Programme Structure and Syllabus

for

2-Year M.Tech.

in

ENGINEERING GEOLOGY

Department of Applied Geology
Indian Institute of Technology
(Indian School of Mines)
Dhanbad-826004

(Recommended to be effective from Academic Session 2019-20 onwards)

PG Course Template for
2-Year M. Tech. Programme in ENGINEERING GEOLOGY

Semester I

Course No.	Course Name	L	T	P	C
	Theory				
GLC 579	Geotechnical Behaviour of Earth Materials	3	0	0	9
GLC 580	Soil Engineering	3	0	0	9
GLC 581	Structural Geology for Site Engineering	3	0	0	9
GLC 592	Programming in MATLAB	3	0	0	9
GLC 559	Resource Evaluation and Geostatistics	3	0	0	9
	Practical				
GLC 582	Geotechnical Behaviour of Earth Materials Practical	0	0	2	2
GLC 583	Structural Geology for Site Engineering Practical	0	0	2	2
	Total	**15**	**0**	**4**	**49**

Semester II

Course No.	Course Name	L	T	P	C
	Theory				
	Department Elective 1	3	0	0	9
GLD 572	• Advanced Geostatistics and Exploration Economics				
GLD 574	• Geospatial Analysis				
	Department Elective 2	3	0	0	9
GLD 591	• Rock Slope Engineering				
GLD 570	• Hyperspectral Remote Sensing				
	Department Elective 3	3	0	0	9
GLD 592	• Environmental Geotechnology				
GLD 593	• Applied Hydrogeology				
	Open Elective 1 (Table-1)	3	0	0	9
	Open Elective 2 (Table-1)	3	0	0	9
	Practical				
GLC 584	**Departmental Practical 1** Soil Engineering Practical	0	0	2	2
GLC 562	**Departmental Practical 2** Resource Evaluation and Geostatistics	0	0	2	2

	Practical				
	Total	**15**	**0**	**4**	**49**

Semester – III

Course No.	Course Name	L	T	P	C
GLC 585	Thesis Unit 1	0	0	0	9
GLC 586	Thesis Unit 2	0	0	0	9
GLC 587	Thesis Unit 3	0	0	0	9
GLC 588	Thesis Unit 4	0	0	0	9
	Total	**0**	**0**	**0**	**36**

Semester – IV

Course No.	Course Name	L	T	P	C
 GLD 594 GPD 552	**Department Elective 4** • Geotechniques of Dams, Tunnels and Underground Space • Geophysical Methods for Groundwater Exploration **or** **Open Elective 3** (Table-1)	3	0	0	9
 GLD 577 GPD 523	**Department Elective 5** • Digital Image Processing • Artificial Intelligence and Machine learning in Geosciences **or** **Open Elective 4** (Table-1)	3	0	0	9
GLC 589	Thesis Unit 5	0	0	0	9
GLC 590	Thesis Unit 6	0	0	0	9
	Total	**6**	**0**	**0**	**36**

Table 1. Table of Open Electives (any one or from Department Electives or Other Departments)

Course No.	Course Name	L	T	P	C	S#
GLD 575	Modern Instrumental Methods in Exploration Geosciences	3	0	0	9	W
GLO 596	Rock Deformation Kinematics for Engineering Geology	3	0	0	9	W

GLO 597	Engineering Geomorphology	3	0	0	9	W
GPD 551	Engineering Geophysics	3	0	0	9	W

A. Syllabus of Department Core (DC): Theory Courses

1. Course Name: Geotechnical Behaviour of Earth Materials

Course Code: GLC 579
L-T-P = 3-0-0
Credit = 9
Syllabus & Lecture Plan:

Unit	Description	No. of Classes
1.	Geotechnical Engineering : introduction, definition, significance	1
2.	Geotechnical grounds: requirement, definition, significance in engineering geological projects	4
3.	Concept of rock strata : rocks, rock material, rock mass and types of discontinuity	3
4.	Deformation and physico-mechanical properties: concept of stress, strain, deformability, physical and mechanical properties of rocks, methods of determination.	7
5.	Geotechnical characterization: discontinuity, geotechnical parameters, influence of geotechnical parameters on geotechnical behaviour of rock mass	4
6.	Rock mass classification system : single parametric, multi-parametric (RQD, RMR, GSI, Q, etc)	6
7.	Shear strength of rock mass and scaling effect : joint wall compressive strength, joint wall roughness coefficient, shear strength criteria, various scales of measurement	5
8.	In-situ stress : concept , methods, and significance	5
9.	Field techniques of geotechnical investigation : instruments, data collections, and analysis	4
	Total Classes =	**39**

Recommended Textbooks:

1. Lama and Vutukari. (1978). Mechanical Properties of Rocks. Trans Tech Pub. II.pp.28-314 & 45-243.

2. Jaeger and Cook. (1984). Fundamentals of Rock Mechanics. 2nd Ed, John Wiley and Sons.

Other References:

1. Jumkis, A.R. (1983). Rock Mech. 2nd Ed, Trans Tech Vol.7, pp.1-613.

2. Reddy, D.V. (2016). Engineering Geology, VikasPbl, pp. 1-410.

Course Goal / Learning Outcome:

The students will establish concepts related to fundamental aspects of ground with special reference to their geotechnical response with respect to external forces for development of engineering geological projects.

Learning Objectives

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

1. Classify various kinds of grounds
2. Understand about the stress, deformation, physico-mechanical properties of Earth's materials.
3. Use the various geotechnical parameters relevant for characterizing the geological strata.
4. Classify the rock mass for various geotechnical purposes
5. Utilize different methods for In-situ stress measurements and explain its significance in development of engineering geological projects.

Unit-wise Learning Outcome:

1. Get introduced to the key of Geotechnical Engineering

2. Get to know Geotechnical grounds for various Engineering Geological projects.

3. Understand the concept of rock strata

4. Understand the deformation and physico-mechanical properties of rocks

5. Understand the Geotechnical characterization of rockmass.

6. Get to know the Rock mass classification system

7. Will know how to determine the Shear strength of rock mass and scaling effect

8. Will know the concept of In-situ stress

9. Get to know the various field techniques of geotechnical investigation

2. Course Name: Soil Engineering

Course Code: GLC 580

L-T-P = 3-0-0

Credit = 9

Syllabus & Lecture Plan:

Unit	Description	No. of classes
1.	Factors influencing nature and formation of soils. Soil structure, types of bonds, Soil phase relationship, Important clay materials.	8

2.	Engineering properties of soils, Genetic and engineering classification of soils, Complexity of soil nature.	8
3.	Permeability and flow through soil media, Capillary water rise in soil, Soil stress and seepage, compressibility and consolidation.	6
4.	Shear strength of Cohesion-less and cohesive soils. Soil stress, effective stress, pore water pressure parameters. Earth pressures: active and passive.	8
5.	Stability analysis of soil slopes and Soil exploration. Type of foundations, settlement of foundations, bearing capacity, pile foundations.	7
6.	Type of soils as an aggregate material.	2
	Total Classes =	**39**

Recommended Textbooks:

1. Murthy, V.N.S.(2018). Text book of Soil mechanics and foundation Engineering.
2. Sehgal S.B. (2007).Textbook of soil mechanics, CBS Publishers.

Other References:

1. Ranjan, G and Rao, A.S. (2005).Basic and Applied soil mechanics, New Age Publishers.

Course Goal / Learning Outcome:

The primary objective of the course is to provide theoretical background for different soil properties and techniques used for determination of soil strength and stability as a geomaterials helpful for industry / engineering construction organisations.

Learning Objectives:

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

1. Apply different methods to determine soil properties.
2. Determine strength of soil.
3. Stability analysis of soil slopes.

Unit-wise Learning Outcome:

1. Understanding of weathering and its associated processes that determines soil formation.
2. Concept of engineering properties of soils and its use in developing man-made structure.
3. Fluid motion through soil grain, compressibility and consolidation of soil will be understood.
4. Understanding of shear strength and Earth pressures of soil.
5. Concept of slope stability analysis and understanding of foundation design.
6. Will know the different soil types for various purpose for aggregate making.

