Annexure-II

CENTRAL UNIVERSITY OF KARNATAKA

Curriculum
for

4-year Graduation Programme:
Bachelor of Science in Research with Geology as Major

Effective from 2022-23 AY

July 2022

Department of Geology
School of Earth Sciences
Central University of Karnataka
Kalaburagi-585367, Karnataka

Department of Geology
BSc in Research with Geology as Major

Part A: About 4-year Graduation Programme: BSc in Research with Geology as Major

I: PREAMBLE

The higher education system deserves to be given highest priority to enable the young generation of students to acquire skill, training and knowledge in order to enhance their thinking, comprehension and application abilities and prepare them to compete, succeed and excel globally. Sustained initiatives are required to reform the present higher education system for improving and upgrading the academic resources and learning environments by raising the quality of teaching and standards of achievements in learning outcomes across undergraduate programs in geosciences. One of the significant reforms based on National Education Policy 2020, in the undergraduate education is to introduce the four-year graduation programme with multiple exit options, which makes it student-centric, interactive and outcome-oriented with well-defined aims, objectives and goals to achieve.

Geology is the study of the Earth, the materials of which it is made, the structure of those materials, and the processes acting upon them. It includes the study of organisms that have inhabited our planet. An important part of geology is the study of how Earth's materials, structures, processes and organisms have changed over time. Geology can also refer generally to the study of the solid features of any celestial body (such as the geology of the Moon or Mars). In this context the Central University of Karnataka introduced 4-year Graduation Programme in Geology (BSc in Research with Geology as Major) to reduce the disparity between the need and availability of competent professionals to cater the requirements of our nation. This programme is basically an academic programme which focuses on preparing the students for research, as well as, for application of Geological knowledge in various field settings.

II: Graduate Attributes

Some of the characteristic attributes of a graduate in Geology are

a) Develop a systematic understanding of both core areas and advanced topics in the study of the Earth, by viewing Earth from new and challenging perspectives of time, space, process and pattern.
b) Stimulate students to see Geology as a vital component of our culture, where science develops as informed curiosity about the Earth and Society's environment, promoting human development and sustainability through the search for energy sources, raw materials, water supplies, sites for safe waste disposal, and the mitigation of natural hazards.
c) Provide students interact with high-level scientific expertise and advanced equipment in an environment committed to scientific advance.
d) Develop skills and thereby equip students with the foundations for their professional careers or additional study.
e) Provide an excellent preparation for a career in professional practice in industrial or environmental Earth Sciences, research in Geosciences, and specialist areas of other physical and natural sciences.
f) Formulate a coherent written, electronic or oral presentation on the basis of material gathered and organised independently on a given topic.
g) Develop oral presentation and participation skills during seminars and group-work, and in written form through online e- learning tools, dissertations and essays.

h) Skills to recognise and articulate a problem and then apply appropriate conceptual frameworks and methods to solve it.
i) Emphasis is placed on larger, integrated problem-solving exercises, during which students are taught how to process complex data sets using a diverse range of skills and knowledge.
j) Competency in both field and laboratory skills, and in data analysis, interpretation and presentation that permit the successful pursuit of pure or applied problems in geology.
k) Ability to collect, analyse, synthesise data, summarise and inter-relate diverse processes and facts, to formulate and test hypotheses and reach conclusions through projects.
l) Time management skills are developed through interaction with the assessment process in all years.
m) Ability to use digital resources
n) Avoid unethical behaviour such as fabrication, falsification or misrepresentation of data or committing plagiarism, not adhering to intellectual property rights, and adopting objectives, unbiased and truthful actions in all aspects of work.
o) Provide an excellent preparation for a career in professional practice in Earth Sciences, and specialist areas of other physical and natural sciences.
p) After completing course in Geology, the student is expected to be fully knowledgeable about the subject and not only from the point of view of examination.

III: Objectives

The Central University of Karnataka aims to create qualified professionals to meet the increasing social needs of the hour. Hence, this curriculum is instituted with the following objectives:

- To shape skilled and qualified geologists to serve the industrial, management, educational and developmental sectors of the society and the country.
- To contribute to the existing knowledge bank in geological sciences with an integrated and interdisciplinary approach.
- To bring subjects like environmental geology, disaster management, water security, resource management, application of remote sensing and GIS in the field of Geology, etc., as academic subjects into the mainstream.
- To develop in-depth knowledge and skills in qualitative and quantitative research methods through laboratory, field and web modes of learning.

IV. Vision Statement:

To emerge as a Centre of excellence in the field of Geology in teaching, learning, research, training, practicing and producing human resources of very high standard.

Geology is the study of the Earth, the materials of which it is made, the structure of those materials, and the processes acting upon them.

V. Mission Statements (MS):

MS 1. To shape skilled and qualified geologists to serve the industrial, management, educational and developmental sectors of the society and the country.

MS 2. To contribute to the existing knowledge bank in geological sciences with an integrated and interdisciplinary approach.

MS 3. To develop in-depth knowledge and skills in qualitative and quantitative research methods through laboratory, field and web modes of learning.

MS 4. Expose the student to the vast scope of Geosciences as a theoretical and experimental science with applications in solving most of the geogenic problems in nature.

MS 5. Emphasize the need for integrating Geosciences as one of the most important branches of science for pursuing the interdisciplinary and multidisciplinary higher education and/or research in interdisciplinary and multidisciplinary areas.

VI: Qualification Descriptors (QD):

Once the programme is completed, the students will be able to

QD 1. Demonstrate a systematic, extensive and coherent knowledge and understanding of the academic field of Geology as a whole and its applications, and links to related disciplinary areas/subjects of study; including a critical understanding of the established theories, principles and concepts, and of a number of advanced and emerging issues;

QD 2. Demonstrate procedural knowledge that creates different types of professionals related to Geology, including research and development, teaching and government and public service;

QD 3. Demonstrate skills in areas related to one's specialization area and current developments in the academic field of Geology, including a critical understanding of the latest developments in the area of specialization, and an ability to use modern established techniques of analyses and enquiry within the field of specialization.

QD 4. Demonstrate skills in identifying information needs, collection of relevant quantitative and/or qualitative data drawing on a wide range of sources from the field and labs around the world, analyses and interpretation of data using methodologies as appropriate to the subject of Geology in the area of his/her specialization.

QD 5. Use knowledge, understanding and skills in Geology for critical assessment of a wide range of ideas and complex problems and issues relating to the various sub fields.

QD 6. Communicate the results of studies undertaken in the academic field of Geology accurately in a range of different contexts using the established and emerging concepts, constructs and techniques;

QD 7. Address one's own learning needs relating to current and emerging areas of study in Geology, making use of research, development and professional materials as appropriate, including those related to new frontiers of knowledge in science.

QD 8. Demonstrate subject-related and transferable skills that are relevant to some of the Geology related jobs and employment opportunities in the public and private sector.

Mapping Qualification Descriptors (QDs) with Mission Statements (MS)

	MS-1	**MS-2**	**MS-3**	**MS-4**	**MS-5**
QD-1	3	3	3	2	1
QD-2	3	3	3	3	2
QD-3	1	3	2	3	3
QD-4	1	3	1	3	2

QD-5	1	2	2	2	3
QD-6	1	3	2	1	2
QD-7	2	2	2	1	2
QD-8	2	2	1	1	2

* '3' for 'High-level' mapping, 2 for 'Medium-level' mapping, 1 for 'Low-level' mapping.

VII: Program Learning Outcomes (PLOs):

The student graduating in Geology should be able to

PLO 1. Acquire a fundamental/systematic or coherent understanding of the academic field of Geology, its different learning areas and applications in basic Geology like Mineralogy, Petrology, Stratigraphy, Paleontology, Economic geology, Hydrogeology, etc. and its linkages with related interdisciplinary areas/subjects like Geography, Environmental sciences, Remote Sensing, GIS, Information Technology etc.

PLO 2. Demonstrate procedural knowledge that creates different types of professionals related to the disciplinary/subject area of Geology, including professionals engaged in research and development, teaching and government/public service;

PLO 3. Acquire skills in areas related to one's specialization area within the disciplinary/subject area of Geology and current and emerging developments in the field of Geosciences.

PLO 4. Recognize the importance of RS&GIS, modelling simulation and computing, and the role of approximation and mathematical approaches to describing the physical world.

PLO 5. Plan and execute Geology-related experiments or investigations, analyze and interpret data/information collected using appropriate methods, including the use of appropriate software such as programming languages and purpose-written packages, and report accurately the findings of the experiment/investigations while relating the conclusions/findings to relevant theories in Geology.

PLO 6. Demonstrate relevant generic skills and global competencies such as problem-solving skills that are required to solve different types of geoscience-related problems with well-defined solutions, and tackle open-ended problems that belong to the disciplinary area boundaries.

PLO 7. Demonstrate investigative skills, including skills of independent investigation of geoscience-related issues and problems.

PLO 8. Demonstrate analytical skills involving paying attention to detail and ability to construct logical arguments using correct technical language related to Geology and ability to translate them with popular language when needed.

PLO 9. Demonstrate professional behavior such as being objective, unbiased and truthful in all aspects of work and avoiding unethical, irrational behavior such as fabricating, falsifying or misrepresenting data or committing plagiarism; the ability to identify the potential ethical issues in work-related situations; appreciation of intellectual property, environmental and sustainability issues; and promoting safe learning and working environment.

Mapping of Program Learning Outcomes (PLOs) with Qualification Descriptors (QDs)

	QD-1	QD-2	QD-3	QD-4	QD-5	QD-6	QD-7	QD-8
PLO-1	**3**	**1**	**2**	**3**	**3**	**2**	**2**	**1**
PLO-2	**3**	**3**	**3**	**3**	**2**	**2**	**2**	**2**
PLO-3	**1**	**2**	**2**	**3**	**3**	**3**	**2**	**2**
PLO-4	**2**	**3**	**3**	**3**	**3**	**3**	**3**	**2**
PLO-5	**1**	**2**	**3**	**3**	**3**	**3**	**3**	**2**
PLO-6	**2**	**3**	**3**	**3**	**3**	**3**	**3**	**3**
PLO-7	**2**	**3**	**2**	**3**	**3**	**2**	**3**	**3**
PLO-8	**1**	**1**	**2**	**3**	**3**	**3**	**3**	**3**
PLO-9	**2**	**1**	**1**	**3**	**1**	**3**	**3**	**3**

*'3' in the box for 'High-level' mapping, 2 for 'Medium-level' mapping, 1 for 'Low-level' mapping.

VIII. Other Information

1. **Name of the Course:** 4-years Graduation Programme, **BSc in Research with Geology as Major** with multiple exit options: (Exit options: award of Certificate after 1 year/ award of Diploma after 2nd year/ award of BSc in Geology after 3rd year)
2. **Duration of the Course**: Four years (Eight semesters) with multiple exit options after 1/2/3 years
3. **Eligibility and Attendance**: As per University rules
4. **Intake:** As per University norms
5. **Medium of Instruction and examination**: English
6. **Miscellaneous**: All other matters not referred to specifically shall be governed as per the Ordinances of the University as revised from time to time.
7. **Course structure and credit allocation**: Each credit denotes 1hour for theory and two-hours for practicum.

IX. SCHEME OF STUDY

This is a Bachelor of Science program with Life Sciences and Geology as major courses and one minor course, which will be opted by a student of his/her choice as per the course structure of the University, based on the guidelines of NEP. The students study Life Sciences as another major course and selected minor courses upto second year, and in third year there will be courses related to the Geology only for the students who opted Geology subject. The students based on merit will have a chance to enter into the fourth year of the programme. The four-year BSc in Research with Geology as Major program, is with a total of 178 credits. The students have the option of multiple exit as per rules and regulations of the University.

Out of 178 credits, 88 credits of Discipline Specific Core (DSC) Courses and 4 credits of Ability Enhancement Compulsory (AEC) Courses are mandatory while 42 credits of Discipline Specific Elective (DSE) Courses, 12 credits of Generic Elective Courses (GEC) from Interdisciplinary disciplines, 12 credits of Minor Courses (MC) from Interdisciplinary disciplines, 12 credits of Skilled Enhancement Courses (SEC) as well as 8 credits of Value Addition Courses (VAC).

A detailed list of Discipline Specific Core Courses (DSC), Discipline Specific Elective Courses (DSE), Skill Enhancement Courses (SEC), Generic Elective Courses (GE), Minor Courses (MC), Ability Enhancement Compulsory Courses (AEC), and Value Addition Courses (VAC), are given in following section.

