Kurukshetra University, Kurukshetra

Department of Geophysics

Scheme of Examinations and Syllabus of

M. Sc. (Tech.) Applied Geophysics I to VI Semester

Under CBCS-LOCF

(w.e.f. session 2020-2021)

in phased manner

Vision and Mission of Kurukshetra University

Vision

Be globally acknowledged as a distinguished centre of academic excellence.

Mission

To prepare a class of proficient scholars and professionals with ingrained human values and commitment to expand the frontiers of knowledge for the advancement of society.

Introduction

The sustainable development of society needs energy resources, clean drinking water, safety, advanced technologies and clean Earth environment. Geophysics is the study of physical processes of Earth and its surrounding space. It is a multidisciplinary subject with applications from Physics, Geology, Computer Science, Electronics etc. The interior of Earth can only be studied by indirect methods like propagation of seismic wave. The study of different phases from Earth provides constraints which are used to interpret physical properties of Crust, Mantle, Outer Core and Inner Core. The Earth processes are studied to know about origin of the Earth. The geophysics applications include Oil & Gas exploration, Ground Water exploration, Archaeological studies, Environmental studies, Seismic Hazard, Mineral explorations, Civil engineering, Geotechnical etc. The outer space applications include study of moonquakes, gravity field and magnetic field.

Vision and Mission of the Department of Geophysics

Vision

Be recognized as distinguished department in the Geophysical World for learning and research in Applied Geophysics.

Mission

To prepare the professionals in the broad spectrum of Applied Geophysics e.g. earthquake hazards, hydrocarbon exploration, tectonics, mineral and ground water resources etc. to serve the society.

Programme Outcomes (PO) of Post Graduate Science CBCS Programmes/Courses in the Faculty of Sciences, Kurukshetra University, Kurukshetra

PO1	Knowledge	Capable of demonstrating comprehensive disciplinary knowledge one has gained during course of study
PO2	Research Aptitude	Develop research aptitude. Capability for asking relevant/appropriate questions. Capable of identifying, formulating and analyzing the research problems and to draw conclusions from analysis of research problems.
PO3	Communication	Ability to communicate effectively on general and scientific topics with the scientific community and with society at large.
PO4	Problem Solving	Capability of applying knowledge to solve scientific and other problems.
PO5	Individual and Team Work	Capable to learn and work effectively as an individual and as a member or leader in team(s) and in multidisciplinary settings. Facilitate cooperative or coordinated efforts on the part of a group and act together as a group or as a team.
PO6	Investigation of Problems	Ability of critical thinking and analytical reasoning. Ability to use disciplinary and research based knowledge including design of experiments, analysis and interpretation of data to provide valid conclusions.
PO7	Modern Tool usage	Ability to use and learn techniques, skills and modern tools for scientific practices.
PO8	Science and Society	Ability to apply reasoning to assess the different issues related to society and the consequent responsibilities relevant to the professional scientific practices.
PO9	Life-Long Learning	Ability to acquire knowledge and skills including learning ‘How to learn’ that are necessary for participating in learning activities throughout life.
PO10	Ethics	Capable of demonstrating the ability to identify ethical issues related to one’s work, avoid unethical behaviour such as fabrication, falsification or misrepresentation of data or committing plagiarism and adopting objective, unbiased and truthful actions in all aspects of work.
PO11	Project Management	Ability to demonstrate knowledge and understanding of the scientific principles and apply these as a member / leader of a team to manage projects

Programme Specific Outcomes (PSOs) for M.Sc. (Tech.) Applied Geophysics

PSO1: Understand the interior of Earth using latest Geophysical knowledge pertaining to various sub-fields within the discipline of Applied Geophysics.

PSO2: Inculcating analytical ability, research aptitude and relevant skills in the students useful for their professional life.

PSO3: Ability to demonstrate and communicate Geophysical knowledge, understanding of Geophysical techniques/principles and apply the same to solve geophysical problems relevant to society.

PSO4: Learning the techniques of data acquisition, data processing and data interpretation for Geophysical methods and their applications for the benefit of society.

DEPARTMENT OF GEOPHYSICS KURUKSHETRA UNIVERSITY KURUKSHETRA

SCHEME OF EXAMINATION, TEACHING LOAD AND SYLLABUS OF
M.Sc. (Tech) Applied Geophysics

FIRST SEMESTER EFFECTIVE FROM THE SESSION 2020-21:

S.No.	Course no. & Course	Teaching Load (hrs/week/group) L	T	P	Marks Distribution Th/P	CW	Total	Credit	Duration of Exam (Hours)
1.	GP-101: Mathematical Methods in Geophysics	4	½	0	60	40	100	4	3
2.	GP-102: Solid Earth Geophysics	4	½	0	60	40	100	4	3
3.	GP-103: Numerical Methods & Computer Programming	4	½	0	60	40	100	4	3
4.	GP-104: Basic Geology	4	½	0	60	40	100	4	3
5.	GP-105: Geology Lab	0	0	12	90	60	150	6	4
6.	GP-106: Computer Lab	0	0	12	90	60	150	6	4
	Semester Total	16	2	24			700	28	

SECOND SEMESTER EFFECTIVE FROM THE SESSION 2020-21:

S.No.	Course no. & Course	Teaching Load (hrs/week/group) L	T	P	Marks Distribution Th/P	CW	Total	Credit	Duration of Exam (Hours)
1.	GP-201: Remote Sensing & GIS	4	½	0	60	40	100	4	3
2.	GP-202: Advanced Computing	4	½	0	60	40	100	4	3
3.	GP-203: Geophysical Signal Processing	4	½	0	60	40	100	4	3
4.	GP-204: Geophysical Fields & Waves	4	½	0	60	40	100	4	3
5.	GP-205: Geophysical Lab - I	0	0	12	90	60	150	6	4
6.	GP-206: Geophysical Lab - II	0	0	12	90	60	150	6	4
7.	GP-207: Geological Field Training	4 hrs/week*					100	4	30 min. per student
8.	OE-206: Dynamics of the Earth@	2	0	0	35	15	50	2	2
9.	OEL-I Open Elective paper**	-		-	-	-	-		
	Semester Total	18	2	24			850	34	

THIRD SEMESTER EFFECTIVE FROM THE SESSION 2021-22:

S.No.	Course no. & Course	Teaching Load (hrs/week/group)			Marks Distribution				Duration of Exam
		L	T	P	Th/P	CW	Total	Credit	(Hours)
1.	GP-301: Seismology	4	½	0	60	40	100	4	3
2.	GP-302: Gravity & Magnetic Prospecting	4	½	0	60	40	100	4	3
3.	GP-303: Groundwater Geophysics	4	½	0	60	40	100	4	3
4.	GP-304: Electrical Prospecting	4	½	0	60	40	100	4	3
5.	GP-305: Geophysical Lab-III	0	0	12	90	60	150	6	4
6.	GP-306: Geophysical Lab-IV	0	0	12	90	60	150	6	4
7.	OE-306 Earthquake Hazard and Mitigation @	2	0	0	35	15	50	2	2
8.	OEL-II: Open Elective paper**	-		-	-	-	-	-	-
	Semester Total	18	2	24			750	30	

FOURTH SEMESTER EFFECTIVE FROM THE SESSION 2021-22:

S.No.	Course no. & Course	Teaching Load (hrs/week/group)			Marks Distribution				Duration of Exam
		L	T	P	Th/P	CW	Total	Credit	(Hours)
1.	GP-401: Petrophysics & Well Logging	4	½	0	60	40	100	4	3
2.	GP-402: Physical Oceanography & Marine Geophysics	4	½	0	60	40	100	4	3
3.	GP-403: Seismic Prospecting	4	½	0	60	40	100	4	3
4.	GP-404: Geophysical Inversion	4	½	0	60	40	100	4	3
5.	GP-405: Geophysical Lab – V	0	0	12	90	60	150	6	4
6.	GP-406: Geophysical Lab - VI	0	0	12	90	60	150	6	4
7.	GP-407: Geophysical Field Training-I	4 hrs/week*					100	4	30 Min. per student
	Semester Total	16	2	24			800	32	

FIFTH SEMESTER EFFECTIVE FROM THE SESSION 2022-23:

S.No.	Course no. & Course	Teaching Load (hrs/week/group)			Marks Distribution				Duration of Exam
		L	T	P	Th/P	CW	Total	Credit	(Hours)
1.	GP-501: Near Surface Geophysics	4	½	0	60	40	100	4	3
2.	GP-502: Electromagnetic and Magenotelluric Methods	4	½	0	60	40	100	4	3
3.	GP-503: Geophysical Lab-VII	0	0	12	90	60	150	6	4
4.	GP-504: Geophysical Lab-VIII	0	0	12	90	60	150	6	4
5.	GP- Elective – I	4	½	0	60	40	100	4	3
6.	GP- Elective – II	4	½	0	60	40	100	4	3
	Semester Total	16	2	24			700	28	

SIXTH SEMESTER EFFECTIVE FROM THE SESSION 2022-23:

S.No.	Course no.& Course	Th/P CW	Marks Distribution Total	Credit	Duration of Exam Hours
1.	GP-601: Dissertation	4 hrs/week*	400	16	30 min. per student
2.	GP- 602: Comprehensive Viva-Voce		100	4	30 min. per student
3.	GP- 603: Seminar	1 hr/week*	100	4	01 Hour per student
4.	GP-604: Geophysical Field Training-II	4hrs/week*	100	4	30 min. per student
	Semester Total		700	28	

@For the students of other departments of the university.

*Credited to the teacher(s) associated with Field training/dissertation work/seminar of the students

**Students have to opt one course each in second and third semester to be offered by other departments of the university or these courses can be opted though MOOCS/Swayam. However, students can opt for summer/industrial training in lieu of open elective course of 3rd semester. This training can be done in the summer vacation falling in the period intervening between second and third semester and as per university guidelines.

Elective – I   Solid Earth

GP-506: Computational Seismology
GP-507: Geomagnetism
GP-508: Whole Earth Dynamics
GP-509: Solid Mechanics
GP-510: Numerical Simulation of Earth System
GP-511: Non-linear Geophysics

Elective – II

GP-512: Geotomography
GP-513: Seismic Data Analysis & Reservoir Geophysics
GP-514: Reservoir Modelling
GP-515: Radiometric Exploration
GP-516: Advanced Remote Sensing & Image Processing
GP-517: Artificial Intelligence & Machine Learning in Geophysics

GP-101: Mathematical Methods in Geophysics

Credits: 4

Max. Marks: 60
Time: 3 hours

Course Outcomes:

After completion of this course, the students will be able to:

CO101.1: Learn the concept of different mathematical special functions for the solution of geophysical problems.

CO101.2: Understand the concept of complex variables and different series for the application in geophysics

CO101.3: Learn the basics of Laplace and Fourier transforms and its application in geophysics.

CO101.4: Learn different kinds of partial different equations and its solutions.

Special Notes:

Nine questions will be set and students will attempt five questions. Question no. 1 will be compulsory and based on the conceptual aspects of the whole syllabus. It can have 5 to 10 parts. The answers should not be in yes/no. In addition to question no. 1, there will be four units in the question paper each containing two questions belonging to four units in the syllabus. Students will select one question from each unit.

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.

RECOMMENDED BOOKS

(1) Applied Mathematics for Engineers and Physicists by L .Pipes & L.R. Horwell

(2) Mathematical Methods for Physicists by G. Arfken

(3) Mathematical Physics by B.S. Rajput
(4)Elementary Applied Partial Differential Equations: With Fourier series and Boundary Value Problems by Richard Haberman
(5) Integral Transforms by I. Sneddon
(6) Elements of Partial Differential Equations by I. Sneddon

GP-102: Solid Earth Geophysics

Credits: 4

Max. Marks: 60
Time: 3 hours

Course Outcomes:

After completion of this course, the students will be able to:

CO102.1: Understand the basics of geophysics and origin of solar system as well as to develop concept of different theories for the evolution of earth

CO102.2: learn different radiometric dating techniques and to develop concept of gravity and its essential features.

CO102.3: Develop concept on magnetic properties of the earth and heat flow inside the earth.

CO102.4: Understand earthquake seismology, internal structure of the earth and mountain building

Special Notes:

Nine questions will be set and students will attempt five questions. Question no. 1 will be compulsory and based on the conceptual aspects of the whole syllabus. It can have 5 to 10 parts. The answers should not be in yes/no. In addition to question no. 1, there will be four units in the question paper each containing two questions belonging to four units in the syllabus. Students will select one question from each unit.