3. Course Name: Structural Geology for Site Engineering

Course Code: GLC 581
L-T-P = 3-0-0
Credit = 9
Syllabus & Lecture Plan:

Unit	Description	No. of Classes
1.	Introduction to structural Geology, Scope of structural geology with special reference to engineering geology.	3
2.	Anisotropy and heterogeneity in deformed rocks.	3
3.	Geological stresses and strains, Behaviour of rocks under stress.	6
4.	Geometric analysis of folds, faults, joints, ductile shear zones and rock cleavages.	10
5.	Structural evaluation of sites of construction: Preparation and interpretation of fence diagram. Structure contour maps, Isopach and Isochore maps. Joint and fracture maps, Stereographic projections.	10
6.	Isometric projections, Block diagrams, Fence diagrams.	5
7.	Geomorphic and structural evaluation of river valley projects-considerations.	2
	Total Classes =	**39**

Recommended Textbooks:

1. David, G.P.(2009). Engineering Geology; Principle and practice.
2. Ramsay, J.G and Huber, M.I.(1987). Techniques of modern structural geology; Vol. II folds and fractures.

Other References:

1. Billings, M.P. (2000). Structural geology, 3rd Edition.

Course Goal / Learning Outcome:

The primary objective of the course is to introduce fundamental and advanced aspects of structural geology in engineering geological aspects.

Learning Objectives:

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

1. Understand the fundamentals of structural geology
2. Carry out stress-strain analysis of highly fractured and jointed rock mass
3. Apply the knowledge for river valley projects

Unit-wise Learning Outcome:

1. Get introduced to key role of rock structures for constructions.
2. Concept of change in nature of rocks with change in directional and spatial deformation.
3. To understand the behaviour of rock under stress.
4. The effect of discontinuities associated with construction site.
5. Structural evaluation of sites for construction on the basis of structural mapping techniques.
6. Concept of block diagram and fence diagram.
7. The effect of geomorphological features on river valley projects.

4. Course Name: Programming in MATLAB

- **a. Course Code: GLC 592**
- **b. L-T-P = 3-0-0**
- **c. Credit = 9**
- **d. Syllabus & Lecture Plan:**

Unit	Description	No. of Classes
1.	Introduction: Why MATLAB?, History, Its strengths and Weaknesses, Competitors, Starting MATLAB, Using MATLAB as a calculator, Quitting MATLAB	3
2.	Basics: Familiar with MATLAB windows, Basic Operations, MATLAB-Data types, Rules about variable names, Predefined variables,	5
3.	Programming-I. Vector, Matrix, Array Addressing, Built-in functions, Mathematical, Operations, Dealing with strings (Array of characters). Array of array (cell) concept.	7
4.	Programming-II: Script file, Input commands, Output	6

	commands, Structure of function file, Inline functions, Comparison between script file and, Function file.	
5.	Conditional statements and Loop: Relational and Logical Operators, If-else statements. Switch- case statements, For loop, While loop, Special commands (Break and continue).	5
6.	Creating a database, Import data from large database, Modifying table content, Export data to own file or database, 2D Plotting: In-built functions for plotting. Multiple plotting with special graphics, Curve fitting. Interpolation, Basic fitting interface, 3D Plotting: Use of meshgrid function. Mesh plot, Surface plot, Plots with special graphics.	6
7.	GUI: Creating menu window for providing input, Creating graphical user interface.	4
8.	Applications in Geoscience	3
	Total Classes =	**39**

e. Recommended Text Book

1. Mikhailov, E. E. (2018). *Programming with MATLAB for Scientists: A Beginner's Introduction*. CRC Press.

Other References:

1. Trauth, M., Gebbers, R., Sillmann, E., & Marwan, N. (2007). *MATLAB®Recipes for Earth Sciences*. Springer Berlin Heidelberg.
2. Attaway, S. (2013). *Matlab: A Practical Introduction to Programming and Problem Solving*. Elsevier Science.

f. Course Goal / Learning Outcome:

The primary objective of the course is to introduce programming, data analysis and plotting in MATLAB and its applications in earth sciences.

g. Learning Objectives:

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

1. Write and read MATLAB programs
2. Work with other MATLAB programs and its applications especially in the field of geosciences.

Unit-wise Learning Outcome:

Upon completion of this course, the student will able to understand:

1. What is MATLAB programming language and its strength and weakness
2. Basic operations in MATLAB; rules and type of variables
3. Vector, Matrix function in MATLAB

4. How to input commands in MATLAB and what is its output, structure of function file
5. Relational and logical operators; If-else commands
6. Various type of plotting options using MATLAB
7. Basic knowledge on Graphical User Interface (GUI)
8. How MATLAB programming can be used in solving geosciences problems

4. Course Name: Resource Evaluation and Geostatistics

Course Code: GLC 559
L-T-P = 3-0-0
Credit = 9
Syllabus & Lecture Plan:

Unit	Description	No. of Classes
1.	Sampling: Theory, Methods, Sample optimisation, Errors, drill core logging and Core sampling.	3
2.	Resources and Reserves: Terminology, Classification Schemes, *viz.* USGS, UNFC, AAPG Schemes.	3
3.	Plans and Sections for Ore Evaluation: Structure Contour Plans, Isopach & Isochore Maps, Isograd Plan, Assay Plan, Ore Distribution Plan, Transverse and Longitudinal Vertical Sections, Slice Plan and Isometric Projection.	2
4.	Conventional Methods of Ore Evaluation: Polygonal, Triangular, Sectional, Random Stratified Grid, Contouring, and Distance weighting.	3
5.	Scales of Measurements; Basic concepts of Exploration Statistics: Universe, Population, and Sample; Random Variables; Probability distributions, viz. discrete and continuous; Characterization of Continuous Frequency distribution; Exploratory Data Analysis.	6
6.	Classical Statistics: Probability distributions: Theoretical models, Characteristics and Properties of Normal (Gausian), Lognormal, Binomial, Negative Binomial, Poisson and Exponential; Graphical and Numerical Techniques of Model Fit to Normal and Lognormal distributions, and their applications in Mineral Exploration. Tests of Hypotheses (Statistical Tests, viz. t, F and chi-squared goodness of fit); Trend Surface analysis and application in Mineral Exploration.	7
7.	Geostatistical Concepts and Theories: What, When and Why of Geostatistics; Regionalized Variable Theory; Random Function. Geostatistical Schools of Thought, *viz.* American, South African and French; Stationarity assumptions in geostatistics.	6
8.	Geostatistical Semi-variogram Analysis: Definition, Characteristics, Properties; Relation with Covariogram;	7

	Computation of Experimental Semi-variograms in One, Two and Three-Dimensions.	
9.	Theoretical Models of Semi-variogram: Models with Sill and without Sill, Nested Models and Trend Models.	2
	Total Classes =	**39**

Recommended Text Books:

1. Gandhi, S.M. and Sarkar, B.C. (2016) Essentials of Mineral Exploration and Evaluation, Elsevier, USA, 410 p.
2. Sinclair, A.J. and Blackwell, G.H. (2002) Applied Mineral Inventory Estimation, Cambridge Univ. Press, 378 p.

Other References:

1. Armstrong, M. (1998) Basic Linear Geostatistics, Springer, Berlin, 154 p.
2. Barnes, M.P. (1980) Computer-assisted Mineral Appraisal and Feasibility, SME, New York, 167 p.
3. Caers, Jeff (2005) Petroleum Geostatistics; SPE, 88 p.
4. Chiles, J.P. and Definer, P. (1999) Geostatistics - Modelling Spatial Uncertainty, John Wiley and Sons, New York, 695 p.
5. Clark, I. (1979) Practical Geostatistics, Elsevier Applied Science Publ. London, 151 p.
6. David, M. (1977). Geostatistical Ore Reserve Estimation, Elsevier Scientific Publ. Co. Amsterdam, 364p.
7. Deutsch, Clayton V. (2002) Geostatistical Reservoir Modelling; Oxford University Press, 376p.
8. Dubrule, Oliver (1998) Geostatitics in Petroleum Geology; AAPG Continuing Education Course Note Series #38.
9. Goovaerts, P. (1997) Geostatistics for Natural Resources Evaluation, Oxford Univ. Press, Oxford, 483p.
10. Isaaks, E.H. and Srivastava, R. M. (1989) An Introduction to Applied Geostatistics, Oxford University Press, 561 p.
11. Journel, A. G. and Huijbregts, C. J. (1978) Mining Geostatistics, Academic Press, London, 600 p.
12. Kelkar, Mohan and Perez, Godofredo (2002) Applied Geostatistics for Reservoir Characterization; SPE, 263 p.
13. Marjoribanks, Roger W. (1997) Geological Methods in Mineral Exploration and Mining. Springer-Science+Business Media, Dordrecht, 115 p.
14. Moon, C., Whateley, M. K.G., and Evans, A.M. (2006) Introduction to Mineral Exploration. Blackwell Publ., Oxford, 481 p.
15. Peters, W. C. (1978) Mining and Exploration Geology. John Wiley and Sons, Chichester and New York, 696 p.
16. Popoff, C. (1966) Computing Reserves of Mineral Deposits–Principles and Conventional Methods, USBM Inf. Circular, 8283.