Course Structure

(IA 40% and End Semester Examinations 60%)

Semester I						
Course type	**Code**	**Title**	**Credit**	**L**	**T**	**P**
DSC 1		***LS**	**6**			
DSC 2	UGLTC10001	Earth System Science	**6**	**5**	**1**	
AEC 1		Language	**2**	**2**		
VAC 1		*LS	**2**			
GE 1	UGLTG10001	Fundamentals of Geology/Understanding of Planet Earth	**3**	**3**		
MC 1	UGLTM10001	Geotourism/Introduction to Gemmology	**3**	**3**		
		Total	**22**			
Semester II						
Course type	**Code**	**Title**	**Credit**	**L**	**T**	**P**
DSC 3		***LS**	**6**			
DSC 4 (T)	UGLTC20002	Mineralogy and Geochemistry	**4**	**4**		
DSC 4 (P)	UGLPC20003	Practical: Mineralogy and Geochemistry	**2**			**2**
AEC 2		Environmental Science	**2**	**2**		

SEC 1	UGLTS20001	Introduction to GIS	**2**	**2**		
GE 2	UGLTG20002	Engineering Geology/Integrated Watershed Development	**3**	**3**		
MC 2	UGLTM20002	Mineral Economics/ Medical Geology	**3**	**3**		
		Total	**22**			
(AWARD OF CERTIFICATE)						
Semester III						
Course type	**Code**	**Title**	**Credit**	**L**	**T**	**P**
DSC 5		***LS**	**6**			
DSC 6 (T)	UGLTC30004	Petrology	**4**	**4**		
DSC 6 (P)	UGLPC30005	Practical: Petrology	**2**			**2**
SEC 2		***LS**	**2**			
VAC 2	UGLTV30001	Introduction to Geophysics	**2**	**2**		
GE 3	UGLTG30003	Geographic Information System in Geology/ Applications of Remote Sensing	**3**	**3**		
MC 3	UGLTM30003	GIS in Public Health/Natural Resources Management	**3**	**3**		
		Total	**22**			
Semester IV						
Course type	**Code**	**Title**	**Credit**	**L**	**T**	**P**
DSC 7		***LS**	**6**			
DSC 8 (T)	UGLTC40006	Ore Geology & Indian Mineral Deposits	**4**	**4**		
DSC 8 (P)	UGLPC40007	Practical: Ore Geology	**2**			**2**
DSE 1	UGLTD40001/ ULSTD40001	Remote sensing and GIS/Geoinformatics/ Surveying/***LS**	**4**	**4**		
SEC 3	UGLPS40001/ ULSPS40003	Practical: Remote sensing and GIS/Practical: Surveying/***LS**	**2**			**2**
GE 4	UGLTG40004	Climate change and Geological Hazards/Natural Hazards and Disaster Management	**3**	**3**		
MC 4	UGLTM40004	Isotope Geology/ Water and Sanitation	**3**	**3**		
		Total	**24**			
(AWARD OF DIPLOMA) **Note: After 2nd year, the student has to choose a Major (Life Sciences or Geology)**						
Semester V						
Course type	**Code**	**Title**	**Credit**	**L**	**T**	**P**
DSC 9	UGLTC50008	Principles of Stratigraphy and Indian Geology	**6**	**5**	**1**	
DSC 10 (T)	UGLTC50009	Structural Geology	**4**	**4**		
DSC 10 (P)	UGLPC50010	Practical: Structural Geology	**2**			**2**
DSC 11 (T)	UGLTC50011	Paleontology	**4**	**4**		
DSC 11 (P)	UGLPC50012	Practical: Paleontology	**2**			**2**
DSE 2	UGLTD50002	Marine Geology/Marine Mineral Resources/Coal and Petroleum Geology/Isotope Geochemistry	**3**	**3**		

VAC 3	UGLFV50002	Fieldwork: Geological Field Methods and Mapping	**2**			**2**
		Total	**23**			
Semester VI						
Course type	**Code**	**Title**	**Credit**	**L**	**T**	**P**
DSC 12	UGLTC60013	Mineral Exploration and Mining	**6**	**5**	**1**	
DSC 13 (T)	UGLTC60014	Hydrogeology	**4**	**4**		
DSC 13 (P)	UGLPC60015	Practical: Hydrogeology	**2**			**2**
DSC 14 (T)	UGLTC60016	Engineering Geology	**4**	**4**		
DSC 14 (P)	UGLPC60017	Practical: Engineering Geology	**2**			**2**
DSE 3	UGLTD60003	Geogenic disasters/Disaster Management/ Gemmology	**3**	**3**		
SEC 4	UGLTS60002/ UGLFS60001	Geostatistics/Fieldwork	**2**	**2**		
		Total	**23**			
(AWARD OF BACHELOR DEGREE: B.Sc. in Geology)						
Semester VII						
Course type	**Code**	**Title**	**Credit**	**L**	**T**	**P**
DSC 15	UGLTC70018	Research Methodology and publication ethics	**4**	**4**		
DSE 4	UGLTD70004	Descriptive Mineralogy and Petrology	**4**	**4**		
DSE 5	UGLTD70005	Advanced Remote Sensing and Hydrogeology	**4**	**4**		
DSE 6	UGLTD70006	Exploration Geophysics and Mineral Processing	**4**	**4**		
SEC 5	UGLRS70003	Mini Project	**4**			**4**
VAC 4	UGLTV50003	Technical Tools for Research	**2**	**2**		
		Total	**22**			
Semester VIII						
Course type	**Code**	**Title**	**Credit**	**L**	**T**	**P**
DSE 7	UGLID80002	Internship	**8**			**8**
DSE 8	UGLRD80002	Project work	**12**			**12**
		Total	**20**			
(BACHELOR OF SCIENCE IN RESEARCH WITH GEOLOGY as MAJOR)						

***Compulsory course from Life Sciences Dept.**

Note on credits and duration of exam

Credits	IA Marks	ES Marks	Total Marks
1	10	15	25
2	20	30	50
3	30	45	75
4	40	60	100
5	50	75	125
6	60	90	150

YEAR I- (SEMESTER-I & II)

SEMESTER I
Discipline Specific Core Course 2: Earth System Science
(Credits: 6, Theory: 6)

(i) Course learning outcome (CLOs):

1. Students of this course will study and understand the essentials and fundamentals of the Earth and the structural dynamics of the earth.
2. Also they will gain especially the knowledge of interior of the Earth and various planets and even they will be able to analyse beyond earth scopes in extra-terrestrial context.
3. This course will enrich students' knowledge on the brief history of Earth and its evolution and how to date earth materials along with analysis of climatic variations over those dated ages. Volcanic and Earthquake history and its science. Describe three ways in which tectonic processes drive magmatism on Earth, Explain the relationship between mantle convection and plate tectonics.
4. Explain the process of formation and distribution of various landforms

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9
CLO1	3	1	1				2	3	2
CLO2	3	2	2	2	2		1	1	
CLO3	3	2	2		1	1	2		
CLO4	2	3	2		3	2	1	2	1

(ii) Broad contents of the course:

The course presents an understanding of the processes in action on the earth's surface and their impact on man and his institutions. This course also covers topics related to role of geomorphic agents in the formation of various landforms, deformation behavior of various geological structures, and geodynamic evolution of continents and oceans.

(iii) Skills to be learnt:

This course will give wide range of idea to the students to understand the origin of entire solar system and planets, including earth. The students are exposed to the Geological time scale and be able to appreciate the dynamics of earth evolution through time. Students will acquire skills related to geological and geomorphological mapping.

(iv) The detail contents of this course and references and suggested books:

Unit 1: (15 hours)

Earth as a Planet: Age and origin of earth; Origin of the Universe; Solar System and its planets; Meteorites and Asteroids; Structure of earth: Core, Mantle, Crust, Hydrosphere, Atmosphere, and Biosphere; Convection in Earth's core and production of its magnetic field; Geological time scale

Unit 2: (15 hours)

Plate Tectonics: Continental drift theory; Sea-floor spreading mechanisms; Concept of plate tectonics: Plate boundaries and types; Super continents and Super continental cycle

Unit 3: (15 hours)

Volcanoes and Earthquake: Volcanoes, Types of volcanoes, Products and their distribution; Earthquakes and Earthquake belts; Classification of Earthquakes; Causes and effects of Earthquakes; Recording of Earthquakes; History of Earthquakes in India

Unit 4: (15 hours)

Introduction to Geomorphology: Introduction, history, factors, and scales in geomorphology; Geomorphic principles and processes; Erosion cycles

Unit 5: (15 hours)

Landforms: Weathering, Landforms formed by Fluvial, Aeolian, Glacial, Peri-glacial and Coastal processes; Karst landforms.

Unit 6: (15 hours)

Tectonic geomorphology: Geoid, hypsometry, major morphological features, sea level changes, mountains, rates of uplift and denudation, tectonics and drainage development; Major geomorphic features of India

Books Recommended:

1. A Text Book of Geomorphology. Dayal. P, Rajesh Publication, New Delhi 2007
2. Alien, P.A., 1997. Earth Surface Processes, Blackwell publishing
3. Arthur Holmes, (1992) Principles of Physical Geology. Chapman and Hall, London.
4. Bloom, A.L., 1998. Geomorphology: A Systematic Analysis of Late Cenozoic Landforms, Pearson Education.
5. Bridge, J.S. and Demicco, R.V., 2008. Earth Surface Processes, Landforms and Sediment Deposits, Cambridge University Press.
6. Duff, P. M. D., & Duff, D. (Eds.). (1993). Holmes' Principles of Physical Geology. Taylor & Francis.
7. Earth: An Introduction to Physical Geology (10th Edition), Tarbuck, E.J., Lutgens, F.K & Dennis Tasa. Prentice Hall, 2010
8. Emiliani, C. (1992) Planet earth: cosmology, geology, and the evolution of life and environment. Cambridge University Press
9. Esterbrook, D.J., 1992. Surface Processes and Landforms, MacMillan Publ.
10. Geodynamics: Third Edition, Turcotte, D. L. and Schubert, G., Cambridge University Press, 2014.
11. Geomorphology. Charley, R.J., Suhumm, S.A & Sugden, D.E, Routledge, 1985
12. Kale, V.S. and Gupta A 2001 1ntoduction to Geomorphology, Orient Longman Ltd.
13. Leeder, M. and Perez-Arlucea M 2005 Physical processes in earth and environmental sciences, Blackwell publishing
14. Mahapatra, G.B., (1994) A text book of Physical Geology. CBS Publishers
15. Mantle Dynamics: Mantle Convection in the Earth and Planets, Schubert, G., Turcotte, D. L. and P. Olson, Cambridge University Press, 2001
16. Miller, (1949) An Introduction to Physical Geology. East West Press Ltd.
17. Parbin Singh. (Reprint: 2018). Engineering and General Geology. S.K. Kataria and Sons, New Delhi.
18. Physical Geology. Carla. W Montgomery, Wm C. Brown Publishers, 1990
19. Press and Siever (1998) Understanding Earth, WH Freeman & Co.
20. Principles of Geomorphology, W.D Thornburry Wiley, 1969
21. Spencer, E.V., (1962) Basic concepts of Physical Geology. Oxford & IBH.
22. Summerfield M A 1991 Global Geomorphology, Prentice Hall.
23. Wllcock, P.R., Iverson R M (2003) Prediction in geomorphology, AGU Publication.

General Elective (GE)
General Elective Paper 1 (GE 1): Fundamentals of Geology
(Credits: 3, Theory: 3)

(i) Course learning outcome (CLOs):

1. The study of this paper strengthens students' knowledge with respect to understanding the essentials of the structural dynamics of the earth.
2. The students will be able to analyse beyond earth scopes in extra-terrestrial context.
3. The students will be able to increase their knowledge on the brief history of Earth and its evolution.
4. The students will also gain knowledge on how to date earth materials along with analysis of climatic variations over those dated ages.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9
CLO1	3	1	1				2	3	2
CLO2	3	2	2	2	2		1	1	
CLO3	3	2	2		1	1	2		
CLO4	2	3	2		3	2	1	2	1

(ii) Broad contents of the course:

The course presents an understanding of the processes in action on the earth's surface and their impact on man and his institutions.

(iii) Skills to be learned:

The students will understand the origin of our solar system and planets, including earth. The students are exposed to the Geological time scale and be able to appreciate the dynamics of earth evolution through time.

(iv) The detail contents of this course and references and suggested books:

Unit 1: (15 hours)

Geology - its perspective, scope and branches; General characteristics and origin of the Universe, Solar System and its planets; Extra-terrestrial bodies

Unit 2: (15 hours)

Concept of plate tectonics; sea-floor spreading and continental drift; Origin of oceans, continents, mountains and rift valleys

Unit 3: (15 hours)

Volcanoes, types of volcanoes, products and their distribution, and volcanic landforms; Earthquakes and Earthquake belts; Classification of Earthquakes, Causes and Effects of Earthquakes; Recording of Earthquakes; Seismic zones of India

Books Recommended:

1. Arthur Holmes, (1992) Principles of Physical Geology. Chapman and Hall, London.
2. Duff, P. M. D., & Duff, D. (Eds.). (1993). Holmes' principles of physical geology. Taylor & Francis.

3. Emiliani, C. (1992) Planet earth: cosmology, geology, and the evolution of life and environment. Cambridge University Press
4. Emiliani, C. (1992). Planet earth: cosmology, geology, and the evolution of life and environment. Cambridge University Press.
5. Gross, M. G. (1977). Oceanography: A view of the earth.
6. Mahapatra, G.B., (1994) A text book of Physical Geology. CBS Publishers.
7. Miller, (1949) An Introduction to Physical Geology. East West Press Ltd.
8. Parbin Singh. (Reprint: 2018). Engineering and General Geology. S.K. Kataria and Sons, New Delhi.
9. Press and Siever (1998) Understanding Earth, WH Freeman & Co.
10. Spencer, E.V., (1962) Basic concepts of Physical Geology. Oxford & IBH.

OR
General Elective Paper 1 (GE 1): Understanding of Planet Earth
(Credits: 3, Theory: 3)

(i) Course learning outcome (CLOs): After the completion of this course students will be able to:

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

1. Strengthen knowledge with respect to understanding the essentials of the structural dynamics of the earth
2. Analyse beyond earth scopes in extra-terrestrial context
3. Increase their knowledge on the brief history of Earth and its evolution
4. Gain knowledge on how to date earth materials along with analysis of climatic variations over those dated ages

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9
CLO1	3	1	1				2	3	2
CLO2	3	2	2	2	2		1	1	
CLO3	3	2	2		1	1	2		
CLO4	2	3	2		3	2	1	2	1

(ii) Broad contents of the course:

The course will help in understanding the planet Earth, the various features of Earth and the processes acting on and within the Earth's surface.