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.

RECOMMENDED BOOKS:

(1) The Solid Earth by C.M.R. Fowler
(2) Understanding the Earth by I.G. Guass, P.S. Smith and R.G.L. Wilson
(3) The dynamic Earth by P.J. Wyllie
(4) Introduction to Geophysics by B.F. Howell
(5) Physics and Geology by J.J. Jacobs, R.D. Russel and J.T. Klilson
(6) Fundamental of Geodynamics by A.E. Schieddeggar
(7) Fundamentals of Geophysics by W. Lowrie

GP-103: Numerical Methods And Computer Programming

Credits : 4

Max. Marks: 60
Time: 3 hours

Course Outcomes:

On completion of this course, the students will be able to:

CO103.1: Learning about the problem solving approach and different operating systems used for computer programming to be used in processing.

CO103.2: Learning and acquiring knowledge of FORTRAN and its functions used for developing the codes used for processing and interpretation of geophysical problems.

CO103.3: Acquiring knowledge of C along with its functions for the development of programs.

CO103.4: Developing ability to make codes/ programs with problem solving approach towards various geophysical problem and numerical methods to be used in data processing and interpretation in geophysics.

Special Notes:

(i) Nine questions will be set and students will attempt five questions. Question no. I will be compulsory and based on the conceptual aspects of the whole syllabus. It can have 5 to 10 parts. The answers should not be in yes/no. In addition to question no. I, there will be four units in the question paper each containing two questions belonging to four units in the syllabus. Students will select one question from each unit.

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

RECOMMENDED BOOKS

(1) Fundamentals of computers by V. Rajaraman
(2) FORTRAN 77 and Numerical methods by C. Xavier
(3) FORTRAN Programming and Numerical methods by R.C. Desai

(4) Let us C by Yashwant Kanetkar
(5) The C programming language by Brian W. Kernighan and Dennis Ritchie
(6) Advanced UNIX- A Programmers guide by Stephen Prata

GP-104: Basic Geology

Credits : 4

Max. Marks: 60
Time: 3 hours

Course Outcomes:

On completion of this course, the students will be able to:

CO104.1: understand basic concept of geology and different geological process responsible for landforms.
CO104.2: familiarize with minerals and their identification and occurrence in the earth.
CO104.3: Gain basic knowledge of rocks, their process of formation and occurrence in the earth.
CO104.4: Gain knowledge of different geological structures associated with deformation processes

Special Notes:

(i) Nine questions will be set and students will attempt five questions. Question no. I will be compulsory and based on the conceptual aspects of the whole syllabus. It can have 5 to 10 parts. The answers should not be in yes/no. In addition to question no. I, there will be four units in the question paper each containing two questions belonging to four units in the syllabus. Students will select one question from each unit.

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.

RECOMMENDED BOOKS:

(1) Rutley's Elements of Mineralogy By H.H. Read
(2) Structural Geology by M.P. Billings
(3) Principles of Physical Geology by A.H. Holmes

(4) A Text Book of Geology by P.K. Mukherjee
(5) The Principles of Petrology by G.W. Tyrrell
(6) Manual of Field Geology by R.R Compton
(7) An introduction to structural geology by A.K. Jain
(8) Structural Geology by Haakon Fossen

GP-105: Geology Lab

Credits : 6

Max. Marks: 90
Time: 4 hours

<u>Course Outcomes:</u>

On completion of this course, the students will be able to:

CO105.1: develop practical knowledge of minerals, rocks and landforms,
CO105.2: learn effective ccommunication, presentation and understanding of geological knowledge.
CO105.3: know the use of toposheet, bruntone/clinometer in geology
CO105.4: learn to interpret and construct of geological maps and cross section

1. Continental scale land forms of India
2. Physical properties of important rock forming minerals
3. Megascopic study and identification of important igneous, sedimentary and metamorphic rocks
4. Study of Toposheets
5. Uses of bruntone/clinometer and measurement of dip and strike of beds
6. Study of geological map and construction of cross section of area comprising of horizontal, unconformable, inclined, folded and faulted rocks.

GP-106: Computer lab

Credits : 6

Max. Marks: 90
Time: 4 hours

<u>Course Outcomes:</u>

On completion of this course, the students will be able to:

CO106.1: Acquaintance with the different computer operating systems.
CO106.2: Learn to run or operate the exercises using computer software's.
CO106.3: Learn to write codes/programs in Fortran and simple exercise in C.
CO106.4: Able to tackle the coding on computational problems and their solution on computers.

(1) Exposure to computer operating system : DOS, WINDOWS, UNIX/LINUX

(2) Simple exercises based on available computer softwares

(3) Programming exercises on computational problems and their solution on computers. These include the following:

(i) Matrix operations

(ii) Matrix inversion

(iii) Numerical integration

(iv) Solution of simultaneous equations

(v) Linear curve fitting

(vi) Correlation coefficient, standard deviation etc.

(vii) Numerical differentiation

(viii) Solution of differential equation

(ix) Solution of transcendental and algebraic equation using Newton Raphson method

GP-201: Remote Sensing and GIS

Credits : 4

Max. Marks: 60
Time: 3 hours

Course Outcomes:

After the completion of the course, the students will be able:

CO201.1: To understand the basic concepts of remote sensing and Aerial Photogrammetry including physical basis and photo-characteristics of various rock types etc.

CO201.2: To gain knowledge about Remote sensing sensors, satellite programmes, basic image interpretation, visual interpretation and digital image analysis.

CO201.3: To gain the knowledge about GIS and its components, GPS and its segments, creation of thematic layers, raster and vector data.

CO201.4: understand image interpretation and methodology for preparation of various thematic maps and applications of RS & GIS.

Special Notes:

(i) Nine questions will be set and the students will attempt five questions. Question No.1 will be compulsory and based on the conceptual aspects of the whole syllabus. It can have five to ten parts. Answers should not be in yes/no. In addition to question No. 1, there will be four units in the question paper each containing two questions belonging to four units in the syllabus. Students will select one question from each unit.

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)

Recommended Books:

1. Remote Sensing Geology (Springer Verlag). R.P. Gupta
2. Remote Sensing in Geology (John Wiley & sons). B.S. Siegel and A.R. Gillespie
3. Remote Sensing and image interpretation (John Wiley & sons). T.M. Lillesand and R.W. Kiefer
4. Remote Sensing Principles and interpretation (WH Freeman Company. F.F. Reeds
5. Remote Sensing fro Earth Resources (AEG publication), D.P. Rao
6. Principles of Remote sensing (ELBS London). P. J. Kuran
7. Advances in Geophysics Vol. 1 and 13 (Academic press) H.E. Landesberg
8. Handbook of Information issued by GSI (Airborne Mineral surveys and exploration wing), AEC (Atomic Minerals Divisions) and NGRI.
9. Principles of GIS, P. A. Burrough
10. Indian Society of GeomaticsNews letters 2004-2005
11. GPS: Theory and Practice (Springer Verlag). B. Hofman-wellenhof, H.lichtenegger and J.Collins

GP-202 Advanced Computing

Credits : 4

Max. Marks: 60
Time: 3 hours

Course Outcomes:

On completion of this course, the students will be able to

CO202.1:.learn basics of programming and C++
CO202.2: understand simple concepts of programming in C++.
CO202.3: gain knowledge of advanced concepts of programming in C++.
CO202.4: understand concepts of programming in MatLab and GMT.

Special Notes:

(i) Nine questions will be set and students will attempt five questions. Question no. I will be compulsory and based on the conceptual aspects of the whole syllabus. It can have 5 to 10 parts. The answers should not be in yes/no. In addition to question no. I, there will be four units in the question paper each containing two questions belonging to four units in the syllabus. Students will select one question from each unit.

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.

Suggested Books

1. The C++ programming language: Bjarne Stroustrup
2. The C++: The complete reference: Herbert Schildt
3. Object oriented programming C++: Petroleum Geology: Chapman, R.E.
4. Programming in C++: Robert Lafore
5. Programming in MatLab: Marc E. Herniter
6. Generic Mapping tools: Wessel and Smith

GP-203: Geophysical Signal Processing

Credits: 4

Max. Marks: 60
Time: 3 hours

Course Outcomes:

On completion of this course, the students will be able to

CO203.1: Understand the basic concepts of signal and system theory.
CO203.2: Understand the concept of discrete transforms and their applications in geophysics.
CO203.3: Analyze the time series using the concepts of geophysical signal processing.
CO203.4: Design and apply the filters to the geophysical signals.

Special Notes:

(i) Nine questions will be set and students will attempt five questions. Question No.1 is compulsory and based on the conceptual aspects of the whole syllabus. It can have 5 to 10 parts. The answer should not be in yes and no. In addition to Question 1, there will be four unit question paper each containing two questions belonging to four units in the syllabus. Students will select one question from each unit.

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.

Recommended Books

1. Signal and Systems, M.L. Meade and C.R.Dillon , Chapman and Hall London
2. Digital Signal Processing, 1975, Oppenheim, A.V. and R.W. Schafer, Prentice Hall, Englewood Cliffs, New Jersey
3. An Introduction to Statistical Communication Theory, J. B. Thomas, John Wiley, New York
4. Spectral Analysis in Geophysics, 1974, Markus Bath, Elsevier, Amsterdam
5. Signal Analysis, 1977, A. Popoulis, McGraw Hill New York

GP-204: Geophysical Fields and Waves

Max. Marks 60

Credits : 4 Time 3 Hrs

Course Outcomes:

On completion of this course, the students will be able to

CO204.1: Understand the basic concepts about the different types of Geophysical fields and associated laws.
CO204.2: Understand the basic of heat conduction processes in the earth and its applications.
CO204.3: Understand the basic of wave theory and fundamentals of electromagnetics theory.
CO204.4: Understand the basic of Electromagnetic methods.

Special Notes:

Nine questions will be set and students will attempt five questions. Question No.1 is compulsory and based on the conceptual aspects of the whole syllabus. It can have 5 to 10 parts. The answer should not be in yes and no. In addition to Question 1, there will be four unit question paper each containing two questions belonging to four units in the syllabus. Students will select one question from each unit.

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.

Books Recommended

1. Geodynamics applications of continuum Physics to geological problems : Turcotte & Schubert
2. Interpretation theory in Applied Geophysics: F.S. Grant & G.F. West
3. Electromagnetic theory: J. Stratton
4. Heat conduction: I.R. Ingersoll
5. Solid Earth: C.F. Fowler
6. Fundamentals of Geophysics: W. Lowrie
7. Introduction to theoretical Geophysics: C.B. Officer
8. Geophysical Electromagnetic Theory and Methods: Michael S. Zhdanov,

GP-205: Geophysical Lab-I

Credits : 6

Max. Marks: 90
Time: 4 hours

Course Outcomes:

After the completion of the course, the students will be able

CO205.1: To write advanced programs in C++.
CO205.2: To write programs in Matlab and make plots in GMT.
CO205.3: To identify linear features using satellite images, prepare drainage map, land use map.
CO205.4: To prepare geomorphology and hydrogeomorphology map.

Section – A

1. Exercise based on basic concepts in C++.
2. Exercise based on if/while/for/Break/continue Statements in C++.
3. Exercise based on Data Structure in C++.
4. Exercises based on Pointers in C++.
5. Exercise based on Modular Programming in C++
6. Getting started with MatLab: Basics.
7. Numerical methods in MatLab.
8. Plotting maps in GMT.

Section – B

1. Preparation of base maps
2. Use of satellite image for identification of linear features.
3. Preparation of land use land cover map
4. Preparation of drainage map
5. Preparation of Geomorphology map
6. Preparation Hydrogeomorphology map
7. Simple exercises on digital image processing

GP-206: Geophysical Lab-II

Credits : 6

Max. Marks: 90
Time: 4 hours

<u>Course Outcomes:</u>

On completion of this course, the students will be able to

CO206.1: Apply convolution, correlation, and autocorrelation in time and frequency domain.
CO206.2: Compute Fast Fourier Transform of a given signal.
CO206.3: Design and apply filters to the geophysical data.
CO206.4: Use signal processing software MatLab in application to time series data.

