PG Course Template for
3-Year M.Sc. Tech. Applied Geology Programme

Semester I

Course No.	Course Name	L	T	P	C
GLC 501	Advanced Mineralogy	3	0	0	9
GLC 502	Applied Geochemistry	3	0	0	9
GLC 503	Methods of Structural Geology	3	0	0	9
GLC 504	Micropaleontology and Vertebrate Palaeontology	3	0	0	9
GLC 505	Mathematics for Geoscientists	3	0	0	9
GLC 506	*Mineralogy and Geochemistry Practical*	*0*	*0*	*3*	*3*
GLC 507	*Methods of Structural Geology Practical*	*0*	*0*	*2*	*2*
GLC 508	*Micropaleontology and Vertebrate Paleontology Practical*	*0*	*0*	*2*	*2*
	Total	**15**	**0**	**7**	**52**

Semester II

Course No.	Course Name	L	T	P	C
GLC 509	Igneous Petrology	3	0	0	9
GLC 510	Metamorphic Petrology	3	0	0	9
GLC 511	Applied Sedimentology	3	0	0	9
GLC 512	Petroleum Geology	3	0	0	9
GLC 513	Coal Geology	3	0	0	9
GLC 514	*Igneous and Metamorphic Petrology Practical*	*0*	*0*	*3*	*3*
GLC 515	*Sedimentology and Petroleum Geology Practical*	*0*	*0*	*3*	*3*
GLC 516	*Coal Geology Practical*	*0*	*0*	*2*	*2*
GLS 517	Sedimentary Field Training**	0	0	0	S/X
	Total	**15**	**0**	**8**	**53**

***"Sedimentary Field Training" of two weeks duration during winter vacation after I Semester with credit counted in II Semester.*

Course Structure for
3-Year M.Sc. Tech. Applied Geology Programme

Semester III

Course No.	Course Name	L	T	P	C
GLC 518	Principles and Applications of Geostatistics	3	0	0	9
GLC 519	Engineering Geology	3	0	0	9
GLC 520	Hydrogeology	3	0	0	9
	Departmental Elective 1	**3**	**0**	**0**	**9**
GLD 521	Stratigraphy				
GLD 522	Coalbed Methane, Shale Gas and Gas Hydrate Exploration				
	Open Elective 1 (Table 4)	**3**	**0**	**0**	**9**
GLC 524	*Principles and Applications of Geostatistics Practical*	*0*	*0*	*2*	*2*
GLC 525	*Engineering Geology and Hydrogeology Practical*	*0*	*0*	*3*	*3*
	Total	**15**	**0**	**5**	**50**

Semester IV

Course No.	Course Name	L	T	P	C
GLC 526	Ore Geology	3	0	0	9
GLC 527	Exploration Geology and Mineral Economics	3	0	0	9
	Departmental Elective 2	**3**	**0**	**0**	**9**
GLD 528	Geotechnical Engineering				
GLD 529	Organic Geochemistry				
	Departmental Elective 3	**3**	**0**	**0**	**9**
GLD 530	Geodynamics				
GLD 531	Sequence Stratigraphy and Basin analysis				
	Open Elective 2 (Table 4)	**3**	**0**	**0**	**9**
GLC 533	*Ore and Exploration GeologyPractical*	*0*	*0*	*2*	*2*
GLS 535	Structural and Economic Geology Field Training[#]	0	0	0	S/X
	Total	**15**	**0**	**5**	**50**

[#]*"Structural and Economic Geology Field Training" of two weeks duration during winter vacation after III Semester with credit counted in IV Semester.*

Course Structure for
3-Year M.Sc. Tech. Applied Geology Programme

Semester V

Course No.	Course Name	L	T	P	C
GLC 536	Thesis Unit 1	0	0	0	9
GLC 537	Thesis Unit 2	0	0	0	9
GLC 538	Thesis Unit 3	0	0	0	9
GLC 539	Thesis Unit 4	0	0	0	9
	Total	**0**	**0**	**0**	**36**

Semester VI

Course No.	Course Name	L	T	P	C
	DE 4/OE 3	3	0	0	9
GLD 540	Geomorphology				
GLD 541	Geochemical Analytical Techniques				
	OR				
	Open Elective 3 **(Table 4)**				
	DE 5/OE 4	3	0	0	9
GLD 543	Computer Applications in Geology				
GLD 544	Kinematics of Rock Deformation				
	OR				
	Open Elective 4 **(Table 4)**				
GLC 546	Thesis Unit 5	0	0	0	9
GLC 547	Thesis Unit 6	0	0	0	9
GLS 548	Summer Training/Internship[##]	0	0	0	S/X
	Total	**6**	**0**	**0**	**36**

[##]*"Summer Training/ Internship" S/X Letter Credit only.*

Table 1. LIST OF DEPARTMENTAL CORE COURSES (DC): Theory

Sl. No.	Course No.	Course Name	L	T	P	C	S#
1.	GLC 501	Advanced Mineralogy	3	0	0	9	M
2.	GLC 502	Applied Geochemistry	3	0	0	9	M
3.	GLC 503	Methods of Structural Geology	3	0	0	9	M
4.	GLC 504	Micropaleontology and Vertebrate Paleontology	3	0	0	9	M
5.	GLC 505	Mathematics for Geoscientists	3	0	0	9	M
6.	GLC 509	Igneous Petrology	3	0	0	9	W
7.	GLC 510	Metamorphic Petrology	3	0	0	9	W
8.	GLC 511	Applied Sedimentology	3	0	0	9	W
9.	GLC 512	Petroleum Geology	3	0	0	9	W
10.	GLC 513	Coal Geology	3	0	0	9	W
11.	GLC 518	Principles and Applications of Geostatistics	3	0	0	9	M
12.	GLC 519	Engineering Geology	3	0	0	9	M
13.	GLC 520	Hydrogeology	3	0	0	9	M
14.	GLC 526	Ore Geology	3	0	0	9	W
15.	GLC 527	Exploration Geology and Mineral Economics	3	0	0	9	W

S# - Semester in which course may be offered. M = Monsoon Semester; W = Winter Semester.

Table 2. LIST OF DEPARTMENTAL CORE COURSES (DC): Practical

Sl. No.	Course No.	Course Name	L	T	P	C	S#
1.	GLC 506	Mineralogy and Geochemistry Practical	0	0	0	3	M
2.	GLC 507	Methods of Structural Geology Practical	0	0	0	2	M
3.	GLC 508	Micropaleontology and Vertebrate Paleontology Practical	0	0	0	2	M
4.	GLC 514	Igneous and Metamorphic Petrology Practical	0	0	0	3	W
5.	GLC 515	Sedimentology and Petroleum Geology Practical	0	0	0	3	W
6.	GLC 516	Coal Geology Practical	0	0	0	2	W
7.	GLC 524	Principles and Applications of Geostatistics Practical	0	0	0	2	M
8.	GLC 525	Engineering Geology and Hydrogeology	0	0	0	3	M
9.	GLC 533	Ore and Exploration Geology Practical	0	0	0	2	W

S# - Semester in which course may be offered. M = Monsoon Semester; W = Winter Semester.

Table 3. LIST OF DEPARTMENTAL ELECTIVE COURSES (DE)

Sl. No.	Course No.	Course Name	L	T	P	C	S#	
1.	GLD 521	Stratigraphy	3	0	0	9	M	DE-1
2.	GLD 522	Coalbed Methane, Shale Gas and Gas Hydrate Exploration	3	0	0	9	M	
3.	GLD 528	Geotechnical Engineering	3	0	0	9	W	DE-2
4.	GLD 529	Organic Geochemistry	3	0	0	9	W	
5.	GLD530	Geodynamics	3	0	0	9	W	DE-3
6.	GLD531	Sequence Stratigraphy and Basin Analysis	3	0	0	9	W	
7.	GLD 540	Geomorphology	3	0	0	9	W	DE-4
8.	GLD 541	GeochemicalAnalytical Techniques	3	0	0	9	W	
9.	GLD 543	Computer Applications in Geology	3	0	0	9	W	DE-5
10.	GLD 544	Kinematics of Rock Deformation	3	0	0	9	W	

S# - Semester in which course may be offered. M = Monsoon Semester; W = Winter Semester. DE : Department Elective

***Table 4.*Table of Open Electives (any one or from Department Electives or Other Departments)**

Sl. No.	Course No.	Course Name	L	T	P	C	S#
1.	GLO 523	Atmosphere, Ocean and Climate Dynamics	3	0	0	9	M
2.	GLO 532	Environmental Geology	3	0	0	9	M
3.	GLO 542	Remote Sensing and GIS	3	0	0	9	W
4.	GLO 545	Nuclear Geology	3	0	0	9	W

S# - Semester in which course may be offered. M = Monsoon Semester; W = Winter Semester.DE : Open Elective

Detail Syllabus

3-Year M. Sc. Tech. Programme in Applied Geology

Syllabus of Departmental Core (DC) Theory Courses

1.Course Name: Advanced Mineralogy
1.a.Course Code: GLC 501
1.b.L-T-P = 3-0-0
1.c.Credit = 9
1.d.Syllabus& Lecture Plan:

Unit	Description	No. of Classes
1.	**Basics of mineralogy:** Definition, coordination number, chemical bonding, Pauling's rule	**7**
2.	**Silicate Structure:** Basis for classification of silicates with example	**2**
3.	**Silicate minerals:** Composition, structure, paragenesis and property of different silicate minerals Neso silicate – Olivine, Zircon, Sphene, Garnet, Al2SiO5, Topaz, Staurolite, Chloritoid their physical and optic properties.	**8**
4.	Soro and ring silicates (Epidote, Beryl, Cordierite, Tourmaline) Inosilicate (Single Chain) Pyroxene, Wollastonite, Amphibole,	**8**
5.	Phyllosilicates-Mica Group, Clay minerals, Framework Silicate-Feldspar group, Silica Minerals, Nepheline group, Scapolite, Zeolite group	**8**
6.	Non silicate Minerals: Oxides, hydroxides, Sulphides, Sulphates, Carbonate, Phosphate, Halides	**4**
7.	Introduction to equipments related to rock and mineral analysis	**2**
	Total Classes	**39**

1.e. Recommended Books:

1. Introduction to Mineralogy by William D. N., 2000, Oxford University Press.
2. Manual of Mineralogy (Revised) by Klein C., Hurlbut C. S. Jr., 1985, John Wiley & Sons.

1.f. CourseGoal / Learning Outcome:

The primary objective of the course is to introduce fundamental understanding of mineral composition and their occurrence in different rock.

1.g. Learning Objectives:

Upon completion of the course, students will be able to:

1. Learn about composition of common rock forming minerals
2. Which kind of rock the minerals may appear depending on the different geological processes involved

3. Identifying different minerals by physical and optical properties.

2.Course Name: Applied Geochemistry

2.a.Course Code GLC 502

2.b. L-T-P = 3-0-0

2.c. Credit = 9

2.d. Syllabus & Lecture Plan:

Unit	Description	No of classes
1	Origin and abundance of elements in the solar system and in the Earth and its constituents. Geochemistry of atmosphere, hydrosphere.	2
2	Atomic structures and properties of elements in the periodic table	2
3	Geochemical classification of elements. Special properties of LILE, HFSE and rear earth elements.	4
4	Principles of ionic substitution in minerals; element partitioning in mineral/rock formation and concept of simple distribution coefficients and exchange reaction distribution coefficients; element partitioning in mineral assemblages and its use in the pressure-temperature estimation.	6
5	Chemistry of natural waters. Mineral stability in Eh-pH diagram. Elemental mobility in surface environment. Concept of agrochemical-biogeochemical cycling and global climate.	5
6	Oceans and atmosphere: their compositions, evolution, steady state, and global mass balance, rock-water interaction: congruent and incongruent dissolution.	2
7	Application of Geochemical (major, trace and REE) data: In classification, determination of in tectonic environment and petrogenesis of igneous rocks by using different types of geochemical diagrams. Application of geochemical data in Mineral exploration	4
8	Introduction: Discovery of Radioactivity and isotopes as well and its influence on Earth Sciences. Nuclide types, their abundances, and atomic weights. Decay mechanisms of radioactive atoms. Radioactive decay and growth.	3
9	Basic principles of radiometric dating methods of Rocks: Ar -Ar, Rb-Sr, Sm-Nd, U-Th-Pb, Re-Os and Pb-Pb methods of dating	6
10	Stable isotope systematics: Carbon, Oxygen, Hydrogen and Sulphur and their implication	3
11	Application of stable isotope geology in palaeoclimate interpretations, ore geology, mineral and hydrocarbon exploration.	2
	Total hours	**39**

2.e. Text books Recommended/References:

1. Albarède F. (2003) Geochemistry An Introduction; Cambridge University Press.
2. Faure G. (1986) Principles of Isotope Geology; John Wiley and sons 2nd Eds.

Other References:

1. Faure G. (1991) Principles and Applications of Inorganic Geochemistry; Macmillan Publishing Company.
2. Hoefs EJ. (1996) Stable Isotope Geochemistry: Springer,4thEds.
3. Mason B, Moore CB. (1991) Principles of Geochemistry: Willey eastern Ltd,4th Eds.
4. Gopalan K. (2017) Principles of Radiometric dating: Cambridge University Press, 1st edition

2.f. Course Goal / Learning Outcome

In this course the students will study the fundamental concepts, principles and applications of geochemistry and brief introduction in isotope geology.

2.g. Learning Objectives

Upon completion of the course, students will be able to:

1. Understand the methods of dissolution, dilution and analysis of different types of chemical elements.
2. They will understand various types of data interpretation techniques.

