

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF THE DEPARTMENT: **Earth Sciences**

1. Subject Code: **ES-252** Course: **Statistics**

2. Contact Hours: **L : 3 T : 1 P : 0**

3. Examination Duration (Hrs): **Theory**

0	3
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Practical

0	0
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4. Relative Weightage **CWS**

2	5
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PRS

0	0
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MTE

2	5
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ETE

5	0
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PRE

0	0
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5. Credits :

0	4
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6. Semester: **Spring**

7. Pre-requisite: **Nil**

8. Subject Area: **DCC**

9. Objective: To provide basic concepts of probability and statistics

10. Details of Course:

S. No	Contents	Contact Hours
1	Role of Statistics in Earth Sciences	2
2	Basic Concepts of Theory of Probability: Laws of probability, conditional probabilities; Bayes' theorem and its role in earth sciences	4
3	Univariate Distributions and their Properties: Cumulative distribution function, order statistics, sampling and statistics; Examples from earth sciences	5
4	Estimators and their Assessment: Unbiased and efficient estimates, estimates of population parameters, confidence intervals for means and variances; Maximum likelihood estimates; Examples from earth sciences	5
5	Tests of Hypothesis: Statistical decisions and hypotheses; Tests involving the normal distributions, tests of significance for large and small samples; Applications to problems in earth sciences	6
6	Bivariate Analysis: Linear regression and correlation; Method of least squares; Generalized correlation coefficient; Probability interpretation of regression and correlation; Applications to problems in earth sciences	6
7	Analysis of Spatial Relationships: Measures of autocorrelation; Estimating correlation measures; Semivariograms; Bias and precision; Applications to problems in earth sciences.	4
8	Use of Statistics in Modeling: Kriging; Conditional simulation; Simulated annealing; Examples from earth sciences	6
9	Introduction to Methods of Multivariate Statistics: Multiple regression, discriminant analysis, principal component analysis and factor analysis with examples of earth sciences.	3
	Total	42

11. Suggested Books:

S. No	Name of Books/ Authors	Year of Publication
1	Jensen, J.R., Lake, L.W., Corbett, P.W.M. and Goggin, D.J., "Statistics for Petroleum and Geoscientists", Prentice-Hall	1997
2	Davis, J.C., "Statistics and Data Analysis in Geology", John Wiley & Sons	2002
3	Borradaile, G.J., "Statistics of Earth Science Data", Springer	2003
4	Lipschutz, S. and Lipson, M., "Theory and Problems of Probability", McGraw-Hill	2000
5	Schabenberger, O. and Gotway, C.A., "Statistical Methods for Spatial Data Analysis", Chapman & Hall	2004

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF THE DEPARTMENT: **Earth Sciences**

1. Subject Code : **ES-351** Course Title: **Principles of Geophysics**
2. Contact Hours : **L : 3 T : 1 P : 0**
3. Examination Duration (Hrs) : **Theory:** 3 **Practical:** 0
4. Relative Weightage **CWS** 2 5 **PRS** 0 0 **MTE** 2 5 **ETE** 5 0 **PRE** 0 0
5. Credits: 4
6. Semester: **Autumn**
7. Subject Area: **DCC**
8. Pre-requisite: **Nil**
9. Objective: To provide an over view of the basic principles and tools of Geophysics
10. Details of Course:

S. No	Contents	Contact Hours
1	Introduction, history of development of earth sciences	3
2	An overview of geophysics methods and their essential features, problems of inversion and non-uniqueness in geophysics	4
3	Earth as a planet and member of the solar system, earth's structure and constitution, origin and evolution of earth	5
4	Major features of the earth's gravitational field and their relationship with tectonic processes in the crust and upper mantle, figure of the earth	4
5	Earthquakes, global seismicity and tectonics, internal structure of the earth as derived from seismology	7
6	Methods of age determination, geochronology, thermal and electrical properties inside the earth and their relationship with the tectonic processes	6
7	Magnetic field of the earth and its origin, paleomagnetism and its applications, linear magnetic anomalies polar wandering and sea floor spreading	7
8	Basic concepts of Plate Tectonics, evolution of earth's crust and the Indian subcontinent	6
	Total	42

11. Suggested Books:

S. No	Name of Books/ Authors	Year of Publication
1	Lowrie, W., "Fundamentals of Geophysics", Cambridge University Press	1997
2	Davies, G.F., "Dynamic Earth: Plates, Plumes and Mantle Convection", Cambridge University Press	2000
3	Anderson, D.L., "New Theory of the Earth", Cambridge University Press	2007
4	Fowler, C.M.R., "The Solid Earth: An Introduction to Global Geophysics", Cambridge University Press	2004
5	Stein, S. and Wysession, M., "An Introduction to Seismology, Earthquakes and Earth Structure", Wiley Blackwell	2002

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF THE DEPARTMENT: **Earth Sciences**

1. Subject Code : **ES-352** Course Title: **Electrical Prospecting**
2. Contact Hours : **L: 3 T: 0 P: 2**
3. Examination Duration (Hrs) : **Theory:** **Practical:**
4. Relative Weightage **CWS** **PRS** **MTE** **ETE** **PRE**
5. Credits:
6. Semester: **Spring**
7. Subject Area: **DCC**
8. Pre-requisite: **ES-353**
9. Objective: To impart knowledge of the theory and applications of electrical prospecting methods of geophysical exploration

10. Details of Course:

S. No	Contents	Contact Hours
1	Electrical properties of rocks, mode of conduction, fundamental assumptions used in electrical prospecting	5
2	Basic laws and equations, effect of anisotropy and inhomogeneity	5
3	Point and line sources; Relationship between point and line source potential distribution, half-space solution, apparent resistivity, depth of investigation and vertical resolution	5
4	Measuring systems, electrode configurations, principle of superposition and principle of reciprocity, sounding and profiling techniques	4
5	Potential distribution over a layered earth, the Kernel function, resistivity transform function, recurrence relations, apparent resistivity functions	5
6	Computation of apparent resistivity model curves using digital filter theory, applications to field data, transformation of data, inclined layer problem	5
7	Data interpretation: Approximate methods, automatic iterative methods, principle of equivalence and suppression in data interpretation	5
8	Electrical profiling of near-vertical contact, dike, sphere and cylinder	4
9	Self-potential method; Induced polarisation method; Charged body method of electrical prospecting	4
	Total	42

List of Practicals

1. Recording of vertical electrical sounding data using Schlumberger, Wenner and two-electrode configurations and generation of anomaly curves
2. Recording of electrical resistivity profiling data, their analysis and interpretation
3. Graphical interpretation of resistivity sounding data using partial curve matching technique
4. Field set-up and data acquisition procedure for multi-electrode resistivity survey
5. Data acquisition and generation of pseudo section for resistivity imaging
6. Depth of investigation and vertical resolution of field resistivity data

11. Suggested Books:

S. No	Name of Books/ Authors	Year of Publication
1	Kearey, P., Brooks, M, and Hill, I., “An Introduction to Geophysical Exploration”, Blackwell	2002
2	Parasnis, D.S., “Principles of Applied Geophysics”, Chapman & Hall	1997
3	Keller, G.V, and Frischknecht, F.C., “Electrical Methods in Geophysical Prospecting”, Pergamon	1981
4	Patra, H.P., “Geosounding Principles: Time Varying Geoelectric Soundings”, Elsevier	1980
5	Koefoed, O., “Geosounding Principles: Resistivity Sounding Measurements”, Elsevier	1980

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF THE DEPARTMENT: **Earth Sciences**

1. Subject Code : **ES - 353** Course Title: **Mathematical Methods in Geophysics**
2. Contact Hours : **L: 3 T: 1 P: 0**
3. Examination Duration (Hrs) : **Theory: 3** **Practical: 0**
4. Relative Weightage **CWS 2 5 PRS 0 0 MTE 2 5 ETE 5 0 PRE 0 0**
5. Credits: **4**
6. Semester: **Autumn**
7. Subject Area: **DCC**
8. Pre-requisite: **MA-101, MA102**
9. Objective: To provide knowledge of mathematical techniques used in the solution of geophysical problems

10. Details of Course:

S.No.	Contents	Contact Hours
1	Role of Applied Mathematics in Geophysics: Laplace's equation for solving potential field problems in gravity, magnetic and resistivity methods; Diffusion equation for studying fluid flow and electromagnetic processes in earth; Wave equation for simulating seismic and electromagnetic responses	8
2	Method of Separation of Variables to Solve PDEs: Illustration through examples simulating geophysical responses of layered earth to various exciting source fields	8
3	Transform Methods to Solve PDEs: Reduction of dimension of the problem, conversion of wave and diffusion equations to Helmholtz equation and its solution for simple targets	8
4	Green's Function Method to Solve PDEs: Green's function as an impulse response function, examples of Green's functions for different boundary conditions and their use in solving PDEs	4
5	Integral Equations: Formulation of geophysical problems in terms of Fredholm's integral equations of first and second kind; Volterra's equations of first and second kind, analytical solution of simple integral equations	6
6	Approximate Solution of PDEs: Gram-Schmidt orthogonalization to generate a basis set of functions from a given set of functions; Approximation of functions in terms of basic orthonormal functions and their use in solving PDEs	8
Total		42

11. Suggested Books:

S. No	Name of Books/ Authors	Year of Publication
1	Strang, G., "Introduction to Applied Mathematics", Wellesley–Cambridge	1986
2	Morse, P.M., and Feshbach, H., "Methods of Theoretical Physics" Feshbach	2004
3	Courant, R. and Hilbert, D., "Methods of Mathematical Physics", Springer	1989
4	Arfkan, G.B., "Mathematical Methods for Physicists", Academic Press	2005

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF THE DEPARTMENT: **Earth Sciences**

1. Subject Code : **ES-354** Course Title: **Seismic Prospecting**
2. Contact Hours : **L : 3 T : 0 P : 2**
3. Examination Duration (Hrs) : **Theory: 3 Practical: 0**
4. Relative Weightage **CWS 1 5 PRS 1 5 MTE 3 0 ETE 4 0 PRE 0 0**
5. Credits: **4** 6. Semester: **Spring**
7. Subject Area: **DCC** 8. Pre-requisite: **ES-355, ES-357**
9. Objective: To impart basic knowledge of theory and applications of seismic prospecting
10. Details of Course:

S. No	Contents	Contact Hours
1	Introduction, role of seismic prospecting in geophysical exploration; Seismic waves and laws governing their reflection, refraction, attenuation and scattering	4
2	Sources of seismic energy: Explosives, impact, vibroseis and airgun, and their main characteristics, recording of seismic signals, geophones and their response characteristics, principles of digital recording of seismic signals	5
3	Seismic refraction surveys, head waves, critical and crossover distance, Interpretation of seismic refraction data for flat and dipping refractors, applications	5
4	Data acquisition on land and water covered areas, principles of CDP shooting, noise survey, coherent and incoherent noise, grouping of geophones, uphole surveys, multiplexing.	6
5	Processing of seismic data, static corrections, deconvolution, velocity analysis	6
6	Dynamic corrections, stacking and migration, seismic time sections	6
7	Interpretation of seismic data for structural and stratigraphic traps	5
8	Direct location of hydrocarbons, amplitude-versus-offset (AVO), processing and attributes	5
	Total	42

List of Practicals

1. Familiarization with working of exploration seismograph and geophones
2. Conducting small scale seismic survey
3. Interpreting the data obtained in the small scale seismic survey
4. Interpreting seismic refraction data from literature
5. Determining seismic velocity by $X^2 - T^2$ method
6. Computation of depth to reflector from travel time data of reflections
7. Computations of elastic constants and Q from velocity and attenuation data
8. Computing seismic velocities in porous media using different techniques