17. Rendu, J.M. (1981) An Introduction to Geostatistical Methods of Mineral Evaluation, SAIMM Monograph, Johannesburg, 84p.
18. Wellmer, F. W. (1998) Statistical Evaluation in Exploration for Mineral Deposits, Springer, Hannover, 379 p.

Course Goal / Learning Outcome:

The key objective of the course is to introduce the students with the techniques of resource evaluation and principles of Geostatistics for mineral and petroleum exploration and evaluation. Tutorial covers techniques of sampling, reserve estimation and problem solving for mineral and petroleum geostatistics.

Learning Objectives:

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

1. Conceptualise sampling and resource estimation of mineral deposits and petroleum reservoirs;
2. Understand the utilisation of classical statistical tools and tests as applicable in exploration;
3. Apply concepts and principles of geostatistics for characterisation of mineral deposits and petroleum reservoirs.
4. Carry out Spatial data analysis.
5. Solve geostatistical problems related to characterisation of mineral deposits and petroleum reservoirs.

Prerequisite:

This is a pre-requisite course for course on "Advanced Geostatistics and Exploration Economics".

Unit-wise Learning Outcome:

1. Theory and procedures of mineral sampling;
2. Resources and Reserves – terminologies and classification schemes;
3. Plans and Sections for Ore Evaluation;
4. Conventional Methods of Ore Evaluation;
5. Basic concepts of Exploration Statistics;
6. Mineral Deposit Statistics;
7. Geostatistical Concepts and Theories;
8. Semi-variogram Analysis;
9. Mathematical models of Semi-variogram.

B. Syllabus of Department Core (DC): Practical Courses

5. Course Name: Geotechnical Behaviour of Earth Materials Practical

Course Code: GLC 582

L-T-P = 0-0-2
Credit = 2
Syllabus & Lecture Plan:

Unit	Description	No. of Classes
1.	Exercise on engineering geological maps	1
2.	Exercise on delineation of geotechnical grounds	2
3.	Establishment of geotechnical strata	1
4.	Zonation of rock strata and geotechnical mapping	1
5.	Excessive on geotechnical mapping on an area	1
6.	Geotechnical classification of ground	2
7.	Preparation of stress-strain behaviour curve of rocks, determination of strength, modulus and poison ratio of rocks.	1
8.	Determination of rebound hardness	1
9.	Slake durability tests	1
10.	Calculation of in situ stress	1
11.	Practical Examination	1
	Total Classes =	**13**

Recommended Textbooks:

1. Lama and Vutukari (1978). Mechanical Properties of Rocks. Trans Tech Pub. II.pp.28-314 & 45-243.
2. Jaeger and Cook (1984). Fundamentals of Rock Mechanics. 2nd Ed, John Wiley and Sons.

Other References:

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

Course Goal / Learning Outcome:

The students will able to classify various types of geotechnical ground and Earth's materials for engineering geological applications.

Learning Objectives:

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

1. Classify various kinds of grounds
2. Calculate strength, deformation, modulus and Poisson, ratio of rocks
3. Delineate various kind of geotechnical ground
4. Develop various geotechnical zones.
5. Classify the rock mass for various geotechnical purposes
6. Determine in-situ stress.

7. Assess the rebound value of rocks and rocks strata
8. Calculate durability of rocks.

Unit-wise Learning Outcome:

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

1. Concept of engineering geological maps
2. Hands-on experience of geotechnical grounds
3. categorization of geotechnical strata
4. Zonation of rock strata
5. Concept of geotechnical mapping
6. Geotechnical classification and ground condition
7. concept of elastic properties of rock
8. Hands-on experience of rebound hardness
9. Slake durability tests and its application
10. In situ stress determination

6. Course Name: Structural Geology for Site Engineering Practical

Course Code: GLC 583

L-T-P = 0-0-2

Credit = 2

Syllabus & Lecture Plan:

Unit	Description	No. of Classes
1.	Interpretation of topographic maps.	1
2.	Interpretation of geological maps.	1
3.	Preparation and interpretation of fence diagram.	1
4.	Structure contour maps.	1
5.	Isopach and isochore maps.	1
6.	Analysis of Fracture and Lineament array.	1
7.	Structural Geometry by stereographic projection.	2
8.	Construction profiles of folds.	1
9.	Analysis of stress.	1
10.	Structural analysis using DIPS software.	2
11.	Practical Examination	1
	Total Classes =	**13**

Recommended Textbooks:

1. David, G.P. (2009). Engineering Geology; Principle and practice.

2. Ramsay, J.G and Huber, M.I. (1987). Techniques of modern structural geology; Vol. II folds and fractures.

Other References:

1. Billings, M.P. (2000). Structural geology, 3rd Edition.

Course Goal / Learning Outcome:

The primary objective of the course is to introduce fundamental and applied aspects of structural geology in the field of engineering geological projects.

Learning Objectives:

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

1. Knowledge on fundamentals of structural geology
2. Stress-strain analysis of highly jointed and folded rock mass
3. Application for river valley projects

Unit-wise Learning Outcome:

1. This will develop skill of analyzing topographic maps that shall help in field expeditions.
2. This will help to correlate geological entities over a 2-D map
3. Hands-on experience of making fence diagram and its application.
4. Hands-on experience of making structural contours to analyse the geomorphic features over surface.
5. Hands-on experience of making contours maps having equal true and vertical thickness will be given.
6. With this the different fractures and its orientation will be demonstrated by 2-D projection. The lineament density and frequency will be understood.
7. Angular relationship between joints and planes will be understood using stereographic projection technique.
8. To understand the sub-surface morphology of folds with the help of profiles
9. The forces acting on a rock body depending upon direction of application and its effect on the overall nature of rock will be studied.
10. To visualize the rock slope virtually using DIPS for kinematic analysis and predict probable rock failure directions.

C. Syllabus of Department Elective (DE)

7. Course Name: Advanced Geostatistics and Exploration Economics

Course Code: GLD 572

L-T-P = 3-0-0

Credit = 9

Syllabus & Lecture Plan:

Unit	Description	No. of Classes
1.	Problems and constraints semi-variograophy, viz. anisotropy, non-stationarity, regularisation, presence of nugget effect and presence of trend. Extension, Estimation and Dispersion variances: definitions, methods of calculations.	6
2.	Ordinary Kriging: definition, point/block estimation procedures; Influence of Nugget variance on kriged weights, Effect of Nugget variance on kriged weights, Screen Effect, Negative kriging weights –causes and consequences; Practice of semi-variogram mode; Generalised geostatistical evaluation scheme.	7
3.	Non-linear and Non-parametric Geostatistics: Lognormal, Disjunctive and Multi-Gaussian, Indicator and Probability kriging.	3
4.	Geostatistical applications: optimisation of exploration drilling, calculation of mineral inventory, establishment of grade-tonnage relations, calculation of planning cut-off grade; misclassified tonnages; geostatistical grade control plan.	8
5.	Geostatistical Conditional Simulation - Theory, techniques and applications with special reference to Simulated Annealing Simulation.	2
6.	Geostatistical case studies of selected mineral deposits.	5
7.	Economic concepts for Exploration Strategy; Valuation of Mineral Properties: Valuation Techniques, Approaches and Methodology, viz. Cost approach: Appraised Value Method, Market approach, The Income Approach; Mineral Valuation Codes	8
	Total Classes =	**39**

Recommended Text Books:

1. Journel, A. G. and Huijbregts, C. J. (1978) Mining Geostatistics, Academic Press, London.
2. Gocht, Werner R., Zantop, Half, Eggert, Roderick, 1988: International Mineral Economics, Springer Publication.