3.Course Name: Methods ofStructural Geology

3.a Course Code: GLC 503

3.b. L-T-P = 3-0-0

3.c. Credit = 9

3.d. Syllabus & Lecture Plan:

Unit	Description	No. of classes
1.	**Methods of Subsurface Structural mapping**: Preparation and interpretation of structure contour, isopach and isochore maps. Stratigraphic sections and Fence diagrams. Preparation of cross sections of folds - concentric-arc method, kink-style construction, and dip-isogon method	6
2.	**Tectonites**: Different types and their significance. Petrofabric analysis. Relationship between deformation and metamorphism and criteria for recognition. Relative dating of orogenic belts	6
3.	**Structural Analysis**: Projection of fold geometry. Down-plunge projection of folds. Interference patterns in superposed folding and structural geometry in superposed folding. Behavior of lineations in superposed deformations. Use of foliations and lineations in tectonic analysis. Different phases of analysis, analysis of slate belts with simple and multiple deformations. Mapping in gneiss terranes. Migmatite complexes, reworking of basement rocks, mantled gneiss domes	12
4.	**Analysis of Fractures**: Fractures and fracture types. Joint-array Analysis and its significance. Fault-array Analysis. Lineament-Array analysis and its significance for regional exploration programme.	6
5.	**Analysis of Shear Zones**: Different types, Shear zone rocks, Shear sense indictors. Concept of thrust belt geometry. Balanced cross-sections of thrust-belts. Applications of balanced cross-sections	6
6.	**Analysis of areas of growth faulting**: Structural characters, mechanisms of development, associated structures, and determination	3

	of depth to detachment.	
7.	Salt Domes and impact structures	3
	Total classes =	39

3.e. Recommended Books

1. Badgley, PC (1965) Structural Methods for the Exploration Geologist. Oxford Book Company, Calcutta.
2. Davis, GH and Reynolds, SJ (1996) Structural Geology of Rocks and Regions (2nd Ed.). John Wiley & Sons.

Other References:

1. Ghosh, SK (1993) Structural Geology. Pergamon Press.
2. Groshong, RH, Jr. (2006). 3-D Structural Geology:A Practical Guide to Quantitative Surface and Subsurface Map Interpretation. Springer-Verlag, Berlin.
3. Marshak, S and Mitra, G (1988) Basic Methods of Structural Geology. Prentice Hall.
4. Ramsay, JG and Huber, MI (1987). The Techniques of Modern Structural Geology. Academic Press.
5. Roberts, J.L. (1982) Introduction to Geological Maps and Structures. Pergamon Press.
6. Roland, S.M., Duebendorfer, E.M. and Schiefelbein, I.M. (2007) Structural Analysis and Synthesis. Blackwell Publishing, Oxford
7. TearpockandBischke, R.E. (2003). Applied Subsurface Geological Mapping withStructuralMethods (Second Edition). Prentice Hall PTR, New Jersey, 822p.
8. Twiss, RJ and Moores, EM (1992). Structural Geology. W. H. Freeman & Company.
9. Woodward, NB, Boyer, SE and Suppe, J (1989) Balanced Geological Cross-sections. Amer. Geophys. Union.

3.f. Course Goal / Learning Outcome*

The primary objective of the course is to provide theoretical background for different structural techniques used in industry / exploration organisations.

3.g. Learning Objectives**

Upon completion of the course, students will be able to:

1. Apply different methods to determine subsurface structural geometry.
2. Identify and interpret geometry of folds.
3. Determine shear sense in shear zones.
4. Carry out mapping and analysis of thrust belts.

4.Course Name: Micropalaeontology and Vertebrate Palaeontology

4.a.Course Code: GLC 504

4.b. L-T-P = 3-0-0

4.c. Credit = 9

4.d. Syllabus & Lecture Plan:

Unit	Description	No. of Classes
1.	Introduction to various groups of microfossils with their general stratigraphic distribution. Sampling and separation techniques of microfossils from different types of sedimentary rocks. International coding system of core samples	**5**

2.	Morphology and Ecology of Foraminifera, Ostracod and Nannoplankton	**5**
3.	Application of micropaleontology in fossil fuel exploration and paleoclimate: Biostratigraphy, productivity index, aeration in marine water, palaeodepth and marine transgression & regression, palaeolatitude, bacterial degradation of organic carbon, sedimentation rate.	**8**
4.	Stable isotopes of microfossils. Use of microfossils: case studies	**5**
5.	Origin of vertebrates and their general evolutionary patterns, Classification and characteristic features of vertebrates (Agnathans, Fishes, Amphibia, Reptilia, Aves and Mammalia), General skeletal pattern with its different components in vertebrates	**5**
6.	Dentition patterns, variation in molar teeth and its implication	**3**
7.	Adaptation, evolution and phyllogeny of: Equids, Proboscids and Hominids	**6**
8.	Dinosaurs and their extinction.	**2**
	Total Classes	**39**

4.eReccommended Books

1. Saraswati, P. K., and Srinivasan, M. S. (2016). Micropaleontology: Principles and Applications. Fourth edition: Springer, Switzerland, pp. 223.
2. Armstrong, H., and Brasier, M., (2005). Microfossils (2nd Edition). Blackwell Publishing, USA, pp. 296.

Other References

3. Haq, B. U., and Boersma, A., (1998). Introduction to marine micropaleontology (2nd Edition). Elsevier, Amsterdam, pp. 376.
4. Benton, M., (2005). Vertebrate paleontology. Blackwell, pp. 472.
5. Carroll, R. L., 1988. Vertebrate Paleontology and Evolution. WH Freeman, pp. 698.
6. Romer, A., Vertebrate paleontology (3rd Edition). University of Chicago Press, pp. 687.

4.fCourse Goal / Learning Outcome

The primary objective of the course is to introduce students with kinds of microfossils, their separation, identification and uses. This course is designed in such a way that students can use their knowledge for exploration, paleoclimate, paleoceanography and paleogeographic study

4.g. Learning Objectives

Upon completion of the course, students will be able to:

1. Gaining knowledge about the groups of microfossils
2. How these groups can be helpful for fossil fuel exploration
3. Understanding paleoclimatic, paleoceanographic and paleogeographic variations through micropaleontology
4. The case studied will be more helpful for the student to understand the objectives.

5. Course Name: Mathematics for Geoscientists
5.a. Course Code GLC 505
5.b. L-T-P = 3-0-0
5.c. Credit = 9
5.d. Syllabus & Lecture Plan:

Unit	Description	No. of Classes
1.	Relationships between geological variables: Straight line, Quadratic equations, Polynomial functions, Negative and Fractional powers, Transcendental functions	**5**
2.	Manipulation of equations, Trigonometric functions, Cartesian coordinates, Matrices	**5**
3.	Vectors, Triangular diagrams, Graph theory, Polar graphs, Projections	**5**
4.	Statistics and Data Analysis: Frequency distribution, Histograms, Probability, Correlation coefficient, Regression, Least squares method, Curve fitting, Error estimation; Principal Component Analysis, Analysis of Uni-variate and Multi-variate data	**7**
5.	Probability distributions, Tests of Significance: Null hypothesis, Normal test, t-test, Chi-squared test and F-test; R environment	**7**
6.	Applications of Differential Calculus for geological problems	**5**
7.	Applications of Integral Calculus for geological problems	**5**
8.	**Total Classes**	**39**

5.e. Recommended Books:

1. David Waltham, 2000. Mathematics: A Simple Tool for Geologists, 2nd Edition, Blackwell Science, 201p.
2. L.D. Knoring and V.N. Dech, 1993. Mathematics for Geologists, A.A. Balkema, 200p.

Other References:

1. John C. Davis, 2002. Statistics and Data Analysis in Geology, Wiley, 656p.

D. Marsal and D.F. Merriam, 2014. Statistics for Geoscientists, 1st Edition, Elsevier, 176p

5.f. Course Goal/Learning Outcome

The students will appreciate and understand the indispensable mathematical tools as applied to geological studies.

5.g. Learning Objectives

Upon completion of the course, students will be able to:

1. Learn about the basic mathematical concepts and their applications to geology
2. Learn about different statistical methods used for geological data analysis
3. Develop fundamental mathematical skills required for geological interpretation.

6.Course Name: Igneous Petrology
6.a. Course Code: GLC 509
6.b. L-T-P = 3-0-0
6.c. Credit = 9
6.d. Syllabus & Lecture Plan:

Unit	Description	No. of Classes
1.	Classification of igneous rocks. IUGS classification. Textures and structures of igneous rocks. Origin and evolution of magmas.	**7**
2.	Compositional variation in magmas. Crystallization of magma and their representations in phase diagrams (binary system and ternary diagrams).	**5**
3.	Influence of volatiles and role of oxygen fugacities in magmatic crystallizations. Assimilation Fractional Crystallization AFC) processes. Nature and type of partial melting in the mantle. Magmatic differentiation and fractionation models.	**7**
4.	Representation of chemical analysis of igneous rocks. Major and Trace element systematics in igneous rocks. Silica/alumina saturation, variation diagrams, their applications and limitations.	**5**
5.	Granites and their origin, I-, S-, A- type granites. Pegmatites, their nature, occurrence and petrogenesis. Alkaline rocks and their origin. Anorthosites and their petrogenesis.	**5**
6.	Lamprophyres and their petrography and origin. Ultramafic and layered rocks, nature and origin. Carbonatites, Petrography and their petrogenesis. Kimberlites and their origin.	**5**
7.	Lunar rocks. Magmatism in relation to plate tectonics. Petrographic and chemical characteristics of igneous rocks in the following tectonic settings: Mid Oceanic Ridge, Island Arcs, Oceanic plateaus, Continental Margins, Continental Rifts and Continental intraplates.	**5**
8.	**Total Classes**	**39**

6.e. Recommended Books:

1. McBirney, A.R., 1993. Igneous Petrology, Jones & Bartlett Publishers, Boston 508 p.
2. Cox, K.G., Bell, J.D., Pankhurst, R.J., 1993. The Interpretation of Igneous Rocks, Chapman and Hall, London; 450 p.

Other References:

1. Philpotts, A.R., Ague, J.J., 2009. Principles of Igneous and Metamorphic Petrology, Cambridge University Press, New York; 684 p.
2. Best, M.G., 2003. Igneous and Metamorphic Petrology, Blackwell Publishing; 729 p.
3. Wilson, M., 2007. Igneous Petrogenesis – A Global Tectonic Approach, Springer, Dordrecht; 466 p.

4. Gill, R., 2010. Igneous Rocks and Processes: A Practical Guide, Wiley-Blackwell, Oxford; 428 p.
5. Winter, J.D., 2014. Principles of Igneous and Metamorphic Petrology, PHI Learning Private Limited, Delhi; 702 p.

6.f Course Goal / Learning Outcome* This a core course of geology and will help the student learn in detail the different igneous rocks, the petrogenetic processes and tectonic environments for their emplacement.

6.g. Learning Objectives: Upon completion of the course, students will be able to:

1. Learn about the magmatic differentiation processes
2. Understand the petrogenesis of igneous rocks
3. Understand the diversity of igneous rocks and the variety of tectonic environments for their emplacement

7.Course Name: Metamorphic Petrology
7.a.Course Code: GLC 510
7.b. L-T-P = 3-0-0
7.c. Credit = 9
7.d. Syllabus & Lecture Plan:

Unit	Description	No. of Classes
1.	**Basics of metamorphism:** Definition, agent of metamorphism, types of metamorphism.	2
2.	**Structure and texture of metamorphism:** Processes involved during metamorphic texture formation, Texture formed during different types of metamorphism,	5
3.	**Rock Nomenclature:** Classification of metamorphic rocks depending on texture and composition	2
4.	**Thermodynamics:** Definition of thermodynamic parameters, phase rule, First, second and third law, Gibb's free energy, chemical potential, activity, Equilibrium Constant, Geothermobarometry	6
5.	**P-T-t path**: different types of P-T-t path, derivation of P-T-t information using textural relation and geothermobarometry.	2
6.	**Stable mineral assemblage in metamorphic rocks:** close system and open system, application of phase rule in such systems.	3
7.	**Chemographic projections**: ACF, AFM, AKFM, CMS diagram Compatible diagram, Schrienmaker's rule petrogenetic grid and pseudo section	3
8.	Metamorphic reactions: Different types of reaction in metamorphism	3

	and the process	
9.	**Metamorphism of rocks with different protoliths:** pelitic, mafic, ultramafic and calcareous rock metamorphism, development of characteristic mineral assemblage during metamorphism depending on protolith.	**9**
10.	**Metasomatism**: metamorphic fluids, mass transport and minerals developed during metasomatism	**2**
11.	**Relationship with tectonics:** Description of typical metamorphic assemblage/facies in relation to different tectonic setup	**2**
12.	**Total Classes**	**39**

7.e.Recommended Books:

1. Principles of Igneous and Metamorphic Petrology by John D. Winter., 2009, by Prentice Hall.
2. Igneous and Metamorphic Petrology, Myron G. Best, 2002, by Wiley, John & Sons

Other References:

1. Metamorphic Petrology, by Francis J. Turner, 1980, by Taylor & Francis Inc

7.f. Course Goal/Learning Outcome

The primary objective of the course is to introduce fundamental understanding of process, reaction, mineral assemblage formed in different protoliths during metamorphism. Constructing and being able to understand different graphical representation used in metamorphic petrology. Relation between tectonics and metamorphism.