11. Suggested Books:

S. No	Name of Books/ Authors	Year of Publication
1	Sheriff, R.E and Geldart, L.P., "Exploration Seismology", Cambridge University Press	1995
2	Telford, W.M, Geldart, L.P and Sheriff, R.E., "Applied Geophysics", Cambridge University Press,	1999
3	Kearey, P, Brooks, M and Hill, I., "An Introduction to Geophysical Exploration", Blackwell Science Ltd.	2002
4	Dobrin, M.B and Savit, C.H., "Introduction to Geophysical Prospecting", McGraw-Hill	1988
5	Gadallah, M.R and Fisher, R.L., "Applied Seismology: A Comprehensive Guide to Seismic Theory and Applications", McGraw-Hill	2004
6	Yilmaz, O., "Seismic Data Analysis", Society of Exploration Geophysicists	2001

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF THE DEPARTMENT: **Earth Sciences**

1. Subject Code : **ES-355** Course Title: **Geophysical Signal Processing**
2. Contact Hours : **L: 3 T: 1 P: 0**
3. Examination Duration (Hrs) : **Theory: 3** **Practical: 0**
4. Relative Weightage **CWS 2 5 PRS 0 0 MTE 2 5 ETE 5 0 PRE 0 0**
5. Credits: **4**
6. Semester: **Autumn**
7. Subject Area: **DCC**
8. Pre-requisite: **MA-201M**
9. Objective: To familiarize the students with basic signal processing techniques applied in the field of geophysics

10. Details of Course:

S. No.	Contents	Contact Hours
1	Definitions, properties and classification of signals and systems	2
2	Review of Fourier series; Fourier transform; Laplace transform, and convolution theorem as applicable to geophysical problems; Transfer function formulation, poles, zeroes and their interpretation, minimum phase signals; Hilbert transform, spectral factorization	12
3	Sampling theorem, aliasing, effect of sampling on spectrum, discrete Fourier transform, fast Fourier transform, review of Z-transform, interrelations between Z-transform and discrete Fourier transform	8
4	Stochastic processes, autocorrelation and cross correlation, stationarity, wide-sense stationarity, ergodicity, power spectral density; Wiener-Khinchin theorem as applicable to geophysical problems	11
5	Digital filtering of geophysical data, amplitude and phase response of filters, ideal and realizable low pass, high pass, band pass and notch filters; Wiener filtering, extrapolation, matched filters and routinely used spectral windows in geophysical data processing	9
	Total	42

11. Suggested Books:

S. No	Name of Books/ Authors	Year of Publication
1	Lyons R.G., "Understanding Digital Signal Processing", Prentice-Hall	2004
2	Ingle, V.K. and Proakis, J.G., "Digital Signal Processing Using MATLAB", Cengage-Engineering	2006
3	Proakis, J.G. and Dimitris, D.K., "Digital Signal Processing", Prentice-Hall	2006
4	Hayes, M.H., "Schaum's Outline of Digital Signal Processing", McGraw-Hill	1998
5	Robinson. E.A., and Durrani, T.S., "Geophysical Signal Processing", Prentice-Hall	1985
6	Oppenheim, A.V., Schafer. R.W. and Buck, J.R., "Discrete-Time Signal Processing", Prentice-Hall	1999

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF THE DEPARTMENT: **Earth Sciences**

1. Subject Code : **ES-356** Course Title: **Stratigraphy and Geology of India**

2. Contact Hours : **L : 2 T : 1 P : 0**

3. Examination Duration (Hrs) : **Theory: 2** **Practical: 0**

4. Relative Weightage **CWS 2 5 PRS 0 0 MTE 2 5 ETE 5 0 PRE 0 0**

5. Credits: **3**

6. Semester: **Spring**

7. Subject Area: **DCC**

8. Pre-requisite: **ES-359**

9. Objective: To introduce the principles of stratigraphy and provide an overview of the major stratigraphic horizons and tectonic features of India

10. Details of Course:

S. No	Contents	Contact Hours
1	Introduction	1
2	Nomenclature, classification schemes; Geological Time Scale and Correlation	5
3	Broad outline of the stratigraphic and tectonic features of India	2
4	Elements of Precambrian stratigraphy	5
5	Elements of Paleozoic stratigraphy	5
6	Elements of Mesozoic stratigraphy	5
7	Elements of Cenozoic stratigraphy	5
	Total	28

11. Suggested Books:

S. No	Name of Books/ Authors	Year of Publication
1	Ramakrishnan, M, and Vaidyanathan, R., "Geology of India, Vol. 1 and 2", Geological Society of India publication	2008
2	Kumar, R., "Fundamentals of Historical Geology and Stratigraphy of India", Wiley International	1985
3	Wadia, D.N., "Geology of India", Macmillan	1966
4	Krishnan, M.S., "Geology of India", CBS	1982
5	Dey, A.K., "Geology of India", National Book Trust	1965

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF THE DEPARTMENT: **Earth Sciences**

1. Subject Code **ES-357**: Course Title: **Seismology**
2. Contact Hours : **L : 3 T : 0 P : 2**
3. Examination Duration (Hrs) : **Theory:** **Practical:**
4. Relative Weightage **CWS** **PRS** **MTE** **ETE** **PRE**
5. Credits:
6. Semester: **Autumn**
7. Subject Area: **DCC**
8. Pre-requisite: **Nil**
9. Objective: To impart basic knowledge of earthquakes, theory of seismic wave propagation and their application for studying the internal structure of earth

10. Details of Course:

S. No	Contents	Contact Hours
1	Introduction: Study of earthquakes including historical perspective, earthquake effects and discussion of various types of field observations in seismology, salient features of seismograms	3
2	Ray Theory and Travel Time Tables: Ray Theory, construction of travel time tables, inversion of travel time tables.	9
3	Reflection and Transmission of Body Waves: Reflection and refraction of plane elastic waves, attenuation and scattering of seismic waves, spherical waves and geometrical spreading	9
4	Surface Waves and Free Oscillations: Rayleigh and Love waves. dispersion and dispersion curves; Normal modes and rays, spheroidal and toroidal modes of free oscillations in spherical non-rotating earth; Causes of mode splitting in free oscillation.	8
5	Earthquake Source Parameters: Methods of hypocenter location. Intensity and magnitude scales, fault plane solutions and other source parameters, discrimination between earthquake and nuclear explosion	5
6	Seismological Instruments: Theory of seismographs; Electromagnetic seismographs; Seismological observatory and Seismic arrays; Strong motion instruments; Strain seismographs..	6
7	Earthquake prediction: Seismicity and seismic zoning	2
	Total	42

List of Practicals

1. Visit to a seismological observatory and familiarization with working of a seismograph and strong motion accelerographs
2. Preparation of isoseismal map of a given earthquake
3. Reading seismograms of earthquakes
4. Determination of epicentral distance and origin time of an earthquake
5. Location of epicenter of an earthquake
6. Computation of magnitude of an earthquake
7. Determination of fault plane solution of an earthquake
8. Computation of source parameters of an earthquake
9. Inversion of travel time data of an earthquake

11. Suggested Books:

S. No	Name of Books/ Authors	Year of Publication
1	Aki, K. and Richards, P.G .,“Quantitative Seismology: Theory and Methods”, University Science Books	2002
2	Stein, S., and Wysession, M., “An Introduction to Seismology, Earthquakes and Earth Structure”, Wiley Blackwell	2002
3	Shearer, P., “Introduction to Seismology”, Cambridge University Press	1999
4	Lay, T.L. and Wallace, T.C., “Modern Global Seimology”, Academic Press	1995
5	Scholz, C.H., “Mechanics of Earthquakes and Faulting”, Cambridge University Press	2002

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF THE DEPARTMENT: **Earth Sciences**

1. Subject Code : **ES-358** Course Title: **Economic Mineral Deposits**

2. Contact Hours : **L : 2 T : 1 P : 0**

3. Examination Duration (Hrs) : **Theory:** **Practical:**

4. Relative Weightage: **CWS** **PRS** **MTE** **ETE** **PRE**

5. Credits: 6. Semester: **Spring**

7. Subject Area: **DCC** 8. Pre-requisite: **ES-361**

9. Objective: To impart basic knowledge of different types of economic mineral deposits, processes of their formation and occurrences in India

10. Details of Course:

S. No	Contents	Contact Hours
1	Historical background, distribution, morphology and disposition of ore bodies, classification of ore bodies	4
2	Physical characteristics, structure and texture of ore minerals	4
3	Processes of ore formation; Endogenic ore deposits including magmatic, pegmatitic, contact metasomatic and hydrothermal deposits; Exogenic ore deposits including sedimentary, residual, supergene enrichment and mechanically concentrated deposits; Metamorphic and metamorphosed deposits	13
4	Geology of selected ore deposits of India	4
5	Elementary idea about fossil fuel deposits; Importance of minerals in national economy	3
	Total	28

11. Suggested Books:

S. No	Name of Books/ Authors	Year of Publication
1	Park, C.F. and MacDiarmid, R. "Ore Deposits", Freeman	1975
2	Banerjee, D.K. "Mineral Resources of India", The World Press	1992
3	Evans, A.M. "Geology and Industrial Minerals – An Introduction", Blackwell	1993
4	Guilbert, J.M.F and Park, C.F., "Geology of Ore Deposits", Freeman	1995
5	Misra, K.C., "Understanding Mineral Deposits", Kluwer	2000

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF THE DEPARTMENT: **Earth Sciences**

1. Subject Code : **ES-359** Course Title: **Basic Geology**
2. Contact Hours : **L : 3 T : 0 P : 2**
3. Examination Duration (Hrs) : **Theory:** **Practical:**
4. Relative Weightage **CWS** **PRS** **MTE** **ETE** **PRE**
5. Credits:
6. Semester: **Autumn**
7. Subject Area: **DCC**
8. Pre-requisite: **Nil**
9. Objective: To give a concise knowledge of physical geology, processes on the surface of the earth, landforms and structural geology

10. Details of Course:

S. No	Contents	Contact Hours
1	Introduction to earth sciences and its branches, interior of the Earth and its composition	5
2	Weathering of rocks and deposition	3
3	Landforms from different processes - fluid, glacial, aeolian and coastal	7
4	Sea floor spreading and plate tectonics	5
5	Orogeny, volcanism and earthquakes	3
6	Folds, faults and unconformities – different types and formation	7
7	Joints, cleavages and foliation	6
8	Outcrop pattern, cross section, maps	6
	Total	42

List of Practicals

1. Preparation of different landform maps of India
2. Drainage morphometry
3. Structural problems related to folds, faults and unconformities
4. Study of plate tectonic models

11. Suggested Books:

S. No	Name of Books/ Authors	Year of Publication
1.	Siddhartha, K., "The Earth's Dynamic Surface", Kishalaya	2000
2.	Brown, G., Hawkesworth, C. and Wilson C., "Understanding the Earth", Cambridge University Press	1992
3	Holmes, A., "Principles of Physical Geology", Nelson	1965
4	Chernicoff, S., Fox, H., A. and Tanner, L.H., "Earth: Geologic Principles and Histories", Houghton Mifflin	2002
5	Mukhopadhyay, D.K., "Structural Geology for Petroleum Geologist", Association of Petroleum Geologists	2006
6	Strahler, A.H., Strahler, A., "Introducing Physical Geography", Columbia University	2006

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF THE DEPARTMENT: **Earth Sciences**

1. Subject Code : **ES-360** Course Title: **Field Training - I**
2. Contact Hours : **L : 0 T : 0 P : 0**
3. Examination Duration (Hrs) : Theory: Practical:
4. Relative Weightage **CWS** **PRS** **MTE** **ETE** **PRE**
5. Credits:
6. Semester: **Spring**
7. Subject Area: **DCC**
8. Pre-requisite: **ES-357, ES-359**
9. Objective: To provide training in different aspects of geological mapping in the field.