Exercises based on

(i) Convolution model in the time & frequency domain

(ii) Computation of FFT

(iii) Autocorrelation & Cross correlation

(iv) Inverse filtering

(v) Deconvolution using Z-transform

(vi) Predictive Deconvolution filter

(vii) Exposure to basic signal processing softwares like PITSA & MATLAB

OE-206: Dynamics of the Earth

Max. Marks: 35
Credits : 2 Time: 2 hours

Course Outcomes:

On completion of this course, the students will be able to:
CO206.1: Acquiring knowledge about the solar system and evolution of the earth.
CO206.2: Learn about the gravity and magnetic field of the Earth to enhance the understanding of geophysical knowledge.

Special Notes:
Five questions will be set and students will attempt three questions. Question No. I will be compulsory of 20 marks and based on the conceptual aspects of the whole syllabus. The answers should not be in yes/no. In addition to question no. 1, there will be two units in the question paper each containing two questions of 15 marks each belonging to two units in the syllabus. Students will select one question from each unit.

Unit-I:
Origin and age of the solar system and the Earth, Evolution of Earth from its origin to the present, Continental drift and sea-floor spreading, Plate-tectonic theory and interactions of different types of plate boundaries, Earth's internal and external structure and composition, variation of seismic velocity, density, temperature and pressure from surface to the centre of the Earth. Rheological properties of Earth, evolution, structure and composition of Earth's atmosphere.

Unit-II:
The gravity field of the Earth, shape and size of the Earth, Gravity anomalies, theory of isostasy and its significance in distribution of land and ocean, origin of the Earth's magnetic field, thermal structure of the Earth, global seismicity, characteristics of earthquakes: origin, distribution, causes and results. Interior of the Earth based on seismic waves. Geodynamics of Indian subcontinent, origin and tectonics of the Himalaya.

Recommended Books:

1. Lowrie, W., Fundamentals of Geophysics, 2nd Edition, Cambridge University Press, 2007.
2. Lillie, R. J., Whole Earth Geophysics: An introduction textbook for geologist and geophysicists, Prentice Hall, New Jersey.
3. Davies, G. F., Dynamic Earth: Plates, Plumes and Mantle Convection, Cambridge University Press, 2000.
4. Fowler, C. M. R., The Solid Earth: An introduction to global Geophysics, 2nd Edition, Cambridge, University Press, 2004.
5. Stacey, F. D., and Davis, P., Physics of the Earth, 4th Edition, Cambridge University Press, 2008.
6. Bott, M. H. P., The interior of the Earth, 2nd Edition, Edward Arnold, London, 1982

GP-207: Geological Field Training

Credit : 4 | Max Marks : 100
Time: 30 Minutes per student

Course Outcomes:

On completion of this course, the students will be able to

CO207.1:.Understand rocks and structures in their natural environment and their natural relationship to one another.

CO207.2: Gain experience to use different geological field equipments in the field and collecting geological and structural data.

CO207.3: Learn to prepare geological and structural map, their analysis and interpretation.

CO207.4: Learn how to adopt in field work environment and how to work as a team in the field

GP-301: Seismology

Credits : 4 | Max. Marks 60
Time 3 Hrs

Course Outcomes:

On completion of this course, the students will be able to

CO301.1: Understand the basic concepts and principles of Seismology to explore interior of earth.

CO301.2: Acquiring knowledge of earth's structure through seismograms to know more about the earth's interior to develop research aptitude.

CO301.3: Learn about the different model to understand the heterogeneous earth and able to communicate the geophysical knowledge.

CO301.4: Learn about the earthquakes and its related parameters for the benefits of the society.

Special Notes:

(i) Nine questions will be set and students will attempt five questions. Question No.1 is compulsory and based on the conceptual aspects of the whole syllabus. It can have 5 to 10 parts. The answer should not be in yes and no. In addition to Question 1, there will be four unit question paper each containing two questions belonging to four units in the syllabus. Students will select one question from each unit.

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.

Recommended Books:

(1) Elementary Seismology: C.F. Richter
(2) Introduction to theory of seismology : K.E. Bullen
(3) Seismology and Plate Tectonics: David Gubbins
(4) Seismic waves and Sources: A. Ben-Menham & S.J. Singh
(5) Modern Global Seismology: Lay & Wallace
(6) Seismology: Shearer

GP-302: Gravity & Magnetic Prospecting

Credits : 4

Max. Marks: 60
Time: 3 hours

Course Outcomes:

On completion of this course, the students will be able to
CO302.1: Understand the basic concepts and principles of Gravity and Magnetic methods.
CO302.2: Learn the working of different types of gravitymeters and magnetometers.
CO302.3: Plan the gravity and magnetic surveys including airborne and magnetic gradient surveys, corrections applied to gravity and magnetic data.
CO302.4: Interpret the gravity and magnetic data, applications of gravity and magnetic methods in geophysical exploration.

Special Notes:
(i) Nine questions will be set and students will attempt five questions. Question no. I will be compulsory and based on the conceptual aspects of the whole syllabus. It can have 5 to 10 parts. The answers should not be in yes/no. In addition to question no. I, there will be four units in the question paper each containing two questions belonging to four units in the syllabus. Students will select one question from each unit.

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.

Recommended Books:

(1) Basic Exploration Geophysics: Robinson
(2) Applied Geophysics: Telford et al.
(3) Introduction to Geophysical Prospecting: Dobrin & Saviet
(4) Geophysical prospecting for oil: Nettleton

(5) Introduction to Geophysical Exploration: Keary & Brooks
(6) Gravity and Magnetic methods of prospecting: B.S. Rama Rao & IVR Murthy

GP-303: Groundwater Geophysics

Credits : 4

Max. Marks: 60
Time: 3 hours

Course Outcomes:

After the completion of the course, the students will be able:

CO303.1: To understand the basic concept of Geohydrology, Hydrogeophysics, hydrological cycle, distribution of water etc.

CO303.2: To understand about the hydrological properties of water bearing materials and groundwater flow characteristics.

CO303.3: To understand about the classification of water bearing rocks, groundwater exploration and management, watershed characterization etc.

CO304.4: To apply geological and geophysical methods for groundwater exploration and to learn various groundwater quality parameters.

Special notes:

Nine questions will be set and the students will attempt five questions. Question No.1 will be compulsory and based on the conceptual aspects of the whole syllabus. It can have five to ten parts. Answers should not be in yes/no. In addition to question No. 1, there will be four units in the question paper each containing two questions belonging to four units in the syllabus. Students will select one question from each unit.

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.

Recommended Books:

1. Groundwater hydrology (John Wiley and Sons), David K. Todd
2. Principles of Hydrology, Ward
3. Handbook of Applied Hydrology, V.T. Chow
4. Introduction to groundwater Hydrology, Heath & Trainer

5. Hydrology. O. Meinzer
6. Hydrogeology (John Wiley and Sons). Davis, S.N., Dewiest, J.R.N.
7. Groundwater (Tata McGraw Hill), Tolman, C.F.
8. Groundwater (Wiley Eastern Ltd.) H.M. Raghunath
9. Basic Exploration Geophysics. Robinson
10. Hydrogeophysics (Kluwer Publishers), Y.Rubin and S. Hubbard
11. Karanth: Development, Assessment and Management of Water Resources

GP 304: Electrical Prospecting

Max. Marks: 60

Credits : 4 Time: 3 hours

Course Outcomes:

On completion of this course, the students will be able to

CO304.1: Learn about the basics of Electrical prospecting.
CO304.2: Understand the Electrode Configurations, Induced Polarization and Self Potential method.
CO304.3: Understand the basics of D.C. Resistivity method, acquisition and processing.
CO304.4: Capable of Interpretation of Electrical resistivity Data.

Special Notes:
Nine questions will be set and students will attempt five questions. Question No.1 is compulsory and based on the conceptual aspects of the whole syllabus. It can have 5 to 10 parts. The answer should not be in yes and no. In addition to Question 1, there will be four-unit question paper each containing two questions belonging to four units in the syllabus. Students will select one question from each unit.

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.

Recommended Books :

1. Electrical method of geophysical prospecting: Keller, G.V. and Frish Knecht,
2. Geosounding principles: Koefoed, O.
3. The application of Kernel functions in neterpretating geoelectrical measurements, Geoexploration monograph series no. 2Gebruder, Brorntraegr, Berlin : Koefoed, O.
4. Direct current geoelectric sounding: Bhattacharya, B.K. and Patra, H.P.
5. Principles of direct current prospecting Gebruder: Kunetz, G.
6. Interpretation theory in applied geophysics, Mg Graw Hill Co. N.York
7. Kaufman and Keller, The Magnetic Sounding Methods: Grant, F.S. and West, G.B.,
8. Geoelectromagnetism: Wait, J.R.,
9. Time varying geoelectric sounding: Patra and Mallick, K.

GP-305: Geophysical Lab-III

Credits : 6

Max. Marks: 90
Time: 4 hours

Course Outcomes:
On completion of this course, the students will be able to:
CO305.1: Understand the working of earthquake instruments.
CO305.2: Locate the earthquake epicentre and compute fault plane solution from earthquake data.
CO305.3: Learn to use various software for processing the data for ex. SEISAN, MatLab.
CO305.4: Estimate the source parameters, b-value, Poisson probability, and magnitude of earthquakes.

1. Exposure to earthquake instruments available in the department
2. Identification of seismic phases on seismograms
3. Location of epicenters
4. Fault plane Solutions
5. Frequency magnitude analysis of earthquake data
6. Estimation of decay constant (p-value) from aftershocks data
7. Estimation of b-value from earthquake data.
8. Estimation of source parameters of earthquakes.
9. Estimation of magnitudes of earthquake
10. Estimation of Poisson probability for earthquake occurrences
11. Draw isoseismal lines and prepare intensity map from given data.
12. Exposure to seismological soft wares like PITSA, SEISAN etc.

GP-306: Geophysical Lab-IV

Credits : 6

Max. Marks: 90
Time: 4 hours

Course Outcomes:

On completion of this course, the students will be able to:
CO306.1: Solve geophysical problems based on Gravity, Magnetic and Electrical methods.
CO306.2: Learn acquisition, processing and interpretation of gravity, magnetic and electrical data.
CO306.3: Communicate effectively, demonstrate and understanding of geophysical knowledge.
CO306.4: Tackle the issues of professional geophysical practices.

1. Exposure to the electrical, magnetic and gravity instruments available in the department
2. Interpretation of VES data using partial curve matching, computer programs and filtering techniques
3. Preparing electrical sections and correlation with lithological logs
4. Reduction of gravity data, Applications of drift correction, Free air correction, Bouguer correction.
5. Calculation of Free Air Anomalies & Bouguer anomalies and their interpretation
6. Estimation of Bouguer density using Nettleton mrthod
7. Calculation of Gravity and Magnetic effects due to simple shapes bodies.
8. Reduction of magnetic data
9. Interpretation of magnetic data using various techniques

OE-306: Earthquake Hazard and Mitigation

Max. Marks: 35
Credits : 2 Time: 2 hours

Course Outcomes:

On completion of this course, the students will be able to:

CO306.1: Acquiring knowledge about the earthquakes and related geophysical phenomenon to understand the earth.

CO306.2: Communicate effectively, demonstrate and understanding of geophysical knowledge.

Special Notes:

Five questions will be set and students will attempt three questions. Question No. I will be compulsory of 20 marks and based on the conceptual aspects of the whole syllabus. The answers should not be in yes/no. In addition to question no. 1, there will be two units in the question paper each containing two questions of 15 marks each belonging to two units in the syllabus. Students will select one question from each unit.

UNIT-I:

Earthquakes, Cause of Earthquakes: Volcanic and Tectonic Causes, Seismic waves: Body and Surface waves, Plate Tectonics and Seismicity, Elastic rebound theory, Measurement of earthquakes, seismometer and seismograph, Intensity and magnitude scales,

UNIT-II:

Seismic Hazard: Probabilistic and Deterministic approaches, Seismic Risk, Seismic Gaps, Seismic Zones of India, Strong ground motions and its parameters, Factors affecting strong ground motions, Simulation of strong ground motions

RECOMMENDED BOOKS

(1) Introduction to seismology: Peter M. shearer
(2) Modern Global Seismology: Lay & Wallace
(3) Earthquake Hazard Analysis: L. Reiter
(4) An introduction to seismology, earthquakes and Earth structure: Stein & Wysession

GP-401: Petrophysics And Well Logging

Max. Marks: 60

Credits: 4 Time: 3 hours

Course Outcomes:

After completion of this course, the students will be able to:

CO401.1: Develop knowledge about the well logging technique and petrophysical properties of reservoirs

CO401.2: Learn lithological logs (spontaneous and Gamma-Gamma ray logging)

CO401.3: Understand the porosity logs for the determination of different types of porosities of rocks.