7.g. Learning Objectives

Upon completion of the course, students will be able to:

1. Understanding process and control of physico-chemical and compositional control on metamorphism of rocks.
2. Application of thermodynamics on stability of minerals during metamorphism.
3. Evaluating P-T-t path from textural relation and geothermobarometry
4. Relating tectonic setting with metamorphism.

8.Course Name:Applied Sedimentology

8.a. Course Code: GLC 511

8.b. L-T-P = 3-0-0

8.c. Credit = 9

8.d. Syllabus & Lecture Plan:

Unit	Description	No. of classes
1	Nature and origin of sedimentary rocks, its significance, composition and classification. Earth surface processes, Sediment transport in different systems.	2
2	Texture of sediments: Particle size of detrital rocks, definition, measurement, size parameters, grain size distribution and causal factors,	6

	grain size distributions and environmental analysis, Sphericity and roundness, packing and fabric, porosity and permeability. Mathematical treatment of grain size data	
3	Sedimentary structures and their genetic significance and importance in rock record, Biogenic structures.	6
4	Palaeocurrent analysis: Vector properties and palaeocurrent, scalar properties and palaeocurrent, presentation and interpretation of palaeocurrent data.	2
5	Petrology of important clastic (Sandstone, shale, conglomerate and breccia) and non-clastic (Carbonates) rock groups.	3
6	Provenance studies: Methodology and significance, paleoclimatic and paleoenvironmental analysis.	3
7	Classification of environments, Environmental parameters, Sedimentary Facies Analysis; Its importance in paleoenvironmental reconstruction,	7
8	Tectonic control of sedimentation. Evolution of sedimentary basins.	2
9	Diagenesis; changes in mineralogy, fabric and chemistry: Mudstones, sandstones, carbonate rocks.	6
10	Cyclic sediments: Seismic and sequence stratigraphy.	4
	Total hours	**39**

8.e. Recommended Books:

1. Emery, D., and K.J. Myers, 1996: Sequence stratigraphy; Oxford, Blackwell Science,297 pp.
2. Reading, H.G., 1978**:** Sedimentary Environment and Facies, Elsevier, 557pp

Other References:

1. Reineek, H.E. and Singh, I.B., 1973: Depositional Sedimentary Environment, Springer-Verlag, 439pp.
2. Sengupta, S.M., 2007: Introduction to Sedimentology, CBS publisher, 314pp.
3. Selley, R.C., 2000: Applied Sedimentology, Academic Press, 523pp.
4. Tucker, M.E., 2001: Sedimentary Petrology, Blackwell Publishing, 251pp.
5. *Pettijohn E.J.*; *Sedimentary Petrology* – CBS Publishers & Distributors

8.f. Course Goal / Learning Outcome*

In this course the students will study the fundamental concepts, principles and applications of sedimentology.

8.g. Learning Objectives**

Upon completion of the course, students will be able to:

1. Identify and study various types sedimentary rocks in field and under microscope
2. Can understand the difference between various types of sedimentary rocks such as sandstones, shale, conglomerates and carbonates
3. Understand various types of sedimentary structures and their geological significance
4. Understand various types of sedimentary depositional environments and their importance for hydrocarbon systems, ore deposits and groundwater accumulation

9. Course Name: Petroleum Geology
9a.Course Code: GLC 512
9.b. L-T-P = 3-0-0
9.c. Credit = 9
9.d. Syllabus & Lecture Plan:

Unit	Description	No. of Classes
1.	Petroleum: its different states of natural occurrence. Basic concepts of organic geochemistry. Origin of petroleum, Geochemistry and maturation of kerogen; Biogenic and Thermal effect. Distribution of Petroleum in space and time.	**8**
2.	Petrographic and geochemical methods of Oil Exploration: Petrographic: Microscopic organic analysis, Thermal Alteration Index, Vitrinite Reflectance, Geochemical: Combustion methods (Carbon ratio and Total Organic Carbon), Stable isotope method, Time Temperature Index (TTI), Arrhenius equation, Lopatin's method, Concept of cooking time, Level of Organic Metamorphism (LOM) and Rock Eval Pyrolysis method	**8**
3.	Introduction to migration of oil and gas: geologic framework of migration; short and long distance migration, primary and secondary migration; geologic factors controlling hydrocarbon migration; forces responsible for migration, migration routes and barriers.	**5**
4.	Oil field water- characters and classifications	**2**
5.	Reservoir rocks: general attributes and petrophysical properties. Classification of reservoir rocks - Clastic and Carbonate reservoirs. A brief account on Reservoir Characterization. Blowout problem.	**6**
6.	Hydrocarbon traps: definition; classification of hydrocarbon traps - structural, stratigraphic and combination; time of trap formation and time of hydrocarbon accumulation. Cap rocks - definition and general properties.	**6**
7.	Petroleum Geology of important Indian basins (offshore and onshore).	**2**
8.	Introduction to oil and gas exploration with reserve estimation.	**2**
	Total Classes	**39**

9.e. Recommended Books:

1. Tissot, B. P., and Welte, D. H., Petroleum Formation and Occurrence. Springer-Verlag, Germany.
2. North F. K., Petroleum Geology. Allen & Unwin Inc., London.

Other References:

1. Selley, R. C.,Elements of Petroleum Geology. Academic Press, USA.
2. Selly, R. C. and Sonnenberg, S. A., Elements of Petroleum Geology, Elsiver-Academic Press

3. Slatt, R. M., Stratigraphic Reservoir Characterization for Petroleum Geologists, Geophysicists, and Engineers. Elsevier, Hungary

9.f. Course Goal/Learning Outcome:

The primary objective of the course is to introduce the students with the geochemical, origin and accumulation aspects of hydrocarbons. Depositional environment of sediments, their stratigraphic positions, exploration using microfossils also included in this course for better understanding. Also student will gain knowledge about some hydrocarbon fields in India.

9.g. Learning Objectives:

Upon completion of the course, students will be able to:

1. Brief idea about the hydrocarbon system.
2. Chemical and physical properties of hydrocarbons
3. Hydrocarbon basins in India
4. Support of microfossils for hydrocarbon exploration

10.Course Name: Coal Geology

10.a.Course Code: GLC 513

10.b. L-T-P = 3-0-0

10.c. Credit = 9

10.d. Syllabus & Lecture Plan:

Unit	Description	No. of Classes
1.	Coal and its properties: Different varieties and ranks of coal. Type of Depositional processes. Coalification process and its causes.	7
2.	Structural features: Sediments closely associated with coal.	2
3.	Lithotypes, microlithotypes and macerals: their physical and optic properties. Maceral analysis of coal; Mineral and organic matter in coal; Petrographic methods and tools of examination.	7
4.	Industrial evaluation of coal: Application of coal petrography. Proximate and ultimate analyses; Industrial evaluation of coal characteristics with reference to coal classification.	7
5.	Distribution of different coalfields: Geological and geographical distribution of different coalfields with special reference to India. Geology and petrography of different coalfields and lignite fields of India (Jharia, Raniganj coalfields).	7
6.	Coal for various industries: Uses of coal for various industries e.g. carbonization, liquefaction power generation, gasification and coalbed methane production; Organic Petrology and Introduction to coal-based Nanomaterials	7
7.	Organic Petrology: Organic Petrology and Introduction to coal-based	2

	Nanomaterials	
	Total Classes	39

10.e. Recommended Books:

1. Taylor, G.H., Teichmüller, M., Davis, A., Diessel, C.F.K., Littke, R., Robert, P., 1998. Org. Petrol. GerbrüderBorntraeger, Berlin.16, 704.
2. vanKrevelen, D.W., 1993. Coal: Typology-chemistry-physics-constitution. Elsevier Science, Amsterdam, 963.

10.fCourse Goal/Learning Outcome:

The primary objective of the course is to introduce fundamental aspects of coal such as origin, transport, formation, types, physical properties and depositional environments and industrial utilization to the students

10.g. Learning Objectives:

Upon completion of the course, students will be able to:

1. Distinguish between different types coal based on physical, chemical and petrogarphical and other properties.
2. Origin and effect of various depositional environments in shaping of various coal types
3. Role of Coal Geology in industrial utilization.

11.Course Name: Principles and Applications Geostatistics

11.a.Course Code: GLC 518

11.b. L-T-P = 3-0-0

11.c. Credit = 9

11.d. Syllabus & Lecture Plan:

Unit	Description	No. of Classes
1.	Statistical Concepts of Universe, Population, Sampling Unit and Sample; Concept of Random Variable; Probability distributions: Discrete and Continuous distribution; Characterization of continuous distribution; Theoretical models of probability distributions, *viz*. Normal and Lognormal – their properties, characteristics and probability calculations; Techniques of Normal and Lognormal model fit (graphical and numerical) Tests of Significance (t, F and Chi-squared goodness of fit tests).	**8**
2.	Geostatistical concepts and theories; Regionalized Variables; Random Function; Schools of geostatistical thoughts; Why Geostatistics**;** Stationarity and intrinsic hypotheses; Exploratory data analysis.	**5**
3.	Semi-variogram: definition and properties; Relationship with covariogram; Characteristics of Experimental semi-variogram; calculation of semi-variograms in 1-, 2-, and 3-dimensions; mathematical models of semi-variogram; Practical difficulties associated	**7**

	with semi-variography, viz. spatial anisotropy, non-stationarity and proportional effect, regularization, nugget effect, and presence of trend.	
4.	Extension, Estimation and Dispersion variances: definitions, formulation and methods of calculation. Kriging : Introduction and definition; Linear kriging – ordinary and simple kriging; solving kriging system of equations for point and block; Properties of kriging; Influence of nugget effect on kriging weights; Shadow effect and Screen effect. Negative kriging weights- causes and remedies; Techniques of semi-variogram model fit, viz. Hand fit, Least square fit, and Point Kriging Cross-Validation.	**9**
5.	Introductory capsule on other types of kriging. Practice of kriging: geostatistical evaluation of mineral deposit, mineral inventory, grade-tonnage relationships, role of kriging variance in optimization of exploration drilling, misclassified tonnages, and geostatistical grade control.	**7**
6.	Introduction to geostatistical conditional simulation. Simulated Annealing Simulation.	**3**
	Total Classes	**39**

11.e Recommended Books:

1. Chiles, J.P. and Delfiner, P. (1999) Geostatistics - Modelling Spatial Uncertainty, John Wiley and Sons, New York, 695 p.
2. Clark, I. (1979) Practical Geostatistics, Elsevier Applied Science Publ. London, 151 p.

Other References:

1. David, M. (1977) Geostatistical Ore Reserve Estimation, Elsevier Scientific Publ. Co. Amsterdam, 364 p.
2. David, M. (1988) Handbook of Applied Advanced Geostatistical Ore Reserve Estimation, Elsevier, Amsterdam, 216p.
3. Davis, J.C. (1986) Statistics and Data Analysis in Geology, 2nd Edition, John Wiley & Sons, New York, 646 p.
4. Gandhi, S.M. and Sarkar, B.C. (2016) Essentials of Mineral Exploration and Evaluation, Elsevier, USA, 410 p.
5. Goovaerts, P. (1997) Geostatistics for Natural Resources Evaluation, Oxford Univ. Press, Oxford, 483p.
6. Isaaks, E.H. and Srivastava, R. M. (1989) An Introduction to Applied Geostatistics, Oxford University Press, 561 p.
7. Journel, A. G. and Huijbregts, C. J. (1978) Mining Geostatistics, Academic Press, London, 600 p.
8. Kitanidis, P.K. (1997) Introduction to Geostatistics-Applications in Hydrogeology, Cambridge Univ. Press, 249 p.
9. Olea, R.A. (1999) Geostatistics for Engineers and Earth Scientists, Kluwer Academic Publ., Dordrecht, 303p.
10. Rendu, J.M. (1981) An Introduction to Geostatistical Methods of Mineral Evaluation, SAIMM Monograph, Johannesburg, 84p.

11. Sinclair, A.J. and Blackwell, G.H. (2002) Applied Mineral Inventory Estimation, Cambridge Univ. Press, 378 p.
12. Wellmer, F. W. (1998) Statistical Evaluation in Exploration for Mineral Deposits, Springer, Hannover, 379 p.

11.f. Course Goal / Learning Outcome*:*

The key objective of the course is to introduce the students with the principles of Geostatistics for exploration and evaluation.

11.g. Learning Objectives*:*

Upon completion of the course, students will be able to:

1. Understand the utilisation of classical statistical tools and tests as applicable in exploration and evaluation;
2. Apply concepts and principles of geostatistics for characterisation of deposits.
3. Carry out Spatial data analysis;
4. Kriging and Simulation.