10. Details of Course:

S. No	Contents	Contact Hours
1	Determination of dip and strike of various strata	20
2	Making outcrop maps	20
3	Preparation of geological sections	12
4	Preparation of contour maps of elevation	12
5	Collection of rock samples	15
6	Preparation of field report	05
	Total	84

11. Suggested Books: **NIL**

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF THE DEPARTMENT: **Earth Sciences**

1. Subject Code : **ES-361** Course Title: **Mineralogy and Petrology**
2. Contact Hours : **L : 3 T : 0 P : 2**
3. Examination Duration (Hrs) : **Theory:** **Practical:**
4. Relative Weightage: **CWS** **PRS** **MTE** **ETE** **PRE**
5. Credits:
6. Semester: **Autumn**
7. Subject Area: **DCC**
8. Pre-requisite: **Nil**
9. Objective: To provide concise knowledge of mineralogy and petrology
10. Details of Course:

S. No	Contents	Contact Hours
1	Introduction to minerals and identification of minerals using megascopic and microscopic properties	5
2	Classification of silicate minerals based on structures, crystal systems applicable to minerals	5
3	Mineral families, their description and identification	7
4	Rocks and their classification, identification of rocks in hand specimen	5
5	Texture, structure and fabric of important igneous, metamorphic and sedimentary rocks	5
6	Igneous, metamorphic and sedimentary rocks, their origin and characteristics	8
7	Distribution, geological setting and genesis of select igneous, metamorphic and sedimentary provinces in India	7
	Total	42

List of Practicals

1. Identification of important minerals based on physical properties and under microscope
2. Identification of megascopic specimen of igneous, sedimentary and metamorphic rocks and under microscope
3. CIPU norm calculation/AFM diagrams for metamorphic rocks
4. Grain size analysis of sediments

11. Suggested Books:

S. No	Name of Books/ Authors	Year of Publication
1	Klein, C., "Mineral Science", John Wiley & Sons	2002
2	Read, H.H., "Rutley's Elements of Mineralogy", Springer	1988
3	Raymond, L.A., "Petrology : The Study of Igneous, Sedimentary, and Metamorphic Rocks", McGraw-Hill College	2001
4	Lye, K., "Rocks and Minerals", Steck-Vaughn Co	1994
5	Perkins,D., "Mineralogy", Prentice-Hall	1998

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF THE DEPARTMENT: **Earth Sciences**

1. Subject Code : **ES-451** Course Title: **Gravity and Magnetic Prospecting**

2. Contact Hours : **L : 3 T : 0 P : 2**

3. Examination Duration (Hrs): **Theory: 3 Practical: 0**

4. Relative Weightage **CWS 1 5 PRS 1 5 MTE 3 0 ETE 4 0 PRE 0 0**

5. Credits: **4**

6. Semester: **Autumn**

7. Subject Area: **DCC**

8. Pre-requisite: **ES-353**

9. Objective: To impart techniques of gravity and magnetic data acquisition, processing and interpretation for different platforms

10. Details of Course:

S. No	Contents	Contact Hours
1	Introduction to gravity and magnetics as inverse square fields, physical properties of earth materials and their variability	2
2	Data acquisition procedures for different types of gravity & magnetic surveys (land, marine and airborne)	6
3	Corrections applied to gravity and magnetic data of different platforms (land, marine and airborne), regional residual separation procedures	8
4	Forward modelling problems and solutions for both gravity and magnetic source models of regular geometry, forward modelling algorithms for gravity and magnetic anomaly sources of arbitrary shape (2½D and 3D)	9
5	Qualitative Depth rules and semi-quantitative methods of interpretation	3
6	Analytic signal method for interpretation of gravity and magnetic data, Werner deconvolution method, Quantitative interpretation for 2D, 2½D and 3D gravity and magnetic anomaly sources	9
7	Equivalent stratum principle in gravity and magnetics and applications, geological applications of gravity and magnetics	5
	Total	42

List of Practicals

1. Density and magnetic susceptibility measurements of different rock samples (sedimentary, igneous and metamorphic types)
2. Land gravity data acquisition with a gravimeter and data cleaning
3. Land data acquisition with magnetometer (vertical field intensity and total field intensity) and data cleaning
4. Different regional-residual separation methods – graphical, ring residual, analytic continuation and derivative methods through exercises
5. Quantitative interpretation of gravity anomaly maps and profiles
6. Quantitative interpretation exercises for both gravity and magnetic data of different surveys (land, marine and airborne)
7. Methods for transforming geophysical interpretation remodels to geological interpretation

11. Suggested Books:

S. No	Name of Books/ Authors	Year of Publication
1	Campbell, W.H., “Introduction to Geomagnetic Fields”, Cambridge University Press	2003
2	Watts, A.B., “Isostasy and Flexure of the Lithosphere”, Cambridge University Press	1997
3	Telford, W.M., Geldart, L.P, and Sheriff, R.E., “Applied Geophysics”, Cambridge University Press	1999
4	Parasnis, D.S., “Principles of Applied Geophysics”, Chapman & Hall	1997
5	Hinze, W.J., “The Utility of Regional Gravity and Magnetic Anomaly Maps”, Society of Exploration Geophysics	1985
6	Grant F.S, and West, G.F., “Interpretation Theory in Applied Geophysics”, McGraw-Hill	1965

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF THE DEPARTMENT: **Earth Sciences**

1. Subject Code : **ES-452** Course Title: **Numerical Modeling in Geophysics**
2. Contact Hours : **L: 3 T: 1 P: 0**
3. Examination Duration (Hrs) : **Theory:** **Practical:**
4. Relative Weightage **CWS** **PRS** **MTE** **ETE** **PRE**
5. Credits:
6. Semester: **Spring**
7. Subject Area: **DCC**
8. Pre-requisite: **MA-202M**
9. Objective: To provide comprehensive knowledge of advanced methods of numerical modeling in geophysics.
10. Details of Course:

S.No.	Contents	Contact Hours
1	Introduction: Role of numerical modeling in Geophysics	2
2	Approximation of Functions: Gram-Schmidt orthogonalization algorithm and its various numerical implementations, advantages of orthonormal basis, improvement of condition number	6
3	Optimization Methods: Methods for finding maxima/minima of non-linear functions	4
4	Eigen Analysis: Jacobi, Givens, Householder methods; LR; QR methods	6
5	Sparse Matrices and Equation Solvers: Definition and examples of sparse matrices and their importance, storage of sparse matrices, Semi-iterative methods like conjugate gradient and its variants	6
6	Finite Difference Method to Solve PDEs: Overview of Different difference formulae for derivatives, their use in FDM, explicit and implicit schemes and their numerical stability	6
7	Finite Element Method to Solve PDEs: Variational and weighted residual approaches, generation of stiffness matrix and special matrix solvers for stiffness matrix equation	6
8	Integral Equation Method to Solve PDEs: Secondary field formulation and generation of volume integral equations, solution using moments method, comparison with FDM and FEM	6
Total		42

11. Suggested Books:

S. No	Name of Books/ Authors	Year of Publication
1	Schilling, R.J., and Harries, S.L., “Applied Mathematical Methods”, Thomson Brookes	2000
2	Press, W.H., Teukolsky, S.A., Vetterling W.T. and Flannery B.P., “Numerical Recipes: The Art of Scientific Computing”, Cambridge University Press	2007
3	Dahlquist, A. and Bjork, A., “ Numerical Methods”, Prentice-Hall	2003

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF THE DEPARTMENT: **Earth Sciences**

1. Subject Code : **ES-453** Course Title: **Electromagnetic Prospecting**
2. Contact Hours : **L: 3 T: 0 P: 2**
3. Examination Duration (Hrs) : **Theory: 3** **Practical: 0**
4. Relative Weightage **CWS 1 5 PRS 1 5 MTE 3 0 ETE 4 0 PRE 0 0**
5. Credits: **4**
6. Semester: **Autumn**
7. Subject Area: **DCC**
8. Pre-requisite: **ES-353**
9. Objective: To impart knowledge of theory, data acquisition, processing, interpretation and application of electromagnetic prospecting methods for geophysical exploration
10. Details of Course:

S. No	Contents	Contact Hours
1	Methods of Electromagnetic Prospecting: physical principles, dip angle technique, intensity measurements, phase component measurements, airborne electromagnetic method	4
2	Depth sounding methods: parametric and geometric sounding, data acquisition for different source-receiver geometries and their interpretation	6
3	Maxwell's equations in time and frequency domain, wave equation, Helmholtz equation, long wavelength approximation, boundary conditions, polarization of electromagnetic field	6
4	Solution of the wave equations; Schelkunoff potential, wholespace Green's function, time-domain Green's function and their applications for different source geometries	4
5	Harmonic line source, loop source, conducting sheet in a dipole field, conducting half-space in dipole field, multiple conductor, transient response, layered earth response	4
6	Reflection and refraction of plane waves, wave impedance, plane wave impedance of an n-layered isotropic earth, normal incidence, oblique incidence	6
7	MT/AMT formulation of response of 1-D earth; MT sounding and profiling, telluric measurements, telluric data analysis, depth rules; IP methods	6
8	Applications and recent case studies	6
	Total	42

List of Practicals

1. Estimation of model parameters from the Turam data
2. Interpretation of electromagnetic response using phasor diagram
3. Field procedure and recording of VLF data
4. Analysis of VLF data by filtering
5. Field procedure and data acquisition using time domain electromagnetic instrument
6. Analysis and interpretation of decay curves of time domain electromagnetic response
7. Magnetotelluric field setup, system and sensors
8. Processing and analysis of time series data recorded in field

11. Suggested Books:

S. No	Name of Books/ Authors	Year of Publication
1	Nabighian, M.N., "Electromagnetic Methods in Geophysics", Vol. I Theory, Society of Exploration Geophysics	1987
2	Nabighian, M.N., "Electromagnetic Methods in Geophysics Vol. II Applications", Society of Exploration Geophysics	1991
3	Wait, J.R., "Goelectromagnetism", Academic Press	1982
4	Parasnis, D.S., "Principles of Applied Geophysics", Chapman & Hall	1997
5	Telford, W.M. Geldart, L.P, and Sheriff, R.E., "Applied Geophysics", Cambridge University Press	1990

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF THE DEPARTMENT: **Earth Sciences**

1. Subject Code : **ES-454** Course Title: **Geophysical Inversion**
2. Contact Hours : **L: 3 T: 1 P: 0**
3. Examination Duration (Hrs) : **Theory:** **Practical:**
4. Relative Weightage **CWS** **PRS** **MTE** **ETE** **PRE**
5. Credits:
6. Semester: **Spring**
7. Subject Area: **DCC**
8. Pre-requisite: **ES-353**
9. Objective: To provide knowledge of the theory and applications of different methods of inverting geophysical data
10. Details of Course:

S. No	Contents	Contact Hours
1	Introduction: Illustration of forward and inverse problems in geophysics	2
2	Formulation of various inverse problems in geophysics, reduction to a matrix equation, linear inverse problem, solution of inverse problem	5
3	The least square, minimum norm and Marquardt solutions of a matrix equation, overdetermined and underdetermined problems, weighted least squares and weighted damped least squares solution	5
4	The singular value decomposition of the matrix, generalized inverse, application to geophysical problems	5
5	The Rao-Mitra generalized inverse, solution of a general system of equations, applications to geophysical inversion.	4
6	Computational aspects of various matrix inversion methods: Linearization and parameterization, advanced inversion methods	6
7	Linear regularization methods: Backus-Gilbert inversion method; Tikhonov's regularization method, computational aspects and applications	5
8	Introduction to non-linear inversion methods: non-linear inverse problems, convergence and non-uniqueness of non-linear problems, maximum entropy methods	6
9	Examples of solution of inverse problems from literature	4
	Total	42

11. Suggested Books:

S. No	Name of Books/ Authors	Year of Publication
1	Indira, N.K. and Gupta, P.K., "Inverse Methods: General Principles and Applications to Earth System Sciences", Narosa Publishing House	1998
2	Lawson, C.L. and Hanson, D.J., "Solving Least Square Problems", Prentice-Hall	1974
3	Menke, W., "Geophysical Data Analysis: Discrete Inverse Theory", Academic Press	1984
4	Tarantola, A., "Inverse Problem Theory", SIAM	2004

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF THE DEPARTMENT: **Earth Sciences**

