectability of mineral deposits with airborne gravity gradiometry, gravity gradiometry in oil exploration, case histories.

EG 205: Elective II (any one)

EG 205A: Hydrogeology & Ground water investigations
EG 205B: Image Processing and Elements of GIS
EG 205C: Principles of Stratigraphy

EG-205A: Hydrogeology and Groundwater Investigations

L	IS	ES	T
2	20	30	50

Units	Hydrogeology and Groundwater Investigations
1	Definition of Hydrology and its relation with other sciences. Hydrologic cycle. Origin, occurrence and distribution of subsurface water. Porosity and different types of pore spaces in rocks.
2	Concept of water table and piezometric surface. Importance of water table in hydrogeological studies. Aquifer - its definition, different types and characteristics.
3	Dynamics of subsurface water: Darcy's law and its range of validity. Basic concepts of permeability/hydraulic conductivity, specific yield, transmissivity and storage coefficient.
4	Basics of well hydraulics related to a pumping well: Concepts of drawdown, cone of depression, specific capacity, specific drawdown and boundary conditions. Equilibrium and non-equilibrium conditions.
5	Groundwater investigations: Geological, hydrogeological and geophysical approaches; Groundwater inventory. Study of flow nets and it importance in groundwater investigation. Hydrogeological studies carried out in drilled wells.
6	Basic concept of groundwater management - equation of hydrologic equilibrium. Safe yield and overdraft.

Suggested Books:

1) **Groundwater Hydrology** (2nd Edn) - D.K. Todd, *John Wiley & Sons, New York*
2) **Hydrogeology** - Davis, S. N., and DeWiest, R. J. M., *John Wiley & Sons, New York*
3) **Ground Water** - *H.M. Raghunath* (1983), Wiley Eastern Ltd., New delhi
4) **Introduction to Ground Water Hydrology** - R.C. Heath and F.W. Trainer, John Wiley & Sons, New York.
5) **Ground Water Assessment Development and Management** - *K.R. Karanth*, (1987), *Tata McGraw-Hill, New Delhi*
6) **Hydrogeology Principles and Practice** - *K. M.Hiscock*, (2005), *Blackwell Publishing*

L	IS	ES	T
2	20	30	50

EG-205C: Principles of Stratigraphy

Units	Topic	No. of Lecturers
1.	Principles of stratigraphy, Modern development in stratigraphy, Steps in stratigraphic studies. Evolution of Geological Time Scale. Significant events in geological time	4
2.	Formal stratigraphic classifications: rock, time and time-rock units. The Stratigraphic Code, Local Example: the Jaintia Group. Lithostratigraphy. Biostratigraphy, Chronostratigraphy, Magnetostratigraphy.	6
3.	Methods of Correlation: physical and time (isochronous/ diachronous patterns), Correlation of lithostratigraphic units, Shaw's Graphic correlation. Sediment accumulation and gaps in the stratigraphic record: diastems, unconformities.	4
4.	Stratotypes, Facies in stratigraphy. Walther's Law of succession of facies. Types of Stratigraphic facies.	3
5.	Stratigraphy and Distribution of Tertiary rocks of upper Assam and Surma basins, Assam Arakan Mobile Belt, Meghalaya Basin and Arunachal foredeep.	4
6.	Generalised stratigraphic successions of different petroliferous basins of India.	4

Reference:

1) Sam Boggs, 1995, Principles of Sedimentology and Statigraphy, Printice Hall, New Jersey, 765p.
2) Mial A.D. 1999. Principles of Sedimentary Basin Analysis. 3rd edition.Springer-Verlag.
3) Schoch, R. M. 1989. Stratigraphy, principles and methods.
4) Weller, J. Marvin 1960. Stratigraphic principles and practice. Harper's Geoscience series.
5) Krishnan, M.S. 1982. Geology of India and Burma, CBS Publishers, Delhi

Semester III

EG 301: Geophysical Tools III: Electrical & EM Techniques

L	Pr	IS	ES	PrM	T
4	2	40	60	50	150

Unit 1: *Surveying natural potentials*
Exploring shallow natural potentials, Telluric currents, Telluric current surveying, Magneto telluric surveying, Cagniard's relations for depth of penetration and resistivity of the medium, Interpretation of MT data over a two layered earth, strike, rotation swift strike, polar diagram, tipper, skew, ellipticity, TE and TM modes, continental lower crust, MT study over cratons, Field examples.