Other References:

1. Agnerian, H., 1996: Valuation of Exploration Properties. CIM Bulletin, v. 89, no. 1004, pp. 69-72.
2. Armstrong, M. (1998) Basic Linear Geostatistics; Springer, Berlin.
3. Chiles, J.P. and Definer, P. (1999) Geostatistics - Modelling Spatial Uncertainty, John Wiley and Sons, New York, 695p.
4. Clark, I. (1979) Practical Geostatistics, Elsevier Applied Science Publ., London.
5. David, M. (1977) Geostatistical Ore Reserve Estimation, Elsevier Scientific Publ. Co., Amsterdam.
6. David, M. (1988). Handbook of Applied Advanced Geostatistical Ore Reserve Estimation, Elsevier Sc. Publ., Amsterdam.
7. Gandhi, S.M. and Sarkar, B.C. (2016) Essentials of Mineral Exploration and Evaluation, Elsevier, USA, 410 p.
8. Goovaerts, P. (1997) Geostatistics for Natural Resources Evaluation, Oxford Univ. Press, Oxford, 483p.
9. Isaaks, E.H. and Srivastava, R. M. (1989) An Introduction to Applied Geostatistics, Oxford University Press, Oxford.
10. Kitanidis, P.K. (1997) Introduction to Geostatistics - Applications in Hydrogeology, Cambridge Univ. Press, 249p.
11. Olea, R.A. (1999) Geostatistics for Engineers and Earth Scientists, Kluwer Academic Publ., Dordrecht, 303p.
12. Rendu, J.M. (1981) An Introduction to Geostatistical Methods of Mineral Evaluation, SAIMM Monograph, Johannesburg.
13. Sinclair, A.J. and Blackwell, G.H. (2002) Applied Mineral Inventory Estimation, Cambridge Univ. Press, 378 p.
14. Wackernagel, H. (1998) Multivariate Geostatistics - An Introduction with Applications. Second Revised Edn. Springer-Verlag, Berlin, 291 p.
15. Wellmer, F. W. (1998) Statistical Evaluations in Exploration for Mineral Deposits, Springer, Berlin, 379 p.
16. Chatterjee, K.K., 2008: Introduction to Mineral Economics. New Age International Pvt Ltd Publishers.406p.

Course Goal / Learning Outcome:

The key objective of the course is to introduce the students with the techniques of Advanced Geostatistics for modelling of mineral and petroleum deposits.

Learning Objectives:

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

1. Apply the knowledge of advanced geostatistics for modelling and characterisation.
2. Evaluate mineral and petroleum deposits.
3. Understand the concepts of exploration economics.
4. Carry out valuation of mineral and petroleum deposits.

Prerequisite:

For taking this course, 1st semester course on "Resource Evaluation and Geostatistics" is a prerequisite course.

Unit-wise Learning Outcome:

1. Problems and constraints of semi-variography associated with semi-variography;
2. Kriging and practice of semi-variography;
3. Non-linear and Non-parametric Geostatistics;
4. Geostatistical applications;
5. Geostatistical Conditional Simulation;
6. Geostatistical case studies;
7. Exploration Economics.

8. Course Name: Geospatial Analysis

Course Code: GLD 574

L-T-P = 3-0-0

Credit = 9

Syllabus & Lecture Plan:

Unit	Description	No. of Classes
1.	Basic GIS operations and mapping: elements of map creation, using basemaps, DEM/Terrain Data and online map/WMS data. Working with raster and vector data; attributes, styling, logical grouping and symbology, file storage formats (BIL, BIP, BSQ), composer, importing table (csv) data and spreadsheets, interpolation, sampling raster data, operations, digitizing map data, overlay GPS data and generating basic statistics. Common geospatial analysis tools.	8
2.	Georeferencing and map projections: projections and coordinate systems, registration, rectification, ground control points (GCPs), ortho-rectification, warping. Best practices in map projection, convert map projection, convert coordinates among projections. Georeferencing Topo Sheets, Scanned Maps, Aerial Imagery.	8
3.	Advanced GIS operations: using table joins, spatial joins, spatial queries and generating advanced statistics, polygon analysis, and heatmaps. DEM and 3D data models; interpolation and overlay of observations (vector and raster data) onto 3D surfaces and rasters.	6
4.	Classification operations: Classification; post classification	7

	tools, confusion matrix and accuracy assessment.	
5.	Advanced Workflows and batch operations: Batch processing and automating complex workflows using Modelling Framework. Automating map creation. Web mapping.	6
6.	Lidar data and GIS: data sampling, cloud points processing and analysis, 2D and 3d modeling using LIDAR scanner and GPS.	4
	Total Classes =	**39**

Recommended Textbooks:

1. Demers, M. N. (2008). Fundamentals of Geographic Information Systems, 3RD ED. Wiley India Pvt. Limited.
2. Longley, P. A., Goodchild, M., Maguire, D. J., & Rhind, D. W. (2010). Geographic Information Systems and Science.

Other References:

1. Liu, J.G., and Mason, P. (2013), Essential Image Processing and GIS for Remote Sensing, John Wiley & Sons.

Course Goal / Learning Outcome:

The primary objective of the course is to impart knowledge of geospatial methods critical assessment, integration and presentation (visualization) of available data to carry out independent GIS-based research.

Learning Objectives:

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

1. Enhance, integrate and retrieve information from various sources
2. Handle elevation data and create 3-dimensional surfaces,
3. Basic and advanced GIS operations
4. Properly work with spatially referenced data
5. Develop a GIS Model and Workflow.

Unit-wise Learning Outcome:

1. Basic GIS operations using various types of geospatial (raster and vector) data.
2. Understanding georeferencing, map projections, and its applications.
3. Working with tables and database in GIS.
4. Classification operations and accuracy assessment in GIS.
5. Creating basic and complex workflows, modelling framework and automation in GIS.
6. Working with Lidar data and cloud point analysis.

9. Course Name: Rock Slope Engineering

Course Code: GLD 591

L-T-P = 3-0-0

Credit = 9

Syllabus & Lecture Plan:

Unit	Description	No. of Classes
1.	Landslide classification, Natural landslides in soils and rocks. Types and modes of slope failure, Mechanics of landslides.	8
2.	Stability of slopes. Plane wedge and circular failures analyses. Hoek charts and graphical procedures. Hazard/Risk Zonation mapping of landslide prone areas. Kinematic and Rockfall analysis.	8
3.	Instrumentation in landslides. Investigations. Collection of data and analysis of geological data, Stereographic method etc. Slope analysis and factor of safety using limit equilibrium methods.	8
4.	Application of RMR/RSR classification in slope stability evaluation. Remedial measures for stabilizing slopes. Slope Mass Rating and its application. Computer programmes for slope stability and computer aided design in rock slope engineering.	8
5.	Instrumentations for monitoring slope movements. Landslides in India. Case studies.	4
6.	Slope stability problems in opencast mines. Case studies.	3
	Total Classes =	**39**

Recommended Textbooks:

1. Hoek, E and Bray, J. (1981). Third Edition; Rock slope Engineering.
2. Duncan C. Wyllie and Chris Mah. (2005).Fourth Edition; Rock slope Engineering.

Other References:

1. Goodman R.E(1968). A model for the mechanics of jointed rock.

Course Goal / Learning Outcome:

The primary objective of the course is to introduce fundamental and advanced aspects rock slope engineering through engineering geological investigation.

Learning Objectives:

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

1. Knowledge on different types of failures.
2. Knowledge on Instrumentation in landslides both surface and sub-surface.

Unit-wise Learning Outcome:

1. will describe different kind of land (rock and soil) failure types and its causes. The mechanics of material movements.
2. understand about the structural aspects of rock slope and the methods to investigate different rock failure types using different methods.
3. Concept of different techniques associated with geological data collection, map formation and probabilistic analysis of failure will be learned.
4. will be exposed to different rock slope classification depending upon slope-joint relationship that shall help in field analysis.
5. Concept of devices used to monitor landside events with special consideration towards recent and previous landslide occurred in India with the help of some case studies.
6. will know about the causes of slope instability problem in mine regions. Causes and remedial measures required shall be considered.