1. Subject Code : **ES-455** Course Title: **Geophysical Well Logging**
2. Contact Hours : **L : 3 T : 0 P : 2**
3. Examination Duration (Hrs) : **Theory:** **Practical:**
4. Relative Weightage **CWS** **PRS** **MTE** **ETE** **PRE**
5. Credits:
6. Semester: **Autumn**
7. Subject Area: **DCC**
8. Pre-requisite **ES-352**
9. Objective: To impart a basic knowledge of theory, data acquisition, processing and applications of geophysical well logging methods in hydrocarbon exploration in particular

10. Details of Course:

S. No	Contents	Contact Hours
1	Introduction, objectives of geophysical well logging, general classification of well logging methods, formation evaluation: Its importance and applications, different well logging softwares for formation evaluation	8
2	Electrical logging: Focused and unfocussed tools (Normal, Lateral and SP logs), micro-resistivity tools and their role in formation evaluation	6
3	Induction logging, concept of departure curves and geometric factors; Porosity, permeability, water and oil saturation estimation based on electrical logging measurements	8
4	Porosity logs: Neutron, density, neutron and sonic logs; Individual departure curves for environmental corrections; Cross plots for determination of lithology, fluid type, saturation and mineral identification of rock matrix; Assessing the influence of clay/shale content on porosity estimations	10
5	NMR technique for permeability, bound and free-water estimations; Wellbore seismic	4
6	Auxiliary logging devices: Caliper; Dipmeter; Cement bond logging; Casing collar locators; Temperature logging	4
7	Wire line sampling: Rock sampling, fluid sampling and pressure measurements; Geological applications of well logging	2
	Total	42

Practical Exercises

1. Open hole wireline log data. Understanding of header information, different track data and related details
2. Qualitative interpretation of integrated well log data – identification of permeable formations for possible hydrocarbon accumulation
3. Introduction to resistivity departure curves and their applications – estimation of resistivity of mud, mud cake and mud filtrate at borehole temperature of perspective strata
4. Processing of resistivity, SP, gamma-ray, dual induction log and porosity log data
5. Formation evaluation of integrated well log data for clean sands
6. Formation evaluation of integrated well log data for shaly sands (Waxman– Smits model)
7. Formation evaluation of integrated well log data for carbonate rocks

11. Suggested Books:

S. No	Name of Books/ Authors	Year of Publication
1	Serra, O., “Well Logging and Geology”, TECHNIP	2003
2	Theys, P., “Log Data Acquisition and Quality Control”, Gulf Publishing Company	1999
3	Ellis, D.V., and Singer, J.M., “Well Logging for Earth Scientists”, Elsevier	1987
4	Schlumberger Education Services, “Schlumberger Log Interpretation Principles/ Applications”, Schlumberger	1987
5	Serra, O., “Fundamentals of Well Log Interpretation, Vol. 1. The Acquisition of Logging Data”, Elsevier	1984
6	Lynch, E.J., “Formation Evaluation”, Harper & Row.	1962

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF THE DEPARTMENT: **Earth Sciences**

1. Subject Code : **ES-456** Course Title: **Field Training - II**
2. Contact Hours : **L : 0 T : 0 P : 0**
3. Examination Duration (Hrs) : **Theory:** **Practical:**
4. Relative Weightage **CWS** **PRS** **MTE** **ETE** **PRE**
5. Credits:
6. Semester: **Spring**
7. Subject Area: **DCC**
8. Pre-requisite: **ES-352, ES-354 and ES-451**
9. Objective: To impart training in conducting field geophysical surveys and interpreting the data obtained in such surveys

10. Details of Course:

S. No	Contents	Contact Hours
1	Intensive training in the collection and interpretation of data using	
	(1) Resistivity meter	18
	(2) Exploration Seismograph	16
	(3) Gravimeter	15
	(4) Magnetometer	15
	(5) Ground Penetrating Radar	15
2	Preparation of Field report	5
	Total	84

11. Suggested Books: **NIL**

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF THE DEPARTMENT: **Earth Sciences**

1. Subject Code **ES-201** Course Title: **Introduction to Geosciences**

2. Contact Hours : **L : 2 T : 0 P : 0**

3. Examination Duration (Hrs): **Theory**

0	2
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Practical

0	0
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4. Relative Weightage **CWS**

1	5
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PRS

0	0
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MTE

3	5
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ETE

5	0
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PRE

0	0
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5. Credits :

0	2
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 6. Semester: **Spring**

7. Pre-requisite: **Nil** 8. Subject Area: **GSC**

9. Objective: To provide an overview of Earth Sciences including earth processes, resources and geohazards.

10. Details of Course:

S. No	Contents	Contact Hours
1	Earth, its place in solar system, physical features on its surface, other basic features (mass, shape, size, density, etc.) and its interior	4
2	Minerals, rocks, gems and gemstones,	3
3	Volcanoes, earthquakes and tsunamis, glaciers, landslides, mudflows and avalanches	4
4	Evolution of life on earth through ages	2
5	Remote sensing, GIS and GPS	3
6	Mineral exploration and geophysical exploration	3
7	Groundwater, hydrocarbons and coal	3
8	Rock deformation, mining and tunneling	4
9	Geological divisions of India and plate tectonics	2
Total		28

11. Suggested Books:

S. No	Name of Books/ Authors	Year of Publication
1	Press, F.and. Siever, R., "Understanding the Earth", W.H. Freeman & Co.	1998
2	Moore, J.S and Wicander, R., "Physical Geology", Brooks-Cole	2001
3	Lowrie, W., "Fundamentals of Geophysics", Cambridge University Press	1997

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF THE DEPARTMENT: **Earth Sciences**

1. Subject Code: **ES-202** Course Title: **Basic Petrology**

2. Contact Hours : **L : 3 T : 0 P : 2**

3. Examination Duration (Hrs): **Theory**

0	3
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Practical

0	2
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4. Relative Weightage **CWS**

1	5
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PRS

1	5
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MTE

1	5
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ETE

4	0
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PRE

1	5
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5. Credits :

0	4
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 6. Semester: **Spring**

7. Pre-requisite: **Nil** 8. Subject Area: **BSC**

9. Objective: To impart basic knowledge of rocks, their origin, types, textures and structures

10. Details of Course:

S. No	Contents	Contact Hours
1	Fundamental concepts in igneous petrology	2
2	Concepts of magma, fractional crystallization, liquid immiscibility, magma mixing and assimilation	8
3	Igneous structures and textures and field relationships	3
4	Classification of igneous rocks	3
5	Types of metamorphism, agents of metamorphism	3
6	Metamorphic textures and structures	3
7	Concept of metamorphic facies and grade	3
8	Classification of metamorphic rocks	2
9	Classification and formation of sedimentary rocks	6
10	Texture and structures of different types of sedimentary rocks	4
11	Petrological characteristics of sedimentary rocks	5
	Total	42

List of Practicals

1. Study of different rock types in hand specimen
2. Microscopic study of mineral assemblages of different igneous, metamorphic and sedimentary rocks

11. Suggested Books:

S. No	Name of Books/ Authors	Year of Publication
1	Raymond, L. A., "Petrology: The Study of Igneous, Sedimentary and Metamorphic Rocks", McGraw Hill College	2001
2	Best, M.G., "Igneous and Metamorphic Petrology", Wiley-Blackwell	2002
3	Yardley , B.W.D., "Introduction to Metamorphic Petrology", Longman Scientific and Technical	1989
4	Tucker , H.E., "Sedimentary Petrology" ,Wiley-Blackwell	2001
5	Pettijohn, F.J., "Sedimentary Rocks", Harper-Collins	1975
6	Vernon, R.H and Clarke, G., "Principles of Metamorphic Petrology", Cambridge University Press	2008

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF THE DEPARTMENT: **Earth Sciences**

1. Subject Code: **ES-203** Course: **Structural Geology-I**
2. Contact Hours : **L : 3 T : 0 P : 2**
3. Examination Duration (Hrs): **Theory**

0	3
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Practical

0	2
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4. Relative Weightage **CWS**

1	5
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PRS

1	5
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MTE

1	5
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ETE

4	0
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PRE

1	5
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5. Credits:

0	4
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 6. Semester: **Autumn**
7. Pre-requisite: **Nil** 8. Subject Area: **BSC**
9. Objective: To introduce basic concepts of tectonic structures in rocks
10. Details of Course:

S. No	Contents	Contact Hours
1	Geological significance and recognition of unconformities; Morphology of folds	4
2	Geometric classifications of folds	3
3	Genetic classifications of folds	3
4	Mechanism and causes of folding	3
5	Strain distribution in different types of folds	3
6	Outcrop patterns of different types of folds	2
7	Geometric and genetic classification of faults, effects of faulting on outcrops, large scale faults and their tectonic significance	8
8	Geometric and genetic classification of joints	4
9	Foliation, their descriptive terminology, origin and relation to major structures	5
10	Different types of lineations, their origin and their relation to major structures	4
11	Different types of shear zones and their development	3
	Total	42

List of Practicals

1. Contour, stratum contour, dip and strike problems
2. Plunge and pitch of lineations
3. Completion of outcrop pattern
4. Geological maps - cross-section through different types of structures and geological history
5. Dip isogon studies and classification of folds
6. Geological structures in hand specimen

11. Suggested Books:

S. No	Name of Books/ Authors	Year of Publication
1	Ramsay, J.G., "Folding and Fracturing of Rocks", McGraw-Hill	1967
2	Hobbs, B. E., Means, W.D and Williams, P.F., "An Outline of Structural Geology", John Wiley & Sons	1976
3	Ragan, D. M., "Structural Geology : An Introduction to Geometrical Techniques", John Wiley & Sons	1985
4	Pollard, D.D and Fletcher, R.C., "Fundamentals of Structural Geology", Cambridge University Press	2005
5	Mukhopadhyay, D.K., "Structural Geology for Petroleum Geoscientists", Association of Petroleum Geologists	2006

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF THE DEPARTMENT: **Earth Sciences**

1. Subject Code: **ES-204** Course Title: **Field Training-I**

2. Contact Hours **L : 0 T : 0 P : 0**

3. Examination Duration (Hrs): **Theory**

0	0
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Practical

0	0
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4. Relative Weightage **CWS**

0	0
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PRS

5	0
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MTE

0	0
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ETE

0	0
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PRE

5	0
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5. Credits :

0	3
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 6. Semester: **Spring**

7. Pre-requisite: **Nil** 8. Subject Area: **BSC**

9. Objective: To introduce geological mapping including identification of rocks, rock structures and other field parameters

10. Details of Course:

S. No	Contents	Contact Hours
1	Study of topo-sheets and geological maps	8
2	Determination of location on maps	8
3	Measurements of dip and strike of planar surfaces	8
4	Measurement of lineation	8
5	Measurement of stratigraphic columns	12
6	Geological mapping	30
7	Plotting and analysis of field data	20
Total		84

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF THE DEPARTMENT: **Earth Sciences**

1. Subject Code: **ES-205** Course Title **Crystallography and Mineralogy**

2. Contact Hours : **L : 3 T : 0 P : 2**

3. Examination Duration (Hrs): **Theory**

0	3
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Practical

0	2
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4. Relative Weightage **CWS**

1	5
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PRS

1	5
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MTE

1	5
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ETE

4	0
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PRE

1	5
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5. Credits :

0	4
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6. Semester: **Autumn**

7. Pre-requisite: **Nil**

8. Subject Area: **BSC**

9. Objective: To provide basic knowledge of crystals, crystal systems and minerals

10. Details of Course:

S. No.	Contents	Contact Hours
1	Classification of crystal systems, seven crystal systems	4
2	Miller indices and crystal forms	2
3	Crystal defects, polymorphism, isomorphism, pseudomorphism, exsolution and twinning	5
4	Physical properties of minerals	3
5	Different groups of minerals: Silicates, carbonates, sulphates, oxides and other mineral groups; Genesis, distribution, occurrence and association of different mineral groups	11
6	X-ray diffraction; theory, instrumentation, Bragg's law	8
7	Introduction to optical microscopy; isometric minerals, uniaxial and biaxial minerals, optic figures, optical properties of minerals	9
	Total	42