12.Course Name: Engineering Geology
12a.Course Code: GLC 519
12.b. L-T-P = 3-0-0
12.c. Credit = 9
12.d. Syllabus & Lecture Plan:

Unit	Description	No. of Classes
1.	**Advances inEngineering geology:** Introduction, definition, development of subject, and significance and geotechnical ground	**1**
2.	**Geological strata :** rocks, rock material, rock mass, and geomechanical classification of rock mass	**3**
3.	**Construction materials:** definition, types of stones, parameters, testing, cement-aggregates reactions.	**3**
4.	**Dams:** definition, elements, and classification.	**2**
5.	**Geotechnical investigation for dam and reservoir sites:** geotechnical parameters, dam foundation, preparation and treatments.	**3**
6.	**Geotechnical stability of dams:** Forces acting on dam, parameters, causes of failure.	**3**
7.	**Methods of anchoring of strata :** grouting, grout, and classification of grouting	**3**
8.	**Tunnels:** definition: elements, parameters, and classification, geotechnical investigation.	**2**
9.	**Methods of tunnelling:** Old methods, and modern methods.	**2**
10.	**Ground reaction and support system :** types of ground, rock load, parameters and support system and strengthening of strata	**4**
11.	**Roads and Highways :** introduction, classification of roads, types of	**3**

	pavements, geotechnical investigation and methods of construction	
12.	**Bridges and buildings:** elements of bridge, types of bridge, and types of building foundation and geotechnical investigation	**2**
13.	**Mass movements and slope stability:** landslide, mines bench and dump.	**3**
14.	**Earthquakes and seismicity:** elements of earthquake, measurements, classification, seismic zones of India, impacts, and design, Induced seismicity and reservoir induce seismicity.	**3**
15.	**Shoreline geotechnics :** geotechnical condition of ground, problems**,** design and mitigation measures	**2**
	Total Classes	**39**

12.e. Recommended Books:

1. Rahm, P.H (1985). Engineering Geology. An Environmental Approach, Elsevier, XI, pp.1-589
2. Jaeger, J.C. and Cook, N.G.W. (1986). Fundamentals of Rock Mechanics. 2nd Ed, John Wiley and Sons.

Other References:

1. Reddy, D.V. (2016). Engineering Geology, Vikas Pbl, pp. 1-410.

12.f. Course Goal / Learning Outcome:

The student will gained knowledge for developments of engineering geological projects and geotechnical mitigation measures of natural hazards.

12.g. Learning Objectives:

Upon completion of the course, students will be able to:

1. Classify various geological strata for their engineering use.
2. Apply various techniques for development of various types engineering structures
3. Determine expected loads and design and evaluate the capacity of support systems

13.Course Name: Hydrogeology

13a.Course Code: GLC 520

13.b. L-T-P = 3-0-0

13.c. Credit = 9

13.d. Syllabus & Lecture Plan:

Unit	Description	No. of Classes
1.	**Introduction to Hydrogeology**: Water on Earth; Types of water; Distribution of water; Role of water in Earth's climate; Hydrological cycle and its components	**2**
2.	**Occurrence of Groundwater:**Water-bearing properties of rocks — porosity, intrinsic permeability, specific yield and specific retention; Vertical distribution of water; Zone of aeration and zone of saturation; Classification of rocks according to their water-bearing properties;	**10**

	Aquifers; Classification of aquifers; quantitative assessment of aquifer properties; Concepts of drainage basins and groundwater basins; Basics of vadose zone hydrology.	
3.	**Aquifer Characteristics:** Aquifer parameters: transmissivity, hydraulic conductivity and storage coefficient; Determination of permeability in laboratory; Concept of heterogeneity and anisotropy; Characteristic differences between confined and unconfined aquifers; Water table and piezometric surface; Fluctuations of water table and piezometric surface; Water table contour maps; Hydrographs; Hydrostratigraphic units.	**6**
4.	**Principles of Groundwater Movement:** Hydrostatic pressure; Fluid potential; Energy in groundwater; Hydraulic head; Theory of groundwater flow; Darcy's law and its applications; Specific discharge; Limitations of Darcy's Law; Reynolds Number; Governing equation for flow through porous medium; Steady and non-steady state flow - Initial and boundary Conditions; Solution of flow equations; Dupuit's Assumption; Boussinesq Equation; Streamlines and flownet analysis; Groundwater flow patterns, Groundwater-Surface water interactions; Determination of flow direction	**12**
5.	**Well Hydraulics:**Flow through aquifers: 2-D groundwater flow equations; Flow in steady and non-steady state conditions; Evaluation of aquifer parameters of confined, semi-confined and unconfined aquifers - Thiem, Theis and Jacob methods; numerical problems on pumping test.	**5**
6.	**Groundwater Quality:** Physical and chemical properties of water; chemical reactions; Quality criteria for different uses; Graphical presentation of groundwater quality data; Saline water intrusion (Ghyben-Herzberg relation)	**2**
7.	**Management of Groundwater:** Over-exploitation of groundwater; Groundwater problems in urban/rural settings; Climate change impact on ground water resources; Groundwater potential mapping; Rainwater harvesting and managed aquifer recharge; Conjunctive use of surface and groundwater; Groundwater governance.	**2**
	Total Classes	**39**

13. e. Recommended Books/References:

1. Groundwater Hydrology by D. K. Todd and L. W. Mays, 3rd Edition, 2011, Wiley India.
2. Applied Hydrogeology by C. W. Fetter, 4th Edition, 2014, Pearson New International.

Other References:

1. Groundwater by H. M. Raghunath, 3rd Edition, 2007, New Age International Publishers.
2. Physical and Chemical Hydrogeology by P. A. Domenico and F. W. Shcwartz, 2nd

Edition, 1997, Wiley.

3. Elements of Physical Hydrology by G. M. Hornberger, J. P. Raffensperger, P. L. Wiberg and K. N. Eshleman, 1st Edition, 1998, The Johns Hopkins University Press.

13.f.Course Goal / Learning Outcome:

In this course the students will study the fundamental concepts and principles of occurrence, movement and quality of groundwater, focussing on quantitative analysis.

13.g. Learning Objectives:

Upon completion of the course, students will be able to:

1. Assess the role of water in Earth's climate
2. Distinguish between confined & unconfined aquifers
3. Apply Darcy's Law to groundwater flow and geological material interpretation;
4. Use pump test data for groundwater flow applications.
5. Develop skills in approaching complex problems involving flow and storage of groundwater
6. Gain knowledge on sustainable development of groundwater resources.

14.Course Name: Ore Geology

14a.Course Code: GLC 526

14.b. L-T-P = 3-0-0

14.c. Credit = 9

14.d. Syllabus & Lecture Plan:

Unit	Description	No. of Classes
1.	Ore forming processes: Introduction to different ore forming processes and their geodynamic settings.	10
2.	Geochemical concepts of the ore system: Partition of trace elements, Phase diagrams of ore minerals. Calculation of thermo-barometric parameters for oxide and sulphide phases. Different types of chemical reactions involved in hydrothermal alterations and supergene enrichment.	9
3.	Introduction to Ore microscopy: Qualitative and Quantitative methods in the identification of Ore minerals.	6
4.	Introduction to ore textures, microstrutures and applications: Ore textures and paragenesis. Industrial application of ore microscopy and process mineralogy.	7
5.	Fluid Inclusion Studies and Application: Nature of ore forming fluids. Fluid inclusions and their application in the genesis of ores. Isotopes and their bearing on ore genesis and application.	7
	Total Classes	39

14.e. Recommended Books/References:

1. Kula C Misra. 2001. Understanding Mineral Deposits. Kluwer Publ.
2. Craig, J.R and Vaughan, D.J., 1981. Ore Microscopy and Ore petrography. John Wiley &sons.

Other References:

1. Robb, L. (2005) Introduction to Ore-Forming Processes by, Blackwell Publishing Ltd.
2. H.L.Barnes (Ed). 1997. Geochemistry of Hydrothermal deposits. III Edn. John Wiley & Sons.
3. A.M. Evans. 1997: Ore Geology and Industrial minerals- An introduction (III edn.) Geoscience, Texas

14.f. Course Goal / Learning Outcome:

The course deals with the natural mineral resources and their association with different host rocks during their formation. The fundamental concepts regarding the origin of the mineral can be well understood with a thorough knowledge on the mineral assemblages, textural features, paragenetic order and metallogeny.

14.g.Learning Objectives*:*

Upon completion of the course, students will be able to:

1. Understand the different ore systematic at divergence geological setting and terrains with implications for exploration.
2. Identification of minerals based on their optical properties and textural behaviour and their application in mineral beneficiation industries.
3. To know the source and depositional environment based on isotopic and fluid inclusion studies.

15.Course Name: Exploration Geology and Mineral Economics

15.a.Course Code: GLC 527

15.b. L-T-P = 3-0-0

15.c. Credit = 9

15.d. Syllabus & Lecture Plan:

Unit	Description	No. of Classes
1.	**Methods of Geological Prospecting and Exploration**: Principles and concepts of mineral exploration, methods of Prospecting and Exploration. Different Stages of mineral Exploration. Radiometric survey. Remote sensing in mineral exploration.	**7**
2.	**Sampling and Subsurface exploration:** Sampling theory, objectives and methods. Exploration drilling technique, planning, drill core logging and sampling. Planning of the Geological plans and sections for ore body evaluation.	**6**
3.	**Reserve Estimation:** Cut-off grade concepts and applications, Reserve Estimation– principles, practices and different conventional methods.	**4**
4.	**Principles of Geochemical Exploration**: Geochemical cycle, geochemical mobility and association of elements. Primary and secondary dispersions of elements; Determination of background, and	**4**

	geochemical anomalies; Pathfinder and target elements for geochemical exploration.	
5.	**Geochemical methods of mineral exploration**: Methods of geochemical explorations, Procedures for geochemical sampling; Interpretation of geochemical surveys.	**5**
6.	**Mineral Economics** **World resources of minerals:** Classification of mineral resources with special reference to UNFC and JORC schemes. Mineral markets, Import-Export policies and International Trade. Demand analysis of minerals, Royalty and Taxes. India's status in mineral production.	**5**
7.	**Mineral Policies and Regulations:** International and national mineral policies. Mines and Mineral policies. Mines and Minerals (Development and Regulation) act. Marine and mineral resources and laws of sea.	**4**
8.	**Economics of Deposit:** Economic evaluation of mineral deposit. **Mineral conservation:** Methods of mineral conservation and substitution	**4**
	Total Classes	**39**

15.e. Recommended Books:

1. Reedman, J H. Techniques in Mineral Exploration: 1979. Applied Science Publishers Ltd., UK.
2. Peters, W.C. Exploration and Mining Geology (2nd Ed.); 1987. John Wiley & Sons, New York.

15.f. Course Goal/Learning Outcome:

The primary objective of the course is to introduce the fundamental aspects of exploration strategies followed in Greenfield and Brownfield exploration. Different sampling methodologies and resource methodologies are basic ingredients of the course. Apart from the basic exploration technique, the economic evaluation is done before mining.

15.g. Learning Objectives:

Upon completion of the course, students will be able to:

1. Understand the different approaches of mineral exploration using different tools.
2. Can build up confidence in sampling and reserve estimation.
3. Mineral economics of a deposit need to be understood by different methodologies.

Syllabus of Departmental Core (DC) Practical Courses

16.Course Name: Mineralogy and Geochemistry Practical
16a.Course Code: GLC 506
16.b. L-T-P = 0-0-2
16.c. Credit = 2
16.d. Syllabus & Lecture Plan:

Unit	Description	No. of Classes
	Mineralogy	
1.	**Sub-heading in bold letters (or theme):** brief listing/description of topics/sub-themes to be covered in each unit	
2.	**Identification of minerals:** Common silicate minerals and their characteristic property under microscope- Olivine, Orthopyroxene, Clinopyroxene, Amphibole group, Mica Groups, Feldspar Group, Quartz	**4**
3.	**Identification of minerals:** Common accessory minerals and other important minerals Silicate Structure characteristic property under microscope- Sphene, Zircon, Monazite, Epidote, Scapolite, Staurolite, Al_2SiO_5 polymorphs, Tourmaline etc.	**2**
4.	**Geochemistry**	
5.	Sample preparation methods (Destructive and non-destructive), A-solution and B- Solution preparation	**2**
6.	Wet chemical analyses and titrimetric analyses of major and some trace elements	**2**
7.	Data presentation and associated problems.	**2**
8.	Practical examination	1
9.	**Total Classes**	**13**

16.e Recommended Books:

1. Introduction to Mineralogy by William D. N., 2000, Oxford University Press.
2. Potts P.J. (1987) A handbook of silicate rock analysis; Blackie

Other References:

3. Manual of Mineralogy (Revised) by Klein C., Hurlbut C. S. Jr., 1985, John Wiley & Sons
4. Rollinson H.R. (1993) Using geochemical data: evaluation, presentation, interpretation; Prentice Hall publication.

16.f. Course Goal / Learning Outcome:

The primary objective of the course is to train students in identifying common rock forming minerals.

16.g. Learning Objectives*:*

Upon completion of the course, students will be able to:

1. Learn identifying common rock forming minerals
2. Learn identifying accessory/other important minerals
3. Understanding relationship between rock composition and mineral occurrence. Getting between a mineral rock composition and associated minerals.

17.Course Name: Methods ofStructural Geology Practical

17a.Course Code: GLC 507

17.b. L-T-P = 0-0-2

17.c. Credit = 2

17.d. Syllabus & Lecture Plan:

Unit	Description	No. of classes
1.	**Subsurface Mapping**: Preparation and interpretation of fence diagram, structure contour, and isopach / isochore maps	2
2.	**Structural analysis**: Construction of profiles of cylindrical folds, analysis of areas of superposed folding.	7
3.	**Analysis of areas with faults**: Depth to detachment, Balanced cross-section, Restoration of section	2
4.	**Lineament and fracture Analysis**	1
5	Practical examination	1
	Total classes =	13

17.e. Recommended Books:

1. Marshak, S and Mitra, G (1988) Basic Methods of Structural Geology. Prentice Hall.
2. Richard H. Groshong, Jr. (2006). 3-D Structural Geology: A Practical Guide to Quantitative Surface and Subsurface Map Interpretation. Springer-Verlag, Berlin.

Other References:

1. Roland, S.M., Duebendorfer, E.M. and Schiefelbein, I.M. (2007) Structural Analysis and Synthesis. Blackwell Publishing, Oxford

17.f. Course Goal / Learning Outcome*

The primary objective of the course is to provide practical tools for different structural techniques used in industry / exploration organisations.