Unit2: *Electrical resistivity surveying*
Current flow across a boundary, Measuring resistivity, Equipment for electrical resistivity surveying, Sounding and profiling, Forward and Inverse methods of resistivity data interpretation, Resistivity profiles over faults and dykes. Applications of linear filter theory; determination of filter coefficients, sinc response filter length, Recurrence relations: Flathe and Pekeris relations, determination of resistivity transforms, Potential due to a point source in an anisotropic medium, triangle of anisotropy. Dar Zarrouk parameters, principle of equivalence, Resistivity modeling

Unit 3: *Induced polarization surveying*
Source of induced potential, time domain and frequency domain measurements of IP, chargeability, percent frequency effect and metal factors, Results of IP surveying, Field examples.

Unit 4: *Electromagnetic surveying*
Principle of electromagnetic induction; magnetic field due to acurrent carrying loop, elliptical polarization, plane of polarization, dip and tilt angles, nomograms for quantitative determination of parameters by dip angle method, VLF and AFMAG methods, TURAM method. Basic principles of transient electromagnetic methods, brief account of various time domain systems, frequency sounding and geometric sounding, merits of time domain methods over frequency domain methods.

Unit 5: *Ground Penetrating Radar Methods*
Basic similarity with seismic, antennas, pulse width and central frequency, time windows and samples; reflection and transmission coefficients, Field procedure and interpretation: monostatic and bistatic arrangements, profiling and stacking, reflection and diffraction, distance determination, migration, depth of penetration and resolution, vertical and lateral resolution. GPR applications: fracture mapping, structures in sand and moraines, mapping ground water table.

EG-302: Geophysical Tools IV: Well Logging & its applications

L	Pr	IS	ES	PrM	T
4	2	40	60	50	150

Unit 1: *Logging tools and field practices*
Reservoir properties and Petrophysics of rock, Basic concept of log interpretation, Permeable zone indication logs (Spontaneous Potential, Gamma ray, Spectral gamma ray logs), Resistivity logs (Normal and lateral devices, Dual Laterolog-Micro spherically focused tool, Dual induction-spherically focused logs), Porosity logs (Compensated Neutron tool, Compensated Sonic tool, Litho-density tool), Miscellaneous tools (CBL/VDL, Dipmeter log, Caliper, Repeat Formation Tester), Welsite computed logs(or, Quick-look logs), Production logging tools, Perforation practices

Unit 2: *Advanced logging tools*
Tools offered by the MAXIS-500 Services & EXCELL-2000 Services like FMI (Full-bore-formation Micro Imager), CHFR (Cased Hole Formation Resistivity Tool), CAST (Circumferential Acoustic Scanning Tool), DSI(Dipole Sonic Imager), IPLT (Integrated Porosity Lithology Tool), CMR (Combinable Nuclear Magnetic Resonance Tool); Families of PEX(Platform Express Tools) & LWD (Logging while Drilling Tools) etc.

Unit 3: *Formation evaluation*
Various log response equations related to reservoir parameters of rocks, Borehole environment correction and depth matching, Use of logs to identify permeable beds, calculation of formation water resistivity, porosity, resistivity and water saturation of flushed zones and Uninvaded zones, Differentiation of clean sands, shaly sands and complex rocks with qualitative use of well logs.

Unit 4: *Log correlation*
Well log correlation techniques and their uses e.g., Preparation of synthetic seismogram

Unit 5: *Electro Facies Analysis*
Facies and depositional environments from logs, Identifying different surfaces (e.g., Sequence boundaries, Transgressive surfaces, Maximum flooding surfaces) and system tracts (Lowstand System Tract, Transgressive System Tract, Highstand System Tract) Type1 and Type2 sequences

References:

1) Dewan, J. T., Essentials of Modern Open-hole Log Interpretation, PennWell Books, 1983.
2) Rider, Malcolm, The Geological Interpretation of Well Logs, 2nd Edition, Rider-French Consulting Ltd, Scotland, 2002.
3) Bassiouni, Zaki, Theory, Measurement, and Interpretation of Well Logs, SPE Textbook Series Vol.4, 1994
4) Telford, M., Geldart, L.P., Sheriff, R.E., Applied Geophysics, 2nd edition, Cambridge University Press, 1990.
5) Brock James, Applied Open-Hole Log Analysis, Gulf Publishing Company, 1986