10. Course Name: Hyperspectral Remote Sensing

Course Code: GLD 570
L-T-P = 3-0-0
Credit = 9
Syllabus & Lecture Plan:

Unit	Description	No. of Classes
1.	Hyperspectral Remote Sensing (HRS) Sensors & Systems: Characteristics of multi-spectral, super-spectral and hyper-spectral sensor. Platforms: Airborne, Spaceborne, Laboratory and Hand-Held. Integration of Hyperspectral Data with LIDAR. HRS Instruments (Earth observation): AVIRIS, Hyperion, HyspIRI, PRISMA, PROBA, EnMAP, HIUSI, HYSI etc.	3
2.	HRS Spectral libraries and corrections: Hughes phenomenon. Redundant and noisy bands, selective narrow bands. Spectral Libraries: USGS, ASTER, Field Campaigns. Correction of HRS data. Solar irradiance, Radiance, Reflectance, and Calibration. Reflectance Spectra: topographic and atmospheric effects. Methods of atmospheric correction. Equal Area Normalization, Flat Field Correction etc.	5
3.	Basic operations and Indices: Building 3D cube/hypercube, pixel/image spectra, target spectra, laboratory spectra, pure end member spectra. Position and shape of narrow absorption features. Operations over spectra such as finding Continuum, removing continuum, normalization, derivative, interpolation, smoothing, linear fit (slope and offset), parabolic fit etc. Common Hyperspectral Indices (for Vegetation, Soil, Mineral). Red-edge.	6

4.	Hyperspectral Data Processing: Data mining methods: Feature Selection Methods, and Information Extraction Methods. Extraction of image spectra by pixel and unique absorption features. Spectral mixture analysis (unmixing), pure spectral signatures (endmembers), numerical inversion and abundance fractions. Linear and Non-linear spectral unmixing techniques. PC Transform, MNF Transform, PPI etc. Supervised and unsupervised classification methods. Matched (Derivative, Locally Adaptive) Filtering, SAM, Cross-Correlation, Linear Unmixing, SoM Classifier etc. ML Classification, SVM-based approaches. Iterative optimization methods: Clustering, ISODATA, K-means etc. Accuracy assessment.	12
5.	Spectral indicators and their applications (Case Studies): HRS in mineral targeting and exploration, soil type, composition and characteristics, gemstone identification, acid mine drainage, environmental degradation/stress indicators, effect of metals/heavy metals on vegetation, biophysical and biochemical properties of vegetation (Forest, Wetland, Crops, species identification, pigment(s), nitrogen, water content, stress, pests and disease), Global Change Studies.	10
6.	HRS of Planets and Moons in Solar System: Hyperspectral Missions and Case Studies of Moon, Mercury, Mars, Jupiter, Saturn, Titan etc.	3
	Total Classes =	**39**

Recommended Textbooks:

1. Borengasser, M., Hungate, W. S., & Watkins, R. (2007). Hyperspectral Remote Sensing: Principles and Applications. CRC Press.
2. Chang, C. I. (2007). Hyperspectral Data Exploitation: Theory and Applications. Wiley.

Other References:

1. Chang, C. I. (2013). Hyperspectral Data Processing: Algorithm Design and Analysis. Wiley.
2. Eismann, M. T. (2012). Hyperspectral Remote Sensing. SPIE.
3. Kalacska, M., & Sanchez-Azofeifa, G. A. (2008). Hyperspectral Remote Sensing of Tropical and Sub-Tropical Forests. CRC Press.
4. Sun, D. W. (2010). Hyperspectral Imaging for Food Quality Analysis and Control. Elsevier Science.
5. Thenkabail, P. S., & Lyon, J. G. (2016). Hyperspectral Remote Sensing of Vegetation. CRC Press.

Course Goal / Learning Outcome:

The primary objective of the course is to impart knowledge and applications of Hyperspectral remote sensing (HRS) in the field of geosciences.

Learning Objectives:

Upon completion of the course on hyperspectral remote sensing (HRS), students will be able to understand:

1. Importance of Spectral libraries.
2. Characteristics of HRS sensors & systems.
3. Basic and advanced methods employed in HRS data analysis.
4. Current and future applications of HRS.

Unit-wise Learning Outcome:

1. Know hyperspectral sensors, systems and data.
2. Learn about hyperspectral libraries and typical corrections.
3. Commonly used basic operations used in the processing of hyperspectral data.
4. Know about hyperspectral data processing, algorithms, and classification methods.
5. Case studies showing applications of spectral indicators.
6. Case studied involving hyperspectral remote sensing of planets and moons in solar system.

11. Course Name: Environmental Geotechnology

Course Code: GLD 592

L-T-P = 3-0-0

Credit = 9

Syllabus & Lecture Plan:

Unit	Description	No. of Classes
1.	Introduction to Environmental Geotechnology	2
2.	Scope of Environmental Geology, Changes in the environment caused by geological and anthropogenic activities	3
3.	Engineering geological studies for environmental evaluation and development	4
4.	Environment issues related to Environmental aspects of opencast mining projects with emphasis on impact of mine dumps, environmental impact of engineering projects.	6
5.	Environmental aspects of water, Impact of unplanned urbanization on groundwater regimes.	6
6.	Nuclear waste and disposal: Radiation and dangerous radioactive products and half life, natural and anthropogenic sources; site selection for nuclear waste disposal.	4
7.	Land reclamation and restoration	3
8.	Mass movements	6
9.	Environmental planning, management and economics (EMP and EIA) and Preparation of Project Feasibility Report	5

Total Classes = 39

Recommended Textbooks:

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

Other References:

1. D R Caotes. (1981) Environmental Geology.
2. L Lindgren. (1986) Environmental Geology, Prentice Hall Publ.
3. K S Valdiya. (1987) Environmental Geology: Indian Context. Tata McGraw Hill Publ.
4. Carla W Montgomery (1989) Environmental Geology (II Edn.), Wm C Brown Publ.
5. Saxena M. M.(1996) Environmental analyses of water soil and air.
6. Reply, E. A. (1996) Environmental effects of mining.
7. D Merrits, Dewet, A and Menking K.(1998) Environmental Geology, Freeman Publ.
8. Canter L. W. (1998) Environmental Impact Assessment, McGraw Hill Publ.

Course Goal / Learning Outcome:

The key objective of the course is to introduce the students with the implications of environmental impacts of geotechnical projects.

Learning Objectives:

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

1. Acquaint themselves with evaluation of environmental impact.
2. Environmental management.
3. Waste disposal.
4. Remediation.

Unit-wise Learning Outcome:

1. Geological Environment.
2. Causatives of environmental changes.
3. Key environmental issues in Engineering Projects evaluation.
4. Environmental issues related to mining and engineering constructions.
5. Impacts on water.
6. Waste disposal methods.
7. Land use patterns and reclamation.
8. Mass movements and their adverse impacts on environment.
9. Environmental Planning, Environmental Impact assessment.

12. Course Name: Applied Hydrogeology

Course Code: GLD 593
L-T-P = 3-0-0
Credit = 9
Syllabus & Lecture Plan:

Unit	Description	No. of Classes
1.	Introduction to Applied Hydrogeology: What is Hydrology and hydrogeology; Global water cycle and its components; Climate change and its impact on water resources; Storages and fluxes of water on Earth; Hydrologic Budget and its variations in time and space; Monitoring of major hydrologic fluxes.	5
2.	Storages of water on land: Surface water storage; Types of moisture in the subsurface; Variation of moisture with depth; Classification of rocks according to their water-bearing properties; Aquifers/Aquiclude/Aquitard; Water-bearing properties of rocks; Porosity, specific yield and specific retention; Secondary porosity and its potential.	8
3.	Aquifer Properties: Types of aquifer; Characteristics of confined and unconfined aquifers; Water yielding capacity of aquifers; Fundamental differences between confined and unconfined aquifers; Permeability; Transmissivity; Hydraulic conductivity and storage coefficient; Determination of permeability in laboratory; Concept of heterogeneity and anisotropy; Construction of water table and piezometric surface maps; Fluctuations of water table and piezometric surface; Application of fundamental concepts in solving problems.	6
4.	Principles of Groundwater Flow: Hydrostatic pressure; Concept of fluid potential; Energy in groundwater; Hydraulic head in terms of total energy; 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; Groundwater-Surface water interactions; Determination of flow direction.	8
5.	Groundwater flow to wells: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 chemistry: Chemical equilibrium; Equilibrium constant; Reaction coefficients; 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); Solute transport in	3

	groundwater.	
7.	Groundwater Contamination: Types of contaminant; Types of sources and its attributes; Contaminants associated with each source.	2
8.	Groundwater Management: Utilization of groundwater; Groundwater data collection; Groundwater problems in urban/rural settings; Climate change impact on ground water resources; Groundwater potential mapping; Rainwater harvesting; Artificial recharge of groundwater	2
	Total Classes =	**39**

Recommended Textbooks:

1. Groundwater Hydrology by K. E. Todd.(2006). 2nd Edition Wiley India.
2. Applied Hydrogeology by C. W. Fetter. (2007). 4th Edition, Prentice Hall Inc.

Other References:

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

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.

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.

Unit-wise Learning Outcome:

1. Introduction to Applied Hydrogeology: Get introduced to key hydrologic processes
2. Storages of water on land: Get to know how much water is stored and where
3. Aquifer Properties: Understand the fundamental properties of sub-surface storage
4. Principles of Groundwater Flow: Understand the factors driving the movement of water.
5. Groundwater flow to wells: Get to know how water flows in the saturated subsurface in different dimensions.
6. Groundwater chemistry: Will know how to assess the quality and suitability of groundwater.
7. Groundwater Contamination: Will know about the major sources of groundwater contamination.
8. Groundwater Management: Get to know the major issues related to groundwater availability, utilization and management.