(iii) Skills to be learned:

The students will gain knowledge on the origin and evolution of earth. The students are also be able to appreciate the dynamic processes acting upon and shaping the planet Earth.

(iv) The detail contents of this course and references and suggested books:

Unit 1: (15 hours)

Formation of the solar system; Grouping of Planets; Internal Structure of Earth; Origin and Age of Earth; Meteorites; Introduction to minerals and rocks; Standard stratigraphic time scale

Unit 2: (15 hours)

Seismology and Internal structure of Earth; Formation of core, mantle, crust; Convection in Earth's core and its magnetic field; Plate tectonics and concept of plate tectonics; Plate boundaries and landforms; Volcanoes: Types, products and distribution; Earthquakes: Intensity, causes, earthquake belts and distribution

Unit 3: (15 hours)

Origin and evolution of ocean and life; Oceanic current system and effect of Coriolis force; Concepts of Eustasy; Land-air-sea interaction; Atmospheric circulation; Weather and climatic changes; Earth's heat budget; Weathering and Erosion, Mass wasting; Geological works of river, glacier, wind, underground water, ocean and landforms produced by them; Wave erosion and beach processes

Books Recommended:

1. Arthur Holmes, (1992) Principles of Physical Geology. Chapman and Hall, London.
2. Duff, P. M. D., & Duff, D. (Eds.). (1993). Holmes' principles of physical geology. Taylor &Francis.
3. Emiliani, C. (1992). Planet earth: cosmology, geology, and the evolution of life and environment. Cambridge University Press.
4. Gross, M. G. (1977). Oceanography: A view of the earth.
5. Invitation to Oceanography (2009) Paul R. Pinet Jones & Barlett Learning
6. Mahapatra, G.B., (1994) A text book of Physical Geology. CBS Publishers.
7. Miller, (1949) An Introduction to Physical Geology. East West Press Ltd.
8. Parbin Singh. (Reprint: 2018). Engineering and General Geology. S.K. Kataria and Sons, New Delhi.
9. Press and Siever (1998) Understanding Earth, WH Freeman & Co.
10. Spencer, E.V., (1962) Basic concepts of Physical Geology. Oxford & IBH.
11. Trujilo, A. and Thurman, H. (2012) Essentials of Oceanography, 12th Edition, Pearson

Minor
Minor Course 1 (MC 1): Geotourism
(Credits: 3, Theory: 3)

(i) Course learning outcome (CLOs):

After the completion of the course, the student will be able to

1. Know the basic concepts and nature of Geotourism and its related fields
2. Distinguish and identify the potential geological sites of tourist interest, both globally and in India
3. Understand the economic aspects and scope of Geotourism
4. Role of government in development of Geotourism

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9
CLO1	3	2	1				3	2	3
CLO2	3	1	2		2		2	1	
CLO3	3	2	1	2	1	1	3		
CLO4	2	2	2		2	3	2	3	2

(ii) Broad contents of the course:

The course shows the Geological aspects in the field of Tourism. It provides insight into various aspects of Geotourism and its scope in the future.

(iii) Skills to be learned:

This is an applied course where student learns to combine and optimize the tourism potential of spectacular geological monuments and geological heritage sites.

(iv) The detailed contents of this course:

Unit 1: (15 hours)

Tourism and its different forms; Geotourism: Definition, characteristics, and principles of Geotourism; The scope and nature of geotourism; Overlapping with other tourism fields; Development history of Geotourism

Unit 2: (15 hours)

Earth science and Geotourism; Geographical diversity and Geoheritage; Geosites, Geoparks and Geotourism; UNESCO Global Geoparks and Geoconservation; UNESCO global heritage monuments; Global heritage sites; Geotourism and India; Geoheritage sites of India

Unit 3: (15 hours)

Potential of Geotourism in Economic development; Role of Tourism sector in terms of world economy/Indian economy; Role of Geotourism in Tourism industry with special reference to Indian scenario; Entrepreneurship and start-up; Role of local, state and national government in conservation and development of heritage monument sites

Books and materials recommended:

1. A monograph on National Geoheritage Monuments of India. Indian National Trust for Art and Cultural Heritage (INTACH) Natural Heritage Division, New Delhi (2016).
2. Appreciating Physical Landscapes: Three Hundred Years of Geotourism, T. A. Hose (Ed.), Geological Society Special Publication No. 417, London (2016).
3. Economics and Management of Geotourism. Braga, V., Duarte, A., & Marques, C. S. (2022).
4. Geoheritage and Geotourism- a European Perspective, Thomas A. Hose (Ed) Boydell, Press Woodbridge, UK.
5. Geotourism mapping for sustainability: A basin-oriented approach. Chakrabarty, P., & Mandal, R. (2018). GeoJournal of Tourism and Geosites, 21 (1), 174-185.
6. Geotourism, Dowling, R. K., & Newsome, D. (Eds) Elsevier Butterworth Heinemann (2006).
7. Geotourism. Ólafsdóttir, R. (2019). Geosciences, 9 (1), 48.
8. Geotourism: a systematic literature review. Geosciences, 8 (7), 234. Ólafsdóttir, R., & Tverijonaite, E. (2018).
9. Global Geographical Heritage, Geoparks and Geotourism. Singh, R. B., Wei, D., & Anand, S. (2021). Singapore, Springer. 483p.
10. Global Geotourism perspectives, Dowling, R. K., & N ewsome, D. (Eds) USA: Good fellow Publishers Limited (2010).
11. Handbook on Geotourism, Ross Dowling & David Newsome (Eds.) Edward Elgar Publishing (2018).
12. History of Geoconservation, C. V. Burek and C. D. Prosser (Eds.) Special
13. Landscapes and Landforms of India, Kale, V. S. (ed) Springer, Dordrecht (2014).
14. National Geological Monuments. Geological Survey of India, Kolkata, Special Publication, No.61 (2001).

15. Potential Geoheritage & Geotourism Sites in India. Ranawat, P. S., & George, S. (2019). Int J Sci Res Publ, 9(6), 91-96.
16. Recognized geoheritage and geotourism sites in India. Ranawat, P. S., & Student, P. G. D. M. (2020). International Journal of Engineering Applied Sciences and Technology, 4 (11), 224 231.
17. The Principles of Geotourism, Anze Chen, Young C. Y. Ng, and Yunting Lu (Springer), (2015).

OR

Minor Course 1 (MC 1): Introduction to Gemmology
(Credits: 3, Theory: 3)

(i) Course learning outcome:

The basic idea is to make students well versed with the different terminologies used in the gem industry and to provide skills to become a successful gemmologist.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9
CLO1	3	2	1		1		2		2

(ii) Broad contents of the course:

The course covers the various aspects of gem testing using both theoretical as well as lab work by dealing with basics to the advanced techniques of gemstone identification. Further, it deals with the methods employed by diamond industry in cutting a rough diamond into a sparkling gem and how diamonds are graded internationally. Why synthetic gemstones have flooded the market and how they are manufactured is then next topic, including their detection.

(iii) Skills to be learned:

The students will acquire skills which will be useful to them in the gem industries.

(iv) The detail contents of this course and references and suggested books:

Unit 1: (10 hours)

Gemmology: Introduction to Gems, basic properties of gems, Formation of gemstones; Use of refractometers, Polariscope, and Dichroscope; Methods of Specific Gravity determination; Causes of colors in gemstones

Unit 2: (10 hours)

Introduction to special optical properties like chatoyancy, asterism, luminescence, play of colors, labradorescence, inclusions, etc.; Distinction between synthetic and natural gemstones

Unit 3: (15 hours)

Use of Gem Testing Instruments: Hand lens (10x), Detection of double refraction by observing pleochroic colors with the Dichroscope; Identification of gemstones on the basis of pleochroic colors; Detection of double refraction, interference figures and internal strain with the Polariscope

Unit 4: (10 hours)

Study of the fluorescent colors exhibited by various gemstones under ultraviolet (long wave and short wave) light; Measurement of refractive indices and birefringence tests using a gem-testing Refractometer

Books Recommended

1. Babu T.M (1998) Diamonds in India, Geological Society of India
2. Fareeduddin & R. H. Mitchell (2012) Diamonds and their Source rocks in India, Geological society of India
3. Karanth R.V (2008) Gemstones Enchanting Gifts of Nature, Geological society of India
4. Karanth R.V. (2000) Gems and Gem Industry in India, Geological society of India
5. Read, P. G. (1991) Gemmology, Butterworth-Heinemann Ltd.
6. Sinkankas, J. (1969) Mineralogy: A First Course, Van Nostrand Reinhold Company.
7. Webster, R. and edited by Anderson, B.W. (1983) Gems: Their Sources, Descriptions and Identification, Butterworth-Heinemann Ltd.

Semester II

Discipline Specific Core Course 2 (T): Mineralogy and Geochemistry
(Credits: 4, Theory: 4)

(i) Course learning outcome:

1. Studying the basics of mineralogy
2. Crystallography helps in understanding the building blocks of every earth material
3. Explain systematic descriptions and identifications of minerals in hand specimen and under the microscope
4. Describe how and in what environments the minerals and rocks were formed
5. Describe the geochemistry of water and sediments and their chemical behavior in various geochemical environments

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9
CLO1	3	2	3	2	2	1			2
CLO2	3	2	2		2	1	1	1	1
CLO3	3	1	1				2	3	2
CLO4	3	2	3	2	2	1			2
CLO5	2	3	2	1	3	2	1	2	1

(ii) Broad contents of the course:

The course deals with the study of minerals, their chemistry and identification in hand specimen. Further, it also deals with the study of crystals with respect to their morphology, symmetry and the normal crystal classes. It also deals with the geochemical classification of elements. This course covers topics related to symmetry operations, characteristics of different mineral groups, analytical techniques related to mineral study, isotopes, sediment and water geochemistry.

(iii) Skills to be learned:

The students will be able to identify common rock-forming minerals and hand specimens as well as in thin sections. Besides, they will familiarize themselves with Bravais crystal lattice and crystal systems. They can also identify the behavior of various elements under various geochemical environments. Students will understand the characteristics of silicate structures, understanding the rock-forming mineral thin sections using a polarizing microscope, classification of geochemistry, trace elements and REE.

(iv) The detail contents of this course and references and suggested books:

Unit 1: (15 hours)

Mineralogy: An introduction to study of minerals, Definition of minerals; Mineral groups and Silicate structure; Physical and chemical properties of Minerals; Mineral Chemistry; Structure of common rock-forming minerals; Optical properties of common rock forming minerals; Introduction to petrological microscope and identification of common rock-forming minerals; Application of mineralogical information to geological problems.

Unit 2: (15 hours)

Descriptive mineral science: Study of mineral groups based on physical and optical properties and their occurrences for the following groups: Silicates, Oxides, Carbonates, and Phosphates

Unit 3: (15 hours)

Crystallography: Elementary ideas about crystal morphology in relation to internal structures; Crystal parameters and indices; Crystal symmetry and classification of crystals into six systems; Elements of crystal chemistry and aspects of crystal structures, HCP and CCP

Unit 4: (15 hours)

Geochemistry: An introduction to geochemistry, including geochemical abundances, partitioning coefficients and recycling within the earth; Geochemistry of igneous/metamorphic rocks and hydrothermal processes; Average geochemical composition of crust and mantle; Geochemical classification of elements

Books Recommended:

1. Berry, L.G., Mason, B. and Dietrich, R.V., (1982) Mineralogy. CBS Publ.
2. Buerger M. Elementary Crystallogaphy. The MIT Press (May 15, 1978)
3. Cornelis Klein and Barbara Dutrow, The manual of Mineral Science, Wiley Publication 2007
4. Dana, E.S. and Ford, W.E., (2002) A textbook of Mineralogy (Reprints).
5. Deer, Howie and Zussman (1996) Introduction to Rock forming Minerals, Pearson (3rd Edition)
6. Dexter Perkins, Mineralogy, 3 rd edition, Pearson, 2011
7. Flint, Y., (1975) Essential of crystallography, Mir Publishers.
8. Francis Albarède Geochemistry: An Introduction, Cambridge, 2009
9. Frye Keith: Modern Mineralogy. Prentice Hall; First Edition edition (May 1974)
10. Gunter Faure Principles and Applications of Geochemistry. Prentice Hall; 2 edition (December 24, 1997)
11. K.C. Misra, Introduction to Geochemistry: Principles and Applications, Wiley-Blackwell, 2012
12. Kerr, B.F., (1995) Optical Mineralogy 5th Ed. McGraw Hill, New York.
13. Mason B, Principles of Geochemistry, J. Willey & Sons, 1982
14. Moore M. (1982) Principles of Geochemistry, Wiley.
15. Nesse W. D., Introduction to Optical mineralogy. Oxford University Press. 2008
16. Perkin Dexter. (2017), Mineralogy, (Third Edition). Pearson.
17. Putnis A. Introduction to mineral Sciences, Cambridge publication, 1992
18. R.N. Hota (2012) Practical approach to Mineralogy and Crystallography, CBS Publications & Distributions.
19. Ram S. Sharma and Anurag Sharma (2013) Crystallography and Mineralogy - Concepts and Methods. Text Book Series, Geological Society of India, Bangalore
20. Rutley's Elements of Mineralogy. Springer; 27th edition (November 30, 1988)
21. Verma, P. K. (2010). Optical Mineralogy (Four Colour). Ane Books Pvt Ltd. 4. Deer, W. A., Howie,
22. W. H. Blackburn and W. H. Dennen. Principles of mineralogy. Dubuque, IA: Wm. C. Brown Publishers. 1993)
23. William D Nesse. Introduction to Optical Mineralogy. Oxford University Press, USA; 3 edition (August 21, 2003)

Discipline Specific Core Course 4 (P): Practical: Mineralogy and Geochemistry (Credits: 2, Practical: 2)

1. Crystallography: Observation and documentation on symmetry of crystals, Study of 32-point groups, Representation of symmetry on stereograms, Stereographic projection, Axial ratios
2. Descriptive Mineralogy: Study of physical properties of minerals belonging to major groups and their identification with the aid of megascopic characters. Silicates, Oxides, Carbonates, Phosphates
3. Optical mineralogy: Determination of vibration direction, extinction angle, pleochroism and optic sign for rock forming minerals. Identification of common rock forming minerals under optical microscope using their characteristic properties

4. Geochemistry: Types of geochemical data analysis and interpretation of common geochemical plots. Geochemical analysis of geological materials. Geochemical variation diagrams and its interpretations.