EG-303: Seismic Stratigraphy & Basin Analysis

L	Pr	IS	ES	PrM	T
4	2	40	60	50	150

Unit 1: *A brief review on mapping reflecting horizons*
Picking/grading of reflections, Checking of loop closures of isochronal maps, Study of diffraction, Delineation of faults, Identification of multiples, reverberations, Identification of unconformity, Study of migrated and unmigrated sections, Preparation of isochronal /structural maps, Preparation of isopach maps.

Unit 2: *Seismic facies, Sequence analysis and modeling*
Types of reflection characteristics, Different concepts of marine onlap, Identification of stratigraphic features like sand bodies, reefs, wedgeouts etc., Geologic sea level change model, Reflections as constant time indicators, Picking seismic sequences, Picking of Unconformities to separate seismic sequences, Mapping seismic sequences on three dimensions, The modeling concept, The Convolutional model, Forward modeling synthetic seismogram manufacture, Tie-up of seismic horizons with well data

Unit 3: *Seismic attribute analysis and hydrocarbon indicators*
Amplitude as an important discriminant, Velocity as a diagnostic, Measurement of velocity, Resolution, Fresnel zone effects, Phase, frequency and polarity, Prediction of sand shale ratio, Determination of porosity, Detection of abnormal pressure

Unit 4: *Sequence Stratigraphy*
The hierarchy of Units and Bounding Surfaces, System Tracts and Sequence Boundaries, The Sequence Stratigraphy of Clastic Depositional Systems, The Sequence Stratigraphy of Carbonate Depositional Systems.

Unit 5: *Basin Analysis*
Origin of basins, Basin classification, Habitats of major petroliferous belts and their relationship with plate tectonics, Basin models and exploration strategies

EG-304: Reservoir Geophysics

Unit 1: *Rock physics*
Basic rock physics concepts; Stress and strain; Elasticity; Effective medium models; Voigt and Reuss bounds; Hashin-Shtrikman bounds; Bounding average method; Fluid substitution; Gassmann's relations; Velocity, porosity, clay relations; Carbonates; Fluid flow and permeability; Darcy's law; Kozeny-Carman relation; Partial saturation: patchy and uniform saturation; Relative permeability; AVO: Shuey's approximation and Aki-Richard's approximation; Vp-Vs relations; Anisotropy; Fractures.

Unit 2: *Seismic attributes from well logs*
Exploratory data analysis; Lithofacies identification from well logs; Derived distributions of seismic attributes; Seismic well tie; Calibration of seismic data with well data.

Unit 3: *Seismic reservoir characterization*
Seismic attributes: P-wave impedance, S-wave impedance, Vp/Vs ratio, AVO intercept (R0) and gradient (G); Monte Carlo simulation; Lithofacies and pore fluids classification; Confusion matrices; Probability maps; 3D iso-probability plots.

Unit 4: *Geostatistical simulation*
Modeling of reservoir properties away from wells; Geostatistical simulation of reservoir properties: facies, porosity, permeability; Kriging; Two-point algorithms: sequential Gaussian simulation (SGSIM), sequential indicator simulation (SISIM), sequential indicator co-simulation (COSISIM); Experimental variogram; Conditioning to hard and soft data; Multiple-point algorithms: single normal equation simulation (SNESIM) and direct sampling (DS); Training image; Integration of seismic data: cascaded workflow and simultaneous workflow.

Unit 5: *Seismic modeling*
Synthetic seismogram from well log data; Normal incidence 2D seismic time sections: effect of frequency and depth; Born-filtered seismic images: impact of acquisition geometry and frequency; Surface seismic and cross-well seismic imaging.