17.g. Learning Objectives**

Upon completion of the course, students will be able to:

1. Determine structural geometry and interpret the geometry.
2. Identify the suitable sites for detailed exploration.

18.Course Name: Micropalaeontology and Vertebrate Palaeontology Practical
18a.Course Code: GLC 508
18.b. L-T-P = 0-0-2
18.c. Credit = 2
18.d. Syllabus & Lecture Plan:

Unit	Description	No. of Classes
1.	Morphology, identification and systematics of some benthic foraminifera (Based on depth preference and physical properties of marine water).	**5**
2.	Morphology, identification and systematics of some Planktic foraminifera.	**5**
3.	Study of some molar teeth of mammals	**2**
4.	Practical examination	1
	Total Classes	**13**

18.e. Recommended Books:

1. Holbourn, A., Henderson, A. S., and MacLeod, N., (2013)-Atlas of Benthic Foraminifera.-Wiley-Blackwell, pp. 642.
2. Loeblich, A. R., and Tappan, H., 1988. Foraminiferal genera and their classification (Vol. 1 and 2). Van Nostrand Reinhold, USA, pp. 970 and plates 847.

Other References:

1. Practical hand books as available in laboratory.

18. f. Course Goal / Learning Outcome*:*

The primary objective of the course is to introduce students with benthic foraminifera (up to generic level) and planktic foraminifera (up to species level), few aspects of population counts of foraminifera. Also students will be introduced with available molar teeth fossils of vertebrates.

18.g. Learning Objectives:

Upon completion of the course, students will be able to:

1. Identify of benthic (with their depth, food and oxygen preference) and planktic groups with biostratigraphic ages.
2. Apply census count for understanding paleo-events
3. Identify teeth with food pattern and animal forms.

19.Course Name: Igneous and Metamorphic PetrologyPractical
19a.Course Code: GLC 514
19.b. L-T-P = 0-0-2
19.c. Credit = 2
19.d. Syllabus & Lecture Plan:

Unit	Description	No. of Classes
1	Exercises on Crystal Fractionation and Partial Melting of Igneous Rock Suites.	**2**

2	Exercises on the construction and interpretation of Spider diagrams of N-type MORBs, E-type MORBs, OIBs etc.	**2**
3	Thin Section study of acid, basic and ultramafic rocks; Textures of Igneous Rocks.	**2**
1.	**Texture:** Identification of metamorphic textures under microscope in different rock composition of different metamorphic grade. Texture which will be covered are-Foliation (I phyllite schist, gneiss), mineral layering, Pressure Shadow, Pre, Syn, Post Kinematic porphyroblast, Granoblastis texture, Crenulation Cleavage, Sympletitic texture, Coronae texture	**4**
2.	**Schrienemakers Method, ternary Diagram**-ACF, AKF, A(K)FM	**2**
3.	Practical examination	1
4.	**Total Classes**	**13**

19.e. Recommended Books:

1. Gill, R., 2010. Igneous Rocks and Processes: A Practical Guide, Wiley-Blackwell, Oxford; 428 p
2. Principles of Igneous and Metamorphic Petrology by John D. Winter., 2009, by Prentice Hall.
3. Igneous and Metamorphic Petrology, Myron G. Best, 2002, by Wiley, John & Sons

Other References:

1. Cox, K.G., Bell, J.D., Pankhurst, R.J., 1993. The Interpretation of Igneous Rocks, Chapman and Hall, London; 450 p.
2. Philpotts, A.R., Ague, J.J., 2009. Principles of Igneous and Metamorphic Petrology, Cambridge University Press, New York; 684 p.
3. Metamorphic Petrology, by Francis J. Turner, 1980, by Taylor & Francis Inc

19.f. Course Goal / Learning Outcome:

1.The student will learn to solve problems in igneous petrogenesis and also learn to identify igneous rocks under thin section.

2.The primary objective of the course is also to train students in identifying different metamorphic texture and using that information to build up the geological history of the rock.

19.g. Learning Objectives:

Upon completion of the course, students will be able to:

1. Learn petrographic identification of igneous rocks and texture
2. Understand the petrogenesis of igneous rocks using different numerical solutions for solving problems in igneous petrogenesis
3. Explaining reasons for development of specific texture in the rock.
4. Understand effect of composition and physical condition on occurrence of metamorphic mineral.
5. Building up geological history of a rock by integration of information gathered from microstructures.

20.Course Name: Sedimentology and Petroleum Geology Practical
20.a.Course Code: GLC 515
20.b. L-T-P = 0-0-2
20.c. Credit = 2
20.d. Syllabus & Lecture Plan:

Unit	Description	No of classes
1	Representation of grain size distribution data; Plotting of cumulative distribution curves, Determination of different statistical parameters Interpretation of sedimentary environments.	1
4	Observation of common siliciclastic, carbonate rocks and heavy minerals under thin section.	4
5	Analysis and interpretation of Palaeocurrent data	1
6	Interpretation of geologic structures from surface geological maps and borehole data; reconstruction of structural developments through different time planes.	2
7	Preparation of structure contour and isopach maps of reservoir facies and drawing oil/water contact from borehole data.	2
	Interpretation of Rock Eval pyrolysis data for study of geochemical methods of hydrocarbon exploration	1
5	Hydrocarbon Reserve Estimation	1
6	Practical examination	1
	Total classes	**13**

20.e. Recommended Books:

1. Emery, D., and K.J. Myers, 1996: Sequence stratigraphy; Oxford, Blackwell Science, 297 pp.
2. Reading, H.G., 1978**:** Sedimentary Environment and Facies, Elsevier, 557pp

Other References:

1. Reineek, H.E. and Singh, I.B., 1973: Depositional Sedimentary Environment, Springer-Verlag, 439pp.
2. Sengupta, S.M., 2007: Introduction to Sedimentology, CBS publisher, 314pp.
3. Selley, R.C., 2000: Applied Sedimentology, Academic Press, 523pp.
4. Tucker, M.E., 2001: Sedimentary Petrology, Blackwell Publishing, 251pp.
5. *Pettijohn E.J.*; *Sedimentary Petrology* – CBS Publishers & Distributors

20.fCourse Goal / Learning Outcome:

In this course the students will study the fundamental concepts, principles and applications of sedimentology through practical exercises.

20.g. Learning Objectives:

Upon completion of the course, students will be able to:

1. Analysis and interpretation of grain size data.
2. Identify and study various types sedimentary rocks in hand specimens
3. Can understand the difference between various types of sedimentary rocks such as sandstones and carbonates under microscope
4. Understand various types of sedimentary structures in hand specimens of sketches and their geological significance
5. Analysis and Interpretation of palaeocurrent data

21.Course Name: Coal Geology Practical
21a.Course Code GLC 516
21.b. L-T-P = 0-0-2
21.c. Credit = 2
21.d. Syllabus & Lecture Plan:

Unit	Description	No of Classes
1.	**Megascopic identification:** Megascopic identification of different varieties of coal	**2**
2.	**Lithotypes:** Identification of lithotypes, lithotype logging and cleat attributes	**2**
3.	**Seam Formation Curves:** Preparation of Seam Formation Curves	**1**
4.	**Identification of macerals**: Identification of macerals and minerals under transmitted light; Identification of macerals and minerals under reflected light; Reflectance measurements and rank determination of coal.	**4**
5.	**coal Reserve:** Estimation of coal Reserve and quality	**1**
6.	**Coding of coal characters:** Coding and decoding of coal characters following International Coal classification	**1**
7.	**Location of coalfields:** Location of coalfields on geographical maps and comments about quality of coal.	**1**
8.	Practical examination	1
	Total Classes	**13**

21.e. Recommended Books:

1. Taylor, G.H., Teichmüller, M., Davis, A., Diessel, C.F.K., Littke, R., Robert, P., 1998. Org. Petrol. GerbrüderBorntraeger, Berlin.16, 704.

21.f. Course Goal/Learning Outcome:

The primary objective of the coal geology practical course is to introduce fundamental aspects of coal and their types and reserve estimation. To develop capability to differentiate various types of lithotypes, cleats and macerals.

21.g. Learning Objectives:

Upon completion of the course, students will be able to:
Distinguish among different types coal, lithotypes and macerals

22.Course Name: Field Training (Sedimentary Terrain Mapping Training)
22.a.Course Code GLS 517
22.b. L-T-P = 0-0-0
22.c. Credit = S/X
22.d. Course Goal / Learning Outcome:

This is a training related to geological mapping in sedimentary terrain. This is a very fundamental requirement of the 3-years Applied Geology branch to train the students how to map sedimentary basins. In this mainly students are generally taken to coal or ore metal bearing sedimentary basins. They learn how to take locations, measurement of Dip and Strike of sedimentary beds, lithological contact tracing, lithology preparations. They also map tectonic features such as faults and igneous intrusive in they come across during the course of mapping.

23. Course Name: Principles and Applications Geostatistics Practical
23a.Course Code GLC 524
23.b. L-T-P = 0-0-2
23.c. Credit = 2
23.d. Syllabus & Lecture Plan:

Unit	Description	No. of Classes
1.	Frequency Distribution Analysis – with equal support and unequal support	**2**
2.	Sample Composite Analysis	**1**
3.	Drill hole statistics	**1**
4.	Fitting of normal distribution (graphical and numerical)	**1**
5.	Fitting of lognormal distribution (graphical and numerical)	**1**
6.	Chi-squared goodness of fit test	**1**
7.	Semi-variography in 1-Dimension	**1**
8.	Semi-variography in 2-Dimensions	**1**
9.	Estimation Variance	**1**
10.	Kriging	**1**
11.	Ore Evaluation Problem – Stope Block Estimation	**1**
12.	Practical examination	1
	Total Classes	**13**

23.e. Recommended Books:

1. Clark, I. (1979) Practical Geostatistics, Elsevier Applied Science Publ. London, 151 p.

2. David, M. (1977) Geostatistical Ore Reserve Estimation, Elsevier Scientific Publ. Co. Amsterdam, 364 p.

Other References:

1. Gandhi, S.M. and Sarkar, B.C. (2016) Essentials of Mineral Exploration and Evaluation, Elsevier, USA, 410 p.
2. Moon, C., Whateley, M. K.G., and Evans, A.M. (2006) Introduction to Mineral Exploration. Blackwell Publ., Oxford, 481 p.
3. Rendu, J.M. (1981) An Introduction to Geostatistical Methods of Mineral Evaluation, SAIMM Monograph, Johannesburg, 84p.
4. Sinclair, A.J. and Blackwell, G.H. (2002) Applied Mineral Inventory Estimation, Cambridge Univ. Press, 378 p.
5. Wellmer, F. W. (1998) Statistical Evaluation in Exploration for Mineral Deposits, Springer, Hannover, 379 p.

23.f. Course Goal / Learning Outcome:

The key objective of the course is to introduce the students with the ability to solve classical statistical and geostatistical exercises.

23.g. Learning Objectives:

Upon completion of the course, students will be able to:

1. Understand the utilisation of classical statistical tools and tests practical exercise solving.
2. Apply concepts and principles of geostatistics for characterisation of deposits.
3. Carry out Semi-variography.
4. Perform Kriging and Simulation.

24. Course Name: Engineering geology and Hydrogeology Practical

24.a.Course Code GLC 525

24.b. L-T-P = 0-0-2

24.c. Credit = 2

24.d. Syllabus & Lecture Plan:

Unit	Description	No. of Classes
1.	Exercise on engineering geological maps general.	**1**
2.	Preparation of zonation map and sections	**1**
3.	Geotechnical analysis of engineering geological map of hydropower site	**1**
4.	Evaluation of geotechnical problem along tunnel alignment.	**1**
5.	Identification of suitable road alignments	**1**
6.	Delineation of problematic zones in valley side slopes	**1**
7.	**Characterization of Groundwater:** Preparation of water table and piezometric surface; Maps of water table and piezometric surface fluctuations of; Water table contour maps; Hydrographs; Determination of groundwater flow direction; 3-point problems.	**4**
8.	**Darcy's Law:** Laboratory measurements of flow through saturated media; Estimation of hydraulic conductivity	**1**
9.	**Permeability Tests:** Determination of permeability using falling and constant head permeameters	**1**

10.	Practical examination	1
	Total Classes	**13**

24.e. Recommended Books:

1. Jumkis, A.R. (1983). Rock Mech. 2nd Ed, Trans Tech Vol.7, pp.1-613
2. Gripps, J.C.et al., (1993). Engineering Geology of Weak Rocks. Geol. Soc. London, A.A Balkema, pp.1-510.
3. Groundwater Hydrology by K. E. Todd. 2nd Edition, 2006, Wiley India.
4. Applied Hydrogeology by C. W. Fetter, 4th Edition, 2007, Prentice Hall Inc.

Other References:

1. Reddy, D.V. (2016). Engineering Geology, Vikas Pbl, pp. 1-410.
2. Groundwater by H. M. Raghunath, 3rd Edition, 2007, New Age International Publishers.
3. Physical and Chemical Hydrogeology by P. A. Domenico and F. W. Shcwartz, 2nd Edition, 1997, Wiley.
4. Elements of Physical Hydrology by G. M. Hornberger, J. P. Raffensperger, P. L. Wiberg and K. N. Eshleman, 1st Edition, 1998, The Johns Hopkins University Press.

24.f. Course Goal / Learning Outcome*:*

1. The student will gain knowledge for identification of geotechnical problematic zones, their preparation and treatments to improve the strength of ground and construction of engineering geological structures and natural hazards.
2. In this course the students will also study the fundamental concepts and principles of occurrence, movement and quality of groundwater, focusing on quantitative analysis.