Skill Enhancement Courses (SEC)
Skill Enhancement Courses Paper 1 (SEC 1): Introduction to GIS
(Credits: 2, Theory: 2)

(i) Course learning outcome:

1. This course provides a theoretical knowledge of computer system for information
2. To understand the spatial data types and analysis in GIS software

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9
CLO1	3	1	1				2	3	2
CLO2	3	2	2	2	2		1	1	

(ii) Broad contents of the course:

The course contains fundamentals of GIS, sources of data, spatial data, attribute data, analyze data sets and uses in various applications.

(iii) Skills to be learned:

The course provides knowledge of the fundamentals of GIS theory, the stages of data capturing, storing, manipulations and using a GIS environment for mapping, visualization and decision making.

(iv) The detail contents of this course:

Unit 1: (10 hours)

Geographical Information System (GIS): Introduction, Components of GIS; the GIS view of the world, Why is GIS important? Contributing disciplines, Major areas of application, the appeal and potential of GIS, Benefits of computerizing information

Unit 2: (10 hours)

Nature and Source of Geographic Data: Spatial data formats – raster and vector, Choice between raster and vector, data capture, data collection workflow, Primary geographic data capture, Secondary geographic data capture, Obtaining data from external sources, Geographic data formats, Capturing attribute data, Managing a data capture project, Data editing, Data conversion, Geographic data – linkages and matching

Unit 3: (10 hours)

Basic Data models: Raster and Vector data models; Advantages and Disadvantages of Raster and Vector data Models, overlay analysis

Books Recommended:

1. B. Bhatta, Remote Sensing and GIS (2008) Oxford University Press, New York, (ISBN:-0-19-560239-X)

2. Lo, C.P. and A.K.W., Yeung (2007) Concepts and Techniques in Geographic Information, Systems. 2nd, Upper Saddle River, Prentice Hall (ISBN 0-13-149502-X)
3. Longley, P.A., M.F. Goodchild, D.J. Maguire and D.W. Rhind. [2007]. Geographic Information Systems and Science. 2nd , John Wiley & Sons (ISBN 978-0-470-87001-3)
4. Michael N. DeMers (2009) GIS for Dummies. Wiley publications, Inc. (ISBN: 978-0-470-23682-6)
5. Peter A. Burrough and Rachael A. McDonnell (2009) Principles of Geographic Information Systems. Oxford University press, New York (ISNB: 0-19-922862-0)
6. Shahab Fazal (2008) New Age International (P) Ltd., Publishers
7. Tor Bernhardsen (2002) Geographic information System An introduction, 3rd Edition, Wiley India private ltd, New Delhi (ISBN: 978-81-265-1138-9)

Generic Elective (GE)
Generic Elective Paper 2 (GE 2): Engineering Geology
(Credits: 3, Theory: 3)

(i) Course learning outcome:

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

1. Aware of the importance of geological studies and its applicability to various engineering problems
2. Explain the geological investigation for civil engineering projects, engineering properties of rock, properties of Dam, Reservoir, Landslides, etc.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9
CLO1	3	1	1				2	3	2
CLO2	3	2	2	2	2		1	1	

(ii) Broad contents of the course:

To impart sufficient knowledge of engineering geology so as to be able to anticipate the technical problems related to geology of various engineering sites and suggest possible remedial measures. The course covers geological investigation for civil engineering project, concept of Dam, Reservoir, landslide, concept of geotechnical engineering.

(iii) Skills to be learned:

The student will be educated on geological site investigations for engineering structures and will provide skills in geological mapping and making geotechnical measurements. The student will be able to learn the use of dam, reservoir, problem related to landslide, properties of tunnel, earthquake and seismicity etc.

(iv) The detail contents of this course and references and suggested books:

Unit 1: (15 hours)

Introduction: Geology, Engineering geology, Importance of engineering geology, Stages of engineering projects; Earth: Composition and internal structure of earth; Introduction to folds, faults and joints

Unit 2: (15 hours)

Minerals: Introduction, types, physical properties and occurrence; Rocks: Introduction, types, and rock cycle; Engineering properties of rocks, building stones, road metal, and concrete aggregates

Unit 3: (15 hours)

Geological investigation: Dams and reservoirs, tunnels, highways; Earthquakes, Landslides

Books Recommended:

1. Blyth, F.G.H. and M. H. de Freitas (1984) Geology for Engineers, Butterworth- Heinemann Title
2. Chenna Keshvallu (2018) Text book of Engineering Geology, Laxmi Publications
3. Engineering and general geology. Parbin Singh, S K Kataria & Sons.2009
4. Engineering Geology. David George. Springer; 1st edition (November 21, 2008), Elementary surveying, Major Basil Jackson
5. Gokhale, K.V.G. (2006) Principles of engineering geology, BS publications
6. Krynine, D.P and Judd, W.R (2005) Principles of Engineering Geology and Geotechniques, CBS Publishers & Distributors
7. Ries, H. and T. L. Watson, (1949) Elements of Engineering Geology, New York, John Wiley & Sons, Inc.
8. Tony Waltham (2009) Foundations of Engineering Geology, Taylor and Francis.

OR

Generic Elective Paper 2 (GE 2): Integrated Watershed Development
(Credits: 3, Theory: 3)

(i) Course learning outcome:

1. This course introduces the fundamental concepts of watershed management planning and principles.
2. It encompasses the water quality issues, storm water management, drought management, soil erosion, rainwater harvesting and watershed modeling.
3. Finally, the course provides inputs for integrated watershed management.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9
CLO1	3	1	1				2		2
CLO2	2	1	2		2	3	3	1	3
CLO3	3	2			1	1	2		

(ii) Broad contents of the course:

Watershed Management concept and principles, Assessment of water resources i.e., surface water and ground water in a watershed: rainfall-runoff and ground water analysis. Soil erosion estimation. Water quality and guidelines. Watershed Modelling, Drought assessment and management. Integrated watershed management.

(iii) Skills to be learned:

Upon completion of this course, the student will acquire all skills to undertake watershed development and integrated watershed management thereby enhancing his employability with NGOs, Government agencies, etc. working in the fields of watershed and rural development.

(iv) The detail contents of this course and references and suggested books:

Unit 1: (15 hours)

Watershed Development: Concept of watershed, watershed characteristics; Importance of water resources in watershed; Concept of watershed development in relation to water resources

Unit 2: (15 hours)

Salient features of development measures like contour bunding, gully plugs, stream bunds, percolation tank, subsurface dams, afforestation, etc.; Significance of geology in watershed development; Assessment of water resources, i.e., surface water and groundwater in a watershed: rainfall-runoff and groundwater analysis; Soil erosion estimation

Unit 3: (15 hours)

Role of NGO's and State Government in watershed development; Watershed Management: Concept of watershed management in relation to water resources, water balance equation for watershed, sustainability of water resources, conjunctive use of surface and groundwater resources; Concepts of people's participation in community-based watershed management

Books Recommended:

1. Brooks, K.N. Folliott, P.F., Magner, J.A. (2012) Hydrology and the Management of Watersheds, John Wiley & Sons
2. Debarry, P. A. (2004) Watersheds: Processes, Assessment and Management, Wiley
3. Gonenc, I.E., Vadineanu ,A., Wolflin, J.P. (2014) Sustainable Use and Development of Watersheds, Springer
4. Heathcote, I.W. (2009) Integrated Watershed Management: Principles and Practice, John Wiley & Sons Ltd.
5. Karanth K.R. (1987) Groundwater assessment development and management, Tata Mcgrath Hill education.
6. Murthy, J.V.S. (2012) Watershed Management New Age International Publisher
7. Naiman, R.J. (1994) Watershed Management: Balancing Sustainability and Environmental Change, Springer
8. Raghunath H.M. (2003) Groundwater, New age education.
9. Todd, D. K. and Mayo, L. W. (2004) Groundwater hydrology, Wiley.

Minor
Minor Course 2 (MC 2): Mineral Economics
(Credits: 3, Theory: 3)

(i) Course learning outcome:

1. To understand the global and Indian scenario of important metallic and non-metallic resources
2. To understand the categorization of mineral resources
3. To understand the importance of exclusive economic zones of India
4. To know the mineral policies and legislation in India

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9
CLO1	3	1	1	2	3		2	3	2
CLO2	2	2	1		2	2	3	1	3

CLO3	3	1	2		3	1	2		1
CLO4	2	1	2		1	1	2	3	2

(ii) Broad contents of the course:

The course includes introductory aspects of mineral economics, categorization of mineral resources, global and Indian scenario of metallic, non-metallic and hydrocarbon resources and introduction to mineral policies and legislation in India.

(iii) Skills to be learned:

Skills related to categorization of mineral resources, and policies and legislation regarding mineral resources.

(iv) The detail contents of this course and references and suggested books:

Unit 1: (10 hours)

Introduction: Definition, Concept and Scope of Mineral Economics. Mineral Resources and Reserves. Categorization of mineral resources as Strategic, Critical and Essential Minerals.

Unit 2: (15 hours)

Global Mineral Resources – Metallic mineral resources including Fe, Mn, Cu, Pb, Zn, Al, Au, Ag, PGE, COLTAN, Lithium and non-metallic mineral resources including Limestone, Dolomite, Baryte, Mica, Asbestos; precious and semi-precious stones. Role of India in the world market for the above resources.

Unit 3: (20 hours)

Global resources of Coal, Petroleum and Natural Gas. Indian scenario for these hydrocarbons. Listing of various minerals of India into strategic, critical and essential minerals. Exclusive economic zones of India and their strategic importance in the production of marine minerals, National mineral policy of India and Mineral Legislation in India.

Books Recommended:

1. An Introduction to Mineral Economics by K. K. Chatterjee. New Age International Pvt. Ltd., 2015.
2. International Mineral Economics: Mineral Exploration, Mine Valuation, Mineral Markets, International Mineral Policies by Werner R. Gocht, Half Zantop and Roderick G. Eggert. Springer Verlag, 1988.
3. Mine and Mineral Economics by Subhash C. Ray and Indra N. Sinha. PHI Learning Pvt. Ltd., 2016.
4. Mineral Economics (4^{th} edition) by R. K. Sinha and N. L. Sharma. Oxford and IBH Publishing Co. Pvt. Ltd., 2019.
5. Mineral Economics and Policy by John E. Tilton and Juan Ignacio Guzmán. RFF Press, 2016.
6. Mineral Economics: An Indian Perspective by K. R. Randive and Sanjeevani Jawadand. Nova Science Publishers Inc., 2020.

OR

Minor Course 2 (MC 2): Medical Geology
(Credits: 3, Theory: 3)

(i) Course learning outcome:

On completion of the course, the student will be able to

1. Understand the distribution of trace elements
2. Get knowledge on cyclic movement of elements through the abiotic-biotic environments
3. Acquire acquaintance on the influence on human health, flora and fauna

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9
CLO1	3	3	2				2	3	2
CLO2	2			2	3			1	
CLO3	3	2	2		1	1	2		2

(ii) Broad contents of the course:

The course is designed to include the basic concepts of Medical Geology, interaction between abundances of elements and isotopes and the health of humans and plants.

(iii) Skills to be learned:

The course provides a basic understanding or geogenic and anthropogenic distribution of trace elements, their toxic effects on human health and that of flora and fauna.

(iv) The detail contents of this course and references and suggested books

Unit 1: (15 hours)

Basics of Medical Geology: Introduction, history, perspectives, and prospects of medical geology; Significance of medical geology

Unit 2: (15 hours)

Public health and Geology: Introduction to public health; Natural distribution and abundance of elements; Biological functions of elements; Geological factors and their influence on human health – Groundwater, earthquakes, and volcano

Unit 3: (15 hours)

Geochemical elements and their impact on Human health: Radon, Arsenic, Selenium, Mercury, Iodine, Fluoride

Books Recommended:

1. Dissanayake, C. B. and Chandrajith, R. (2009) Introduction to Medical Geology, Springer Verlag Berlin Heidelberg
2. Eisenbud, M. and T. Gesell. (1997) Environmental radioactivity from natural, industrial, and military sources, Academic Press
3. Miomir Komatina (2004) Medical Geology, Volume 2, Effects of Geological Environments on Human Health, Elsevier Science
4. Olle Selinus (2013). Essentials of Medical Geology, Revised edition, Springer

YEAR II- (SEMESTER-III & IV)

Semester III

Discipline Specific Core Course 6 (T): Petrology
(Credits: 4, Theory: 4)

(i) Course learning outcome:

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

1. Describe the origin of various rocks in different geological environments
2. Understand the structures and textures of various types of rocks
3. Enhance the knowledge on classifications of rocks and their importance
4. Explain the magmatism, sedimentation and metamorphic processes
5. Explain the significance of various lithological formations, their relations to tectonic settings and their multidisciplinary applications

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9
CLO1	3	1	1		3		2	3	2
CLO2	3	2	2	2	2	3	3	1	3
CLO3	3	2	2	2	1	1	2		
CLO4	2	3	2	1	3	2	1	2	1
CLO5	3	2	2	1	2	2	2	2	3

(ii) Broad contents of the course:

Petrology is the science of rocks. This course covers topics related to basics of petrology, tracing their history in the geological time period, covering various physical and chemical aspects of the earth systems. Understanding of melt generation and crystallization mechanism and their link to tectonic settings is vital for the geological assessment of an area.