13. Course Name: Geotechniques of Dams, Tunnels and Underground Space

Course Code: GLD 594

L-T-P = 3-0-0

Credit = 9

Syllabus & Lecture Plan:

Unit	Description	No. of Classes
1.	Types of dams and Geological Site Characterization of Dams	3
2.	Dam Foundation problems	4
3.	Treatment of Foundations of Concrete, Rock-Fill and earth dams	4
4.	Treatment of Foundation seepage	2
5.	Reservoir induced seismicity-case studies	2
6.	Types of Tunnelling and Tunnelling methods	3
7.	Conditions of Tunnelling Ground and controlling techniques	4
8.	Geohydrological hazards in tunnelling and underground space	4
9.	Geotechnical problems associated with tunnels (including stand-up time,Bridging capacity of rocks, overbreaks, arching action)	8
10	Stability in tunnels and underground space: Support requirements	5
	Total Classes =	**39**

Recommended Textbooks:

1. Fell R. McGregor, P., Stapledon, D. Bell, G., Foster, M (2015). Geotechnical Engineering of Dams, 2nd Edition, CRC Press.
2. Lunardi. P (2008). Design and construction of tunnels. Springer.

Other References:

1. Guglielmetti, V., Grasso,P. Mahtab, A., Xu, S. (2008). Mechanized tunneling in Urban areas. Methodology and Construction Control.

Course Goal / Learning Outcome:

The primary objective of the course is to introduce fundamental aspects of geological controls on the construction of Dams, Tunnels and underground space to the students.

Learning Objectives:

Upon completion of the course, students will be able to

1 Plan and design a dam, tunnel or an underground space based on the geological controls.
2 Understand ground conditions and support requirements in the tunnels and underground space.
3 Understand Reservoir induced seismicity.

Unit-wise Learning Outcome:

Upon completion of the course, students will be able to

1 Plan and design a dam, tunnel or an underground space based on the geological controls.
2 Understand ground conditions and dam foundations
3 Treatment of soft and damaged foundations
4 Treatment of leaking foundations
5 Reservoir induced seismicity and effects on tunnel
6 Tunnelling methods based on types of tunnelling
7 Ground conditions of Tunneling
8 Hazards of groundwater in tunnels
9 Safety and stability in tunnels
10 Support requirements and remediation in tunnels

14. Course Name: Geophysical Methods for Groundwater Exploration

Course Code: GPD 552

L-T-P = 3-0-0

Credit = 9

Syllabus & Lecture Plan:

Unit	Description	No. of Classes
1.	Introduction to Groundwater: Groundwater: Problems and definition. Definition of groundwater table. Definition of aquifers, classifications of aquifers; confined and un-confined, perched, aquiclude, aquitard, aquifuge etc. groundwater flow in unconfined aquifer.	7

2.	Hydraulic Properties: Hydraulic properties of soils, porosity, permeability, transmissibility, hydraulic conductivities, empirical relations among hydraulic parameters. Geophysical methods for groundwater exploration.	7
3.	Estimation of Hydraulic Properties: Geophysical methods and hydro-geochemical methods for aquifer parameter estimations and fracture characterization in various hydro-geological settings of India. Interpretation of hydro-geological sections.	7
4.	Hydro-geological cycles and sustainability: Hydro-geological cycles, linkage to other geo-cycles, their importance to groundwater exploration and sustainability.	4
5.	Geophysical Methods for Groundwater Management: Application of geo-physical methods (DC resistivity/Electromagnetic (EM), Well logging etc) and remote sensing (RS) and geographical information systems (GIS) for groundwater management.	7
6.	Groundwater Quality Assessment: Geophysical and hydro-geochemical methods for groundwater pollution assessment. Modelling of groundwater quality index, quantification of role of each geophysical/hydro-geochemical parameter for groundwater quality assessment.	7
	Total Classes =	**39**

Recommended Textbooks**:**

1. Kirsch, R., 2006. Groundwater Geophysics- A Tool for Hydrogeology, Springer-Verlag Berlin Heidelberg, pp. 500
2. Parasnis, D.S., 1997. Principles of Applied Geophysics. Fifth edition, Chapman & Hall, 2-6 Boundary Row, London SE1 8 HN, UK

Other References:

1. Schwartz, W.F., Zhang, H., 2004. Fundamentals of Groundwater, John Wiley & Sons, Inc. pp. 583
2. Telford, W.M., Geldart, L.P., Sheriff, R.E., 2004. Applied Geophysics, 2nd Edition, Cambridge University Press
3. Todd, D. K., 1959. Groundwater hydrology, John Wiley and Sons, New York, pp.535

Course Goal / Learning Outcome:

The primary objective of the course is to introduce fundamental and advanced aspects of geophysical technology for exploration of groundwater management.

Learning Objectives:

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

1. Knowledge on groundwater systems.
2. Knowledge on geophysical technology for groundwater management.
3. Knowledge on sustainable techniques for groundwater protection.

Unit-wise Learning Outcome:

1. Groundwater fundamentals : elements and parameters

2. Hydraulic analysis of groundwater
3. Geophysical methods of determining aquifer properties and hydraulics
4. Hydrogeological cycles
5. Geophysical metyhod of groundwater management
6. Groundwater quality and assesment

15. Course Name: Digital Image Processing

Course Code: GLD 577
L-T-P = 3-0-0
Credit = 9
Syllabus & Lecture Plan:

Unit	Description	No. of Classes
1.	Introduction to Digital image Processing. Human perception of color, image display, lookup tables, resampling techniques, data formats, color composites. Camera systems. SLR, DSLR, HD & HDR images.	5
2.	Image analysis techniques: software formats, raster and vector, color space, histograms & stretching, image math, masking, mosaicking,	5
3.	Pre-processing, calibration, image normalization, gain and offset, destriping, spatial and spectral subset. Band ratios, indexes, image sharpening, principal components.	5
4.	Image convolution, kernels and image filters, fourier filtering, morphological filters, texture filters, and user-defined filter kernels.	7
5.	Image fusion techniques. Spectral libraries, usage and interpretation. Spectral analysis tools.	7
6.	Image Classification: class statistics, supervised and unsupervised classifications.	7
7.	Near real-time Direct Satellite Broadcast System and near-real time data processing to derive major parameters related to earth's atmosphere, land, ocean, and biosphere.	3
	Total Classes =	**39**

Recommended Textbooks:

1. Liu, J.G., and Mason, P. (2013), Essential Image Processing and GIS for Remote Sensing, John Wiley & Sons.
2. Jensen, J.R. (1996), Introductory Digital Image Processing: A Remote Sensing Perspective, Prentice Hall.

Other References:

1. Gonzalez, R.C., and Woods, R.E. (2013), Digital Image Processing Using MATLAB, Tata McGraw-Hill Education.
2. Gonzalez, R.C., Woods, R.E., and Eddins, S.L. (2009), Digital Image Processing, Pearson Education India.
3. Richards, J.A. (2012), Remote Sensing Digital Image Analysis: An Introduction, Springer Science & Business Media.

Course Goal / Learning Outcome:

The primary objective of the course is to impart knowledge of image processing algorithms necessary for critical assessment and visualization.

Learning Objectives:

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

1. Image Enhancement and Fusion operations
2. Image Math operations and its applications
3. Image Filtering in spatial and frequency domains
4. Image Classification and error calculations

Unit-wise Learning Outcome:

1. Basic knowledge related to images, colors, formats, and systems.
2. Learn fundamentals of basic image processing and methods.
3. Know about commonly used algorithms, indices and methods.
4. Know about image convolution, kernals, types, and its applications.
5. Spectral analysis tools and image fusion techniques.
6. Know supervised and unsupervised image classification methods.
7. Near real-time download and processing using Direct Satellite Broadcast System.