CO401.4: Learn different kinds of electrical and resistivity logging techniques for the determination of saturation of hydrocarbon

Special Notes:

Nine questions will be set and students will attempt five questions. Question No.1 is compulsory and based on the conceptual aspects of the whole syllabus. It can have 5 to 10 parts. The answer should not be in yes and no. In addition to Question 1, there will be four unit question paper each containing two questions belonging to four units in the syllabus. Students will select one question from each unit.

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

Recommended Books:

1. Standard Methods of Geophysical Formation Evaluation: James K. Hallenburg
2. Practical Formation Evaluation: Robert C. Ransom
3. The geological Interpretation of Well Logs : Malcolm Rider

4. Well Logging for Earth Scientists: Darwin V. Ellis
5. Petrophysics- Theory and Practice of Measuring Reservoir Rock and fluid Transport Properties: Djebbar Tiab and Erle C. Donaldson

GP-402 Physical Oceanography and Marine Geophysics

Credits: 4

Max. Marks: 60
Time: 3 hours

<u>Course Outcomes:</u>

On completion of this course, the students will be able to

CO402.1: Understand the physical properties, movement, and pollution in ocean waters.
CO402.2: Derive equation of motion for ocean waters and understand all the component forces.
CO402.3: Know the resource potential of land below ocean waters and the geophysical signatures in areas of continental margins.
CO402.4: Know the geophysical studies for volcanism, seismicity, crustal deformation and learn about the resource potential in Indian continental margins.

Special Notes:
Nine questions will be set and students will attempt five questions. Question No.1 is compulsory and based on the conceptual aspects of the whole syllabus. It can have 5 to 10 parts. The answer should not be in yes and no. In addition to Question 1, there will be four unit question paper each containing two questions belonging to four units in the syllabus. Students will select one question from each unit

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.

Recommended Books:

1. The Earth, Tarbuck and Lutgens
2. Descriptive Physical oceanography, Pickard Lmerv
3. Estuaries- Introduction, Dyer
4. Oceanography, Ross
5. Dynamical Ocenography, Pond and Pickard
6. The Sea, Hill
7. Nettleton, Gravity and Magnetics in Oil prospecting
8. McQuillin and Ardus, Exploring the geology of shelf area

GP-403: Seismic Prospecting

Credits : 4

Max. Marks: 60
Time: 3 hours

Course Outcomes:

On completion of this course, the students will be able to

CO403.1: Understand the fundamentals of seismic methods in oil and gas exploration.
CO403.2: Design seismic acquisition survey and understand various types of seismic sources.
CO403.3: Design a sequence for processing the seismic data at hand and understand the theory of each processing step.
CO403.4: Gain knowledge of seismic interpretation using concept of amplitude variation with offset (A.V.O.) and pattern recognition.

Special Notes:
Nine questions will be set and students will attempt five questions. Question No.1 is compulsory and based on the conceptual aspects of the whole syllabus. It can have 5 to 10 parts. The answer should not be in yes and no. In addition to Question 1, there will be four unit question paper each containing two questions belonging to four units in the syllabus. Students will select one question from each unit

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.

Recommended Books:

1. Dobrin, M.B Introduction to Geophysical Prospecting
2. W.M.Telford et al Applied eophysics
3. Keary and Brooks Introduction to Geophysical Exploration
4. Waters, R.H.. Reflection Seismology
5. Robinson Basic Exploration Geophysics

6. Sheriff, R.E Seismic Stratigraphy
7. Nelson, H.R New technologies in Exploration Geophysics
8. Lavergne, M. Seismic Methods

GP-404: Geophysical Inversion

Credits : 4

Max. Marks: 60
Time: 3 hours

Course Outcomes:

On completion of this course, the students will be able to:

CO404.1: Differentiate between forward and inverse problems. Ability to formulate inverse problems and solution of linear inverse problems.

CO404.2: Get acquainted with the techniques of Finite difference method and Finite element method.

CO404.3: Acquire the knowledge about the techniques for checking the quality of solution of inverse problems, the Singular Value Decomposition and techniques to solve non-linear inverse problems.

CO404.4: Learn about global optimization techniques and statistical approach of inverse problems.

Special Notes:

(i) Nine questions will be set and students will attempt five questions. Question no. I will be compulsory and based on the conceptual aspects of the whole syllabus. It can have 5 to 10 parts. The answers should not be in yes/no. In addition to question no. I, there will be four units in the question paper each containing two questions belonging to four units in the syllabus. Students will select one question from each unit.

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.

Recommended Books:

(1) Geophysical data analysis: Discrete inverse theory: William Menke
(2) Deconvolution & Inversion: V.P. Dimri
(3) Geophysical Data analysis: Understanding Inverse problem theory & Practice: Max A. Meju
(4) Time series analysis and inverse theory for Geophysicists: David Gubbins
(5) Inverse problem theory methods for data fitting and model parameter estimation : I. Tarantola

GP-405: Geophysical Lab-V

Credits : 6

Max. Marks: 90
Time: 4 hours

<u>Course Outcomes:</u>

On completion of this course, the students will be able to:

CO405.1: Solve geophysical problems using Seismic principles and its techniques/tools to explore interior of earth.

CO405.2: Inculcate research aptitude to enhance the understanding of geophysical knowledge.

CO405.3: Analyse and interpret the geophysical data to communicate effectively and demonstrate for understanding of geophysical knowledge.

CO405.4: Tackle the issues of professional geophysical practices to be used in Industry.

1. Seismic Survey using engineering seismograph
2. Two layer and three layer problems of seismic refraction method for horizontal and dipping interface
3. Identification of faults on seismic refraction data
4. Static and Dynamic corrections to seismic data
5. NMO stretching effect
6. Interpretation of reflection data using $T^2 - X^2$ method, T-ΔT method etc.
7. Estimation of different types of velocities in Seismic method
8. Exposure to seismic data processing

GP-406: Geophysical Lab-VI

Credits : 6

Max. Marks: 90
Time: 4 hours

<u>Course Outcomes:</u>

On completion of this course, the students will be able to:

CO406.1: Solve geophysical problems using inversion techniques/tools.

CO406.2: Communicate effectively, demonstrate and understanding of geophysical knowledge.

CO406.3: Analyse and interpret the geophysical data.

CO406.4: Tackle the issues of professional geophysical practices.

Exercises based on:

(1) Eigen values and Eigen vectors

(2) Formulation & Solution of inverse problems

(3) Linear estimation of parameters

(4) Constrained and Unconstrained least square inversion

(5) SVD analysis

(6) Different techniques of Geophysical Inversion

GP-407: Geophysical Field Training-I

Credits: 4

Max Marks: 100
Time : 30 Minutes per student

Course Outcomes:

After completion of this course, the students will be able to

CO407.1: Inculcate the sense of scientific discussion and research aptitude.

CO407.2: Develop practical knowledge about different geophysical methods with perspective to future research.

CO407.3: Hands-on practice to different geophysical instruments and learning their operations in the field.

CO407.4: Exposure of latest geophysical techniques and software as well as developing concepts of data acquisition, processing and interpretation.

GP-501: Near. Surface Geophysics

Max. Marks: 60

Credits : 4 Time: 3 hours

Course Outcomes:

On completion of this course, the students will be able to:

CO501.1: Learn about the concept and fundamentals of near surface geophysics.

CO501.2: Understand the different applications of geophysical methods to Environmental and Engineering studies.

CO501.3: Learn about the basic of GPR data acquisition, processing and interpretation.

CO501.4: Understand the GIS Applications in Near surface Geophysics.

Special Notes:

Nine questions will be set and students will attempt five questions. Question no. I will be compulsory and based on the conceptual aspects of the whole syllabus. It can have 5 to 10 parts. The answers should not be in yes/no. In addition to question no. I, there will be four units in the question paper each containing two questions belonging to four units in the syllabus. Students will select one question from each unit.

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,

Recommended Books:

1. Near-Surface Geophysics Edited by Dwain K. Butler
2. Applied Geophysics by W. M. Telford et al.
3. Experiments in Engineering Geology by KVGK Gokhale and D M Rao
4. Geotechnical and Environmental Geophysics Edited by Stanley H.Ward
5. Environmental and Engineering Geophysics, P.V.Sharma

GP-502: Electromagnetic and Magnetotelluric Methods

Credits: 4

Max. Marks: 60
Time: 3 hours

Course Outcomes:

On completion of this course, the students will be able to:
CO502.1: Learn about the basic of Electromagnetic method.
CO502.2: Understand the data acquisition, processing and interpretation of various electromagnetic methods.
CO502.3: Learn about the basic of Magnetotelluric method, data acquisition and processing.
CO502.4: Capable of Interpretation of Magnetotelluric Data and its applications.

Special Notes:

Nine questions will be set and students will attempt five questions in all. Question No.1 is compulsory and based on the conceptual aspects of the whole syllabus. It can have 5 to 10 parts. The answer should not be in yes and no. In addition to Question 1, there will be four-unit question paper each containing two questions belonging to four units in the syllabus. Students will select one question from each unit.

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.

Recommended Books:

1. Nabighian, M. N., 1988, Electromagnetic Methods in Geophysics, Volume 1, SEG Publication.
2. Nabighian, M. N., 1991, Electromagnetic Methods in Geophysics, Volume 2, Parts A and B, SEG Publication.
3. MICHAEL S. ZHDANOV, Geophysical Electromagnetic Theory and Methods
4. Grant, F. S., and West, G. F., Interpretation Theory in Applied Geophysics
5. Telford et. al: Applied Geophysics
6. Patra & Mallick: Geosounding Principles Vol.II
7. Geoelectromagnetism: Wait, J.R.,

GP-503: Geophysical Lab-VII

Max. Marks: 90
Credits: 6 Time: 4 hours

<u>Course Outcomes:</u>

After completion of this course, the students will be able to

CO503.1: Get practical exposure to the processing and interpretation of different types of logs and designing of filters.

CO503.2: Hands-on exercise to interpret lithological logs to delineate permeable and impermeable zones.

CO503.3: Interpret resistivity and porosity logs to delineate water bearing and oil/gas bearing zones.

CO503.4: Get exposure of latest geophysical softwares for signal processing and imaging the seismic sections.

(A) Exercises based upon:

- (i) SP log
- (ii) Natural Gamma Log
- (iii) Caliper and Temperature Log
- (iv) Resistivity Log
    - (a) Micro log
    - (b) latero log
    - (c) induction log
- (v) Porosity Logs:
    - (a) Neutron log
    - (b) Acoustic log
    - (c) Density log
- (vi) Computation of formation factor and water saturation.

(B) Exercises based on

- (i) Design of optimum wiener filter
- (ii) Exercises on Seismic Signal Processing softwares like PITSA, GEODEPTH, FOCUS etc

GP-504: Geophysical Lab-VIII

Credits : 6

Max. Marks: 90
Time: 4 hours

Course Outcomes:

On completion of this course, the students will be able to

CO504.1: Demonstrate and apply geophysical knowledge as a member/leader of the team.
CO504.2: Capable of identifying, formulating and analysing the given geophysical problem.
CO504.3: Develop critical thinking and develop skills to write a project report.
CO504.4: Communicate effectively, demonstrate and understanding of geophysical knowledge.

Problems/Case studies based on Geophysical Methods including:

(i) Seismology

(ii) Exploration Seismology

(iii) Seismic Signal Processing

(iv) Gravity & Magnetic Methods

(v) Electrical Methods

(vi) Geophysical Well logging

(vii) Remote Sensing & GIS

GP-506: Computational Seismology

Credits : 4

Max. Marks: 60
Time: 3 hours

Course Outcomes:

On completion of this course, the students will be able to:

CO506.1: Understand the concepts and simulating techniques of earthquake strong ground motions.
CO506.2: Understand the wave attenuation, Quality factor (Q) and techniques of determining Q and earthquake source parameters.
CO506.3: Understand the concepts of earthquake hazard, probabilistic and deterministic approach, microzonation and site amplification functions.
CO506.4: Understand the seismic tomography, velocity analysis, seismicity parameters, fractals, ray tracing, GPS, anisotropy and time predictable model.

Special Notes:
(i) Nine questions will be set and students will attempt five questions. Question no. I will be compulsory and based on the conceptual aspects of the whole syllabus. It can have 5 to 10 parts. The answers should not be in yes/no. In addition to question no. I, there will be four units in the question paper each containing two questions belonging to four units in the syllabus. Students will select one question from each unit.