(iii) Skills to be learned:

Students will acquire skills related to solving lithological problems using various classification schemes and sampling processes; skills related to assessing mineralogical composition and textural differences with special focus on facies analysis using petrological environments. Also, they will be acquiring skills of estimating the occurrences of various related earth materials based on the petrological significance of an area.

(iv) The detail contents of this course and references and suggested books:

Unit 1: (15 hours)

Magma: Types of magma, physical properties of magma, Magma and plate tectonics, magmatic evolution process, Phase rule and its applications, study of binary and ternary granitic and basaltic systems

Unit 2: (15 hours)

Igneous Petrology: Forms of Igneous rocks, Classification of Igneous rocks: IUGS classification. Mineralogy, field characteristics, occurrence, origin and tectonic environments of important igneous rocks; Granodiorite -

Diorite, Syenite – Nephaline Syenite; Gabbro – Peridotite – Dunite; Anothosites, Lampropyres, Kimberlite, Carbonatites; Dolerites, Pegmatites; Rhyolites – Trachytes; Andesites & Dacites, Basalts. Large Igneous Provinces, Layered Igneous Complexes, Continental Alkaline Rocks, Alkaline cratonic associations, I-, S-, A Granites

Unit III: (15 hours)

Sedimentary petrology: Sedimentary processes and their products. Classification of sediments. Diagenesis & Lithification. Sedimentary structures. Classification of sedimentary rocks. Mineral composition, structure and textures of Clastic and non-Clastic sediments and Residual deposits. Origin, occurrence and characteristics of common sedimentary rocks - quartz arenites, arkoses and greywackes. Siliceous and calcareous deposits. Sedimentary environments and facies

Unit IV: (15 hours)

Metamorphic Petrology: Definition, types of metamorphism, Factors of metamorphism. Zones and Grades, concept of metamorphic facies of contact and regional metamorphism. Textures and structures of metamorphic rocks. Chemographic relationship: ACF, AKF and AFM diagrams. Thermodynamic principles of metamorphic reactions. Metamorphic differentiation, metamorphism and plate tectonics. Study of important metamorphic rocks

Books for Reference:

1. Best, M. G. Igneous and Metamorphic Petrology, 2nd Edn., Blackwell, 2003
2. Blatt H., Tracy R.J. and Owens B.E. (2006) Petrology – Igneous, sedimentary and metamorphic rocks (3rd Edition), W.H. Freeman and Company, New York.
3. Bose M.K. (1997) Igneous Petrology. The World Press Pvt. Ltd. 568 p.
4. Collinson, J., Mountney, N., Thompson, D., Sedimentary Structures, Terra Publishing, 3rd Edn., 2006
5. Cox, K. G., Bell, J. D. and Pankhurst, R. J. The Interpretation of Igneous Rocks. Unwin Hyman, 1979
6. Ehlers, WG, and Blatt, H.(1987) Petrology, Igneous, Sedimentary and Metamorphic rocks, CBS Publishers
7. Hall, A. Igneous Petrology, 2nd Edn., Longman, 1996
8. Hatch F.H., Wells A.K and Wells M.K. (1984) Petrology of the igneous rocks. CBS Publishers, 551p.
9. Mason, R., (1978) Petrology of Metamorphic Rocks. CBS Publ.
10. McBirney, A. R. Igneous Petrology, 3rd Edn., Jones & Bartlett, 2006
11. Middlemost, E. A. K. Magmas and Magmatic Rocks. Longman, 1985
12. Nicholls, G. Sedimentology and Stratigraphy. Wiley-Blackwell, 1999
13. Pettijohn, F. J., Sedimentary Rocks, CBS Publication, 2004
14. Philpotts, A. and Ague, J. (2009). Principles of igneous and metamorphic petrology. Cambridge University Press.
15. Prothero, D.R. and Schwab, F. Sedimentary Geology: An Introduction to Sedimentary Rocks and Stratigraphy, 2nd Edn., W.H. Freeman, 2003
16. Ram S. Sharma (2016) Metamorphic Petrology Concepts and Methods. Text Book Series, Geological Society of India, Bangalore
17. Raymond, L. A. (2002). Petrology: the study of igneous, sedimentary, and metamorphic rocks. McGraw-Hill Science Engineering
18. Selley, R.C., Applied sedimentology, 2nd Edn., Academic Press, 2000
19. Tucker, M.E. Sedimentary Petrology, 3rd Edn., Blackwell Science, 2001
20. Turner F.J and Verhoogen J. (1960) Igneous and Metamorphic Petrology, McGraw- Hill.
21. Turner, F.J., (1980) Metamorphic Petrology. McGraw Hill.

22. Winkler, H.G.C., (1967) Petrogenesis of Metamorphic Rocks. Narosa Publ.
23. Winter, J. D. Introduction to Igneous and Metamorphic Petrology. Prentice Hall India, 2010
24. Yardley, B.W.D. Metamorphic Petrology, Longman, 1989

Discipline Specific Core Course 6 (P): Practical: Petrology
(Credits: 2, Practical: 2)

1. Igneous: Study of important igneous rocks in hand samples and thin sections- granite, granodiorite, diorite, gabbro, anorthosites, ultramafic rocks, basalts, andesites, trachyte, rhyolite, dacite.
2. Metamorphic: Megascopic and Microscopic study of Low-grade metamorphic rocks: serpentinites, albite-epidote-chlorite quartz schist, slate, ta1c-tremolite-ca1citequartz schist, Medium to high grade metamorphic rocks: Gneisses, amphibolite, hornfels, garnetiferous schists, sillimanite-kyanite-bearing rocks, Granulites, eclogite, diopside-forsterite marble. Laboratory exercises in graphic plots for petrochemistry and interpretation of assemblages.
3. Sedimentary: Study of mega structures, textures and mineralogy of sedimentary rocks. Study of common sedimentary rocks in hand samples and thin sections.

Value Addition Courses (VAC)
Value Addition Course Paper 2 (VAC 2): Introduction to Geophysics
(Credits: 2, Theory: 2)

(i) Course learning outcome:

1. To understand the different physical properties of earth materials and their controlling factors
2. To understand the different physical fields of earth and, how the physical properties and physical fields can be made use of in earth science studies.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9
CLO1	3	1	1				2	3	2
CLO2	3	2	2	2	2		1	1	

(ii) Broad contents of the course:

The course includes introductory aspects of geophysics, detailed study of physical properties of different earth materials, introduction to different physical fields of the earth.

(iii) Skills to be learned:

The skills that will be taught include computation of physical properties of earth materials, derivation of their units, differentiating earth materials based on physical properties and, solving simple quantitative problems in geophysics.

(iv) The detail contents of this course and references and suggested books:

Unit 1: (15 hours)

Definition of geophysics; Principles of geophysics; Geophysical anomaly and types of anomaly; Study of different physical properties of earth materials and their controlling factors, including density, specific gravity, electrical properties like conductance, resistance, resistivity and its types, pyro- and piezo-electricity; Magnetic properties; Elastic properties; Radioactivity

Unit 2: (15 hours)

Magnetism: Magnetism and palaeomagnetism, earth's magnetic field, magnetism of rocks, magnetostratigraphy – reversals of earth's magnetic field, magnetic anomalies; Seismology: Seismic waves and earth materials, classification of seismic waves, relation between seismic waves' propagation and effect on earth materials, equations for elastic wave velocities and elastic wave velocities in different earth materials, controls of elastic wave velocity, ray paths and wave fronts, reflection and refraction of seismic waves, seismology and internal structure of the earth; Earth's gravity: Introduction, variation of gravity with latitude and longitude, gravity anomaly. Classification of geophysical methods and fields of applications of geophysical methods.

Books for Reference:

1. Exploration Geophysics - An Outline by Bhimasarikaram V.L.S., Association of Exploration Geophysicists, Osmania University, Hyderabad, 1990.
2. Fundamentals of Geophysics by William Lowrie. Cambridge University Press, 2007, second edition.
3. Geophysics: A Very Short Introduction by William Lowrie. Cambridge University Press, 2018.
4. Introduction to Seismology by Peter M. Shearer. Cambridge University Press, 2009, second edition.
5. Looking into the Earth: An introduction to the geological geophysics by Alan E Mussett, M. Aftab Khan and Sue Button. Cambridge University Press, 2000.
6. Outlines of Geophysical Prospecting - A manual for geologists by Ramachandra Rao, M.B., Prasaranga, University of Mysore, Mysore, 1975.
7. Physics for Geologists by Richard E Chapman, UCL Press, 1995.
8. The Solid Earth: An introduction to Global Geophysics by C. M. R. Fowler. Cambridge University Press, 2005.

Generic Elective (GE)
Generic Elective Paper 3 (GE 3): Geographic Information System in Geology
(Credits: 3, Theory: 3)

(i) Course learning outcome:

1. This course provides a theoretical and practical, hands-on approach to spatial database design
2. To understand the spatial data analysis with Geographical Information Systems as applied to the various fields of geosciences.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9
CLO1	3	1	1				2	3	2
CLO2	3	2	2	2	2		1	1	

(ii) Broad contents of the course:

The course contains fundamentals of GIS theory, how to obtain, prepare, translate, document, and analyze GIS data sets and use it in most genuine applications in geosciences.

(iii) Skills to be learned:

The course provides knowledge of the fundamentals of GIS theory, and the stages of developing and using a GIS platform of various geological applications. It also promotes proficiency in the use of the GIS software for visualization, query, mapping, and analytical purposes.

(iv) The detail contents of this course and references and suggested books:

Unit 1: (15 hours)

Introduction to GIS, Components of GIS, Hardware & Software Requirements, Spatial databases and GIS, GIS and the art of digitizing

Unit 2: (15 hours)

Geographic phenomena, Geographic object, Triangulated Irregular Network, Data input, Data output and visualization, Data storage, Query maintenance and spatial analyses, etc.

Unit 3: (15 hours)

Data models, Types of vector data: point, line, polygon and Raster data model, spatial and Non-spatial data and their types, Georeferencing, Map projections, Applications of GIS, Limitations of GIS, Components of GPS

Books Recommended:

1. George Joseph (2005) Fundamentals of Remote Sensing, University press Private Ltd, Hyderabad.
2. Heywood I, el. (2011) An Introduction to Geographical Information Systems, Pearson Education Pvt. Ltd., New Delhi.
3. Kang – tsung – Chang, (2002) Introduction to Geographical Information System, McGraw Hill.
4. Lillesand T.M. and Kiefer R.W. (2002) Remote Sensing and Image Interpretation, John Wiley and Sons, New Delhi.
5. Lo C.P. and Albert K. W. Yeung,(2002) Concepts and Techniques of Geographic Information System, Prentice –Hall, India.
6. P. A. Burrough and R. A. McDonnell, (2000) Principles of Geographical Information System, Oxford University Press.
7. Rolf, A. de (2001) Principles of Geographic Information Systems-An introductory textbook. ITC Educational Textbook Series. Enschede, The Netherlands.
8. T. Sutton, O. Dassau, M. Sutton, A Gentle Introduction to GIS, Chief Directorate: Spatial Planning and Information, Department of Land Affairs, Eastern Cape, South Africa.

OR

Generic Elective Paper 3 (GE 3): Applications of Remote Sensing (Credits: 3, Theory: 3)

(i) Course learning outcome:

1. The course is meant to address the fundamental techniques used for remote sensing.
2. Make aware about aerial photographs and its usage in the field of Geology.
3. At the end of this course, the student will be appraised with all the theoretical knowledge.
4. To gain information and skills to use remotely sensed data for geological applications.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9
CLO1	3	1	1				2	3	2
CLO2	3	2	2	2	2		1	1	
CLO3	3	2	2		1	1	2		
CLO4	2	3	2		3	2	1	2	1

(ii) Broad contents of the course:

This course intends to introduce students to the fundamental principles and techniques of remote sensing, basic properties of electromagnetic radiation and its interaction with matter, It will also include topics like instruments and platforms used for remote sensing, and the ways those systems can be used to determine geological structure and rock types.

(iii) Skills to be learned:

After completion of this course, the student will be well versed with the world of Remote Sensing and the applications and Interpretation of data related to geosciences.