16. Course Name: Artificial Intelligence and Machine Learning in Geosciences

Course Code: GPD 523

L-T-P = 3-0-0

Credit = 9

Syllabus & Lecture Plan:

Unit	Description	No. of Classes
1.	Artificial Intelligence (AI): Definition and application. Definition of Machine Learning (ML). The relation between AI and ML. ML classification algorithm: supervised, reinforcement and unsupervised learning: Principal component analysis (PCA), K-means, Decision Tree (DT), random forest (RF), Logistic regression (LR), Self-organizing map (SOM).	7
2.	Artificial neural networks: Introduction to artificial neural networks (ANNs). Pre-processing and dimension reduction techniques for time/space series modeling/classification.	4
3.	Transfer Function: Types of transfer function, training, validation and test data set selection. Over-fitting, role of regularization, Calibration of model, cross-validation, early	7

	stopping techniques, bias-variance dilemma.	
4.	Optimization: ANNs optimization: local and global techniques. Adaptive neuro-fuzzy systems (ANFIS). Hybrid ML algorithm with ordinary kriging (OK), semi-variogrammodeling, singular spectrum analysis (SSA) for de-noising, interpolation and missing value prediction techniques.	7
5.	Probabilistic methods: Probabilistic inference, Bayesian learning for artificial neural networks, evidence maximization (EA), hybrid Monte Carlo (HMC), Automatic relevance determination (ARD), Gaussian process (GP), Support vector machines (SVM).	7
6.	Deep learning and Big data: Introduction to deep learning. Convolutional neural network (CNN): theory and practices. Application of ML algorithm for earth parameter estimation, classification and prediction of rock-type/litho-logy/litho-facies/mineral boundary for analysis of space-time geoscience data. Application of deep learning to "Big Data" analysis of geoscience.	7
	Total Classes =	**39**

Recommended Textbooks:

1. Bishop C M, (1995) Neural networks for pattern recognition. Oxford University Press.
2. Haykin, S. (1999). Neural networks – a comprehensive foundation (2nd Ed.). Upper Saddle River, NJ: Prentice Hall.

Other References:

1. MacKay, D.J.C., (1992). A practical Bayesian framework for back-propagation networks. Neural Comput, 4 (3), 448–472.
2. Poulton M, (2001). Computational Neural Networks for Geophysical Data Processing, Pergamon, Oxford, U.K.
3. Van der Baan M, and Jutten C, (2000) Neural networks in geophysical applications, Geophysics, 65: 1032–1047.
4. Wasserman, P.D. (1993) .Advanced methods in neural computing. Van Nostrand Reinhold, New York, NY 10003

Course Goal / Learning Outcome:

The primary objective of the course is to introduce fundamental and advanced aspects of Artificial intelligence and machine learning for geo-record analysis and processing.

Learning Objectives:

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

1. Practical knowledge on AI and ML for time/space series data analysis.
2. Practical knowledge on automatic nonlinear classification, regression and prediction of geo-records.

3. Practical knowledge on application of AI and ML with deep network for big data processing.

Unit-wise Learning Outcome:

1. Fundamental concepts on Artificial Intelligence an dMachine learning
2. Artificial neural networks and their applications
3. Transfer functions, their types and use
4. Artificial Neural networks and Neuro Fuzzy systems
5. Probabilistic models for Artificial neural networks
6. Big data analysis

D. Syllabus of Open Elective (OE)

17. Course Name: Modern Instrumental Methods in Exploration Geosciences

Course Code: GLD 575

L-T-P = 3-0-0

Credit = 9

Syllabus & Lecture Plan:

Unit	Description	No. of Classes
1.	Analytical Methods in Geochemistry: Classical and rapid methods of analysis, sample digestion techniques, fusion techniques, gravimetry, determination of concentration of major cations by photometry, chromatography.	9
2.	Mineral Studies: X-Ray Diffractometry, Secondary Electron Microscopy, Electron Probe Micro Analysis, Cathodoluminescence, Thermoluminescence, Optically Stimulated Luminescence.	8
3.	Optical and X-Ray Spectrometry: Atomic Absorption Spectrometry (AAS), Inductively Coupled Plasma – Atomic (Optical) Emission Spectrometry (ICP-AES/OES), X-Ray Fluorescence Spectrometry, Energy Dispersive and Wavelength Dispersive Techniques.	9
4.	Mass Spectrometry: Inductively Coupled Plasma - Mass Spectrometry (ICP-MS), Thermal Ionization Mass Spectrometry (TIMS), Isotope Ratio (Gas Source) Mass Spectrometry (IRMS/GSMS), Secondary Ion Mass Spectrometry (SIMS/SHRIMP), Laser Ablation techniques.	13
	Total Classes =	**39**

Recommended Textbooks:

1. Potts. P.J. (1996) A Handbook of Silicate Rock Analysis, Chapman and Hall, London, 622 pp.
2. Rollinson, H.R. (1993) Using Geochemical Data: Evaluation, Presentation, Interpretation, Pearson Education Limited, Harlow, 352 pp.

Course Goal / Learning Outcome:

The course will introduce the students to both the classical methods and the advanced techniques in vogue for the geochemical analysis of elemental and isotopic concentration in samples of minerals, ores and rocks.

Learning Objectives:

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

1. Know the different geochemical analytical techniques applied in the field of mineral and rock studies.
2. Understand the fundamental principles involved in various geochemical methods.
3. Choose the right technique or method for the type of sample in question.

Unit-wise Learning Outcome:

1. Overview of methods of sample preparation techniques and analysis
2. Instrumental methods for analysis of mineral chemistry and characterization
3. Optical and X-Ray spectrometry and its applications
4. Mass Spectrometry and its applications

18. Course Name: Rock Deformation Kinematics for Engineering Geology

Course Code: GLO 596

L-T-P = 3-0-0

Credit = 9

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 slope stability studies and foundation analysis.	7
2.	Strain: Definition, strain parameters, classification, strain ellipsoid and theory of deformation in two and three dimensions.	5
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, Strain measurement in engineering geology.	6
4.	Experimental Deformation and Rheology: Behaviour of rocks under experimental conditions. Effects of confining pressure,	8

	pore fluid pressure, anisotropy, temperature and scale on rock deformation.	
5.	Development of Structures - I: Mechanisms of folding, and strain variations around folds. Development of secondary cleavage and lineations.	6
6.	Development of Structures - II: Development of rock fractures. Conditions of fault development. Deformation mechanisms.	7
	Total Classes =	**39**

Recommended Textbooks:

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.

Course Goal / Learning Outcome:

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

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.
3. Evaluate engineering projects in deformed rocks.

Unit-wise Learning Outcome:

1. Stress fields and its geological domains
2. Theory of strain
3. Methods of strain analysis

4. Behavior of rocks under experimental deformation
5. Development of structures in the ductile field: folds, cleavage and lineations
6. Developments of structures in the brittle field: Rock fractures, faults and deformation mechanisms

19. Course Name: Engineering Geomorphology

Course Code: GLO 597

L-T-P = 3-0-0

Credit = 9

Syllabus & Lecture Plan:

Unit	Description	No. of Classes
1.	Introduction to Geomorphology	2
2.	Methods of Geomorphic investigations	2
3.	Weathering and erosion : impact on Engineering constructions	4
4.	Structural and lithological controls on landforms and drainage patterns. Impact on feasibility of Geotechnical projects	4
5.	Depositional and Erosional landforms : Fluvial, Aeolian, Glacial and Marine: hazards and its impact in engineering constructions	11
6.	Morphometric analysis of landforms : impact on planning and designing of Engineering projects	6
7.	Impact of climate on geomorphology	3
8.	Applications of Geomorphology in environmental and engineering problems	4
9.	Neotectonics and geomorphology	3
	Total Classes =	**39**

Recommended Textbooks:

1. Fookes P.G, Lee, E. M. and Griffiths J.S. (2007). Engineering Geomorphology: Theory and Practice. Whitties Publishing.
2. Arthur, L. Bloom, Geomorphology (2004): A Systematic Analysis of Late Cenozoic Landforms, Prentice hall of India.

Other References:

1. J. Tricart (1974).Structural Geomorphology, Longman Publishers.
2. Karl W. Butzer, Geomorphology from the Earth (1976), Harper International.
3. R.J. Price, Glacial and Fluvioglacial Landforms (1973). Longman Publishers.

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, and their link with tectonics and climate and their applications in flood control, landslides, transport engineering and others.

Learning 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.

Unit-wise Learning Outcome:

1. Geomorphic domains in the earth
2. Landscape development and methods to study it
3. Erosional effects on Engineering projects
4. Controls on landform development
5. Depositional and erosional landforms and its impact on Engineering constructions
6. Morphometric analysis of landforms
7. Climatic controls on landform development
8. Environment and Geomorphology interactions
9. Role of Neotectonics in landform modification.