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.

RECOMMENDED BOOKS

(1) Quantity Seismology: Aki and Richards

(2) Introduction to seismology: Peter M. shearer
(3) Modern Global Seismology: Lay & Wallace
(4) Earthquake Hazard Analysis: L. Reiter
(5) An introduction to seismology, earthquakes and Earth structure: Stein & Wysession

GP-513: Seismic Data Analysis and Reservoir Geophysics

Credits : 4

Max. Marks: 60
Time: 3 hours

Course Outcomes:

On completion of this course, the students will be able to

CO513.1: Understand the sequence of seismic data processing.

CO513.2: Understand the technique of seismic deconvolution and seismic migration in data processing.

CO513.3: Understand the concepts of seismic modeling in application to the seismic reservoir.

CO513.4: Understand the various seismic reservoir exploration and surveillance techniques: A.V.O. analysis, 4D monitoring, and 4C analysis.

Special Notes:

(i) Nine questions will be set and students will attempt five questions. Question no. I will be compulsory and based on the conceptual aspects of the whole syllabus. It can have 5 to 10 parts. The answers should not be in yes/no. In addition to question no. I, there will be four units in the question paper each containing two questions belonging to four units in the syllabus. Students will select one question from each unit.

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.

Recommended Books:

1. Seismic Data Analysis, Vol. I&II, ÖZYILMAZ.
2. Reservoir Geophysics, Robert E.Sheriff.
3. Seismic Modeling of Geologic Structures, Stuart W.Fagin.
4. Introduction to Seismic Inversion Method, Brian H.Russell

GP-517: Artificial Intelligence & Machine Learning In Geophysics

Credits : 4

Max. Marks: 60
Time: 3 hours

<u>Course Outcomes:</u>

On completion of this course, the students will be able to

CO517.1: Understand basic concepts of machine learning and artificial intelligence.

CO517.2: Understands the concept of seismic methods and know similarity and differences between Inversion and Artificial Intelligence.

CO517.3: Use Python programming language for application in machine learning and artificial intelligence.

CO517.4: Understand the application of machine learning and artificial intelligence in seismic processing and seismic interpretation.

Special Notes:

Nine questions will be set and students will attempt five questions. Question No.1 is compulsory and based on the conceptual aspects of the whole syllabus. It can have 5 to 10 parts. The answer should not be in yes and no. In addition to Question 1, there will be four unit question paper each containing two questions belonging to four units in the syllabus. Students will select one question from each unit

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.

Recommended Books:

1. Anthony Croft et al. Engineering Mathematics
2. Martin C. Brown Python the compelete reference
3. R. Nageshwara Rao Core Python Programming

GP-601: Dissertation

Max. Marks: 400

Credits: 16 **Time : 30 Minutes per student**

Course Outcomes:

On completion of this course, the students will be able to

CO601.1: Demonstrate and apply geophysical knowledge as a member/leader of the team to solve a minor research problem.

CO601.2: Capable of identifying, formulating and analysing the given geophysical problem.

CO601.3: Develop critical thinking and develop skills to write a Dissertation report.

CO601.4: Communicate effectively, demonstrate and understanding of geophysical knowledge.

Objective and Output:

Every student is required to undertake a project in the last semester. The project may be an experimental investigation, field work and laboratory studies, a theoretical investigation accompanied by computation work, data processing and analysis or combination of these. The exact nature of the project and the problem is decided by the chairperson of the department in consultation with faculty members and students. After the project is completed the students will submit two copies of dissertation based on the results obtained in the investigation. Finally the student is expected to defend his findings as embodied in his dissertation before a board of examinations and take an oral examination.

This will inculcate the research aptitude in the students.

GP- 602: Comprehensive Viva-Voce

Credits:4 **Max. Marks: 100**

Time : 30 Minutes per student

Course Outcomes:

On completion of this course, the students will be able to

CO602.1: Prepare themselves for the various competitive examinations held by various organizations including ONGC, GSI, GATE, CSIR-JRF-NET, Ground water boards etc.

CO602.2: Demonstrate comprehensive knowledge and understanding of the Geophysics discipline.

CO602.3: Communicate effectively the Geophysical knowledge.

Note:

Every student shall be required to appear for comprehensive viva-voce examination based on complete M.Tech. (Applied Geophysics) course before a committee of teachers of the department.

GP-603: Seminar

Credits: 4 **Max. Marks: 100**
Time : One Hour per student

<u>Course Outcomes:</u>

On completion of this course, the students will be able to
CO603.1: Communicate effectively on Geophysical topics.
CO603.2: Demonstrate comprehensive knowledge and understanding of the Geophysical principles.
CO603.3: Learn techniques for professional practices including writing a scientific report.

Objective and Output:

In order to inculcate sense of confidence and self reliance and with a view to train the student in the art of public speaking and self expression, each student is required to deliver a talk on a particular topic during sixth semester. The topic of the seminar is selected by the students under the advice of a teacher of the department. This is accompanied by a write up. Besides delivering a seminar talk a student is expected to attend all other seminars delivered by other students. The seminar shall be evaluated by a committee of the teachers of the department.

GP- 604: Geophysical Field Training-II

Credits:4 **Max. Marks: 100**
Time : 30 Minutes per student

<u>Course Outcomes:</u>

On completion of this course, the students will be able to
CO604.1: Learn practical knowledge of different instruments/Geophysical techniques and will be able to do the acquisition, processing and interpretation of Geophysical data. Prepare themselves for the industrial environment.
CO604.2: To develop critical thinking and skills to write the project report.
CO604.3: To work effectively as an individual as well as team work.
CO604.4: Communicate effectively and demonstrate the geophysical knowledge.

CO-PO mapping matrix for the course GP-101 (Mathematical Methods in Geophysics)

COs#	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO101.1	3	2	2	2	-	2	1	1	1	1	1
CO101.2	3	2	2	2	-	2	1	1	1	1	1
CO101.3	3	2	2	2	-	2	1	1	1	2	2
CO101.4	3	1	2	2	-	2	1	1	1	1	1
Average	**3**	**1.8**	**2**	**2**	**-**	**2**	**1**	**1**	**1**	**1.3**	**1.3**

CO-PSO mapping matrix for the course GP-101 (Mathematical Methods in Geophysics)

COs#	PSO1	PSO2	PSO3	PSO4
CO101.1	3	2	3	2
CO101.2	3	2	3	2
CO101.3	3	2	3	3
CO101.4	3	2	3	2
Average	**3**	**2**	**3**	**2.3**

CO-PO mapping matrix for the course GP-102: Solid Earth Geophysics

COs#	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO102.1	3	1	2	1	1	1	1	1	2	1	1
CO102.2	3	1	2	1	1	1	1	1	2	1	1
CO102.3	3	1	2	2	1	2	1	1	2	1	1
CO102.4	3	2	2	2	1	2	1	1	2	1	1
Average	**3**	**1.3**	**2**	**1.5**	**1**	**1.5**	**1**	**1**	**2**	**1**	**1**

CO-PSO mapping matrix for the course GP-102: Solid Earth Geophysics

COs#	PSO1	PSO2	PSO3	PSO4
CO102.1	3	1	3	1
CO102.2	3	2	2	2
CO102.3	3	1	3	1
CO102.4	3	2	2	3
Average	**3**	**1.5**	**2.5**	**1.8**

CO-PO mapping matrix for the course GP-103 (Numerical Methods and Computer Programming)

COs#	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO103.1	3	3	2	1	1	1	1	1	3	1	3
CO103.2	3	3	2	1	1	1	2	1	3	1	2
CO103.3	3	3	2	1	1	2	2	1	3	1	2
CO103.4	3	3	2	1	1	3	3	1	3	1	2
Average	**3**	**3**	**2**	**1**	**1**	**1.8**	**2**	**1**	**3**	**1**	**2.3**

CO-PSO mapping matrix for the course GP-103 (Numerical Methods and Computer Programming)

COs#	PSO1	PSO2	PSO3	PSO4
CO103.1	1	3	3	3
CO103.2	3	2	2	3
CO103.3	3	2	2	3
CO103.4	3	2	3	3
Average	**2.5**	**2.3**	**2.5**	**3**

CO-PO mapping matrix for the course GP-104 (Basic Geology)

COs#	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO104.1	3	1	2	--	1	1	--	--	2	1	1
CO104.2	3	1	2	--	1	1	--	1	2	1	1
CO104.3	3	1	2	--	1	1	--	1	2	1	1
CO104.4	3	1	2	--	1	1	--	1	2	1	1
Average	**3**	**1**	**2**	**--**	**1**	**1**	**--**	**1**	**2**	**1**	**1**

CO-PSO mapping matrix for the course GP-104 (Basic Geology)

COs#	PSO1	PSO2	PSO3	PSO4
CO104.1	2	2	2	2
CO104.2	2	2	2	2
CO104.3	2	2	2	2
CO104.4	2	2	2	2
Average	**2**	**2**	**2**	**2**

CO-PO mapping matrix for the course GP-105 (Geology Lab.)

COs#	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO105.1	3	1	1	1	1	2	1	1	2	1	1
CO105.2	3	2	3	1	2	2	2	1	2	1	2
CO105.3	3	2	2	2	2	2	2	1	2	1	2
CO105.4	3	3	2	3	1	2	2	1	2	1	2
Average	**3**	**2**	**2**	**1.8**	**1.5**	**2**	**1.8**	**1**	**2**	**1**	**1.8**

CO-PSO mapping matrix for the course GP-105 (Geology Lab.)

COs#	PSO1	PSO2	PSO3	PSO4
CO105.1	2	1	3	1
CO105.2	1	2	3	1
CO105.3	1	2	2	3
CO105.4	3	3	2	3
Average	**1.8**	**2**	**2.5**	**2**

CO-PO mapping matrix for the course GP-106 (Computer Lab.)

COs#	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO106.1	3	2	2	2	2	2	2	2	3	1	2
CO106.2	3	2	2	2	2	3	2	2	3	1	2
CO106.3	3	3	2	3	2	2	2	2	3	1	2
CO106.4	3	3	2	3	2	2	2	3	3	1	2
Average	**3**	**2.5**	**2**	**2.5**	**2**	**2.3**	**2**	**2.3**	**3**	**1**	**2**

CO-PSO mapping matrix for the course GP-106 (Computer Lab.)

COs#	PSO1	PSO2	PSO3	PSO4
CO106.1	1	2	3	3
CO106.2	2	2	2	3
CO106.3	2	2	2	3
CO106.4	2	2	3	3
Average	**1.8**	**2**	**2.5**	**3**

CO-PO mapping matrix for the course GP-201 (Remote Sensing and GIS)

COs#	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO201.1	3	1	2	1	1	1	1	-	2	1	1
CO201.2	3	1	2	1	1	1	2	-	2	1	1
CO201.3	3	1	2	1	1	1	2	-	2	1	1
CO201.4	3	1	2	2	1	1	2	-	2	1	1
Average	**3**	**1**	**2**	**1.3**	**1**	**1**	**1.8**	**-**	**2**	**1**	**1**

CO-PSO mapping matrix for the course GP-201 (Remote Sensing and GIS)

COs#	PSO1	PSO2	PSO3	PSO4
CO201.1	2	2	1	1
CO201.2	2	2	1	3
CO201.3	2	2	1	2
CO201.4	2	2	2	2
Average	**2**	**2**	**1.8**	**2**

CO-PO mapping matrix for the course GP-202 (Advanced Computing)

COs#	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO202.1	3	2	2	3	2	2	2	2	2	1	1
CO202.2	3	2	2	3	2	2	2	2	2	1	1
CO202.3	3	2	2	3	2	2	2	2	2	1	1
CO202.4	3	2	2	2	2	2	3	2	2	1	1
Average	**3**	**2**	**2**	**2.8**	**2**	**2**	**2.3**	**2**	**2**	**1**	**1**

CO-PSO mapping matrix for the course GP-202 (Advanced Computing)

COs#	PSO1	PSO2	PSO3	PSO4
CO202.1	2	3	2	1
CO202.2	2	3	2	1
CO202.3	2	3	2	1
CO202.4	2	3	2	2
Average	**2**	**3**	**2**	**1.3**

CO-PO mapping matrix for the course GP-203 (Geophysical Signal Processing)