24.g. Learning Objectives:*:*

Upon completion of the course, students will be able to:

1. Demarcate various kinds of geological strata for their engineering use.
2. Identify and delineate geotechnical weak zones and suggest various kinds of treatments.
3. Determine various geotechnical problems related to foundation of engineering structures and instability of strata.
4. Assess the role of water in Earth's climate
5. Distinguish between confined & unconfined aquifers
6. Apply Darcy's Law to groundwater flow and geological material interpretation;
7. Use pump test data for groundwater flow applications.
8. Develop skills in approaching complex problems involving flow and storage of groundwater
9. Gain knowledge on sustainable development of groundwater resources.

25.Course Name: Ore and Exploration Geology Practical

25.a.Course Code GLC 533

25.b. L-T-P = 0-0-2

25.c. Credit = 2

25.d. Syllabus & Lecture Plan:

Unit	Description	No. of Classes
1.	**Megascopic identification of Ore minerals:** Identification of metallic and non-metallic ore minerals and associated host rock assemblages based on the physical characteristics.	**2**

2.	**Ore microscopic Studies:** Concept of reflected light microscopy and description of optical properties of ore minerals, ore microscopic studies of important oxide, sulphide and complex minerals. Identification of micro textures and micro-structural features of ore mineral assemblages, texture based paragenesis.	**2**
3.	**Applied Ore microscopy**: Particle size measurement and applications in the liberation characteristics of complex mineral assemblages for mineral beneficiation and in other areas. Introductory fluid inclusion petrography.	**2**
4.	**Sampling and Borehole Section Preparation:** Exercises on channel sampling, preparation of geological sections, borehole correlation methods.	**2**
5.	**Reserve Estimation Methods:** Reserve calculation by Polygon method, Triangular method, Sectional method and Contouring method.	**2**
6.	**Geochemical Exploration Data Analysis**: Geochemical contouring, statistical evaluation of geochemical data, drill hole sample value compositing	**2**
7.	Practical examination	**1**
	Total Classes	**13**

25.e. Recommended Books:

1. Craig, J.R and Vaughan, D.J., 1981. Ore Microscopy and Ore petrography. John Wiley &sons.
2. Picot, P. and Johon, Z., 1982. Atlas of Ore minerals. B.R.G.M. Publ. Elsevier, Paris.

Other References:

1. Ramdohr, P. 1980. The ore minerals and their intergrowths, 2nd edn. Oxford, Pergamon press.
2. Sharma, N L and Agarwal Y K. Tables for Mineral Identification.

25.f. Course Goal / Learning Outcome:

The course is focussed to orient the students to identify the different types of ore minerals and associated host rocks and apply the knowledge in the field. The microscopic characterization is needed to understand the textures, associations of different ore minerals at various geological environments of deposition and on their possible origin.

25.g. Learning Objectives:

Upon completion of the course, students will be able to:

1. Distinguish between different types of ore minerals based on their physical properties and their mode of occurrences.
2. Identification of ore minerals under reflected light microscope and their textural characteristics and paragenesis.
3. Possible origin based on the host rocks and ore mineral associations, mode of occurrences and beneficiation approaches.

26.Course Name: Structural and Economic Geology Field Training
26a.Course Code GLS 535
26.b. L-T-P = 0-0-0
26.c. Credit = S/X
26.d. Learning Objectives*:*

This is a training related to geological mapping in structurally deformed metamorphosed terrains. This is another very important and fundamental requirement of the 3-years Applied Geology branch to train the students how to map tectonically deformed areas. In this also students are mainly taken to metallic ore deposit area which are structurally deformed of mainly Precambrian age. They learn how to take locations, measurements of Dip, Strike, Pitch and Plunges of planar and linear elements of a rock in tectonically deformed terrains to find the structural geometry of the area through. During the course of this work they also study the ore minerals (if any) associated with the terrains.

Syllabus of Department Elective (DE) Courses

28.Course Name: Stratigraphy
28.a.Course Code: GLD 521
28.b. L-T-P = 3-0-0
28.c. Credit = 9
28.d. Syllabus & Lecture Plan:

Unit	Description	No. of Classes
1.	Principles of stratigraphic correlation. Stratigraphic code of nomenclature. Geologic Time Scale.	**7**
2.	Precambrian belts of India (South India, Central India, Rajasthan, Eastern Ghat, Singhbhum-Orissa): Age correlations, metamorphism, tectonics and evolution. Archean-Proterozoic boundary problem in India. Concept of Precambrian supercontinents.	**7**
3.	Important Proterozoic basins of Peninsular India: Sedimentation, correlation and evolution. Stratigraphic Boundary Status: Precambrian-Cambrian, Permo-Triassic, Cretaceous- Tertiary, Neogene-Quaternary.	**7**
4.	Phanerozoics of Extra Peninsula**:**Spiti, Kashmir and Salt Range. Stratigraphy, tectonics, and basin evolution of Gondwana sedimentary units; Intracontinental and intercontinental correlations between Gondwana successions.	**7**
5.	Evolution and stratigraphy of Indian Coastlines: Marine Mesozoics of coastal India viz. Cretaceous of Trichinopalli and Jurassic of Kutch. Traps: Deccan, Rajmahal, Sylhet and Rajahmundry Traps and their correlations.	**6**
6.	Tertiary formations of Kutch and Assam–Arakan geological provinces. Lithostratigraphy of different sedimentary cycles vis-à-vis major geologic and tectonic events of the Himalayas. Lithostratigraphy of Siwalik Sediments.	**5**
7.	**Total Classes**	**39**

28.eReccommended Books:

1. M.A. Murphy and A. Salvador, *International Stratigraphic Guide — An abridged version.* International Subcommission on Stratigraphic Classification of IUGS International Commission on Stratigraphy, Episodes, 1999, 255 – 272.
2. R. Vaidyanadhan and M. Ramakrishnan, *Geology of India*. Geological Society of India, Bangalore, 2010, Vol. 1 & 2, 997p.

Other References:

1. Ravindra Kumar. *Fundamentals of Historical Geology and Stratigraphy of India*. New Age International (P) Ltd. Publishers, New Delhi, 1996, 254p.
2. R.S. Sharma, Cratons and Fold Belts of India. Springer, 2009, 304p.

28.fCourse Goal / Learning Outcome:
The student will get to learn in detail the Indian stratigraphy.

28.g Learning Objectives:
Upon completion of the course, students will be able to:

1. Learn the fundamentals of stratigraphic correlation and about the Geologic Time Scale
2. Understand the different stratigraphic groups and formations of India
3. Learn about the significance of Indian Stratigraphy for understanding the evolution of continents

29. Course Name: Coal Bed Methane, Shale Gas and Gas hydrate

29.a. Course Code GLD 522

29.b. L-T-P = 3-0-0

29.c. Credit = 9

29.d. Syllabus & Lecture Plan:

Unit	Description	No. of Classes
1.	**Coal bed methane and shale gas:** generation and accumulation; Micropore, Mesopore and macropore, cleat system	**5**
2.	**Sorption:** principles, sorption isotherms – types and interpretation. CO2, CH4 and N2 adsorption – desorption, hysterisis, langmuir isotherm, Swelling and shrinkage of coal matrix, isotherm construction	**5**
3.	**CBM Reservoir analysis:** CH4 content determination in coal seams; Coal bed methane reservoir analysis	**5**
4.	**CBM Water**: CBM Water production and disposal, injection wells, carbon dioxide sequestration	**3**
5.	**Coalbed Methane Basins**: Potential Indian coalbed methane basins and production, hydraulic fracturing of coal seams; CBM exploration	**7**
6.	**UCG:**In-situ gasification	**2**
7.	**Gas hydrate:** Gas hydrate, occurrence and origin; structure of gas hydrate, Types of gas hydrate	**3**
8.	**Geological setting:** Geological setting of Hydrate; Stability of gas hydrates; Gas hydrate reservoir; Volume of gas in hydrate; inhibitors	**5**
9.	**Gas Hydrate Exploration:** Geological exploration of gas hydrate; Prospect and potentialities of gas hydrate in India	**4**
	Total Classes	**39**

29.e. Recommended Books:

1. Coalbed Methane and Coal Geology-Eds. R.Gayer and I. Harris, Geological Society, London 1996.
2. Shale Gas: Exploration and Environmental and Economic Impacts,2017 AM Dayal and D.Mani (eds) Elsevier.

29.f. Course Goal / Learning Outcome*:*

The primary objective of the course is to introduce fundamental aspects of coal bed methane, shale gas and gas hydrate such as origin, types, reservoir analysis and production to the students.

29.g. Learning Objectives*:*

Upon completion of the course, students will be able to:

Understand the origin, types, reservoir analysis and production of coal bed methane, Shale gas and gas hydrate.

30. Course Name: Geotechnical Engineering
30.a. Course Code GLD 528
30.b. L-T-P = 3-0-0
30.c. Credit = 9
30.d. Syllabus & Lecture Plan:

Unit	Description	No. of Classes
1.	**Geotechnical Engineering**: Introduction, definition and phase relations	**1**
2.	**Geotechnical ground and construction materials:** Needs, parameters, types of ground, types of materials, parameters, testing, cement-aggregates reactions.	**4**
3.	**Water–rock interaction**: weathering indices, durability indices, and chemical reactions.	**2**
4.	**Geotechnical investigations for settlements and ground-foundation interaction:** Identification of sites, new alignments, parameters, ground- foundation interaction, differential settlement.	**5**
5.	**Underground spaces and ground control problems:** definition, elements, parameters, and classification, geotechnical investigation, types of ground, geotechnical problems, subsidence, convergence, etc	**4**
6.	**Loads and anchoring of strata**: parameters, methods, grouting, bolting, wire meshing, etc.	**3**
7.	**Geotechniques of cold region:** characteristics and behaviour of ground, ground control problems, and mitigation measures	**3**
8.	**Geotechnical aspects of resources:** mineral and water exploration and extraction.	**3**
9.	**Energy Geotechniques:** Geothermal energy, fuels, Coal Bed Methane (CBM) exploration and extraction, hydropower.	**4**
10.	**Environmental Geotechniques:** types of waste, carbon dioxide sequestration, geotechnical application in waste management, natural hazards,	**4**
11.	**Rivers and Quaternary Geotechniques**: land forms,neotectonics**, r**iver hydraulics and associate problems, geotechnical applications	**3**
12.	**Shoreline geotechniques:** Erosion, shore dynamics, geotechnical condition of ground, problems**,** shore stability, design and mitigation measures	**3**
	Total Classes	**39**

30.e. Recommended Books:

1. Rahm, P.H (1985). Engineering Geology. An Environmental Approach, Elsevier, XI, pp.1-589
2. Jaeger, J.C. and Cook, N.G.W. (1986). Fundamentals of Rock Mechanics. 2nd Ed, John Wiley and Sons.

Other References:

1. Reddy, D.V. (2016). Engineering Geology, Vikas Pbl, pp. 1-410.
2. Jumkis, A.R. (1983). Rock Mech. 2nd Ed, Trans Tech Vol.7, pp.1-613

3. Gripps, J.C.et al., (1993). Engineering Geology of Weak Rocks. Geol. Soc. London, A.A Balkema, pp.1-510.
4. **Stober,** I. and **Bucher,** K. (2013). Geothermal Energy: From Theoretical Models to Exploration and Development, Springer, 1-277.
5. Hudson, J.A. and Harrison, J. (2000). Engineering Rock mechanics: an introduction to the principles, Elsevier pp. 1-456
6. Morena J. Acosta (Editor) (2011). Advances in Energy Research (Volume 5), Publisher: Nova Science Publishers, Inc., NY, USA, pp1- 419.
7. John, P. (2005). Waste management practices,(2nd Ed) CRC Press pp.1-676.
8. Dentefratta, et al., (2017). Introduction to soil mechanics Laboratory testing, CRC Press, pp.1-267.
9. Report on Shale gas and coal bed methane: potential sources of sustainable energy in future, Erns & Young Pvt. Ltd, pp.1-30.
10. Blinderman, M and Klimenko, A (2017). Underground coal gasification and combustion, WoodheadPbl, pp. 1-662.

30.f. Course Goal / Learning Outcome*:*

The student will gaine a brief knowledge for application of various aspects of geotechniques related to settlements, energy and natural resources and environment.

30.gLearning Objectives:

Upon completion of the course, students will be able to:

1. Classify various kinds of geological strata in geotechnical purview.
2. Apply the geotechnical concepts in various field related to infrastructures and developments.
3. Identify problems related to geotechnical aspects in energy sectors and environment fields.
4. Determine expected loads and design and evaluate anchoring systems

31. Course Name: Organic Geochemistry

31a.Course Code GLD 529

31.b. L-T-P = 3-0-0

31.c. Credit = 9

31.d. Syllabus & Lecture Plan:

Unit	Description	No. of Classes
1.	**Organo-geochemical Cycles and organic matter:**Organo-geochemical Cycles, Fundamental aspects of organic matter formation	5
2.	**Preservation and composition:** Preservation and composition; Diagnostic isotopic fossils.	4
3.	**Macromolecular compounds:**Macromolecular compounds and their role in kerogen, coal and petroleum.	4
4.	**Isotope fractionation:** Isotope fractionation during primary production.	4
5.	**Biomarkers:**Production, transport and alteration of particulate organic matter. Biomarkers and their applications	4
6.	**Kerogen:** Types, structural components, maturity; Analytical Pyrolysis and chemical methods for assessing types and maturity.	5

7.	**KerogenPetrology**: Organic petrographic approach for kerogen characterization	**5**
8.	**Thermal alteration :**Thermal alteration of organic matter and formation of fossil fuels.	**5**
9.	**Organic Geochemical Research:** Organic Geochemical Research for Hydrocarbon Exploration.	**3**
	Total Classes	**39**

31.e. Recommended Books:

1. Organic Geochemistry by Stephen D.Killops and Venessa J. Killops ,2013 (Second Edition)

31.f. Course Goal / Learning Outcome*:*

The primary objective of the course is to introduce fundamental aspects of organic geochemistry such as origin, transport, formation, types, physical properties and depositional environments and industrial utilization to the students.