20. Course Name: Engineering Geophysics

Course Code: GPD 551

L-T-P = 3-0-0

Credit = 9

Syllabus & Lecture Plan:

Unit	Description	No. of Classes
1.	Seismic method: Huygens' Principle, Elastic constants, effect of depth and age, Snell's law, Seismic waves, Seismic reflection and refraction, Analysis of time and distance graphs, Non-parallel interface, multilayered models, Velocity inversion, data correction. Application of seismic method to engineering technology and mineral exploration.	13
2.	Gravity method: Fundamentals of gravity method, Gravity instruments, gravity data acquisition, Gravity data processing, Correction/reduction, Free-air and Bouguer anomalies, Rock densities of rocks and minerals, gravity response of simple shapes and interpretation of gravity anomaly. Application of gravity method to engineering technology and mineral exploration.	7

	3. Magnetic method: Fundamentals concepts of Magnetic method, geomagnetic field, Remanent Magnetism, Magnetic susceptibilities of rocks and minerals, Magnetic instruments, Magnetic data acquisition, Magnetic data processing and Correction/reduction, Magnetic anomaly and interpretation of magnetic anomaly. Application of magnetic method to engineering technology and mineral exploration.	6
	4. Geoelectrical method: Fundamental concepts of geoelectrical method, Archie's law point current electrode on homogeneous Earth, Heterogeneous medium, Resistivity profiling and sounding, Resistivity data acquisition, Processing and its interpretation. Two/Three layered structures, Interpretation techniques of Electrical data, quantitative interpretation. Application of geoelectrical method to engineering technology and mineral exploration	7
	5. Fundamental concepts of electromagnetic method, electromagnetic data acquisition, processing and interpretation. Application of electromagnetic method to engineering technology and mineral exploration.	6
	Total Classes =	**39**

Recommended Textbooks:

1. Telford W. M., Applied Geophysics.
2. Dobrin, M. and Savit, C., Introduction to Geophysical Prospecting.

Other References:

1. William Lowrie. Fundamental of Geophysics.
2. Heiskanen, and Veining Meinsez, Gravity Field of the Earth.

Course Goal / Learning Outcome:

The primary objective of the course is to introduce geophysical methods and their application for engineering prospect such as identification of fault, fracture, joints, syncline/anticline etc. and classification of rocks, mineral, non-minerals etc.

Learning Objectives:

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

1. Understand the application of Geophysical method.
2. Distinguish between different type of rocks, minerals, non-minerals and other geological signature based on physical properties.

Unit-wise Learning Outcome:

1. Seismic reflection and refraction methods and their applications

2. Gravity methods of exploration and their applications
3. Magnetic methods and applications
4. Geo-electrical methods and applications
5. Electro-magnetic methods and applications

E. Syllabus of Departmental Practical Courses

21. Course Name: Soil Engineering Practical

Course Code: GLC 584

L-T-P = 0-0-2
Credit = 2
Syllabus & Lecture Plan:

Unit	Description	No. of Classes
1.	Determination of physical properties of soils.	1
2.	Determination of engineering properties of soils.	2
3.	Determination of Liquid limit of soil	1
4.	Determination of Plastic limit of soil	1
5.	Direct shear strength	1
6.	Triaxial test of soil	1
7.	Pore water pressure determination	1
8.	Permeability by falling head method	1
9.	Permeability by constant head method.	1
10.	Numerical simulation of soil slopes	2
11.	Practical Examination	1
	Total Classes =	**13**

Recommended Textbooks:

1. Murthy, V.N.S. (2018). Text book of Soil mechanics and foundation Engineering.
2. Sehgal S.B. (2007).Textbook of soil mechanics, CBS Publishers.

Other References:

1. Ranjan, G and Rao, A.S. (2005). Basic and Applied soil mechanics, New Age Publishers.

Course Goal / Learning Outcome:

The primary objective of the course is to provide practical background for different soil properties. The techniques will be used for determination of soil strength and stability of geomaterials for industry / engineering construction organisations.

Learning Objectives:

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

1. Apply different methods to determine the physic-mechanical properties of soil.
2. Determination of strength of soil.
3. Stability analysis of soil slopes.

Unit-wise Learning Outcome

1. Will know how to assess and classify the physical properties of soil
2. To understand the engineering properties of soil
3. Hands-on experience will be given to understand the Liquid limit of soil
4. Hands-on experience will be given to understand the Plastic limit of soil
5. Hands-on experience will be given to handle the direct shear test apparatus to get cohesion and angle of friction of soil.
6. To determine the failure load of soil samples in different confining pressure.
7. Hands-on experience of the use of pore water pressure on shear strength can be determined.
8. Soil permeability of clay sized soil grains can be determined.
9. Soil permeability of sand sized soil grains can be determined
10. Will be exposed to simulation of soil slopes and will help in analyzing the stability condition

22. Course Name: Resource Evaluation and Geostatistics Practical

Course Code: GLC 562

L-T-P = 0-0-2

Credit = 2

Syllabus & Lecture Plan:

Unit	Description	No. of Classes
1.	Channel Sampling & Ore Reserve Estimation Exercise	1
2.	Drill Hole Sampling & Ore Reserve Estimation Exercise	1
3.	Ore Reserve Estimation Exercise using Polygonal Method	1
4.	Sample Value Compositing and Reserve Estimation Exercise	1
5.	Mineral Deposit Statistics	1
6.	Normal Distribution Modelling	1
7.	Lognormal Distribution Modelling	1

8.	Chi-squared goodness of fit exercise	1
9.	Construction of 1-D Experimental Semi-variogram and spatial variability characterization	2
10	Construction of 2-D Experimental Semi-variograms and spatial variability characterization	2
11	Practical Examination	1
	Total Classes =	**13**

Recommended Textbooks:

1. Sinclair, A.J. and Blackwell, G.H. (2002) Applied Mineral Inventory Estimation, Cambridge Univ. Press, 378 p.
2. Wellmer, F. W. (1998) Statistical Evaluation in Exploration for Mineral Deposits, Springer, 365 p.

Other References:

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, 364p.
3. Gandhi, S.M. and Sarkar, B.C. (2016) Essentials of Mineral Exploration and Evaluation, Elsevier, USA, 410 p.
4. Rendu, J.M. (1981) An Introduction to Geostatistical Methods of Mineral Evaluation, SAIMM Monograph, Johannesburg, 84 p.

Course Goal / Learning Outcome:

The key objective of the tutorial is to introduce the students with the techniques of sampling, reserve estimation and problem solving for mineral and petroleum geostatistics.

Learning Objectives:

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

1. Carryout mineral and petroleum resource appraisal;
2. Solve geostatistical problems related to characterisation of mineral deposits and petroleum reservoirs.
3. Carry out Spatial data analysis.

Unit-wise Learning Outcome

1. Sample Value Compositing and Reserve Estimation;
2. Mineral Deposit Statistics;
3. Normal Distribution Modelling;
4. Lognormal Distribution Modelling;

5. Construction of 1-D & 2-D Experimental Semi-variogram and spatial variability characterization;
6. Manual Computation of Estimation Variance;
7. Block Kriging Manual Exercise;
8. Computer based modelling for Univariate and Bivariate data;
9. Computer based semi-variography;
10. Computer based Block Kriging.

How the program is different from earlier program

Addition of **Programming in MATLAB** will provide expertise in computer-aided research enhancing the skill to model a virtual scenario efficiently, understanding of programming language will strengthen their ability on working on other MATLAB programs.

Addition of **Applied Hydrogeology** will open a new sight for engineering geologist as water (underground/surface) acts a pivotal role in overall health of a site of study with applications for finding new sources of water can also be done.

Addition of **Engineering Geomorphology** will incur knowledge of weathering and erosion that impacts engineering projects, litho-structural controls on landform, drainage and morphometric patterns.

Addition of **Modern Instrumental Methods in Exploration Geosciences** will introduce students to geochemical analysis of rocks, minerals and ores, choosing right technique for the type of sample in question.

Addition of **Rock Deformation Kinematics for Engineering Geology** to provide theoretical background for techniques of stress and strain analysis in rocks and its application in engineering geology.

Addition of **Artificial Intelligence and Machine Learning in Geosciences** will enhance the knowledge towards Artificial Neural Networking and other programming for changing the algorithm according to ones need.

Addition of **Hyperspectral remote sensing** will impart knowledge about the importance of spectral libraries, sensors and system characteristics for data analysis in the field of geosciences.

Summary:

Total credits in 2 years: **170.00**
Average credit per semester: **42.50**
Average contact hours/week (1^{st} year) (Theory +Practical Classes) = **19.60**
Average contact hours/week (2^{nd} year) (Theory +Practical Classes) = **3.60**