List of Practicals

1. Study of crystal forms in different crystal systems
2. Identification of hand specimen using physical properties
3. Study of properties of minerals under microscope
4. Identification of minerals using X-ray diffraction

11. Suggested Books:

S. No	Name of Books/ Authors	Year of Publication
1	Bloss, F.D., "Crystallography and Crystal Chemistry", Mineralogical Society of America	1971
2	Bloss, F.D., "An Introduction to the Methods of Optical Crystallography", Mineralogical Society of America Monograph	1961
3	Vainshtein, B.K., "Modern Crystallography 1: Fundamentals of Crystals. Symmetry, and Methods of Structural Crystallography (Modern Crystallography)", Springer	2003
4	Klein, C., Cornelius, S.H., and Dana, J.D., "Danas Manual of Mineralogy", John Wiley & Sons	1971
5	Deer, W.A., Howie, R.A. and Zussman, J., "An Introduction to the Rock-Forming Minerals", ELBS	1992
6.	Read, H.H., "Rutley's Elements of Mineralogy", Springer	1988

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF THE DEPARTMENT: **Earth Sciences**

1. Subject Code: **ES-206** Course Title: **Geomorphology**

2. Contact Hours : **L : 2 T : 1 P : 0**

3. Examination Duration (Hrs): **Theory**

0	2
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Practical

0	0
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4. Relative Weightage **CWS**

2	5
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PRS

0	0
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MTE

2	5
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ETE

5	0
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PRE

0	0
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5. Credits :

0	3
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 6. Semester: **Spring**

7. Pre-requisite: **ES-207** 8. Subject Area: **DCC**

9. Objective: To impart basic understanding of different types of landforms and their related physical processes

10. Details of Course:

S. No	Contents	Contact Hours
1	Geomorphology as a branch of geology and its relation to other branches	2
2	Weathering, erosion and deposition, effects of climatic factors on different types of rocks	5
3	Erosion by running water, stages of river development, concept of base level of erosion, ox-bow lakes, karst topography, fluvial landforms	5
4	Wind erosion, desertification, formation of dunes and other depositional processes by wind, aeolian landforms	4
5	Ice, glaciers and ice sheets, moraines, classification of glaciers, glacial landforms	4
6	Coastal processes, marine landforms	4
7	Quantitative geomorphology	2
8	Terrain evaluation and its applications	2
Total		28

11. **Suggested Books:**

S. No	Name of Books/ Authors	Year of Publication
1	Holmes, A., "Physical Geology", Ronald Press	1980
2	Thornbury, W.D., "Principles of Geomorphology", Balkema	1995
3	Ritter, D.F., Kochel, R.C., Miller, J.R., "Process Geomorphology", Waveland	2006
4	Huggett, R., "Fundamentals of Geomorphology", Routledge	2007
5	Bloom, A., "Cenozoic Geomorphology", Eastern Economy	1998

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF THE DEPARTMENT: **Earth Sciences**

1. Subject Code : **ES-207** Course Title: **Physical Geology**

2. Contact Hours: **L : 2 T : 1 P : 0**

3. Examination Duration (Hrs): **Theory**

0	2
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Practical

0	0
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4. Relative Weightage **CWS**

2	5
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PRS

0	0
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MTE

2	5
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ETE

5	0
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PRE

0	0
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5. Credits :

0	3
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6. Semester: **Autumn**

7 Pre-requisite: **Nil**

8. Subject Area: **BSC**

9. Objective: To provide basic understanding of general geology and physical geology

10. Details of Course:

S. No	Contents	Contact Hours
1	Different hypotheses of earth's origin	3
2	Earth's interior and constitution	3
3	Basic concepts of isostasy and its importance	2
4	Earthquakes: Terminology, classification, global distribution, frequency of occurrence; Earthquakes causes and hazards	6
5	Volcanoes : Terminology, classification, global distribution, frequency of occurrence; Volcanic eruption and hazards	3
6	Continental drift, linear magnetic anomalies and mid-oceanic ridges	4
7	Basic concepts of plate tectonics, types of plate boundaries, orogenesis	3
8	Causes and types of mass movements on earth's surface	4
	Total	28

11. Suggested Books:

S. No	Name of Books/ Authors	Year of Publication
1	Holmes, A., "Physical Geology", Ronal	1980
2	Marshak, S., "Essentials of Geology", John Wiley & Sons	2004
3	Press, F. and Siever, R., "Understanding the Earth", Freeman	2000
4	Chernicoff, S., Fox, H.A. and Tanner, L.H., "Earth: Geologic Principles and Histories", Houghton Mifflin	2002

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF THE DEPARTMENT: **Earth Sciences**

1. Subject Code : **ES-208** Course Title: **Statistics and Numerical Methods**

2. Contact Hours : **L : 3 T : 1 P : 0**

3. Examination Duration (Hrs) : **Theory** **Practical**

4. Relative Weightage **CWS** **PRS** **MTE** **ETE** **PRE**

5. Credits:

6. Semester: **Spring**

7. Subject Area: **BSC**

8. Pre-requisite: **Nil**

9. Objective: To provide basic concepts of statistics and numerical methods applicable to geological problems

10. Details of Course:

S. No	Contents	Contact Hours
1	Introduction: Role of mathematical and numerical techniques in geological sciences, measurement systems	2
2	Statistics: Concept of probability, Binomial, Poisson and normal distributions, covariance and correlation; Test of significance: z-test, t-test, f-test and chi-square test	5
3	Matrix Decomposition: LU, Cholesky, QR, and singular value decomposition of a matrix	5
4	Solution of Simultaneous Equations: Gauss Jordan, Gaussian elimination and iterative methods; Eigenvalues and eigenvectors	5
5	Regression Analysis: Linear regression, correlation and correlation coefficient	4
6	Modeling of Data: Linear least square inversion, least squares as a maximum likelihood estimator	4
7	Numerical Integration and Differentiation: Quadrature formulae, trapezoidal and Simpson's rules; Forward, backward and central difference formulae	5
8	Spectral Methods: Fourier transforms, power spectrum and digital filtering	6
9	Multivariate Statistics: Multiple regression, discriminate analysis, principal component analysis and factor analysis	6
	Total	42

11. Suggested Books:

S. No	Name of Books/ Authors	Year of Publication
1	Borradaile, G.J., "Statistics of Earth Science Data", Springer	2003
2	Atkinson, K. and Han John, W., "Elementary Numerical Analysis", John Wiley & Sons	2003
3	Yang, W.Y., Cao, W. and Chung, T.S., "Applied Numerical Methods", John Wiley & Sons	2005
4	Press, W.H., Teukolsky, S.A., Vetterling, W.T. and Flannery, B.P., "Numerical Recipes: The Art of Scientific Computing", Cambridge University Press	2007
5	Davis, J.C., "Statistics and Data Analysis in Geology", 3 rd Ed., John Wiley & Sons	2002

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF THE DEPARTMENT: **Earth Sciences**

1. Subject Code: **ES-209** Course Title: **Paleontology-I**

2. Contact Hours : **L : 3 T : 0 P : 2**

3. Examination Duration (Hrs): **Theory**

0	3
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Practical

0	2
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4. Relative Weightage **CWS**

1	5
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PRS

1	5
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MTE

1	5
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ETE

4	0
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PRE

1	5
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5. Credits :

0	4
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6. Semester: **Autumn**

7. Pre-requisite: **Nil**

8. Subject Area: **BSC**

9. Objective: To introduce basic concepts in paleontology including invertebrate and vertebrate and plant fossils

10. Details of Course:

S. No	Contents	Contact Hours
1	Fundamentals: Definition, objectives and scope, nature of fossil record and their uses, the organic world, classification of animals, their habits and habitats, evolution of life through the ages, migration, dispersal and extinction of life	9
2	Invertebrate Paleontology: Morphology, classification, evolutionary trends, geological history and geographical distribution of brachiopoda, pelecypods, gasteropods, cephalopoda, trilobita, echinoidea, coelenterate and graptolodiea	9
3	Vertebrate Paleontology: Introduction , broad classification and study of vertebrate groups	6
4	Paleobotany: Introduction, Gondwana flora	4
5	Micropaleontology: Introduction, techniques of processing of samples, brief morphology and classification of foraminifers, ostracods, radiolarians and conodonts	6
6	Applied Aspects: Age determination and correlation, paleoecological interpretations with case histories, fossils as a tool in petroleum exploration	8
	Total	42

List of Practicals

1. Megascopic study of important invertebrate, vertebrate and plant fossils
2. Microscopic study of important invertebrate and vertebrate fossils

11. **Suggested Books:**

S. No	Name of Books/ Authors	Year of Publication
1	Walton, J., "An Introduction to the Study of Fossil Plants", Adam & Charles Black	1953
2	Woods, H., "Paleontology Invertebrate", CBS Publications	1963
3	Benton, M.J., "Vertebrate Paleontology", Chapman & Hall	1997
4	Colbert, R.L., "Paleontology", John Willey & Sons	1987
5	Milsom, C., and Rigby, S., "Fossils at a Glance", Blackwell	2004
6	McGowran, B., "Biostratigraphy: Microfossils & Geological Time", Cambridge University Press	2005

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF THE DEPARTMENT: **Earth Sciences**

1. Subject Code: **ES-301** Course Title: **Economic Geology**

2. Contact Hours : **L : 3 T : 0 P : 2**

3. Examination Duration (Hrs): **Theory**

0	3
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Practical

0	2
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4. Relative Weightage **CWS**

1	5
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PRS

1	5
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MTE

1	5
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ETE

4	0
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PRE

1	5
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5. Credits :

0	4
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6. Semester: **Autumn**

7 Pre-requisite: **ES-202 & ES-205**

8 Subject Area: **DCC**

9. Objective: To impart basic understanding of different types of mineral deposit and processes of their formation

10. Details of Course:

Sl. No	Contents	Contact Hours
1	Historical background, distribution, morphology and disposition of ore bodies	2
2	Physical characteristics, structure and texture of ore minerals	2
3	Classification of ore bodies	4
4	Endogenic processes of ore formation; Early and late magmatic segregation and injection, immiscible liquid segregation, different types of hydrothermal ore formation, volcanic exhalative process, metamorphic and metamorphosed processes	12
5	Exogenic processes of ore formation; Mechanical accumulation, sedimentary precipitates, residual concentration, oxidation and supergene enrichment	8
6	Geology of important economic deposits of India: Bauxite, iron, manganese, copper, lead, zinc, gold, chromite, diamond, coal and petroleum	12
7	Importance of mineral deposits in national economy	2
	Total	42

List of practical

1. Locating different important mineral deposits on outline map of India /world.
2. Megascopic study of ore specimens/ industrial minerals
3. Microscopic study of important ore minerals
4. Preparation of polished ore specimen

11. Suggested Books:

S. No	Name of Books/ Authors	Year of Publication
1	Bateman, A. M. and Jensen, M.L., "Economic Mineral Deposits", John Wiley & Sons, 3rd Ed.	1981
2	Guilbert, J.M. and Charles F. P. Jr., "The Geology of Ore Deposits", Waveland	1986
3	Bannerjee, D.K., "Mineral Resources of India", The World Press	1992
4	Evans, A.M., "Ore Geology and Industrial Minerals: An Introduction", Blackwell Science, 3 rd Ed.	1993
5	Mookherjee, A., "Ore Genesis: A Holistic Approach", Allied Publishers	1999
6	Smirnov, V. I., "Geology of Mineral Deposits" MIR Publishers	1976

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF THE DEPARTMENT: **Earth Sciences**

1. Subject Code: **ES-302** Course Title: **Stratigraphy**

2. Contact Hours : **L : 3 T : 1 P : 0**

3. Examination Duration (Hrs): **Theory**

0	3
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Practical

0	0
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4. Relative Weightage **CWS**