31.g. Learning Objectives

Upon completion of the course, students will be able to:

1. Distinguish between different kerogen types based on physical, chemical and petrographical and other properties.
2. Origin and effect of various depositional environments in shaping of various macromolecular components.
3. Role of organic geochemistry in industrial utilization.

32.Course Name: Geodynamics

32.a.Course Code GLD 530

32.b. L-T-P = 3-0-0

32.c. Credit = 9

32.d. Syllabus & Lecture Plan:

Unit	Description	No. of classes
1.	**Methods and sources of information**: Internal structure of the earth. Variation of physical properties inside earth.	7
2.	**Crustal types and their characters**: Tectonic features of continental areas. Main features of ocean basins. Characters of deep ocean floor and oceanic ridges. Different types of continental margins and their characters. Stages in the evolution of oceanic basins.	7
3.	**Tectonic hypotheses of orogenesis**: continental drift, palaeomagnetism, sea floor spreading and distribution of tectonically active zones.	7
4.	**The concept of plate tectonics**: Plate geometry and plate boundaries. Plates in velocity space. Cartesian coordinates, spherical coordinates and reference frame. Finding Euler's pole. Velocity due to rotation about Euler's pole. Angular velocity vectors. Triple junctions. Mechanisms of plate motion.	6
5.	**Tectonics of different plate boundaries**: Different types of tectonic settings. Petro-tectonic assemblages at different plate boundaries.	6

	Activation model and collision model of orogeny. Pacific and Andean type orogeny.	
6.	**Configuration of the Indian plate**: Characters of different tectonic zones and the origin of the Himalayas.	6
	Total classes =	39

32.e Recommended Books:

1. Bearman, G. (1989). The ocean basins: their structure and evolution. Pergamon Press.
2. Boillot, G. (1981). Geology of the continental margins. Longman.

Other References:

1. Condie, K. C. (1997). Plate tectonics and crustal evolution. Butterworth-Heinemann, Oxford
2. Jolivet, L. and Nataf, H.C. (2001). Geodynamics. Oxford & IBH, New Delhi.
3. Kearey, P. and Vine, F. J. (1996). Global Tectonics. Blackwell Publishing, London
4. Kennett, JP (1982). Marine Geology. Prentice-Hall.
5. Moores, E. M. and Twiss, R. J. (1995). Tectonics. W. H. Freeman & Co.
6. Ranalli, G. (1995). Rheology of the Earth (2nd Edition). Chapman & Hall, London.
7. Turcotte, D.L. and Schubert, G. (2002). Geodynamics (2^{nd} Edition). Cambridge University Press
8. Van der Pluijm, B.A. &Marshak, S. (2004). Earth Structure: An Introduction to Structural Geology and Tectonics (2^{nd} Edition). WW Norton & Company.
9. Windley, B.F. (1995). The evolving continents (3rd Edition). John Wiley, Chichester.

32.f Course Goal / Learning Outcome*

The primary objective of the course is to provide theoretical background for understanding evolution of morphotectonic features of the earth.

32.g.Learning Objectives**

Upon completion of the course, students will be able to:

1. Understand different techniques for tectonic reconstructions.
2. Understand the petro-tectonic associations in different regions.
3. Understand the behaviour of the earth in time and space.

33. Course Name: Sequence Stratigraphy and Basin Analysis

33.a. Course Code GLD 531

33.b. L-T-P = 3-0-0

33.c. Credit = 9

33.d. Syllabus & Lecture Plan:

Unit.	Description	No. of classes
	Sequence Stratigraphy	
1	Definitions and key concepts, base level changes, transgressions and regressions.	3
2	Sequence stratigraphic surfaces. Unconformity and correlative conformity	3
3	Systems Tracts: Lowstand, Transgressive, Highstand, Falling stage.	3

4	Hierarchy of sequences and bounding surfaces`	3
5	D Definitions and key concepts, base level changes, traTranssgressions and regressions.	3
6	Sequence stratigraphic surfaces. Unconformity and correlative conformity	3
7	Systems Tracts: Lowstand, Transgressive, Highstand, Falling stage.	3
	Basin Analysis	
8	Definition and scope of basin analysis	2
9	Basin mapping methods: structure and isopach contouring, lithofacies maps, palaeocurrent analysis, Geohistory analysis. Thermal history.	8
10	Regional and global stratigraphic cycles. Tectonic classification of sedimentary basins.	3
11	Characteristics of divergent margin basins, convergent margin basins, transform and transcurrent fault basins, basins developed during continental collision and suturing and cratonic basins.	4
12	Review of Indian basins.	1
	Total classes	39

33.e Recommended Books:

1. Gary Nichols – Sedimentology & Stratigraphy, 2003, Blackwell Publishing Company, Malden, USA
2. Richard C. Selley – Applied Sedimentology, 2000, Academic Press, California, USA.

Other References:

1. H.G. Reading – Sedimentary Environments: Processes, Facies and Stratigraphy, 1996, Blackwell Science Limited, Malden, USA.
2. Hans-Erich Reineck and IndraBir Singh – Depositional sedimentary environments: with reference to terrigenousclastics, 1992, Springer-Verlag.
3. Winfried Zimmerle– Petroleum Sedimentology, 1995, Ferdinand EnkeVerlag, Stuttgart, Germany.
4. B. Biju-Duval – Sedimentary Geology: Sedimentary Basins, Depositional Environments, Petroleum Formation, 2002, Editions Technip, Paris.
5. Andrew Miall – Principles of Sedimentary Basin Analysis. Springer, New York, 1990.
6. Magnus Wangen – Physical Principles of Sedimentary Basin Analysis. Cambridge University Press, New York, 2010.

33.fCourse Goal / Learning Outcome*:*

In this course the students will study the fundamental concepts, principles and applications of sedimentology.

33.g. Learning Objectives:

Upon completion of the course, students will be able to:

1. Identify and study various types sedimentary rocks in field and under microscope
2. Can understand the difference between various types of sedimentary rocks such as sandstones, shale, conglomerates and carbonates
3. Understand various types of sedimentary structures and their geological significance
4. Understand various types of sedimentary depositional environments and their importance for hydrocarbon systems, ore deposits and groundwater accumulation.

34.Course Name: Geomorphology
34.a.Course Code: GLD 540
34.b. L-T-P = 3-0-0
34.c. Credit = 9
34.d. Syllabus & Lecture Plan:

Unit	Description	No. of Classes
1.	Introduction to Geomorphology	2
2.	Methods of Geomorphic investigations	2
3.	Physical, Chemical and Biological processes in weathering	5
4.	Structural and lithological controls on landforms and drainage patterns	4
5.	Depositional and Erosional landforms: Fluvial, Aeolian, Glacial and Marine	11
6.	Morphometric analysis of landforms	6
7.	Impact of climate on geomorphology	3
8.	Applications of Geomorphology in environmental and engineering problems	3
9.	Neotectonics and geomorphology	3
	Total Classes	39

34.e Recommended Books:

1. Principles of Geomorphology– W.D. Thornbury, Wiley Eastern Limited
2. Geomorphology – Arthur H. Bloom, Prentice hall of India

Other References:

1. Structural Geomorphology – J. Tricart , Longman Publishers
2. Geomorphology from the Earth – Karl W. Butzer, Harper International
3. Glacial and Fluvioglacial Landforms – R.J. Price, Longman Publishers

34.f. Course Goal / Learning Outcome:

The primary objective of the course is to introduce fundamental and applied aspects of Geomorphology such as origin, evolution, maintenance and destruction of landforms, their link with tectonics and climate and their applications in flood control, landslides, transport engineering and others.

34.gLearning Objectives

Upon completion of the course, students will be able to gain insights in:

1. Geomorphology as an important earth process that links landform development with climate, tectonics, sedimentary deposits, igneous activity and extra-terrestrial events
2. Quantitatively analyse landforms and landscapes
3. Application of geomorphology in Engineering and environmental problems.

35.Course Name: Geochemical Analytical Techniques
35.a. Course Code GLD 541

35.b. L-T-P = 3-0-0

35.c. Credit = 9

35.d. Syllabus & Lecture Plan:

Unit	Description	No of classes
1	Introduction to geochemical analyses of rocks, minerals, ores, coal and environmental material.	2
2	Classification of geochemical analyses	2
3	Sample preparation methods of whole-rock, minerals and water analyses and isotopic analyses (Destructive and non-destructive methods) and geochemical standards.	6
4	Classical methods; Flame and Ultra-Violet & Infra-Red Spectrophotometer; Atomic Absorption Spectrophotometer; and Inductively Coupled Plasma Spectrophotometer.	8
5	Introduction to Scanning Electron Microscopy (SEM), Cathodo-Luminescence (CL), Thermo- Luminescence (TL), X-Ray Diffractometer (XRD), X-Ray Florescence Spectrometry (XRF), Electron Probe Micro Analyser (EPMA) Ion Probe; Mass Spectrometry, Liquid Chromatography and Gas Chromatography, Neutron activation analyses (INAA), Gamma-ray spectroscopy. SHRIMP and SIMS techniques for U-Pb dating	15
6	Data Processing and Presentation.	6
	Total hours	**39**

35.e. Text books Recommended/References:

1. Potts P.J. (1987) A handbook of silicate rock analysis; Blackie

Other References:

2. Albarède F. (2003) Geochemistry An Introduction; Cambridge University Press.
3. Faure G. (1986) Principles of Isotope Geology; John Wiley and sons 2nd Eds.
4. Faure G. (1991) Principles and Applications of Inorganic Geochemistry; Macmillan Publishing Company.
5. Hoefs EJ. (1996) Stable Isotope Geochemistry: Springer,4thEds.
6. Mason B, Moore CB. (1991) Principles of Geochemistry: Willey eastern Ltd,4th Eds.
7. Gopalan K. (2017) Principles of Radiometric dating: Cambridge University Press, 1st edition

35.f. Course Goal / Learning Outcome

In this course the students will study the fundamental concepts, principles and applications of various analytical techniques foe generating geochemical and isotope data from geological material.

35.g. Learning Objectives

Upon completion of the course, students will be able to:

1. Understand the methods of dissolution, dilution and analysis of different types of chemical elements.
2. They will also understand to interpret results obtained from various types of advanced instruments.

36. Course Name: Computer Applications in Geology

36.a. Course Code: GLD 543

36.b. L-T-P = 3-0-0

36.c. Credit = 9

36.d. Syllabus & Lecture Plan:

Unit	Description	No. of Classes
1.	General Introduction to computers and programming, Flow chart, control of programming	**4**
2.	Database - definition, structure, and types; Geological database.	**7**
3.	Computer Graphics, Construction of geological maps and sections during AutoCAD and Corel draw	**9**
4.	Elementary concepts on Knowledge Based Expert System, Decision Support System, Neural Network, Fuzzy Logic and Genetic Algorithm	**10**
5.	Use of Software Packages in Geology	**9**
	Total Classes	**39**

36.e. Recommended Books:

Learning Python: Powerful Object-Oriented Programming

1. Programming Pearls by Jon Bentley
2. Pro SQL Server 2008 Relational Database Design and Implementation 1st ed. Edition by Louis Davidson, Kevin Kline, Scott Klein, Kurt Windisch

Other references:

3. Essentials of MATLAB Programming by Stephen J. Chapman
4. Engineering and Scientific Computations Using MATLAB by Sergey E. Lyshevski

36.g. Course Goal / Learning Outcome:

The primary objective of the course is to introduce fundamental aspects of computer and programming and usefulness in the field of geology.

36.f. Learning Objectives:

Upon completion of the course, students will be able to:

1. Use efficiently the computer to solve geological problems.
2. Write small computer codes in different computer language to address data compilation and analysis.
3. Will be adverse with different commercial software to solve real time

37. Course Name: Kinematics of Rock Deformation

37.a. Course Code GLD 544

37.b. L-T-P = 3-0-0

37.c. Credit = 9

37.d. Syllabus & Lecture Plan:

Unit	Description	No. of classes
1.	**Stress**: Definition, units, classification, stress ellipsoid, stresses at a point, stress on a plane, Mohr circle construction and stress trajectory. Applications for basin analysis and slope stability studies.	7
2.	**Strain**: Definition, strain parameters, classification, strain ellipsoid and theory	7

	of deformation in two and three dimensions. Applications in basin analysis	
3.	**Strain Analysis**: Measurement of deformation in nature, graphical representation by Flinn, Ramsay, Hossack and Mohr diagrams, progressive deformation, deformation paths and significance of geological structures.	7
4.	**Experimental Deformation and Rheology:** Behaviour of rocks under experimental conditions. Effects of confining pressure, pore fluid pressure, anisotropy, temperature and scale on rock deformation.	6
5.	**Development of Structures - I:** Mechanisms of folding, and strain variations around folds. Development of secondary cleavage and lineations.	7
6.	**Development of Structures - II:** Development ofrock fractures. Conditions of fault development. Deformation mechanisms.	5
	Total classes =	39

37.e Recommended Books:

1. Ghosh, S.K. (1993) Structural Geology. Pergamon Press.
2. Means, W.D. (1976) Stress and Strain. Springer-Verlag.

Other References:

1. Passchier, C.W., and Trouw, R.A.J. (1996). Microtectonics, Springer.
2. Ramsay, J.G. (1967) Folding and Fracturing of Rocks. McGraw-Hill.
3. Ramsay, J.G. & Huber, M.I. (1983). The Techniques of Modern Structural Geology. Vol. 1. Academic Press.
4. Ramsay, J.G. & Huber, M.I. (1987). The Techniques of Modern Structural Geology. Vol. 2. Academic Press.
5. Twiss, R.J. &Moores, E.M. (1992) Structural Geology. W.H. Freeman & Company.
6. Turcotte, D.L. & Schubert, G. (2002). Geodynamics (2^{nd} Edition). Cambridge University Press
7. Van der Pluijm, B.A. &Marshak, S. (2004). Earth Structure: An Introduction to Structural Geology and Tectonics (2^{nd} Edition). WW Norton & Company.