COs#	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO203.1	3	2	2	2	1	2	1	1	2	1	1
CO203.2	3	2	2	1	1	2	1	1	2	1	1
CO203.3	3	2	2	2	1	2	3	1	2	1	1
CO203.4	3	2	2	1	1	2	3	1	2	1	1
Average	**3**	**2**	**2**	**1.5**	**1**	**2**	**2**	**1**	**2**	**1**	**1**

CO-PSO mapping matrix for the course GP-203 (Geophysical Signal Processing)

COs#	PSO1	PSO2	PSO3	PSO4
CO203.1	3	2	3	2
CO203.2	3	2	3	2
CO203.3	3	2	3	2
CO203.4	3	2	3	2
Average	**3**	**2**	**3**	**2**

CO-PO mapping matrix for the course GP-204 (Geophysical Fields and Waves)

COs#	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO204.1	3	1	2	1	1	2	--	--	2	1	1
CO204.2	3	1	2	1	1	1	--	--	2	1	1
CO204.3	3	1	2	1	1	2	1	--	2	1	1
CO204.4	3	1	2	1	1	1	1	--	2	1	1
Average	**3**	**1**	**2**	**1**	**1**	**1.5**	**1**	--	**2**	**1**	**1**

CO-PSO mapping matrix for the course GP-204 (Geophysical Fields and Waves)

COs#	PSO1	PSO2	PSO3	PSO4
CO204.1	2	2	2	1
CO204.2	2	2	2	1
CO204.3	2	2	2	2
CO204.4	2	2	2	2
Average	**2**	**2**	**2**	**1.5**

CO-PO mapping matrix for the course GP-205 (Geophysical Lab.-I)

COs#	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO205.1	2	3	--	2	2	3	--	2	1	1	2
CO205.2	2	2	--	2	2	3	--	3	2	1	2
CO205.3	2	1	2	2	2	3	1	1	2	1	2
CO205.4	2	1	2	2	2	3	1	1	2	1	2
Average	**2**	**1.8**	**2**	**2**	**2**	**3**	**1**	**1.8**	**1.8**	**1**	**2**

CO-PSO mapping matrix for the course GP-205 (Geophysical Lab.-I)

COs#	PSO1	PSO2	PSO3	PSO4
CO205.1	2	2	2	2
CO205.2	2	2	2	2
CO205.3	2	2	2	2
CO205.4	2	2	2	2
Average	**2**	**2**	**2**	**2**

CO-PO mapping matrix for the course GP-206 (Geophysical Lab. – II)

COs#	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO402.1	3	2	2	2	2	3	2	1	2	1	1
CO402.2	3	2	2	2	2	3	2	1	2	1	1
CO402.3	3	2	2	2	2	3	2	1	2	1	1
CO402.4	3	2	2	2	2	3	2	1	2	1	1
Average	**3**	**2**	**2**	**2**	**2**	**3**	**2**	**1**	**2**	**1**	**1**

CO-PSO mapping matrix for the course GP-206 (Geophysical Lab. – II)

COs#	PSO1	PSO2	PSO3	PSO4
CO402.1	3	2	3	3
CO402.2	3	2	3	3
CO402.3	3	2	3	3
CO402.4	3	2	3	3
Average	**3**	**2**	**3**	**3**

CO-PO mapping matrix for the course GP-207 (Geological Field Training)

COs#	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO207.1	3	3	2	2	3	3	2	1	2	1	2
CO207.2	3	1	2	2	3	3	3	1	2	1	2
CO207.3	3	3	2	2	3	3	2	1	1	1	2
CO207.4	3	1	2	2	3	1	2	2	3	1	3
Average	**3**	**2**	**2**	**2**	**3**	**2.5**	**2.3**	**1.3**	**2**	**1**	**2.3**

CO-PSO mapping matrix for the course GP-207 (Geological Field Training)

COs#	PSO1	PSO2	PSO3	PSO4
CO207.1	2	2	1	1
CO207.2	2	2	1	2
CO207.3	1	3	2	2
CO207.4	1	1	2	1
Average	**1.5**	**2**	**1.5**	**1.5**

CO-PO mapping matrix for the course GP-301 (Seismology)

COs#	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO301.1	3	3	2	2	--	1	2	2	3	1	3
CO301.2	3	3	2	1	--	1	2	1	3	1	2
CO301.3	3	3	2	1	1	2	2	2	3	1	2
CO301.4	3	3	2	2	1	3	2	3	3	1	2
Average	**3**	**3**	**2**	**1.5**	**1**	**1.8**	**2**	**2**	**3**	**1**	**2.3**

CO-PSO mapping matrix for the course GP-301 (Seismology)

COs#	PSO1	PSO2	PSO3	PSO4
CO301.1	3	2	3	3
CO301.2	3	3	2	3
CO301.3	2	2	2	3
CO301.4	2	2	3	3
Average	**2.5**	**2.3**	**2.5**	**3**

CO-PO mapping matrix for the course GP-302 (Gravity and Magnetic Prospecting)

COs#	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO302.1	3	1	2	1	--	1	1	1	3	1	3
CO302.2	3	-	2	1	--	--	2	1	3	1	2
CO302.3	3	2	2	1	--	2	2	1	3	1	2
CO302.4	3	2	2	1	--	3	3	1	3	1	2
Average	**3**	**1.7**	**2**	**1**	**--**	**2**	**2**	**1**	**3**	**1**	**2.3**

CO-PSO mapping matrix for the course GP-302 (Gravity and Magnetic Prospecting)

COs#	PSO1	PSO2	PSO3	PSO4
CO302.1	1	1	3	3
CO302.2	3	2	2	3
CO302.3	3	2	2	3
CO302.4	3	2	3	3
Average	**2.5**	**1.8**	**2.5**	**3**

CO-PO mapping matrix for the course GP-303 (Groundwater Geophysics)

COs#	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO303.1	3	1	2	1	1	1	1	2	2	1	1
CO303.2	3	1	2	1	1	1	1	2	2	1	1
CO303.3	3	1	2	1	1	1	2	2	2	1	1
CO303.4	3	1	2	1	1	1	2	2	2	1	1
Average	**3**	**1**	**2**	**1**	**1**	**1**	**1.5**	**2**	**2**	**1**	**1**

CO-PSO mapping matrix for the course GP-303 (Groundwater Geophysics)

COs#	PSO1	PSO2	PSO3	PSO4
CO303.1	3	1	2	2
CO303.2	3	2	2	1
CO303.3	3	1	2	1
CO303.4	3	2	2	2
Average	**3**	**1.5**	**2**	**1.5**

CO-PO mapping matrix for the course GP-304 (Electrical Prospecting)

COs#	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO304.1	3	2	2	2	1	2	1	1	2	1	1
CO304.2	3	2	2	2	1	2	1	1	2	1	1
CO304.3	3	2	2	2	1	2	2	2	2	1	1
CO304.4	3	2	2	2	1	2	2	2	2	1	1
Average	**3**	**2**	**2**	**2**	**1**	**2**	**1.5**	**1.5**	**2**	**1**	**1**

CO-PSO mapping matrix for the course GP-304 (Electrical Prospecting)

COs#	PSO1	PSO2	PSO3	PSO4
CO304.1	3	2	3	1
CO304.2	3	2	3	2
CO304.3	3	2	3	3
CO304.4	3	2	3	3
Average	**3**	**2**	**3**	**2.2**

CO-PO mapping matrix for the course GP-305 (Geophysical Lab. – III)

COs#	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO306.1	3	3	2	3	2	2	2	1	1	1	1
CO306.2	3	3	1	2	2	3	2	1	2	1	1
CO306.3	3	3	1	1	2	2	2	1	1	1	2
CO306.4	3	3	2	1	2	2	2	1	2	1	1
Average	**3**	**3**	**1.5**	**1.8**	**2**	**2.3**	**2**	**1**	**1.5**	**1**	**1.3**

CO-PSO mapping matrix for the course GP-305 (Geophysical Lab. – III)

COs#	PSO1	PSO2	PSO3	PSO4
CO306.1	3	2	3	2
CO306.2	3	2	3	3
CO306.3	3	2	2	3
CO306.4	3	2	2	3
Average	**3**	**2**	**2.5**	**2.8**

CO-PO mapping matrix for the course GP-306 (Geophysical Lab. – IV)

COs#	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO306.1	2	1	2	3	1	2	2	1	3	1	2
CO306.2	2	2	2	2	1	3	2	1	3	1	2
CO306.3	2	2	2	2	1	2	2	1	3	1	2
CO306.4	2	1	2	1	1	2	2	3	3	1	1
Average	**2**	**1.5**	**2**	**2**	**1**	**2.3**	**2**	**1.5**	**3**	**1**	**1.8**

CO-PSO mapping matrix for the course GP-306 (Geophysical Lab. – IV)

COs#	PSO1	PSO2	PSO3	PSO4
CO306.1	3	3	3	2
CO306.2	3	3	3	3
CO306.3	3	3	3	2
CO306.4	2	3	2	1
Average	**2.8**	**3**	**2.8**	**2**

CO-PO mapping matrix for the course GP-401: Petrophysics and Well logging

COs#	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO401.1	3	1	2	1	1	2	1	1	2	1	2
CO401.2	3	1	2	2	1	2	1	1	2	1	2
CO401.3	3	1	2	1	1	2	1	1	2	1	2
CO401.4	3	1	2	2	1	2	1	1	2	1	2
Average	**3**	**1**	**2**	**1.5**	**1**	**2**	**1**	**1**	**2**	**1**	**2**

CO-PSO mapping matrix for the course GP-401: Petrophysics and Well logging

COs#	PSO1	PSO2	PSO3	PSO4
CO401.1	3	2	3	2
CO401.2	3	2	3	2
CO401.3	3	2	3	2
CO401.4	3	2	3	2
Average	**3**	**2**	**3**	**2**

CO-PO mapping matrix for the course GP-402 (Physical Oceanography and Marine Geophysics)

COs#	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO402.1	3	1	2	2	1	3	1	1	2	1	1
CO402.2	3	1	2	2	1	3	1	1	2	1	-
CO402.3	3	1	2	2	1	3	1	1	2	1	1
CO402.4	3	1	2	2	1	3	1	1	2	1	1
Average	**3**	**1**	**2**	**2**	**1**	**3**	**1**	**1**	**2**	**1**	**1**

CO-PSO mapping matrix for the course GP-402 (Physical Oceanography and Marine Geophysics)

COs#	PSO1	PSO2	PSO3	PSO4
CO402.1	3	2	3	3
CO402.2	3	2	3	3
CO402.3	3	2	3	2
CO402.4	3	2	3	2
Average	**3**	**2**	**3**	**2.5**

CO-PO mapping matrix for the course GP-403 (Seismic Prospecting)

COs#	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO404.1	3	1	2	1	1	2	1	1	2	1	1
CO404.2	3	1	2	1	1	1	1	1	2	1	1
CO404.3	3	2	2	1	1	2	3	1	2	1	1
CO404.4	3	2	2	1	1	1	3	1	2	1	1
Average	**3**	**1.5**	**2**	**1**	**1**	**1.5**	**2**	**1**	**2**	**1**	**1**

CO-PSO mapping matrix for the course GP-403 (Seismic Prospecting)

COs#	PSO1	PSO2	PSO3	PSO4
CO404.1	3	2	3	3
CO404.2	3	2	3	3
CO404.3	3	2	3	3
CO404.4	3	2	3	3
Average	**3**	**2**	**3**	**3**

CO-PO mapping matrix for the course GP-404 (Geophysical Inversion)

COs#	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO404.1	3	2	1	2	--	2	2	1	3	--	1
CO404.2	3	2	1	2	--	2	2	1	3	--	1
CO404.3	3	2	1	2	--	2	3	1	3	2	2
CO404.4	3	2	1	2	--	3	3	1	3	2	2
Average	**3**	**2**	**1**	**2**	**--**	**2.3**	**2.5**	**1**	**3**	**2**	**1.5**

CO-PSO mapping matrix for the course GP-404 (Geophysical Inversion)

COs#	PSO1	PSO2	PSO3	PSO4
CO404.1	3	1	1	1
CO404.2	3	2	1	2
CO404.3	3	3	2	3
CO404.4	3	3	2	3
Average	**3**	**2.3**	**1.5**	**2.3**

CO-PO mapping matrix for the course GP-405 (Geophysical Lab.-V)

COs#	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO405.1	3	3	2	3	2	2	2	2	3	1	2
CO405.2	3	3	2	2	2	2	2	2	3	1	2
CO405.3	3	2	3	3	2	2	2	2	3	1	2
CO405.4	3	2	3	2	2	3	2	2	3	1	2
Average	**3**	**2.5**	**2.5**	**2.5**	**2**	**2.3**	**2**	**2**	**3**	**1**	**2**