2	5
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PRS

0	0
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MTE

2	5
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ETE

5	0
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PRE

0	0
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5. Credits :

0	4
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6. Semester: **Spring**

7. Pre-requisite: **ES-207**

8. Subject Area: **DCC**

9. Objective: To provide basic understanding of principles of stratigraphy, stratigraphic contacts geological time scale and stratigraphic sequences of India

10. Details of Course

S. No	Contents	Contact Hours
1	Definition and scope of stratigraphy	4
2	Principles of superposition, original horizontality and uniformitarianism	2
3	Geological time scale, purpose, scope and development	6
4	Stratigraphic classification and nomenclature of units, lithostratigraphy, biostratigraphy, chronostratigraphy and geochronology	12
5	Stratigraphic contacts, conformity and unconformity	2
6	Definition, scope and kinds of correlation	2
7	Introduction to facies, transgression and regression	2
8	Broad outline of some of the major stratigraphic sequences of India, Archean Proterozoic, Paleozoic, Mesozoic, Cenozoic stratigraphic units of India	12
Total		42

11. Suggested Books:

S. No	Name of Books/ Authors	Year of Publication
1	Lemon, R.L., "Principles of Stratigraphy", Meril Publishing	1990
2	Boggs, S., Jr., "Principles of Sedimentology and Stratigraphy", Meril Publishing	1987
3	Kumar, R., "Fundamentals of Historical Geology and Stratigraphy of India", Wiley	1985
4	Krishnan, M.S., "Geology of India and Burma", CBS Publications	1985
5	Wadia, D.N., "Geology of India", Tata-McGraw-Hill	1975
6	Ramakrishnan, M. and Vaidyanathan, R., "Geology of India", Vol. I and II, Geological Society of India	2008

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF THE DEPARTMENT: **Earth Sciences**

1. Subject Code: **ES-303**

Course Title: **Plate Tectonics**

2. Contact Hours: **L : 2 T : 1 P : 0**

3. Examination Duration (Hrs): **Theory**

0	2
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Practical

0	0
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4. Relative Weightage **CWS**

2	5
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PRS

0	0
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MTE

2	5
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ETE

5	0
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PRE

0	0
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5. Credits :

0	3
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6. Semester: **Autumn**

7. Pre-requisite: **ES-203 & ES-207**

8. Subject Area: **DCC**

9. Objective: To introduce the concept of plate tectonics and its importance in understanding the major features on the earth's surface including mountain building and seismicity

10. Details of Course

S. No	Contents	Contact Hours
1	Introduction: Review of various hypothesis of the earth's origin, earth's interior and constitution	2
2	Seismology: Types and propagation of seismic waves, propagation paths, interior structure of the earth based on seismological observations	3
3	Earth's Crust: Oceanic and continental types of earth's crust; Composition, mineralogy, major structural features of the earth	4
4	Plate tectonics: Historical background, type of plate margins and sense of displacements of plates	2
5	Creative Plate Margin: Composition, seismic structure and evolution	2
6	Conservative Plate Margin: Transforms faults and plate motions, seismicity, structure and evolution	2
7	Destructive Plate Margins: Surface manifestations, geophysical and geological characteristics, sedimentological, metamorphic and magmatic characteristics	5
8	Orogenesis: Plate tectonics and mountain building processes	4
9	Indian Plate: Configuration and characters of Indian plate margins; Himalayan orogeny and tectonic models	4
	Total	28

11. Suggested Books:

S. No	Name of Books/ Authors	Year of Publication
1	Brown, G.C., Hawkesworth, C.J. and Wilson, R.C.L.(Eds.), "Understanding the Earth", Cambridge University Press	1992
2	Kearey, P. and Vine, F. J., "Global Tectonics", Blackwell	1990
3	Condie, K.C, "Plate Tectonics and Crustal Evolution", Butterworth-Heinemann	1982
4	Cox, A. and Hart, R. B "Plate Tectonics: How it Works", Wiley-Blackwell	1986
5	Gansser, A., "Geology of the Himalayas", John Wiley & Sons	1964
6	Davies, G.F., "Dynamic Earth: Plates, Plumes and Mantle Convection", Cambridge	2000

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF THE DEPARTMENT: **Earth Sciences**

1. Subject Code: **ES-304** Course: **Structural Geology - II**

2. Contact Hours: **L : 3 T : 0 P : 2**

3. Examination Duration (Hrs): **Theory**

0	3
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Practical

0	2
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4. Relative Weightage **CWS**

1	5
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PRS

1	5
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MTE

1	5
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ETE

4	0
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PRE

1	5
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5. Credits :

0	4
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 6. Semester: **Spring**

7. Pre-requisite: **ES-203** 8. Subject Area: **DCC**

9. Objective: To provide in-depth knowledge of techniques of structural analysis for understanding of deformation in rocks

10. Details of Course:

S. No	Contents	Contact Hours
1	Stress in homogeneous and inhomogeneous media and analytical techniques	5
2	Geometry and analysis of fractures, joints and faults	8
3	Homogeneous strain and techniques of strain analysis including Fry method, grain centre method and R_f / Φ method	8
4	Geometry of folds and their classification schemes	3
5	Mechanism of folding and internal strain accommodation	3
6	Shear zones and techniques of their analysis; Examples	4
7	Analysis of foliation and lineation in rocks: Geometry, mechanics and significance	3
8	Techniques of structural analysis in areas of superposed folding	5
9	Different types of deformation mechanism	3
	Total	42

List of Practicals

1. Techniques of strain analysis: determination of finite strain of deformed objects using long-to short axis, center- to- center, Fry and R_f / Φ methods
2. Determination of finite strain from deformed fossils
3. Dip isogon method of fold analysis
4. Determination of strain in ductile shear zones and analysis of brittle fault zones
5. Structural analysis of folded terrains

12. Suggested Books:

S. No	Name of Books/ Authors	Year of Publication
1	Suupe, J., "Principles of Structural Geology", Prentice –Hall	1985
2	Twiss, R. J. and Moores, E. M., "Structural Geology", W.H. Freeman & Co,	1992
3	Davis, G. H. and Reynolds, S. J., "Structural Geology of rocks and regions", JohnWiely & Sons, Inc.	1996
4	Ghosh, S. K. 1993., "Structural Geology: fundamentals and modern developments", Pergamon	1993
5	Ramsay, J.G., Lisle, R.J. "Techniques of Modern Structural Geology", Volume 3: Applications of Continuum Mechanics in Structural Geology (Modern Structural Geology) -Academic Press	2001

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF THE DEPARTMENT: **Earth Sciences**

1. Subject Code: **ES-305** Course Title: **Igneous Petrology**

2. Contact Hours: **L : 3 T : 0 P : 2**

3. Examination Duration (Hrs): **Theory**

0	3
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Practical

0	0
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4. Relative Weightage **CWS**

1	5
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PRS

1	5
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MTE

3	0
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ETE

4	0
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PRE

1	5
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5. Credits :

0	4
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6. Semester: **Autumn**

7. Pre-requisite: **ES-202**

8. Subject Area: **DCC**

9. Objective : To provide in-depth knowledge of igneous rocks including their geochemical characteristics and petrogenesis

10. Details of Course:

S. No	Contents	Contact Hours
1	Processes involving modification of primary magma	4
2	Fractional crystallization and crustal contamination	2
3	Phase diagrams	4
4	Classifications of igneous rocks	2
5	Geochemical characteristics of igneous rocks as petrogenetic indicators	4
6	Rb – Sr isotope evolution in igneous rocks	2
7	Sm – Nd systematics as petrogenetic indicators	2
8	Magmatism and global tectonic processes	3
9	Magmatism at constructive plate margin, mid-oceanic ridges, ocean floor magmatism	6
10	Magmatism at destructive plate margin, subduction zone magmatism, island arc systems	6
11	Intraplate magmatism, carbonatites	4
12	Continental flood basalts, alkaline rocks	3
	Total	42

List of Practicals

1. Microscopic studies of acidic, basic and ultramafic igneous rocks and their petrogenesis
2. Geochemical variation diagram studies
3. CIPW normative calculations based on geochemical data

11. Suggested Books:

S. No	Name of Books/ Authors	Year of Publication
1	Willson, M., "Igneous Petrogenesis: A Global Tectonic Approach", Unwin-Hyman	1989
2	Winter, J., "An Introduction to Igneous and Metamorphic Petrology", Prentice-Hall	2001
3	Hall, A., "Igneous Petrology", John Wiley & Sons	1995

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF THE DEPARTMENT: **Earth Sciences**

1. Subject Code: **ES-306** Course Title: **Ore Geology**

2. Contact Hours : **L : 3 T : 0 P : 2**

3. Examination Duration (Hrs): **Theory**

0	3
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Practical

0	0
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4. Relative Weightage **CWS**

1	5
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PRS

1	5
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MTE

3	0
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ETE

4	0
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PRE

0	0
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5. Credits :

0	4
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 6. Semester: **Spring**

7. Pre-requisite: **ES-301** 8. Subject Area: **DCC**

9. Objective : To provide in-depth knowledge of various ore genetic processes

10. Details of the Course

S. No	Contents	Contact Hours
1	Introduction and basic ideas about ore bodies, texture and structures of ores, ore forming processes	4
2	Trace elements and their source characterization	4
3	Stable isotopes (S, C, O and H) and their application in source characterization and estimation of physico-chemical conditions of ore formation	6
4	Role of fluids in orogenesis; Fluid inclusion studies, geothermometry and geobarometry	4
5	Classification of ore deposits; Ore deposits in important geological settings	2
6	Magmatic ore deposits	4
7	Hydrothermal ore deposits	4
8	Volcanogenic sedimentary ore deposits	4
9	Sedimentary, metamorphic and metamorphosed ore deposits	4
10	Mineralization in space and time, crustal evolution	2
11	Plate tectonics and metallogenesis	4
	Total	42

List of Practicals

1. Identification of ore minerals based on qualitative optical properties
2. Determination of reflectivity and hardness of ore minerals
3. Study of textures and structures in mineral specimen
4. Establishing the paragenesis of mineral associations
5. Discrimination of primary, secondary and pseudo-secondary fluid inclusions in mineral deposits

11. Suggested Books:

S. No	Name of Books/ Authors	Year of Publication
1	Misra, K.C., "Understanding Mineral Deposits", Springer	2000
2	Evans, A.M., "Ore Geology and Industrial Minerals: An Introduction", Blackwell Science, 3 rd Ed.	1993
3	Evans, A.M., "An Introduction to Economic Geology and its Environmental Impact", Blackwell Science	2001
4	Robb, L., "Introduction to Ore-Forming Processes", Blackwell	2005
5	Laznicka, P., "Giant Metallic Deposits", Springer	2006

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF THE DEPARTMENT: **Earth Sciences**

1. Subject Code: **ES-307** Course Title **Sedimentology**

2. Contact Hours: **L: 3 T: 0 P: 2**

3. Examination Duration (Hrs): **Theory**

0	3
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Practical

0	0
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4. Relative Weightage **CWS**

1	5
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PRS

1	5
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MTE

3	0
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ETE

4	0
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PRE

0	0
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5. Credits :

0	4
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6. Semester: **Autumn**

7. Pre-requisite: **ES-202**

8. Subject Area: **DCC**

9. Objective: To provide in-depth knowledge of sedimentary textures and structures and sedimentary processes including depositional environments

10. Details of Course:

S. No	Contents	Contact Hours
1.	Weathering under different climatic conditions and sediment transport by various agents	5
2	Classification and genesis of various sedimentary textures; Siliciclastic sediments; Paleocurrent analysis; Importance in provenance analysis	5
3	Classification of sedimentary structures; Occurrence and distribution of foreland basins and deltas	6
4	Composition and classification of different types of sedimentary rocks and their genetic importance	6
5	Diagenesis of sedimentary rocks, physico-chemical considerations	4
6	Depositional environments, classification of facies	4
7	Models for genetic environments of sandstone, conglomerate, breccia, mudstone, limestone, evaporite, iron deposits, phosphates, cherts, siliceous sediments and volcanoclastic sediments	8
8	Plate tectonics and sedimentary basins; Analysis of coal, oil and petroleum, basins	4
	Total	42