References:

1) Avseth, P., Mukerji, T. and Mavko, G. (2005). *Quantitative Seismic Interpretation*. Cambridge University Press.
2) Mavko, G., Mukerji, T. and Dvorkin, J. (2009). *The Rock Physics Handbook*. Cambridge University Press.
3) Saxena, V., Krief, M. and Adam, L. (2018). *Handbook of Borehole Acoustics and Rock Physics for Reservoir Characterization*. Elsevier.
4) Caers, J. (2011). *Modeling Uncertainty in the Earth Sciences*. Wiley.
5) Remy, N., Boucher, A. and Wu, J. (2009). *Applied Geostatistics with SGeMS*. Cambridge University Press.
6) Mariethoz, G. and Caers, J. (2015). *Multiple-Point Geostatistics: Stochastic Modeling with Training Images*. Wiley.
7) Doyen, P. (2007). *Seismic Reservoir Characterization: An Earth Modelling Perspective*. EAGE.

8) Dubrule, O. (2003). *Geostatistics for Seismic Data Integration in Earth Models*. SEG. Caers, J. (2005). *Petroleum Geostatistics*. SPE.
9) Deutsch, C.V. (2002). *Geostatistical Reservoir Modeling*. Oxford University Press.
10) Goovaerts, P. (1997). *Geostatistics for Natural Resources Evaluation*. Oxford University Press.
11) Liner, C. (2004). *Elements of 3-D Seismology*. Pennwell Pub.
12) Biondi, B. (2006). *3D Seismic Imaging*. SEG.
13) Sen, M.K. (2006). *Seismic Inversion*. SPE.

EG-305: Elective III (Any one)
EG-305A: Decision Analysis and Value of Information
EG-305B: Simulation modeling in environmental science

EG-305A: Decision Analysis and Value of Information

Unit 1: *Basics of decision analysis*
Uncertainties, decisions and prospect values; Decision trees; Flipping the tree: Bayes' rule; Certain equivalents; Perfect information and imperfect information; Value of Information (VOI); VOI for a univariate Gaussian case.

Unit 2: *Directed Acyclic Graphs*
Bayesian networks; Influence diagrams; Examples.

Unit 3: *VOI in spatial problems*
Characteristics of spatial VOI problems; Spatial VOI framework.

Unit 4: *VOI estimation methodologies*
Rigorous Monte Carlo methodology; Simulation-regression methodology.

Unit 5: *Applications of VOI to geosciences*
Examples from petroleum exploration and development, mining and environmental sciences.

References:

1) Eidsvik, J., Mukerji, T. and Bhattacharjya, D. (2016). *Value of Information in the Earth Sciences: Integrating Spatial Modeling and Decision Analysis*. Cambridge University Press.
2) Howard, R.A. and Abbas, A.E. (2015). *Foundations of Decision Analysis*. Pearson.
3) Pyrcz, M.J. and Deutsch, C.V. (2014). *Geostatistical Reservoir Modeling*. Oxford University Press.
4) Cressie, N. and Wikle, C.K. (2011). *Statistics for Spatio-Temporal Data*. Wiley.

EG-305B: Simulation modeling in environmental science

Unit 1: *Introduction to simulation modeling*
Definition of a model; goals of modeling; general uses of modeling; brief review of statistics; steps to modeling; types of models; examples.

Unit 2: *Basics of R*
Introduction to R: vectors; operations on vectors; loops; data structures. Functions: applying functions to matrices, data frames and lists. Plotting: line plots, scatterplots, histograms, boxplots and barplots.

Unit 3: *Model calibration and selection*
Definition of model performance; optimizing model performance; model complexity vs. model performance; model assessment; prediction vs. interpretation.

Unit 4: *Sensitivity analysis (SA)*
Goals of SA; properties of an ideal SA method; steps for SA; simple screening; Morris' method; variance-based SA measures.

Unit 5: *Model evaluation and predictions*
Finding data to evaluate a model; metrics of model performance based on data; comparing models to each other; estimating uncertainty in model predictions; reducing uncertainty with multi-model approaches.

References:

1) Saltelli, A., Chan, K. and Scott, E.M. (2000). *Sensitivity Analysis*. Wiley.
2) Oreskes, N., Shraderfrechette, K. and Belitz, K. (1994). Verification, validation, and confirmation of numerical models in the Earth sciences. *Science*, 263, 641–646.
3) Pebesma, E., Nüst, D. and Bivand, R. (2012). The R software environment in reproducible geoscientific research. *Eos, Transactions American Geophysical Union*, 93:163-163.
4) Schewe, J. and Levermann, A. (2012). A statistically predictive model for future monsoon failure in India. *Environmental Research Letters*, 7:044023.

Semester IV

Project Work.