37.f. Course Goal / Learning Outcome*:

The primary objective of the course is to provide theoretical background for techniques of stress and strain analysis in rocks.

37.g. Learning Objectives**

Upon completion of the course, students will be able to:

1. Measure rock deformation in nature.
2. Understand the evolution of different structures.

Syllabus of Open Elective (OE)Courses

38. Course Name: Atmosphere, Ocean and Climate Dynamics
38.a. Course Code: GLO 523
38.b. L-T-P = 3-0-0
38.c. Credit = 9
38.d. Syllabus & Lecture Plan:

Unit	Description	No. of Classes
1.	Structure and chemical composition of the Earth's atmosphere, lapse rate and stability, convection, radiative-convective equilibrium, pressure and geopotential height, air masses, wind belts and greenhouse gases. Atmospheric turbulence and boundary layer. Atmospheric circulation. Cloud formation, precipitation processes and water balance. Atmospheric pollution.	8
2.	Hypsography of the continents and ocean floor. Physical and chemical properties of seawater and their spatial variations. Residence times. Ocean currents, waves and tides, ocean eddy, stratification, Ekman pumping, important current systems. Major water masses of the world's oceans. Marine Pollution. Harmful Algal Blooms.	7
3.	Air-sea fluxes, interactions and climate feedback. Insolation and heat budget, radiation balance, Walker cell, general circulation of the atmosphere and ocean. Motion of fluids, waves in atmospheric and oceanic systems. Hurricanes and Tornadoes, categories, scales and indexes.	8
4.	Weather and Climate. Classification of climates. Climate Indicators and Indices. Climate variability. General weather systems of India, - Monsoon system, tropical cyclone and jet stream, Western disturbances and severe local convective systems, distribution of precipitation over India.	8
5.	Climatic and sea level changes on different time scales. Sea surface temperature. Global and regional oscillation pattern and climate. Coupled ocean-atmosphere system, El Nino Southern Oscillation (ENSO), El Niño and La-Nina and effect on monsoon systems, drought, and flood events. Climate models, changes in cryosphere, global warming, and climate change.	8
	Total Classes	**39**

38.e. Recommended Books:

1. Atmosphere, Ocean, and Climate Dynamics: An Introduction to Text by J. Marshall and R. A. Plumb
2. The Atmosphere and Ocean: A Physical Introduction by N.C. Wells

Other References:

1. Atmospheric Science by J.M. Wallace and P.V. Hobbs
2. Atmosphere, Weather and Climate by R. G. Barry and R. J. Chorley
3. The Atmosphere: An Introduction to Meteorology by F.K. Lutgens, E.J. Tarbuck, D.G. Tasa
4. Essentials of Meteorology: An Invitation to the Atmosphere by C.D. Ahrens
5. Meteorology : Understanding the Atmosphere by Steven Ackerman, John Knox

6. Essential of Oceanography by Trujillo/ Thurman
7. Essentials of Oceanography, by Tom Garrison
8. Fundamentals of Weather and Climate by Mcllveen
9. Understanding Weather and Climate by Edward Aguado, James E. Burt

38.f. Course Goal/Learning Outcome:

The primary objective of the course is to provide knowledge about fundamental aspects of atmosphere, ocean, land and major issues related to variability and changes observed in the climate.

38.g Learning Objectives:

Upon completion of the course, students will be able to understand:

1. Earth's atmosphere, ocean and land as a system of systems.
2. General circulation and stability of atmosphere.
3. Atmosphere-ocean coupling, feedback effects and climate change.
4. Monsoon system in India and teleconnection.
5. About climate change indicators.

39. Course Name: Environmental Geology

39.a. Course Code: GLO 532

39.b. L-T-P = 3-0-0

39.c. Credit = 9

39.d. Syllabus & Lecture Plan:

Unit	Description	No. of Classes
1.	**Introduction to Environmental Geology:** Fundamental concepts of environmental geology. Changes in the environment caused by anthropogenic processes.	**6**
2.	**Sources of Pollutants:**Sources of Inorganic and organic contaminants. Drinking water standards. Surface and ground water pollution. Geochemistry of toxic elements in natural waters. Introduction to Medical Geology:	**9**
3.	**Earth Processes and impacts**: Study of surface geological processes with reference to their impact on environment.	**6**
4.	**Exploration/Mining and Impacts on Environment:** Environmental problems connected with exploitation of minerals and energy resources. Acid mine drainage. Land use and land degradation due to mining. Soils, erosion and conservation	**8**
5.	**Environmental Management**: Geological solutions to environmental problems. Role of geology in waste disposal, Global warming, Climate change and Mitigation. Environmental planning, management and economics (EMP and EIA).	**10**
	Total Classes	**39**

39.e. Recommended Books:

1. Montgomery, C.W. (1989) Environmental Geology (II Edition). Wm. C Brown Publ.
2. Valdiya, K S (1987) Environmental Geology. Indian Context. Tata McGraw Hill Publ.

Other References:

1. Keller, E A. (2012) Introduction to Environmental Geology (5h Edition). Prentice Hall.

39.f. Course Goal/Learning Outcome:

The primary objective of the course is to introduce the basic tenants of environmental geology, sources of pollutants from natural as well as anthropogenic sources. The subject deals with the adverse effects on the environments and the role of geologist in the remedial measures for environmental contaminants and its safe disposal.

39.g Learning Objectives

Upon completion of the course, students will be able to:

1. Understand the different aspects of environmental problems in the natural system including the different sources i.e. geogenic and anthropogenic sources.
2. Origin and transportation mechanism of the pollutants and their impacts on the society.
3. Know the possible remedial methods as well as disposal of different waste material.

40. Course Name: Remote Sensing and GIS

40.a. Course Code GLO 542

40.b. L-T-P = 0-0-0

40.c. Credit = 9

40.d. Syllabus & Lecture Plan:

Unit	Description	No. of Classes
1.	**Introduction to Remote Sensing**: Basic principles of remote sensing; Historical perspectives of remote sensing; Recent developments and objectives; Definitions; Scope and potential; Advantages and limitations; applications; Remote sensing process.	**4**
2.	**Electromagentic Radiation Principles:**Wave/particle model of electromagnetic (EM) energy; Laws and principles of electromagnetic radiation; EM spectrum; EM wavelength regions and their applications; Scattering, absorption and reflection of EM radiation; Atmospheric window; Terrain energy-matter interactions; Spectral reflectance curves of terrain elements;	**5**
3.	**Remote Sensing Data Collection and Processing:** Types of sensors; Framing and scanning systems; Spatial, spectral, temporal and radiometric resolution of sesnors; Types of platforms, their advantages and limitations; Orbits and swath characteristics; Active and passive remote sensing; Data conversion; Earth observation satellites; Fundamental digital image processing techniques.	**5**
4.	**Aerial Photography:** Aerial platforms; Vantage point, cameras, filters and films; Photogrammetry principles; Geometry of aerial photographs; Scale determination; Photogrammetric measurements; Elements of photointerpretation; Interpretation of aerial photographs.	**4**
5.	**Thermal Infrared remote sensing:** Thermal infrared radiation principles; Kinetic heat and temperature; Radiant energy flux; Thermal radiation laws; Inverse-square law; Emissivity; Thermal properties of terrain; Thermal	**4**

	infrared detectors; Applications, advantages and limitations of thermal infrared remote sensing.	
6.	**Active microwave (RADAR) remote sensing:** RADAR system components; RADAR nomeclature; Advantages and limitations of RADAR; RADAR operations; Polarization; RADAR image geometry; RADAR resolutions; RADAR relief displacement: Foreshortening, layover and shadow; Synthetic aperture radar systems; Fundamental RADAR equation and its components; Surface roughness and electrical characteristics.	**4**
7.	**Introduction to Geographic Information System:** Introduction and definitions; Technology and concepts; Components of GIS; Developments in GIS; Primary features of GIS; Capabilities of GIS; Advantages and limitations of GIS; Introduction to commonly used GIS software.	**3**
8.	**Spatial Referencing:** Coordinate systems: Geographic and projected; Map Projections; Types of map projections and their characteristics; Datum and its nomenclature; Geometry of datum; Regional and geocentric datum; UTM zones; Basics of GPS.	**4**
9.	**GIS Data:** Method of data capture; Nature and source of data; Geographic data models; Fields and entities; Raster and Vector data formats; Advantages and limitations of vector and raster data; File and data access; Database structures: Hierarchical/Relational; Creation of GIS database; Attribute Table; Errors in GIS.	**3**
10.	**GIS Data processing:** Digitization and map composition; Rectification of geo-database; Basic data processing: Overlay, query building, spatial operations, map integration; Joining spatial and attribute data; Steps in a GIS project; Identification of project objectives; Creation of project database; Data integration.	**3**
	Total Classes	**39**

40.e. Recommended Books:

1. Remote Sensing and GIS by B. Bhatta, 2nd Edition, 2009, Oxford University Press.
2. Remote Sensing of the Environment: An Earth Resource Perspective, 2nd Edition, 2000, Prentice Hall Inc.

Other References:

1. Remote Sensing and Image Interpretation, T. M. Lillesand, R. W. Kiefer and J. W. Chipman, 6th Edition, 2007, Wiley Publications.
2. Introduction to Remote Sensing, J. B. Campbell, 4th Edition, 2008, The Guilford Press.
3. Principles of Geographical Information Systems, P. A. Burrough and R. A. McDonnell, 2nd Edition, 1998, Oxford University Press.

40.f. Course Goal / Learning Outcome*:*

This course provides fundamental understanding and working knowledge of the principles and applications of remote sensing and GIS that is fundamental to understand the Earth system.

40.g. Learning Objectives:

Upon completion of the course, students will be able to:

1. Explain the principles of remote sensing and its application.
2. Develop capabilities of understanding and interpreting remote sensing data
3. Acquire knowledge and critical thinking skills to solve a real-world problem with appropriate remote sensing data and processing methods

4. Critically assess the strengths and weaknesses of remote sensing instruments and platforms for a variety of application scenarios
5. Critically evaluate the opportunities and available methods for integrating remote sensing and GIS.

41. Course Name: Nuclear Geology
41.a. Course Code GLO 545
41.b. L-T-P = 3-0-0
41.c. Credit = 9
41.d. Syllabus & Lecture Plan:

Unit	Description	No. of Classes
1.	Radioactivity and radioactive decay, Growth and decay mechanisms (α β γ decay); Decay units and dosage. Neutron activation.	**7**
2.	Mass spectrometry. Geochronology: Dating methods: K-Ar and Ar-Ar methods, Rb-Sr, Sm-Nd and Lu-Hf methods, Re-Os method. Fission track, ^{14}C, U-Pb and Pb-Pb methods.	**6**
3.	Application of Rb-Sr, Sm-Nd, Pb-Pb and Lu-Hf isotopes in petrogenetic studies.	**6**
4.	Stable isotopes: Fractionation mechanisms, Oxygen and hydrogen in hydrosphere and atmosphere. Oxygen/hydrogen isotopes in igneous, metamorphic & sedimentary rocks; their application for ore genesis and climate studies.	**5**
5.	Carbon and its stable isotopes in biosphere, fossil fuels, igneous and metamorphic rocks. Application in ore genesis.	**5**
6.	Sulphur isotopes: fractionation mechanisms (biogenic versus equilibrium process), application in fossil fuels, evolution of marine sulphur& ore genesis.	**5**
7.	Detectors of radioactivity: Geiger, proportional and scintillation counters and spectrometers.	**5**
8.	**Total Classes**	**39**

41.e. Recommended Books:

1. Faure, G. (1977). Principles of Isotope Geology. Wiley, 464 pp.
2. Faure, G. and Mensing, T.M. (2009). Isotopes Principles and Applications. Wiley, 896 pp.

Other References:

1. Dickin, A.P. (2005). Radiogenic Isotope Geology. Cambridge University Press, 492 pp.
2. Allègre, C.J. (2008). Isotope Geology. Cambridge University Press, 512 pp.
3. Hoefs, J. (2015). Stable Isotope Geochemistry. Springer, 389 pp.
4. Gopalan K. (2017) Principles of Radiometric dating. Cambridge University Press, 1st edition

41.f. Course Goal / Learning Outcome:

The students will learn about the various isotopic systematics that are applicable to geological studies.

41.g Learning Objectives:

1. Learn about the fundamentals of radioactivity and its application to geological studies
2. Learn about different isotopic systematics as applied to geology
3. Learn mass spectrometric techniques and understand how isotopes are used for petrogenetic studies.