List of Practicals

1. Grain size analysis using sieves and its statistical analysis
2. Determination of roundness of clastic particles using comparison chart method
3. Statistical analysis of orientation data
4. Thin section study of sandstones and limestones
5. Recognition of major clay minerals from x-ray diffractograms
6. Determination of facies cyclotherms from a vertical log

11. Suggested Books:

S. No	Name of Books/ Authors	Year of Publication
1	Blatt, H., Middleton, G.V. and Murray, T.G., "Origin of Sedimentary Rocks", Prentice – Hall	1982
2	Boggs, S., "Principles of Sedimentology and Stratigraphy", 4 th Ed., Prentice – Hall	2001
3	Leeder, M.R., "Sedimentology and Sedimentary Basins", Prentice – Hall	1999
4	Reading, H.G., "Sedimentary Environments - Processes, Facies and Stratigraphy", Wiley - Blackwell	1996

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF THE DEPARTMENT: **Earth Sciences**

1. Subject Code: **ES-308** Course Title: **Metamorphic Petrology**

2 Contact Hours: **L : 3 T : 0 P : 2**

3. Examination Duration (Hrs): **Theory**

0	3
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Practical

0	0
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4. Relative Weightage **CWS**

1	5
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PRS

1	5
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MTE

3	0
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ETE

4	0
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PRE

0	0
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5. Credits :

0	4
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 6. Semester: **Spring**

7. Pre-requisite: **ES-202** 8. Subject Area: **DCC**

9 Objective: To provide in-depth knowledge of phase rule, classification of metamorphic rocks and metamorphic assemblages

10. Details of the course

S. No	Contents	Contact Hours
1	Various types of metamorphism, metamorphic rocks and facies	4
2	Texture, structure and classification of metamorphic rocks	3
3	Phase rule, metamorphic reactions and phase equilibria in metamorphic rocks	4
4	Graphical representation of various mineral assemblages in different P-T conditions	4
5	Phase diagrams and petrogenetic grid for metamorphic assemblages in various grades of metamorphism	4
6	Thermodynamics of metamorphic reactions and mineral assemblages in different metamorphic isograds	6
7	Concept of facies and different types of metamorphic facies	3
8	Mineral assemblages for different rock types in zeolite, prehnite, pumpellyite, greenschist, amphibolite, granulite, eclogite, and blueschist facies	7
9	Mineral paragenesis and chemographic relations in metamorphism of calcareous, mafic and ultramafic rocks	7
	Total	42

List of Practicals

Microscopic/petrographic studies of metamorphic rocks such as,

- i. Phyllite
- ii. Garnet–biotite-staurolite-mica-schists
- iii. Kyanite-sillimanite-mica schists
- iv. Pelitic gneisses
- v. Migmatite
- vi. Tremolite- actinolite schists
- vii. Amphibolite
- viii. Basic gneiss
- ix. Calc-silicates and
- x. Marbles

11. Suggested Books:

S. No.	Name of Books/Authors	Year of publications
1.	Spear, F.S., “Metamorphic Phase Equilibria and Pressure-Temperature-Time Paths”, Mineralogical Society of America Monograph	1993
2.	Yardley, B.W.D., “An Introduction to Metamorphic Petrology”, Longman-ELBS	1990
3.	Winter, J.D., “An Introduction to Igneous and Metamorphic Petrology”, Prentice-Hall	2001
4.	Best, M.G., “Igneous and Metamorphic Petrology”, Blackwell	2001

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF THE DEPARTMENT: **Earth Sciences**

1. Subject Code : **ES-309** Course Title: **Geophysical Prospecting**
2. Contact Hours : **L : 2 T : 1 P : 0**
3. Examination Duration (Hrs) : **Theory:** **Practical:**
4. Relative Weightage **CWS** **PRS** **MTE** **ETE** **PRE**
5. Credits:
6. Semester: **Autumn**
7. Subject Area: **DCC**
8. Pre-requisite: **MA-101, PH-101**
9. Objective: To introduce basic concepts of geophysical methods and their applications in solving geological problems
10. Details of Course:

S. No	Contents	Contact Hours
1	Introduction: Overview and importance of various geophysical methods in geological studies	2
2	Gravity Method: Basic principles, gravity anomalies, gravimeters, data acquisition procedures, data reduction and processing, interpretation of Bouguer anomalies for basic geometrical shapes, depth rules; Applications	4
3	Magnetic Method: Basic principles, magnetic anomalies, magnetometers, data acquisition procedures, data reduction and processing, interpretation of magnetic anomalies for basic geometrical shapes, depth rules; Applications	5
4	Seismic Methods: Refraction, reflection and attenuation of seismic waves, geophones and hydrophones, recording instruments, seismic refraction method, travel time curves for flat and dipping interfaces, interpretation of refraction profiles, seismic reflection method, CDP shooting, geophone grouping, elementary ideas about processing and interpretation of seismic reflection data; Applications	6
5	Electrical Method: Apparent resistivity, sounding and profiling, different electrode configurations, field procedures, resistivity meters, data interpretation using curve matching method, electrical section; Applications	6
6	Electromagnetic Methods: Basic concepts, dip angle techniques, measurement of amplitude and phase, various transmitter and receiver loop configurations, response curves, airborne electromagnetic method; Applications	5
Total		28

11. Suggested Books:

S. No	Name of Books/ Authors	Year of Publication
1	Telford, W.M., Geldart, L.P and Sheriff, R.E., “Applied Geophysics”, Cambridge University Press	1999
2	Kearey, P, Brooks, M and Hill, I., “An Introduction to Geophysical Exploration”, Blackwell	2002
3	Parasnis, D.S., “Principles of Applied Geophysics”, Chapman and Hall	1997
4	Dobrin, M.B and Savit, C.H., “Introduction to Geophysical Prospecting”, McGraw-Hill	1988

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF THE DEPARTMENT: **Earth Sciences**

1. Subject Code : **ES-310** Course Title : **Applied Geochemistry**

2. Contact Hours : **L : 2 T : 0 P : 2**

3. Examination Duration (Hrs): **Theory**

0	2
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Practical

0	0
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4. Relative Weightage **CWS**

1	5
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PRS

1	5
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MTE

3	0
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ETE

4	0
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PRE

0	0
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5. Credits :

0	3
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 6. Semester: **Spring**

7. Pre-requisite: **CY-101 and ES-202**

8. Subject Area: **DCC**

9. Objective: To introduce geochemistry as a tool for understanding various earth processes

10. Details of Course:

S. No	Contents	Contact Hours
1	Chemical composition of earth, distribution of elements in igneous, sedimentary and metamorphic rocks, internal divisions and differentiation of earth	3
2	Crystal chemistry, silicate structures, isomorphism, polymorphism, substitution, surface chemistry, sorption, ion exchange, colloids in igneous, sedimentary and metamorphic conditions	4
3	Chemical equilibrium, equilibrium kinetics, chemical thermodynamics, enthalpy, free energy, phase equilibria, activity, reaction rates, oxidation-reduction processes	2
4	Aqueous solutions, carbonate equilibria, silicate equilibria	4
5	Sedimentation and diagenesis- organic and inorganic geochemistry	3
6	Radiogenic and stable isotopes, different isotopic systematics, geochronology, petrogenesis	3
7	Analytical techniques for rock, sediments and water compositions	3
8	Geochemical techniques for mineral exploration in different geological environments, geochemical surveys and data analysis	6
Total		28

List of Practicals:

1. Sampling of rocks, sediments and water for geochemical analysis
2. Digestion of rock samples, preparation of solutions for analysis
3. Analysis of major and trace elements in silicate rocks
4. Preparation of standards for geochemical analysis
5. Preparation of various solutions with differing ionic strength
6. Basic principles and demonstration of analytical instruments

11. Suggested Books:

S. No	Name of Books/ Authors	Year of Publication
1	Krauskopf, K.B., and Bird, D.K., "Introduction to Geochemistry", McGraw-Hill	1995
2	Albarede, F., "Geochemistry: An Introduction", Cambridge University Press	2003
3	Walther, J.V., "Essentials of Geochemistry", Johns & Bartlett	2005
4	Gill, R., "Modern Analytical Geochemistry", Addison Wesley	2000
5	Holland H.D., (Ed.), "Treatise of Geochemistry", Elsevier	2001

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF THE DEPARTMENT: **Earth Sciences**

1. Subject Code: **ES-312** Course Title: **Mineral Exploration**

2. Contact Hours : **L : 2 T : 0 P : 2**

3. Examination Duration (Hrs): **Theory**

0	2
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Practical

0	0
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4. Relative Weightage **CWS**

1	5
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PRS

1	5
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MTE

3	0
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ETE

4	0
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PRE

0	0
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5. Credits :

0	3
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 6. Semester: **Spring**

7. Pre-requisite: **ES-301** 8. Subject Area: **DCC**

9. Objective: To introduce basic concepts of mineral exploration including delineation of ore reserves

10. Details of Course:

S. No	Contents	Contact Hours
1	Overview of various stages and data/tools of exploration	2
2	Geological indicators for mineral deposits, lithological and structural controls of mineralization	4
3	Basic concepts of geological and geochemical prospecting	3
4	Different techniques in mineral exploration: Drilling, sampling, bench mapping underground mine mapping, geological plans and sections	8
5	Delineation of subsurface ore bodies of different geometric shapes	3
6	Ore reserve estimation and grade calculation for different types of ore deposits	5
7	Computer software applications in mineral exploration	3
	Total	28

List of Practicals:

1. Exercises on geochemical data interpretation
2. Regional exploration data analysis
3. Exercises related to trenching, pitting and drilling data
4. Interpretation of field exploration data and ore reserve estimation

11. Suggested Books:

S. No	Name of Books/ Authors	Year of Publication
1	Moon, C.J., Whateley, M.K.G. and Evans, A.M., "Introduction to Mineral Exploration", Blackwell Science, 2 nd Ed.	2006
2	Talapatra, A.K., "Modelling and Geochemical Exploration of Mineral Deposits", Capital Publishing	2006
3	Rajendran, S., Srinivasamoorthy, K. and Aravindan S., "Mineral Exploration : Recent Strategies" New India Pub.	2007
4	Edward E. and Hausel, W. D., "Diamond Deposits: Origin, Exploration, and History of Discovery" Society for Mining, Metallurgy & Exploration (SME)	2002
5	Naldrett A. J., "Magmatic Sulfide Deposits: Geology, Geochemistry and Exploration" Springer-Verlag	2004

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF THE DEPARTMENT: **Earth Sciences**

1. Subject Code : **ES-314** Course **Field Training-II**

2. Contact Hours : **L : 0 T : 0 P : 0**

3. Examination Duration (Hrs): **Theory**

0	0
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Practical

0	0
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4. Relative Weightage **CWS**

0	0
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PRS

5	0
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MTE

0	0
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ETE

0	0
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PRE

5	0
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5. Credits :

0	2
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6. Semester: **Spring**

7. Pre-requisite: **ES-204**

8. Subject Area: **DCC**

9. Objective: To introduce field aspects of mapping of mineral deposits in mines

10. Details of Course:

S. No	Contents	Contact Hours
1	Visit to surface and sub-surface mines	10
2	Preparation of geological maps and sections	10
3	Study of ore body configuration and estimation of reserves	12
4	Surface and sub-surface mapping	10
5	Collection of sample and study of ore sections	10
6	Report writing	4
	Total	56

11. Suggested Books: None

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF THE DEPARTMENT: **Earth Sciences**

1. Subject Code: **ES-401** Course Title: **Principles of Remote Sensing**

2. Contact Hours : **L : 2 T : 1 P : 0**

3. Examination Duration (Hrs): **Theory**

0	2
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Practical

0	0
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4. Relative Weightage **CWS**