CO-PSO mapping matrix for the course GP-405 (Geophysical Lab.-V)

COs#	PSO1	PSO2	PSO3	PSO4
CO405.1	3	3	2	3
CO405.2	2	3	3	3
CO405.3	3	2	2	3
CO405.4	2	2	3	3
Average	**2.5**	**2.5**	**2.5**	**3**

CO-PO mapping matrix for the course GP-406 (Geophysical Lab.-VI)

COs#	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO406.1	3	2	1	3	1	2	2	1	3	--	1
CO406.2	3	2	3	1	1	2	2	1	3	1	2
CO406.3	3	2	2	3	1	2	2	1	3	3	2
CO406.4	2	2	1	1	1	2	3	3	3	1	1
Average	**2.8**	**2**	**1.8**	**2**	**1**	**2**	**2.3**	**1.5**	**3**	**1.7**	**1.5**

CO-PSO mapping matrix for the course GP-406 (Geophysical Lab.-VI)

COs#	PSO1	PSO2	PSO3	PSO4
CO406.1	2	3	2	2
CO406.2	2	3	3	1
CO406.3	3	2	2	2
CO406.4	1	3	2	2
Average	**2**	**2.8**	**2.3**	**1.8**

CO-PO mapping matrix for the course GP-407: Geophysical Field Training-I

COs#	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO407.1	3	3	3	3	2	2	1	2	1	2	2
CO407.2	3	2	2	3	2	1	1	2	1	2	2
CO407.3	3	2	2	3	2	2	1	2	1	2	2
CO407.4	3	2	2	3	2	1	1	2	1	2	2
Average	**3**	**2.3**	**2.3**	**3**	**2**	**1.5**	**1**	**2**	**1**	**2**	**2**

CO-PSO mapping matrix for the course GP-407: Geophysical Field Training-I

COs#	PSO1	PSO2	PSO3	PSO4
CO407.1	3	3	2	3
CO407.2	3	2	2	3
CO407.3	3	2	2	3
CO407.4	3	2	2	3
Average	**3**	**2.3**	**2**	**3**

CO-PO mapping matrix for the course GP-501 (Near Surface Geophysics)

COs#	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO501.1	3	2	2	1	1	2	1	1	2	1	1
CO501.2	3	2	2	2	1	2	1	1	2	1	1
CO501.3	3	2	2	2	1	2	2	1	2	1	1
CO501.4	3	2	2	2	1	2	2	1	2	1	1
Average	**3**	**2**	**2**	**1.8**	**1**	**2**	**1.5**	**1**	**2**	**1**	**1**

CO-PSO mapping matrix for the course GP-501 (Near Surface Geophysics)

COs#	PSO1	PSO2	PSO3	PSO4
CO501.1	3	2	3	1
CO501.2	3	2	3	1
CO501.3	3	2	3	3
CO501.4	3	2	3	3
Average	**3**	**2**	**3**	**2**

CO-PO mapping matrix for the course GP-502 (Electromagnetic and Magnetotelluric Methods)

COs#	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO502.1	3	2	2	1	1	2	1	1	2	1	1
CO502.2	3	2	2	1	1	2	2	1	2	1	1
CO502.3	3	2	2	1	1	2	2	1	2	1	1
CO502.4	3	2	2	1	1	2	2	1	2	1	1
Average	**3**	**2**	**2**	**1**	**1**	**2**	**1.7**	**1**	**2**	**1**	**1**

CO-PSO mapping matrix for the course GP-502 (Electromagnetic and Magnetotelluric Methods)

COs#	PSO1	PSO2	PSO3	PSO4
CO502.1	3	2	3	1
CO502.2	3	2	3	3
CO502.3	3	2	3	3
CO502.4	3	2	3	3
Average	**3**	**2**	**3**	**2.5**

CO-PO mapping matrix for the course GP-503: Geophysical Lab-VII

COs#	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO503.1	3	2	2	3	2	2	2	1	2	1	2
CO503.2	3	2	2	3	2	1	1	1	2	1	2
CO503.3	3	2	2	3	2	2	2	1	2	1	2
CO503.4	3	2	2	3	2	1	1	1	2	1	1
Average	**3**	**2**	**2**	**3**	**2**	**1.5**	**1.5**	**1**	**2**	**1**	**1.8**

CO-PSO mapping matrix for the course GP-503: Geophysical Lab-VII

COs#	PSO1	PSO2	PSO3	PSO4
CO503.1	3	3	2	3
CO503.2	3	3	2	3
CO503.3	3	3	2	3
CO503.4	3	3	2	3
Average	**3**	**3**	**2**	**3**

CO-PO mapping matrix for the course GP-504 (Geophysical Lab.- VIII)

COs#	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO504.1	3	2	2	1	3	1	--	1	3	--	3
CO504.2	3	3	2	3	--	2	1	1	3	1	1
CO504.3	3	2	1	2	--	3	3	2	3	1	--
CO504.4	2	1	3	1	2	1	2	1	3	1	2
Average	**2.8**	**2**	**2**	**1.8**	**2.5**	**1.8**	**2**	**1.3**	**3**	**1**	**2**

CO-PSO mapping matrix for the course GP-504 (Geophysical Lab. -VIII)

COs#	PSO1	PSO2	PSO3	PSO4
CO504.1	3	1	3	2
CO504.2	3	3	2	2
CO504.3	1	3	3	2
CO504.4	2	2	3	1
Average	**2.3**	**2.3**	**2.8**	**1.8**

CO-PO mapping matrix for the course GP-506 (Computational Seismology)

COs#	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO506.1	3	2	1	2	1	2	2	1	3	1	2
CO506.2	3	2	1	2	1	2	2	1	3	1	2
CO506.3	3	2	1	2	1	2	2	1	3	1	2
CO506.4	3	2	1	2	1	2	2	1	3	1	2
Average	**3**	**2**	**1**	**2**	**1**	**2**	**2**	**1**	**3**	**1**	**2**

CO-PSO mapping matrix for the course GP-506 (Computational Seismology)

COs#	PSO1	PSO2	PSO3	PSO4
CO506.1	3	3	3	2
CO506.2	3	3	2	2
CO506.3	3	3	2	2
CO506.4	3	3	2	2
Average	**3**	**3**	**2.3**	**2**

CO-PO mapping matrix for the course GP-513 (Seismic Data Analysis and Reservoir Geophysics)

COs#	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO513.1	3	3	2	3	2	2	2	1	2	1	1
CO513.2	3	3	2	3	2	3	3	1	2	1	3
CO513.3	3	3	2	3	2	2	2	1	3	1	1
CO513.4	3	3	2	3	2	3	3	1	2	1	3
Average	**3**	**3**	**2**	**3**	**2**	**2.5**	**2.5**	**1**	**2.3**	**1**	**2**

CO-PSO mapping matrix for the course GP-513 (Seismic Data Analysis and Reservoir Geophysics)

COs#	PSO1	PSO2	PSO3	PSO4
CO513.1	3	2	2	3
CO513.2	3	3	2	3
CO513.3	3	2	2	3
CO513.4	3	3	2	3
Average	**3**	**2.5**	**2**	**3**

CO-PO mapping matrix for the course GP-517 (Artificial Intelligence & Machine Learning in Geophysics)

COs#	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO517.1	3	2	1	3	2	2	2	1	2	1	1
CO517.2	3	2	2	3	2	2	2	1	2	1	1
CO517.3	3	2	2	3	2	2	2	1	2	1	1
CO517.4	3	2	2	3	2	2	2	1	2	1	1
Average	**3**	**2**	**1.8**	**3**	**2**	**2**	**2**	**1**	**2**	**1**	**1**

CO-PSO mapping matrix for the course GP-517 (Artificial Intelligence & Machine Learning in Geophysics)

COs#	PSO1	PSO2	PSO3	PSO4
CO517.1	2	2	2	2
CO517.2	2	3	3	3
CO517.3	2	2	1	1
CO517.4	2	3	2	2
Average	**2**	**2.5**	**2**	**2**

CO-PO mapping matrix for the course GP-601 (Dissertation)

COs#	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO601.1	3	3	2	3	3	3	2	2	3	1	2
CO601.2	3	3	2	3	2	3	2	2	3	2	2
CO601.3	3	3	2	3	3	3	2	2	3	1	2
CO601.4	3	3	3	3	2	3	2	2	3	2	2
Average	**3**	**3**	**2.3**	**3**	**2.5**	**3**	**2**	**2**	**3**	**1.5**	**2**

CO-PSO mapping matrix for the course GP-601 (Dissertation)

COs#	PSO1	PSO2	PSO3	PSO4
CO601.1	3	3	3	3
CO601.2	3	3	3	3
CO601.3	3	3	3	3
CO601.4	3	3	3	3
Average	**3**	**3**	**3**	**3**

CO-PO mapping matrix for the course GP-602 (Comprehensive Viva-Voce)

COs#	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO602.1	3	--	2	1	1	--	2	1	2	1	1
CO602.2	3	--	2	1	1	--	2	1	2	1	1
CO602.3	2	--	3	--	1	--	2	1	2	1	1
Average	**2.7**	**--**	**2.3**	**1**	**1**	**--**	**2**	**1**	**2**	**1**	**1**

CO-PSO mapping matrix for the course GP-602 (Comprehensive Viva-Voce)

COs#	PSO1	PSO2	PSO3	PSO4
CO602.1	2	2	3	2
CO602.2	2	2	3	2
CO602.3	2	2	3	2
Average	**2**	**2**	**3**	**2**

CO-PO mapping matrix for the course GP-603 (Seminar)

COs#	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO603.1	3	2	3	1	2	1	2	1	3	2	1
CO603.2	3	2	3	2	2	1	2	2	3	2	1
CO603.3	3	3	1	2	2	2	2	3	3	3	1
Average	**3**	**2.3**	**2.3**	**1.7**	**2**	**1.3**	**2**	**2**	**3**	**2.3**	**1**

CO-PSO mapping matrix for the course GP-603 (Seminar)

COs#	PSO1	PSO2	PSO3	PSO4
CO603.1	2	3	3	2
CO603.2	3	3	3	2
CO603.3	2	3	3	2
Average	**2.3**	**3**	**3**	**2**

CO-PO mapping matrix for the course GP-604 (Geophysical Field Training- II)

COs#	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO604.1	3	2	2	2	1	2	3	1	2	1	2
CO604.2	3	2	2	2	2	2	3	1	2	1	2
CO604.3	3	2	2	2	3	2	3	1	2	1	2
CO604.4	3	2	2	2	2	2	3	1	2	1	2
Average	**3**	**2**	**2**	**2**	**2**	**2**	**3**	**1**	**2**	**1**	**2**

CO-PSO mapping matrix for the course GP-604 (Geophysical Field Training- II)

COs#	PSO1	PSO2	PSO3	PSO4
CO604.1	3	2	2	3
CO604.2	3	2	2	3
CO604.3	3	2	2	3
CO604.4	3	2	2	3
Average	**3**	**2**	**2**	**3**