(iv) The detail contents of this course and references and suggested books:

Unit 1: (10 hours)

Basic concepts in remote sensing, Electro-magnetic spectrum, Energy sources, Energy interaction in the atmosphere, Atmospheric windows, Atmospheric effects on remotely sensed data, Signatures in remote sensing, Sensors and sensor platforms

Unit 2: (20 hours)

Introduction to aerial photographs, History of aerial photography, Aerial camera, Types of aerial photographs, classification, Principles of stereoscopic viewing, Conditions and cause for stereovision, Aerial photography missions; Use of pocket and mirror stereoscope, Scale of aerial photographs, Stereoscopic parallax, Relief displacement, Measurement of height of objects; Aerial photo interpretation, Photo-recognition elements, Methods of photointerpretation, Advantages and limitations of aerial photographs

Unit 4: (15 hours)

Remote Sensing from space: space crafts and sensors. Visual image interpretation of satellite imagery, image enhancement, digital analysis, preparation of thematic maps; Thermal infrared remote sensing and microwave

remote sensing for geological applications; Remote sensing satellites, Indian Remote Sensing Satellite programme

Books Recommended:

1. Drury S.A, A Guide to Remote Sensing - Interpreting Images of Earth, Oxford Science Publications, Oxford. (1990)
2. Gary L. Prost Remote Sensing for Geologists - A Guide to Image interpretation, Gordon and Breach Science Publishers, The Netherlands. 1997.
3. Miller Victor C. Miller Calvin F. (1961) Photogeology (International Series in the Earth Sciences. McGraw-Hill Book Company, Inc.
4. Paine, D.P (1981) Aerial photography and image interpretation for resource management, Wiley and Sons, New York. 1986.
5. Ramasamy, SM. (1999) Trends in Geological Remote Sensing - Rawat Publishers, Jaipur Rao, D.P. Remote Sensing for Earth Resources, Second Edition, Association of Exploration Geophysicist, Hyderabad p.212, (CERS-236)
6. Reddy A. (2012) Introduction to Remote Sensing and GIS, BS Publications.
7. Sabins, F. F. Jr., (1978) Remote Sensing Principles and Interpretation, Freeman, Sanfrancisco.

Minor
Minor Course 3 (MC 3): GIS in Public Health
(Credits: 3, Theory: 3)

(i) Course learning outcome (CLOs):

This course will enable the students to understand the spatial data types and create thematic map(s) illustrating the results of spatial distribution of data related to public health applications.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9
CLO1	3	2	2	3	2	1	2		1

(ii) Broad contents of the course:

The course contains GIS theory, data collection, preparation of thematic maps, analyze demographic data sets and query for the applications in public health issues.

(iii) Skills to be learned:

The course provides knowledge of the fundamentals of GIS and data tables. It also gives confidence in the use of the GIS software for visualization, manipulation, query, mapping, and display the spatial distribution of disease.

(iv) The detail contents of this course:

Unit 1: (10 hours)

GIS Definitions, Components, Functions of GIS, Trends, Public health & applications

Unit 2: (10 hours)

Data Model: Raster data, Vector data, Spatial data and non-spatial data, Projections & metadata

Unit 3: (10 hours)

Data sources for public health: Introduction, Methods of data sources, Demographic data, Health data, Tables and query

Unit 4: (15 hours)

Mapping health related information: Mapping process, Disease mapping and spatial analysis, Data visualization and exploration, Data integration, Spatial data query and analysis

Books Recommended:

1. B. Bhatta, Remote Sensing and GIS (2008) Oxford University Press, New York, (ISBN:-0-19-560239-X)
2. George Joseph (2005) Fundamentals of Remote Sensing, University press Private Ltd, Hyderabad
3. Kang – Tsung – Chang, (2002) Introduction to Geographical Information System, McGraw Hill
4. Lillesand T.M. and Kiefer R.W. (2002) Remote Sensing and Image Interpretation, John Wiley and Sons, New Delhi
5. M.Anji Reddy (2008) Remote Sensing and Geographical Information System, B.S Publications
6. P. A. Burrough and R. A. McDonnell (2000) Principles of Geographical Information System, Oxford University Press

OR

Minor Course 3 (MC 3): Natural Resources Management
(Credits: 3, Theory: 3)

(i) Course learning outcome (CLOs):

1. Students will be able to understand the basic concept of natural resources both renewable resources and nonrenewable resources
2. Able to understand the current issues dealing with the conservation and management of natural resources.
3. Able to understand the interactions between natural and social processes.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9
CLO1	3	3	3	3	2	3	3	3	2
CLO2	3	3	2			3	2	2	1
CLO3	3		3			2	3	2	1

(ii) Broad contents of the course:

This course covers topics on natural resources such as forest resources, energy resources, food resources, fish and other marine resources, land resources, water resources and mineral resources and their management.

(iii) Skills to be learned:

Students will acquire skills to a broader and integrated systems approach to natural resource management that explores the linkages among different elements of a system

(iv) The detail contents of this course:

Unit 1:

Introduction to Natural Resource: Concept of resource, classification of natural resources, Factors influencing resource availability, distribution and uses. Interrelationships among different types of natural resources. Forest resources: Forest vegetation, status and distribution, Use and over-exploitation, deforestation. Energy resources: Growing energy needs, renewable and non-renewable energy sources, use of alternate energy sources.

Unit 2:

Food resources: World food problems, changes caused by agriculture and over-grazing, effects of modern agriculture, Fish and other marine resources: Production, status, dependence on fish resource, Land resources: Land as a resource. Dry land, land use classification, Land resource management and major issues. Water resources: Use and over-utilization of surface and ground water, drought, conflicts over water, dams-benefits and problems. Mineral resources: Use and exploitation, environmental effects of extracting and using mineral resources.

Unit 3:

Approaches in Resource Management: Ecological approach; economic approach; ethnological approach; implications of the approaches; integrated resource management strategies. Poverty and implications in resource management in developing countries, Water scarcity, ecology and management. Resource Ocean, climate, international fisheries and management commissions; Antarctica: the evolution of an international resource management regime.

Books Recommended:

1. Anderson, David A. (2010) Environmental Economics and Natural Resource Management
2. B.W Pandey (2005) Natural Resource Management
3. Elias T. Ayuk and Ngozi F. Unuigbe (2019) New Frontiers in Natural Resources Management in Africa.
4. Moulton, M.P. and J. Sanderson (1999) Wildlife issues in a changing world. Lewis Publishers, Boca Raton, Florida, 500 pp.
5. Ole Bjørn Røste (2021) Norway's Sovereign Wealth Fund, Sustainable Investment of Natural Resource Revenues.
6. Rajinder Peshin and Ashok K. Dhawan (2019) Natural Resource Management: Ecological Perspectives
7. Sara Valaguzza and Mark Alan Hughes (2022) Interdisciplinary Approaches to Climate Change for Sustainable Growth.
8. Selby, M.J. (1996) Earths Changing Surface. Oxford University Press UK.
9. Siwa Msangi and Duncan MacEwan (2019) Applied Methods for Agriculture and Natural Resource Management, A Festschrift in Honor of Richard E. Howitt.

Semester IV

Discipline Specific Core Course 8 (T): Ore Geology & Indian Mineral Deposits (Credits: 04, Theory-04)

(i) Course learning outcome:

By the end of this course, the student will be able to

1. Processes of formation of ore deposits
2. Gain knowledge on textures and structures of ore deposits
3. Know the occurrence, origin and distribution of important metalliferous and non-metalliferous ore deposits of India.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9
CLO1	3	1	1	2	3		2	3	2
CLO2	2	2	1		2	2	3	1	3
CLO3	3	1	2		3	1	2		1

(ii) Broad contents of the course:

Mineral resources are the raw materials of the basic industries and intern they have bearing on national economy. This course designed to equip the under graduate students to understand the process of formation of both metallic and non-metallic mineral deposits and their distribution and occurrence in India.

(iii) Skills to be learned:

Upon completion of this course, the student will acquire knowledge and skills required for him/herself becoming an ore geologist.

(iv) The detail contents of this course and references and suggested books:

Unit 1: (15 hours)

Introduction: Definition of ores, gangue minerals, tenor, and grade; Morphology of ore bodies; Textures of ore minerals; Some major theories of ore genesis

Unit 2: (15 hours)

Role of fluids and structures in formation of ore deposits; Wall alteration, zoning and paragenetic sequence; Classification of ore deposits

Unit 3: (15 hours)

Ore-forming processes: Magmatic processes, Sedimentary processes, Hydrothermal, Oxidation and Supergene enrichment, Residual and mechanical concentration processes, Metamorphic processes; Global tectonics and metallogeny

Unit 4: (15 hours)

Metallic and Non-metallic ores of India: Metallic ores, Non-metallic and industrial rocks and minerals, Atomic minerals, Gem & Gemstones

Books Recommended:

1. Bateman, A.M. and Jensen, M.L. (1990) Economic Mineral Deposits. John Wiley.
2. Deb, S. (1980) Industrial minerals and rocks of India. Allied Publishers.
3. Evans, A.M. (1993) Ore Geology and Industrial minerals. Wiley
4. Gokhale, K.V.G.K. and Rao, T.C. (1978) Ore deposits of India their distribution and processing, Tata-McGraw Hill, New Delhi.
5. Guilbert, John M. and Charles Frederick Park (2007) The Geology of Ore Deposits, Waveland Press
6. Krishnaswamy, S. (1979) India's mineral resources. Oxford & IBH
7. Laurence Robb. (2005) Introduction to ore forming processes. Wiley.
8. Mukherjee, A. (1999): Ore Genesis – A Holistic Approach. Allied Publishers Ltd., New Delhi, India. P657.
9. Prasad, U. (2006) Economic Geology: Economic Mineral Deposits. CBS Pub.
10. Ridley, J. (2013): Ore Deposit Geology. Cambridge University Press, UK. P398.
11. Sarkar, S.C. and Gupta, A. (2014) Crustal Evolution and Metallogeny in India. Cambridge Publications.
12. Tiwari, S.K. (2010) Ore Geology, Economic Minerals and Mineral Economics, Atlantic Publishers & Distributors (P) Limited

Discipline Specific Core Course 8 (P): Practical: Ore Geology
(Credits: 02, Parctical-02)

1. Megascopic identification of important metallic and non-metallic ore minerals
2. Study of reflected light properties of ore forming minerals, Study of important metallic ore minerals and their textures under reflected light microscope
3. Preparation of maps: Distribution of important ores and other economic minerals in India

Discipline Specific Elective Course 1 (DSE 1): Remote sensing and GIS
(Credits: 4, Theory: 4)

(i) Course learning outcome:

1. This course provides a knowledge on the principles of remote sensing and GIS
2. To understand the spatial data analysis with Geographical Information Systems as applied to the various fields of geosciences.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9
CLO1	3	1	1				2	3	2
CLO2	3	2	2	2	2		1	1	

(ii) Broad contents of the course:

The course contains fundamentals of remote sensing and GIS and use it in most genuine applications in geosciences.

(iii) Skills to be learned:

The course provides knowledge of the fundamentals of remote sensing and GIS theory, and using a GIS platform of various geological applications. It also promotes proficiency in the use of the GIS software for visualization, query, mapping, and analytical purpose.

(iv) The detail contents of this course and references and suggested books:

Unit 1: (10 hours)

Basic principles of Remote Sensing: Definition and components, Electro Magnetic Radiation; Wavelength regions of electro-magnetic radiation; Types of remote sensing with respect to wavelength regions; Reflectance; spectral reflectance of land covers.

Unit 2: (10 hours)

Sensors and platforms: Types of sensors: Multispectral, Hyper-spectral, Microwave, scanners-along track and across track; Platform and their types-Geostationary and Polar orbiting. Satellite missions –MODIS, IRS, LANDSAT, SPOT, marine/ocean observation satellites.

Unit 3: (10 hours)

Aerial Photography: Interpretation keys; Instruments used in the analysis, Applications of aerial photography in geological studies.

Unit 4: (15 hours)

Geographical Information System (GIS): Introduction, functions of GIS. Components of GIS. Coordinate Systems - Geographical Coordinate Systems, Projected Coordinate System, Map projections, Types of basic projections classification - Cylindrical, Conical and Azimuthal projections.

Unit 5: (15 hours)

Data models: Raster and Vector data models. Advantages and Disadvantages of Raster and Vector data Models, overlay analysis and applications of GIS.

Books Recommended:

1. Avery, T. E., Berlin, G. L. (1992) Fundamentals of Remote Sensing and Airphoto Interpretation (472 p). Upper Saddle River, NJ: Prentice Hall.
2. B. Bhatta (2008) Remote Sensing and GIS. Oxford University Press, New York, (ISBN:-0-19-560239-X)
3. Bernhardsen, T. (2002) Geographic information systems: an introduction. John Wiley & Sons
4. Lillesand, T., Kiefer, R. W., & Chipman, J. (2015) Remote sensing and image interpretation. John Wiley & Sons
5. Lo, C.P. and A.K.W., Yeung (2007) Concepts and Techniques in Geographic Information, Systems. 2nd, Upper Saddle River, Prentice Hall (ISBN 0-13-149502-X)
6. Longley, P. A., Goodchild, M. F., Maguire, D. J., & Rhind, D. W. (2005) Geographic information systems and science. John Wiley & Sons
7. Longley, P.A., M.F. Goodchild, D.J. Maguire and D.W. Rhind (2007) Geographic Information Systems and Science. 2nd , John Wiley & Sons (ISBN 978-0-470-87001-3)
8. Michael N. DeMers (2009) GIS for Dummies. Wiley publications, Inc. (ISBN: 978-0-470-23682-6)
9. Peter A. Burrough and Rachael A. McDonnell (2009) Principles of Geographic Information Systems. Oxford University press, New York, (ISNB: 0-19-922862-0)
10. Shamsi, U. M. (2005). GIS applications for water, wastewater, and stormwater systems. CRC press

OR

Discipline Specific Elective Course 1 (DSE 1): Geoinformatics
(Credits: 4, Theory: 4)

(i) Course Learning Outcome:

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

1. Explain the basic concepts of electromagnetic radiation, its interaction with the earth's surface and atmosphere
2. Describe the types of sensors, platforms and types of remote sensing
3. Explain GIS principles and its applications as well as aerial photography

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9
CLO1	3	1	1				2	3	2
CLO2	3	2	2	3	1		2		1
CLO3	3	2	2	2	2		1	1	

(ii) Broad contents of the course:

This course covers topics related to principle of remote sensing, reflectance of earth's surficial features, sensors, platforms, RADAR, LIDAR, SAR imaging, GIS integration with remote sensing and aerial photography.