2	5
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PRS

0	0
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MTE

2	5
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ETE

5	0
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PRE

0	0
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5. Credits :

0	3
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6. Semester: **Autumn**

7. Pre-requisite: **Nil**

8. Subject Area: **DCC**

9. Objective: To introduce the principles of aerial and satellite based remote sensing for studying earth resources

10. Details of Course:

S. No	Contents	Contact Hours
1	Introduction, development of remote sensing technology, advantages; Different platforms of remote sensing; EM spectrum, solar reflection and thermal emission remote sensing	4
2	Interaction of EM radiation with atmosphere including atmospheric scattering, absorption and emission	2
3	Interaction mechanisms of EM radiation with ground, spectral response curves	2
4	Photographic techniques in aerial and spaceborne remote sensing; Spectrogonal photography using various camera, film, filter combinations; Applications and limitations	5
5	Stereo aerial photography, principle of stereoscopy, elements of photogrammetry	2
6	Principles of image interpretation, digital image processing	3
7	Multi-spectral scanners and imaging devices; Salient characteristics of LANDSAT, IRS, SPOT, IKONOS, QuickBird, GeoEye sensors and their applications	5
8	Image characteristics and interpretation of different geological landforms, structures and major igneous, sedimentary and metamorphic rock types; Remote sensing as a fore-runner in all exploration programs	5
	Total	28

11. Suggested Books:

S. No	Name of Books/ Authors	Year of Publication
1	Drury, S. A., "Image Interpretation in Geology", 2 nd Ed., Allen and Unwin	1993
2	Gupta, R. P., "Remote Sensing Geology", 2 nd Ed., Springer	2003
3	Lillesand, T.M., Kiefer, R.W. and Chipman, J.W., "Remote Sensing and Image Interpretation", 5th Ed., John Wiley & Sons	2003
4	Sabins, F.F. Jr., "Remote Sensing-Principles and Interpretation", 3 rd Ed., Freeman	1997

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF THE DEPARTMENT: **Earth Sciences**

1. Subject Code : **ES-402** Course Title: **Well Logging**

2. Contact Hours : **L : 3 T : 1 P : 0**

3. Examination Duration (Hrs) **Theory:** **Practical:**

4. Relative Weightage **CWS** **PRS** **MTE** **ETE** **PRE**

5. Credits:

6. Semester: **Spring**

7. Subject Area: **DCC**

8. Pre-requisite: **Nil**

9. Objective: To introduce geophysical well logging techniques for interpretation of subsurface geology

S. No	Contents	Contact Hours
1	Introduction: Objectives of well logging, classification of well logging methods, formation evaluation and its importance	4
2	Electrical Logging: Basic principles, SP log, normal and lateral logs, focused logs, micro-resistivity tools and their role in formation evaluation; Applications	6
3	Induction Logs: Basic principles, dual induction logs, geometric factors; Applications	6
4	Radiation Logs: Basic principles of different types of radiation logs including gamma ray, gamma-gamma, neutron thermal and chlorine logs; Porosity determination and cross plots; Applications	6
5	Sonic Logs: Basic principles, sonic logging tools, porosity determination; Applications	6
6	NMR Logging: Permeability, bound and free-water estimation using NMR logging techniques; Applications	4
7	Auxiliary Logging Devices: Caliper, dipmeter, cement bond logging, casing collar locators, temperature logging; Applications	6
8	Wire Line Sampling: Rock sampling, fluid sampling and pressure measurements	4
	Total	42

11. Suggested Books:

S. No	Name of Books/ Authors	Year of Publication
1	Serra, O., "Well Logging and Geology", TECHNIP	2003
2	Theys, P., "Log Data Acquisition and Quality Control", Gulf Publishing	1999
3	Ellis, D.V. and Singer, J.M., "Well Logging for Earth Scientists", Elsevier	1987
4	"Schlumberger Log Interpretation Principles/ Applications", Schlumberger Education Services	1987
5	Lynch, E.J., "Formation Evaluation", Harper and Row	1962

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF THE DEPARTMENT: **Earth Sciences**

1. Subject Code: **ES-403** Course: **Principles of GIS**
2. Contact Hours: **L : 2 T : 1 P : 0**
3. Examination Duration (Hrs): **Theory**

0	2
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Practical

0	0
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4. Relative Weightage **CWS**

2	5
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PRS

0	0
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MTE

2	5
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ETE

5	0
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PRE

0	0
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5. Credits:

0	3
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 6. Semester: **Autumn**
7. Pre-requisite: **NIL** 8. Subject Area: **DCC**
9. Objective: To provide basic understanding of GIS technology as applied to studies of earth resources

10. Details of Course:

S. No	Contents	Contact Hours
1	Introduction to GIS; Differences between GIS, CAD and DBMS	3
2	Different components of GIS, hardware and software requirements of GIS	2
3	Concepts of thematic layers, topology; Co-ordinate systems	2
4	Raster and vector data models and their associated advantages and disadvantages; Raster data compression techniques; Various vector data models	5
5	Concept of topology, Digital Elevation Model and its derivatives; Applications	4
6	Triangulated Irregular Network; Raster and vector integration	4
7	GIS analysis operations, error analysis	4
8	Integration of GIS with remote sensing; Geological applications	4
	Total	28

11. Suggested Books:

S. No	Name of Books/ Authors	Year of Publication
1	Chang, K.T., "Introduction to Geographic Information Systems", McGraw-Hill	2008
2	Harvey, F., "A Primer of GIS: Fundamental Geographic and Cartographic Concepts" Guilford Press	2008
3	Lo, C. P., "Concepts and Techniques of Geographic Information Systems" Pearson - Prentice Hall	2007
4	Lillesand, T.M., Kiefer, R.W. and Chipman, J.W., "Remote Sensing and Image Interpretation", 5th Ed., John Wiley & Sons	2003

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF THE DEPARTMENT: **Earth Sciences**

1. Subject Code: **ES-405** Course Title: **Engineering Geology**

2. Contact Hours : **L : 2 T : 1 P : 0**

3. Examination Duration (Hrs): **Theory**

0	2
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Practical

0	0
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4. Relative Weightage **CWS**

2	5
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PRS

0	0
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MTE

2	5
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ETE

5	0
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PRE

0	0
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5. Credits :

0	3
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 6. Semester: **Autumn**

7. Pre-requisite: **ES-203** 8. Subject Area: **DCC**

9. Objective: To introduce basic concepts of engineering geology for planning, site selection and design of major civil engineering structures

10. Details of Course:

S. No	Contents	Contact Hours
1	Introduction to engineering geology; Geological inputs for preparation of master plan for river valley projects	2
2	Different types of dams and related terminology; Criteria for site selection: Stability of dams as related to geological features	3
3	Classification and terminology in tunneling operations; Ground conditions; Geological considerations for construction of tunnels	4
4	Preparation, analysis and interpretation of engineering geological maps and sections for major civil engineering projects	2
5	Engineering properties of rocks and their determination by laboratory and in-situ tests	3
6	Concept of rock mass classification; RMR scheme	2
7	Classification of landslides, slope stability analysis and slope stabilization	3
8	Geological consideration for selecting different building materials; Concrete aggregates and their properties	3
9	Geological investigations related to site selection and construction of highways, buildings, bridges, pipelines and other civil engineering structures	6
Total		28

11. Suggested Books:

S. No	Name of Books/ Authors	Year of Publication
1	Legget, R.F. and Hathway, A., "Geology and Engineering", McGraw-Hill	1988
2	Krynine, D.P. and Judd, W.R., "Principles of Engineering Geology and Geotechnics", CBS Publications	2001
3	Bell, F.G., "Fundamentals of Engineering Geology", Elsevier	2007
4	Gokhale, K.V.G.K., "Principles of Engineering Geology", B.S. Publications	2006
5	Johnson, R.B. and DeGraft, J.V. "Principles of Engineering Geology", John Wiley & Sons	1988

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF THE DEPARTMENT: **Earth Sciences**

1. Subject Code: **ES-407** Course Title: **Hydrogeology**

2. Contact Hours : **L: 2 T: 1 P: 0**

3. Examination Duration (Hrs): **Theory**

0	2
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Practical

0	0
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4. Relative Weightage **CWS**

2	5
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PRS

0	0
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MTE

2	5
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ETE

5	0
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PRE

0	0
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5. Credits :

3

6. Semester: **Autumn**

7. Pre-requisite: **Nil**

8. Subject Area: **DCC**

9. Objective: To provide basic understanding of occurrence and distribution of groundwater in different geological formations, ground water geochemistry and related hydrogeological aspects

10. Details of Course:

S. No	Contents	Contact Hours
1	Hydrologic processes at the earth's surface, hydrologic cycle, residence time, reservoirs and ground water	3
2	Basic principles of groundwater flow, Darcy's law, hydraulic conductivity and transmissivity	4
3	Classification of aquifers, ground water in confined and unconfined beds	3
4	Surface and sub-surface hydrogeologic investigations for ground water exploration under different geological conditions and rock types	4
5	Key reactions of ground water chemistry, saturation, equilibrium kinetics, free energy, oxidation-reduction processes, ion exchange, electric double layer theory	4
6	Ground water chemistry, data representation, water quality and pollution studies	4
7	Principles and uses of isotopes in ground water	3
8	Water level fluctuations and water budgeting	3
	Total	28

11. Suggested Books:

S. No	Name of Books/ Authors	Year of Publication
1	Schwartz, F.W and Zhang. H., “Fundamentals of Ground Water”, John Wiley & Sons	2003
2	Todd, D.K., “Ground Water Hydrology”, John Wiley & Sons	2003
3	Domencio, P.A. and Schwartz, F.W., “Physical and Chemical Hydrogeology”, John Wiley & Sons	2002
4	Appelo, C.A.J and Postma, D., “Geochemistry, Groundwater and Pollution”, Balkema	2005
5	Fitts, C.R., “Groundwater Science”, Academic Press	2002

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF THE DEPARTMENT: **Earth Sciences**

1. Subject Code: **ES-409** Course Title : **Petroleum Geology**

2. Contact Hours: **L : 2 T : 1 P : 0**

3. Examination Duration (Hrs): **Theory**

0	2
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Practical

0	0
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4. Relative Weightage **CWS**

2	5
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PRS

0	0
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MTE

2	5
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ETE

5	0
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PRE

0	0
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5. Credits:

3

6. Semester: **Autumn**

7. Prerequisite: **Nil**

8. Subject area: **DCC**

9. Objective: To impart basic understanding of origin, occurrence, migration and accumulation of hydrocarbon resources

10. Details of the course

S.No.	Contents	Contact Hrs.
1	Physical and chemical properties of petroleum and its mode of occurrence	2
2	Occurrence of petroleum in time and space on global basis	2
3	Biogenic and abiogenic theories of origin of petroleum, source rocks	4
4	Migration and accumulation of petroleum, different types of traps including structural, stratigraphic, combination, fluid barrier, kinetic, chemical(gas hydrates) and biochemical traps	4
5	Petroleum reservoirs, reservoir characteristics, different types of reservoir rocks, reservoir pore space and reservoir fluids	4
6	Petroleum exploration, geological, geophysical and geochemical approaches, data integration	4
7	Estimation of petroleum reserves including volumetric methods	4
8	Petroleum provinces with special reference to India	4
	Total	28

11. **Suggested Books:**

S.No.	Name of Books/ Authors	Years of Publication
1	Barker, C, "Organic Geochemistry in Petroleum Exploration", AAPG Publication	1979
2	Biswas, S.K. (Ed.), "Petroliferous Basins of India", Petroleum Asia Journal	1988
3	Levorsen, H.O., "Geology of Petroleum", Freeman	1976
4	Peter, L.K., "Basic Petroleum Geology", OGCI Publishers	2001
5	Selly, R.C., "Elements of Petroleum Geology", 2 nd Ed., Academic Press	1997
6	Tissot, B.P. and D.H. Welle, "Petroleum Formation and Occurrence", Springer	1993