Table 1: CO-PSO-PO mapping matrix

Course code	PO#											PSO#			
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**1**	**2**	**3**	**4**
GP-101	3	1.8	2	2	--	2	1	1	1	1.3	1.3	3	2	3	2.3
GP-102	3	1.3	2	1.5	1	1.5	1	1	2	1	1	3	1.5	2.5	1.8
GP-103	3	3	2	1	1	1.8	2	1	3	1	2.3	2.5	2.3	2.5	3
GP-104	3	1	2	--	1	1	--	1	2	1	1	2	2	2	2
GP-105	3	2	2	1.8	1.5	2	1.8	1	2	1	1.8	1.8	2	2.5	2
GP-106	3	2.5	2	2.5	2	2.3	2	2.3	3	1	2	1.8	2	2.5	3
GP-201	3	1	2	1.3	1	1	1.8	--	2	1	1	2	2	1.8	2
GP-202	3	2	2	2.8	2	2	2.3	2	2	1	1	2	3	2	1.3
GP-203	3	2	2	1.5	1	2	2	1	2	1	1	3	2	3	2
GP-204	3	1	2	1	1	1.5	1	--	2	1	1	2	2	2	1.5
GP-205	2	1.8	2	2	2	3	1	1.8	1.8	1	2	2	2	2	2
GP-206	3	2	2	2	2	3	2	1	2	1	1	3	2	3	3
GP-207	3	2	2	2	3	2.5	2.3	1.3	2	1	2.3	1.5	2	1.5	1.5
GP-301	3	3	2	1.5	1	1.8	2	2	3	1	2.3	2.5	2.3	2.5	3
GP-302	3	1.7	2	1	--	2	2	1	3	1	2.3	2.5	1.8	2.5	3
GP-303	3	1	2	1	1	1	1.5	2	2	1	1	3	1.5	2	1.5
GP-304	3	2	2	2	1	2	1.5	1.5	2	1	1	3	2	3	2.3
GP-305	3	3	1.5	1.8	2	2.3	2	1	1.5	1	1.3	3	2	2.5	2.8
GP-306	2	1.5	2	2	1	2.3	2	1.5	3	1	1.8	2.8	3	2.8	2
GP-401	3	1	2	1.5	1	2	1	1	2	1	2	3	2	3	2
GP-402	3	1	2	2	1	3	1	1	2	1	1	3	2	3	2.5
GP-403	3	1.5	2	1	1	1.5	2	1	2	1	1	3	2	3	3
GP-404	3	2	1	2	--	2.3	2.5	1	3	2	1.5	3	2.3	1.5	2.3
GP-405	3	2.5	2.5	2.5	2	2.3	2	2	3	1	2	2.5	2.5	2.5	3
GP-406	2.8	2	1.8	2	1	2	2.3	1.5	3	1.7	1.5	2	2.8	2.3	1.8
GP-407	3	2.3	2.3	3	2	1.5	1	2	1	2	2	3	2.3	2	3
GP-501	3	2	2	1.8	1	2	1.5	1	2	1	1	3	2	3	2
GP-502	3	2	2	1	1	2	1.8	1	2	1	1	3	2	3	2.5
GP-503	3	2	2	3	2	1.5	1.5	1	2	1	1.8	3	3	2	3
GP-504	2.8	2	2	1.8	2.5	1.8	2	1.3	3	1	2	2.3	2.3	2.8	1.8
GP-506	3	2	1	2	1	2	2	1	3	1	2	3	3	2.3	2
GP-513	3	3	2	3	2	2.5	2.5	1	2.3	1	2	3	2.5	2	3
GP-517	3	2	1.8	3	2	2	2	1	2	1	1	2	2.5	2	2
GP-601	3	3	2.3	3	2.5	3	2	2	3	1.5	2	3	3	3	3
GP-602	3	--	2.3	1	1	--	2	1	2	1	1	2	2	3	2
GP-603	3	2.3	2.3	1.7	2	1.3	2	2	3	2.3	1	2.3	3	3	2
GP-604	3	2	2	2	2	2	3	1	2	1	2	3	2	2	3

A. Method of Attainment of COs, PSOs & POs:

The attainment of COs can be measured on the basis of the results of internal assessment and semester examination. The attainment is measured on scale of 3 after setting the target for COs attainment. Table 2 shows the CO attainment levels assuming the set target of 60% marks:

Table 2: CO Attainment Levels for internal assessment

Attainment Level	
1 (low level of attainment)	60% of students score more than 60% of marks in class tests of a course.
2 (Medium level of attainment)	70% of students score more than 60% of marks in class tests of a course.
3 (High level of attainment)	80% of students score more than 60% of marks in class tests of a course.

A proper mapping of course outcomes with assessment methods should be defined before measuring the attainment level. The questions in tests for internal assessment are based on COs. The class test – I is based on first two COs (i.e. G101.1 and G101.2) of a course with equal weightage given to both COs. Similarly class test – II is based on next two COs (i.e. G101.3 and G101.4) of a course with equal weightage given to these two COs. For each internal assessment test, the percentage of students attaining the target level of CO is estimated and average percentage will decide the attainment level of COs. Following steps will be followed for determining the attainment level in internal assessment of a course.

(i) Estimate the %age of students scoring set target (say 60%) or more in the question(s) of test -I based on first CO i.e. G101.1
(ii) Estimate the %age of students scoring set target (60%) or more in the question(s) of test -I based on second CO i.e. G101.2
(iii) Estimate the %age of students scoring set target (60%) or more in the question(s) of test -II based on third CO i.e. G101.3
(iv) Estimate the %age of students scoring set target (60%) or more in the question(s) of test -II based on the fourth CO i.e. G101.4
(v) Take average of the percentages obtained above.
(vi) Determine the attainment level i.e. 3, 2 or 1 as per scale defined in table 2.

Note:
(i) In case of practical course, the CO attainment level for internal assessment is based on the seminar delivered by the students. The seminar is based on all COs of the practical courses.
(ii) For the courses of field training, the CO attainment level is based on end semester examination only.
(iii) For the courses in the VI^{th} semester of M.Sc. Tech. (Applied Geophysics) programme, the CO attainment level is based on end term exams only.

For determining the attainment levels for end semester examination, it is assumed that questions in the end term examination are based on all COs of the course. Attainment levels for end semester examination of a course can be determined after the declaration of the results.
The CO attainment levels for end semester examination are given in Table 3.

Table 3: CO Attainment Levels for End Semester Examination(ESE)

Attainment Level	
1 (Low level of attainment)	60% of students obtained letter grade of A or above (for CBCS programs) or score more than 60% of marks (for non-CBCS programs) in ESE of a course.
2 (Medium level of attainment)	70% of students obtained letter grade of A or above (for CBCS programs) or score more than 60% of marks (for non-CBCS programs) in ESE of a course.
3 (High level of attainment)	80% of students obtained letter grade of A or above (for CBCS programs) or score more than 60% of marks (for non-CBCS programs) in ESE of a course.

Overall CO Attainment level of a Course:

The overall CO attainment level of a course can be obtained as:

Overall CO attainment level = 50% of CO attainment level in Internal assessment + 50% of CO Attainment level in End semester examination.

The overall COs attainment level can be obtained for all the courses of the program in a similar manner.

B. Attainment of POs:

The overall attainment level of POs is based on the values obtained using direct and indirect methods in the ratio of 80:20. The direct attainment of POs is obtained through the attainment of COs. The overall CO attainment value as estimated above and CO-PO mapping value as shown in Table 1 are used to compute the attainment of POs. PO attainment values obtained using direct method can be written as shown in the Table 4.

Table 4: PO Attainment Values using Direct Method

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
G101												
G102												
G103												
G104												
-												
-												
G406												
Direct PO attainment	Average of above values	Average of above values	Averag e of above values	--	--	--	--	--	--	--	--	Average of above values

The PO attainment values to be filled in above table can be obtained as follows:

For G101-PO1 Cell:

PO1 attainment value = (Mapping factor of G101-PO1 from Table 1 × Overall CO attainment value for the course G101)/3

For G104-PO1 Cell:

PO1 attainment value = (Mapping factor of G104-PO1 from Table 1 × Overall CO attainment value for the course G104)/3

Similarly values for each cell of Table 4 can be obtained. The direct attainment of POs is average of individual PO attainment values.

In order to obtain the PO attainment using indirect method, a student exit survey based on the questionnaire of POs may be conducted at end of last semester of the program. The format for the same is given in Table 5. Average of the responses from the outgoing students for each PO is estimated.

The overall PO attainment values are obtained by adding attainment values estimated using direct and indirect methods in the proportion of 80:20 as follows:

Overall attainment value for PO1 =

0.8 × average attainment value for PO1 using direct method (from table 4)

+

0.2 × average response of outgoing students for PO1

Similarly overall attainment value can be obtained for each PO.

Table 5: Questionnaire for indirect measurement of PO attainment (For outgoing students)

At the end of my degree program I am able to:

	Please tick any one		
Demonstrate comprehensive disciplinary knowledge I have gained during course of study	3	2	1
Develop research aptitude. Capability for asking relevant/appropriate questions. Capable of identifying, formulating and analyzing the research problems and to draw conclusions from analysis of research problems.	3	2	1
Communicate effectively on	3	2	1

general and scientific topics with the scientific community and with society at large.			
Apply knowledge to solve scientific and other problems	3	2	1
Learn and work effectively as an individual and as a member or leader in team(s) and in multidisciplinary settings. Facilitate cooperative or coordinated efforts on the part of a group and act together as a group or as a team.	3	2	1
Apply critical thinking and analytical reasoning. Use disciplinary and research based knowledge including design of experiments, analysis and interpretation of data to provide valid conclusions.	3	2	1
Use and learn techniques, skills and modern tools for scientific practices.	3	2	1
To apply reasoning to assess the different issues related to society and the consequent responsibilities relevant to the professional scientific practices.	3	2	1
Acquire knowledge and skills including learning 'How to learn' that are necessary for participating in learning activities throughout life.	3	2	1
Demonstrating the ability to identify ethical issues related to one's work, avoid unethical behavior such as fabrication, falsification or misrepresentation of data or committing plagiarism and adopting objective, unbiased and truthful actions in all aspects of work.	3	2	1
To demonstrate knowledge and understanding of the scientific principles and apply these as a member / leader of a team to manage projects	3	2	1
3: Strongly Agree; 2: Agree; 1: Average			

Overall PO attainment values can be written as shown in Table 6:

Table 6: Overall PO attainment Values

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
Direct PO attainment												
Indirect PO attainment												
Overall PO attainment												
Target	2	2	2	2	2	1.5	2	2	2	2	1.5	1.5

The overall PO attainment values obtained above are compared with set target. The set target for each PO may be different and can be finalized by the staff councils of the departments/institutes. If overall PO attainment value is less than the set target value then an action plan may be prepared for improvement in the subsequent academic session.

C. Attainment of PSOs:

The overall attainment level of PSOs is based on the values obtained using direct and indirect methods in the ratio of 80:20. The direct attainment of PSOs is obtained through the attainment of COs. The overall CO attainment value as estimated above and CO-PSO mapping value as shown in Table 1 are used to compute the attainment of PSOs. PSO attainment values obtained using direct method can be written as shown in the Table 7.

Table 7: PSO Attainment Values using Direct Method

	PSO1	PSO2	PSO3	PSO4
GP101				
GP102				
GP103				
GP104				
-				
-				
GP604				
Direct PSO attainment	Average of above values	Average of above values	Average of above values	Average of above values

The PSO attainment values to be filled in above table can be obtained as follows:

For GP101-PSO1 Cell:

PSO1 attainment value = (Mapping factor of GP101-PSO1 from Table 1 × Overall CO attainment value for the course GP101)/3

For GP104-PSO1 Cell:

PSO1 attainment value = (Mapping factor of GP104-PSO1 from Table 1 × Overall CO attainment value for the course GP104)/3

Similarly values for each cell of Table 7 can be obtained. The direct attainment of PSOs is average of individual PSO attainment values.

In order to obtain the PSO attainment using indirect method, a student exit survey based on the questionnaire of PSOs may be conducted at end of last semester of the program. The format for the same is given in Table 8. Average of the responses from the outgoing students for each PSO is estimated.

The overall PSO attainment values are obtained by adding attainment values estimated using direct and indirect methods in the proportion of 80:20 as follows:

Overall attainment value for PSO1 =

0.8 × average attainment value for PSO1 using direct method (from table 7)

+

0.2 × average response of outgoing students for PSO1

Similarly overall attainment value can be obtained for each PSO.

Table 8: Questionnaire for indirect measurement of PSO attainment (For outgoing students)

At the end of my degree program I am able to:

	Please tick any one		
Understand the interior of Earth using latest Geophysical knowledge pertaining to various sub-fields within the discipline of Applied Geophysics.	3	2	1
Gain analytical ability, research aptitude and relevant skills useful for professional life.	3	2	1
To demonstrate and communicate Geophysical knowledge, understanding of Geophysical techniques/principles and apply the same to solve geophysical problems relevant	3	2	1

to society.			
Learn the techniques of data acquisition, data processing and data interpretation for Geophysical methods and their applications for the benefit of society.	3	2	1
3: Strongly Agree; 2: Agree; 1: Average			

Overall PSO attainment values can be written as shown in Table 9:

Table 9: Overall PSO attainment Values

	PSO1	PSO2	PSO3	PSO4
Direct PSO attainment				
Indirect PSO attainment				
Overall PSO attainment				
Target	2	2	2	2

The overall PSO attainment values obtained above are compared with set target. The set target for each PSO may be different and can be finalized by the staff councils of the departments/institutes. If overall PSO attainment value is less than the set target value then an action plan may be prepared for improvement in the subsequent academic session.