(iii) Skills to be learnt:

Students will acquire skills related to interpretation of remotely sensed images, use basic analytical tools in GIS, interpretation of aerial photography.

(iv) The detailed contents of this course, suggested books/references:

Unit I: (10 hours)

Basic principles of Remote Sensing: Definition and components, Electro Magnetic Radiation; Wavelength regions of electro-magnetic radiation; Types of remote sensing with respect to wavelength regions; Black body radiation; Reflectance; spectral reflectance of land covers.

Unit II: (15 hours)

Sensors and platforms: Types of sensors: Multispectral, Hyper-spectral, Microwave, scanners-along track and across track; Platform and their types-Geostationary and Polar orbiting. Satellite missions –MODIS, IRS, LANDSAT, SPOT, marine/ocean observation satellites.

Unit III: (10 hours)

Aerial Photography: Principle keys for interpretation of aerial Photograph: Tone, Texture, Shape, Size, Scale, Pattern, Shadow, and Association; Application of Aerial Photograph: Fluvial landform, Coastal landform, glacial; Landform, Structural landform, Aeolian landform, Land use/ Land cover mapping.

Unit IV: (10 hours)

Introduction, fundamentals and functions of GIS, Components of GIS. Data and information: Types of geological and natural resources data, spatial and time variant, oriented information. Map Projection: Earth's size and shape in time and space. Spherical coordinates, Properties of map projections, Types of basic projections classification - Cylindrical, Conical and Azimuthal projections. Data models: Raster and Vector models. Advantages and Disadvantages of Raster and Vector Models and GIS data processing.

Books for reference:

1. B. Bhatta (2008) Remote Sensing and GIS. Oxford University Press, New York, (ISBN:-0-19-560239-X)
2. Avery, T. E., Berlin, G. L. (1992) Fundamentals of Remote Sensing and Airphoto Interpretation (472 p). Upper Saddle River, NJ: Prentice Hall
3. Colwell, R. N. (Ed.). (1960) Manual of photographic interpretation (Vol. 10). American Society of Photogrammetry
4. Kaspin, V. (1974) Theory of pattern recognition and modern forecasting. Air force systems command wright-patterson afb oh foreign technology division.
5. Lillesand, T., Kiefer, R. W., & Chipman, J. (2015) Remote sensing and image interpretation. John Wiley & Sons
6. Lueder, D. R. (1959) Aerial photographic interpretation: principles and applications
7. Miller, V. C. (1961) Photogeology. New York, McGraw-Hill
8. Reeves, R. G. (1975) Manual of Remote Sensing: Theory, instruments, and techniques (Vol. 1). American Society of Photogrammetry
9. Siegal, B. S., Gillespie, A. R., & Siegal, B. S. (Eds.). (1980) Remote sensing in geology. New York: Wiley
10. Smith, J. T., & Anson, H. (1968). Manual of color aerial photography. American Society of Photogrammetry. George Banta Co., Menasha, WI
11. Thompson, M. M., Eller, R. C., Radlinski, W. A., & Speert, J. L. (Eds.). (1966) Manual of photogrammetry (Vol. 1, p. 61). Falls Church, VA: American Society of Photogrammetry

OR

Discipline Specific Elective Course 1 (DSE 1): Surveying
(Credits: 4, Theory: 4)

(i) Course learning outcome:

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

1. Understand various survey instruments in different field studies
2. Identify locations, measurements of distances and geometry of objects

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9
CLO1	3	1	1				2		2
CLO2	2	1	2		2	3	3	1	3

(ii) Broad contents of the course:

The course contains basics of surveying and instruments for measuring objects position, conventional and modern survey, types of surveying and uses of surveying in various fields.

(iii) Skills to be learned:

After completion of this course, the students will appraise the uses of surveying instruments for accurate measurements of distance between locations, geometry, condition of object and planning and management of land for developmental activities.

(iv) The detail contents of this course:

Unit 1: (20 hours)

Basic concepts of surveying: Definition, Basic measurements, Control networks, Locating position, Locating topographic detail; Computer systems, DGM, CAD, GIS, Vector/raster, Topology, Laser scanner, Summary; Units of measurement, Significant figures, Rounding off numbers, Errors in measurement, Indices of precision, Weight, Rejection of outliers, Combination of errors

Unit 2: (10 hours)

Primary divisions of surveying: Plane surveying, Geodetic surveying**,** Classification, Types and uses of surveying

Unit 3: **(15 hours)**

Conventional surveying: Chain Survey, Prismatic Compass, Plane table surveying, Dumpy level, Theodolite surveying; Modern surveying: Total station survey, Survey specifications, second & third order survey

Unit 4: (15 hours)

Satellite positioning: Introduction, GPS segments, GPS receivers, Satellite orbits, Basic principle of position fixing, Differencing data, GPS field procedures, Error sources, GPS survey planning, Transformation between reference systems, Datums, Other satellite systems, Applications

Reference Books:

1. Pugh, J. C. (1975) Surveying for field scientists (Vol. 559). Pittsburgh: University of Pittsburgh Press.
2. Punmia, B.C., Jain, Ashok K, Jain, Arun K. (2005) Surveying Volume-1, 17th edition, Lakshmi Publication Pvt. LTD, ISBN:81-7008-054-1
3. Schofield, W. (2001) Engineering surveying: theory and examination problems for students. Elsevier
4. Vishwanath, H.S. (2014) Surveying-I. Sapna Book House, ISBN: 9788128011306

Skill Enhancement Courses (SEC)
Skill Enhancement Course Paper 3 (SEC 3): Practical: Remote sensing and GIS
(Credits: 2, Practical: 2)

1. ERDAS Imagine/ArcGIS software: Toposheet/Image display, Interpretation of individual bands, Georeferencing/Geometric correction, Sub setting, AOI layer
2. Raster data, Vector data feature extraction and labeling, Map elements
3. Land use land cover mapping by using unsupervised and supervised classification techniques

Or
Skill Enhancement Course Paper 3 (SEC 3): Practical: Surveying
(Credits: 2, Practical: 2)

Conventional and advanced surveying: Chain survey, Prismatic compass, Plane table surveying, Dumpy level/Auto leveling, Total station and GPS

Generic Elective (GE)
Generic Elective Paper 4 (GE 4): Climate change and Geological Hazards
(Credits: 3, Theory: 3)

(i) Course learning outcome:

1. The course introduces the students to the Earth's climate system.
2. Also learn and explores the science of global climate change using different proxies.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9
CLO1	3	2	1				2	3	2
CLO2	2	1	2		3	2	1	2	1

(ii) Broad contents of the course:

Course topics include the greenhouse effects and the science of global warming and climate change impacts.

(iii) Skills to be learned:

Students should be able to describe how the Earth's climate system works and summarize general atmosphere circulation patterns, ocean circulation patterns and climate oscillations such as the El-Niño Southern Oscillation. Besides, they will also be in a position to illustrate the Earths carbon cycle and quantitatively describe how addition of CO2 to the atmosphere due to burning of fossil fuels influences the climate.

(iv) The detail contents of this course and references and suggested books:

Unit 1: (10 hours)

Global climate change from past, present, and future perspectives; Earth's current climate system; Evidence for past climates; Climate change models

Unit 2: (10 hours)

Factors affecting the earth's climate; Anthropogenic impacts of climate, globally and regionally; Milankovich cycle; Greenhouse Gases and their effect; El Niño; Ocean circulation

Unit 3: (15 hours)

Climate and weather, Weather Forecasting; Climate changes vis-à-vis atmospheric hazards; Changes in rainfall patterns/intensity vis-à-vis storm surges, cyclone, floods, droughts

Unit 4: (10 hours)

Evolution of the Indian monsoon system; Agro-climatic divisions of Indian subcontinent; Climate and landscape evolution; Use of climate proxies to model and motor past and present climate indicators

Books Recommended:

1. Bell, M. and Walker, M.J.C. (1992) Late Quaternary Environmental Change; Physical and human perspective. Longman Scientific and Technical, New York
2. Bell, Martin (2004) Late Quaternary Environmental change: Physical and Human Perspectives
3. Bradely, R.S. (1999) Palaeoclimatology; Reconstructing climates of the Quaternary. 2nd Edition Harcourt Academic Press: San Diego
4. Bradley R. S. (1999) Paleoclimatology: Reconstructing climates of the quaternary. Academic Press v. 64 of International Geophysical series
5. Dawson Alastair G (2013) Ice Age Earth: Late Quaternary Geology and Climate (Physical Environment)
6. Lowe, J.J. and Walker, M.J.C. (1997) reconstructing Quaternary Environments Longman. ISBN 0-582-100166-2. Pp. 1-16, 148-373
7. Peixoto, J. P., Oort, A. H., & Lorenz, E. N. (1992). Physics of climate (Vol. 520). New York: American Institute of Physics
8. Ruddiman, W. F. (2008) Earth's Climate, Past and Future, WH Freeman & Co.
9. TERI, (2004) Looking back to change track, PHI
10. U.B. Mathur, (2010) Climate change: Past, present and future, Geological Society of India

OR

Generic Elective Paper 4 (GE 4): Natural Hazards and Disaster Management (Credits: 3, Theory: 3)

(i) Course Learning Outcome:

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

1. Explain various types of disaster
2. Demonstrate the management of disasters
3. Illustrate application of remote sensing and GIS in disaster management

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9
CLO1	2	3	3	3	2		2	3	2
CLO2	1	3	3	3	2		1		
CLO3	1	2	3	3	2	2		2	1

(ii) Broad contents of the course:

This course covers topics on landslide and land-subsidence, hazard zonation and their mapping, post disaster recovery & rehabilitation. Techniques of monitoring and design against the disasters and disaster related infrastructure development.

(iii) Skills to be learnt:

Students will acquire skills related to different type of risk and hazards, their management, various aspects of remote sensing and GIS in risk management.

(iv) The detailed contents of this course, suggested books/references:

Unit I: (20 hours)

Concepts of disaster; Types of disaster: natural and manmade - cyclone, flood, land slide, land subsidence, fire and earthquake, tsunami and volcanic eruption. Issues and concern for various causes of disasters. Disaster management, mitigation, and preparedness, Techniques of monitoring and design against the disasters, Management issues related to disaster.

Unit II: (15 hours)

Disaster Management in India: Risk, Vulnerability and Hazard Mitigation through capacity building. Legislative responsibilities of disaster management; disaster mapping, assessment-disaster risk & vulnerability reduction. Post disaster recovery & rehabilitation. Disaster related infrastructure development.

Unit III: (10 hours)

Hazard Zonation Mapping, Remote-sensing and GIS applications in real time disaster monitoring. Prevention and rehabilitation.

Books Recommended

1. Bell, F.G. (1999) Geological Hazards, Routledge, London.
2. Bryant, E. (1985) Natural Hazards, Cambridge University Press.
3. Smith, K. (1992) Environmental Hazards. Routledge, London.
4. Subramaniam, V. (2001) Textbook in Environmental Science, Narosa International

Minor
Minor Course 4 (MC 4): Isotope Geology
(Credits: 3, Theory: 3)

(i) Course learning outcome (CLOs):

On successful completion of the course the student will be able to

1. Understand the basic principles of isotope systematics used in geoscience
2. Acquire basic knowledge of geochronology
3. Develop knowledge on the application of isotopes in petrogenetic interpretations

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9
CLO1	3	1	1		3		2	2	2
CLO2	3	1	1		3		2	2	2
CLO3	2	2	1		2		1		1

(ii) Broad contents of the course:

The course aims to allow the student to understand the use of stable and radiogenic isotopes in Geology. The course also aims to allow the student to understand and apply the most used techniques for the geochronology.

(iii) Skills to be learned:

The students will acquire skills required for using isotopes in unrevealing the geological processes.

(iv) The detail contents of this course:

Unit 1: (15 hours)

Nucleosynthesis; Basic physics of nucleus; Goldsmiths' classification of elements; Geochemical classification and Geochemical periodic table; Abundance of elements; Analytical techniques and Mass spectrometers; Geochemical data – Major elements, Trace elements, Radiogenic and Stable isotopes – and their uses

Unit 2: (15 hours)

Radioactive decay and their use in geochronology; Basic principles of Geochronology; Fundamental equations for radiometric age calculations, Isochron method, Model ages, Closure temperature; Interpretation of geologic age; Whole rock and mineral age method

Unit 3: (15 hours)

Different isotopic systems used in Geochronology; Principles of K–Ar, Ar–Ar, Rb-Sr, U–Th–Pb, Sm–Nd, Lu–Hf and Re–Os methods; Radiogenic isotopes and Petrogenesis; Principles of Stable isotope geochemistry, Isotopic fractionation, Different notations used in stable isotope geochemistry; Important stable isotopes – H, C, N, O and S – and their uses

Books Recommended:

1. Albarède, F. (2003). Geochemistry: an introduction. Cambridge University Press
2. Dickin, A. P., Radiogenic Isotope Geology. Cambridge University Press, 1995
3. Faure, G. and Mensing, T. M., Isotopes: Principles and Applications, 3rd Edn. John Wiley & Sons, 2005
4. Geyh, M. A. and Schleicher, H., Absolute age determination. Springer, 1990
5. Hoefs, J., Stable Isotope Geochemistry, 3rd Edn. Springer-Verlag, 1987
6. Longman U.K. Faure, G., Principles of Isotope Geology, 2nd Edn. John Wiley & Sons, 1986
7. Mason, B. and Moore, C.B. (1985): Principles of Geochemistry, 4th edition, Wiley Eastern Limited.
8. Rollinson, H. (2007) Using geochemical data – evaluation, presentation and interpretation. 2nd Edition. Publisher Longman Scientific & Technical.
9. Sharp Zachary (2006). Principles of Stable Isotope Geochemistry. Prentice Hall
10. Walther, J. V. (2009). Essentials of geochemistry. Jones & Bartlett Publishers
11. White, M. William (2014). Isotope Geochemistry. Wiley – Blackwell

OR

Minor Course 4 (MC 4): Water and Sanitation

(Credits: 3, Theory: 3)

(i) Course learning outcome:

1. To comprehend the global picture of water/sanitation/hygiene and health;
2. To know the major technologies and processes of water/sanitation infrastructure in developing countries;
3. To become familiar with the patterns of domestic water use and waste disposal in developing countries, and to describe the modes of transmission of water-related diseases;

4. To understand the principles of operation of a range of appropriate water and sanitation technologies, and to be able to critically evaluate them with respect to multiple criteria;
5. To understand why infrastructure planning in developing countries is so challenging, to know the major obstacles and why many disciplines must work together to address the problem;

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9
CLO1	3	1	1				2		2
CLO2	2	1	2		2	3	3	1	3
CLO3	3	2			1	1	2		
CLO4	2	2	2	1	1	2	1	1	2
CLO5	2		2		2		3		3

(ii) Broad contents of the course:

This course introduces students to the principles of infrastructure planning in developing countries, with a focus on appropriate and sustainable technologies for water and sanitation. The student will be able to tackle the clean water problem from a multi-disciplinary perspective incorporating planning, engineering, environmental, cultural, public health, human rights, institutional and economic perspectives and considering factors such as technical efficacy, appropriateness (simple design, low cost, using local, easily available materials), social acceptability, economic sustainability, institutional viability, and political will.

(iii) Skills to be learned:

The course will highlight tackling of the clean water problem from a multi-disciplinary perspective incorporating planning, engineering, environmental, cultural, public health, human rights, institutional and economic perspectives.

(iv) The detail contents of this course and references and suggested books:

Unit 1: (15 hours)

Introduction to water and sanitation development, Basic concepts, water rich / water poor, and pictorial tour of global water and sanitation.

Unit 2: (15 hours)

Water, sanitation and hygiene-related diseases, Sources of water and water supply planning, Sewage collection systems, Sanitation history.

Unit 3: (15 hours)

Water quality and simple water quality field testing demo, Decentralized household water treatment and safe storage. Centralized wastewater treatment, and reuse. A utility's pro-poor approach in Bangalore's slums (case study), Centralized water treatment: MWRA and Beijing (case study).

Books Recommended:

1. Cairncross, Sandy, and Richard Feachem. Environmental Health Engineering in the Tropics: An Introductory Text. Chichester, UK: John Wiley & Sons, 1993, chapter 1 and appendix C. ISBN: 9780471938859.

2. Colford, John, Jr., and Lorna Fewtrell. "Water, Sanitation and Hygiene: Interventions and Diarrhoea: A Systematic Review and Meta-analysis." Health, Nutrition and Population Discussion Paper, World Bank, 2004.
3. Connors, Genevieve. "When Utilities Muddle Through: Pro-poor Governance in Bangalore's Public Water Sector." Environment and Urbanization 17, no. 1 (2005): 201-218.
4. Esrey, S. A., R. G. Feachem, and J. M. Hughes. "Interventions for the Control of Diarrhoeal Diseases among Young Children: Improving Water Supplies and Excreta Disposal Facilities." Bulletin of the World Health Organization 63, no. 4 (1985): 757- 772.
5. Harleman, D., and S. Murcott. "An Innovative Approach to Urban Wastewater Treatment in the Developing World." Water 21: Magazine of the International Water Association (June 2001).
6. Mara, Duncan. Low Cost Urban Sanitation. Chichester, UK: John Wiley & Sons, 1996, chapter 2. ISBN: 9780471961635.
7. Murcott, S. Implementation, Critical Factors and Challenges to Scale-Up of Household Drinking Water Treatment and Safe Storage Systems. Background Paper on Household Water Treatment and Safe Storage (HWTS), 2006.
8. Nath, K. J., S. Bloomfield, and M. Jones. Household Water Storage, Handling and Point-of-use Treatment. International Scientific Forum on Home Hygiene, 2006, pp. 5 and 24-29.
9. Parker, D. S., J. Barnard, G. T. Daigger, R. J. Tekippe, and E. J. Wahlberg. "The Future of Chemically Enhanced Primary Treatment: Evolution Not Revolution." Water 21: Magazine of the International Water Association (June 2001).
10. Technical Brief No. 52: Water — Quality or Quantity?" Waterlines 22, no. 4 (2004): 15-18. 11. Howard, Guy, and Jamie Bartram. Domestic Water Quantity, Service Level and Health. World Health Organization, 2003.
11. United Nations Development Programme. Human Development Report 2006 — Beyond Scarcity: Power, Poverty and the Global Water Crisis. New York, NY: United Nations Development Programme, 2006, chapter 1. ISBN: 9780230500587.
12. Water and Sanitation Program. Connecting the Slums: A Utility's Approach in Bangalore. New Delhi, India: Water Sanitation Programme South Asia, 2006.
13. World Health Organization and UNICEF. Meeting the MDG Drinking Water and Sanitation Target: A Mid-term Assessment Report. New York, NY: World Health Organization and United Nations Children's Fund, 2004. ISBN: 9789241562782.
14. World Health Organization and UNICEF. Water for Life — Making It Happen. New York, NY: World Health Organization and UNICEF, 2005. ISBN: 9789241562935.
15. World Health Organization. Combating Waterborne Disease at the Household Level. Geneva, Switzerland: World Health Organization, 2007, ISBN: 978921595223.
16. World Health Organization. Guidelines for Drinking-water Quality. 3rd edition, vol. 1. Recommendations. Geneva, Switzerland: World Health Organization, 2004, chapters 1, 2, 3, 4 and 7. ISBN: 9789241546386.

YEAR III- (SEMESTER-V & VI)

SEMESTER – V

Discipline Specific Core Course 9: Principles of Stratigraphy and Indian Geology (Credits: 06, Theory-06)

(i) Course learning outcome:

1. The study of stratigraphy encompasses the aspects of the age of the earth, chronological arrangement of rocks, and appearance and evolution of life through the geologic time.
2. The knowledge of the concepts in stratigraphy, correlation, and sedimentology would enable the students to understand the changes that occurred in the history of the earth
3. And relate them to their field observations
4. Also, in understanding the framework of the stratigraphy of India.
5. The student will gain knowledge about the stratigraphy and geology of India with emphasis on the Stratigraphy of India with respect to Paleozoic, Mesozoic and Cenozoic Era, which will help in understanding the different episodes on the earth during the geologic past.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9
CLO1	3	1	1				2	3	2
CLO2	3	2	2	2	2		1	1	
CLO3	3	2	2		1	1	2		
CLO4	2	3	2		3	2	1	2	1
CLO5	3	2	2	2	3	2	2		

(ii) Broad contents of the course:

The course intends to introduce students to important geological formations of India, from Precambrian to Recent times. Stratigraphers study the composition and arrangement of layered or stratified rocks. With these objectives in mind, it becomes pertinent to understand the basic concepts of Stratigraphy.

(iii) Skills to be learned:

Students will be exposed to the principles of stratigraphy including order of superposition. At the end of the course, students will acquire skills that will enable to recognize different geological formation, their age and economic potential. They will also learn to correlate International Geological Time Scale with Indian Stratigraphic Time Scale.

(iv)The detail contents of this course and references and suggested books:

Unit 1: (15 hours)

Principles of stratigraphy: Fundamentals of litho-, bio- and chrono-stratigraphy; Introduction to concepts of dynamic stratigraphy (Chemostratigraphy, Magnetostratigraphy, Seismic, and Sequence Stratigraphy)

Unit 2: (15 hours)

Code of stratigraphic nomenclature: International Stratigraphic Code – development of a standardized stratigraphic nomenclature; Concepts of Stratotypes, Global Stratotype Section and Point (GSSP); Principles of stratigraphic analysis, Facies concept in stratigraphy, Walther's Law of Facies

Unit 3: (15 hours)

Physiographic and tectonic subdivisions of India; Precambrian evolution of Peninsular India; Stratigraphy and evolution of Dharwar Craton, Aravalli craton, Singhbhum craton; Archaean System and Central Indian Suture Zone

Unit 4: (10 hours)

Introduction to Himalayas: Physiographic divisions and tectono-magmatic evolution; Precambrian of Extra-Peninsular India; Introduction to Proterozoic basins of India; Geology of Vindhyan and Cuddapah basins of India; Delhi Supergroup

Unit 5: (20 hours)

Phanerozoic Stratigraphy of India: Paleozoic Succession of Kashmir and its correlatives from Spiti and Zanskar; Stratigraphy, structure and hydrocarbon potential of Gondwana basins; Mesozoic stratigraphy of India – Triassic successions of Spiti, Jurassic of Kutch, Cretaceous successions of Cauvery basins; Cenozoic stratigraphy of India – Kutch basin, Siwalik successions, Assam, Andaman and Arakan basins

Unit 6: (15 hours)

Volcanic Provinces of India: Deccan, Rajmahal, Sylhet Traps; Stratigraphic boundaries: Important Stratigraphic boundaries in India - Precambrian-Cambrian boundary, Permian-Triassic boundary, and Cretaceous-Tertiary boundary

Books Recommended:

1. Boggs, S., Jr. (1987) Principles of Sedimentology and Stratigraphy, Meril Publishing.
2. Doyle, P. & Bennett, M. R. (1996) Unlocking the Stratigraphic Record. John Wiley
3. Krishnan, M. S. (1982) Geology of India and Burma, CBS Publishers, Delhi
4. Lemon, R.L. (1990) Principles of Stratigraphy, Meril Publishing.
5. Ramakrishnan M, and Vaidynadhan, R (2008) Geology of India, Geological Society of India Publication, Bangalore. Vol. I & II.
6. Ravindra Kumar (1985) Fundamentals of Historical Geology and Stratigraphy of India, John Wiley.
7. Valdiya, K. S. (2010) The making of India, Macmillan India Pvt. Ltd.
8. Wadia, D., (1973) Geology of India. McGraw Hill Book Co.

Discipline Specific Core Course 10 (T): Structural Geology
(Credits: 04, Theory-04)

(i) Course learning outcome:

1. The course deals with geological structures resulting from the action of these forces on rocks.
2. The student will gain knowledge of the geometry of the rock structures,
3. And to understand the mechanism of the evolution of rock structures and its application in the field.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9
CLO1	3	2	2				2		2
CLO2	3	2	2		2	3	3	1	3
CLO3	3	2	2	3	3	3	2		

(ii) Broad contents of the course:

The course is designed for the students to understand the geometry and mechanics of the various geological structures that result through the deformative processes operative within the earth.

(iii) Skills to be learned:

The students learn the skills of identifying different structure and measurements using Brunton compass. This is fundamental to geological mapping. This course also helps to know how to use structures and help students appreciate the dynamic nature of the Earth lithosphere. Learn how to read geologic maps and solve simple map problems using strike and preparations of cross sections.

(iv) The detail contents of this course and references and suggested books:

Unit 1: (20 hours)

Structure and Topography: Introduction, scope and importance; Introduction to maps: Contour maps, Topographic maps, Geological maps; Concept of dip and strike; Outcrop: Introduction, Patterns of different structures and V-rule; Stress and strain in rocks: Introduction, Stress and Strain in rocks, Concept of rock deformation; Measurement of stress-stain; Stress-strain diagram

Unit 2: (15 hours)

Folds: Introduction, Morphology, Types and classification of folds; Fold mechanisms: Buckling, Bending, Flexural slip and flow folding; Recognition of folds

Unit 3: (15 hours)

Fractures and faults: Introduction, Types and classification of fractures and faults; Recognition of faults; Differences between fractures and faults. Unconformities: types and significance.

Unit 4: (10 hours)

Foliation and lineation: Introduction, Description and Origin, Types and classification, Relationship with folds

Books Recommended:

1. Billings, M.P. (1972) Structural Geology. Prentice Hall
2. Davis, G.R. (1984) Structural Geology of Rocks and Region. John Wiley
3. Ghosh, S. K. (2013) Structural geology: fundamentals and modern developments. Elsevier.
4. Haakon Fossen (2010) Structural Geology. Cambridge University Press.
5. Hills, E.S. (1963) Elements of Structural Geology. Farrold and Sons, London.
6. Jain, A.K. (2014) An introduction to structural geology. Text Book series in Geological Sciences for Graduate Students. Geological Society of India, Bangalore
7. Ramsay, J.G. (1967) Folding and fracturing of rocks. McGraw-Hill, New York
8. Roy, Asit K. (1966) Introduction to the study of geological maps. World Press Private Limited.
9. Singh, R. P. (1995) Structural Geology: A Practical Approach. Ganga Kaveri Publ., Varanasi

Discipline Specific Core Course 10 (P): Practical: Structural Geology
(Credits: 02, Parctical-02)

1. Basic idea of topographic contours
2. Topographic sheets of various scales
3. Introduction to Geological maps: Lithological and Structural maps
4. Structural contouring and 3-point problems of dip and strike
5. Exercises of stereographic projections of mesoscopic structural data (planar, linear, folded, etc.)

Discipline Specific Core Course 11 (T): Paleontology
(Credits: 4, Theory: 4)

(i) Course learning outcome:

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

1. To understand the changes that occurred in the history of the earth
2. Describe the usages of fossils for paleoecology, paleobiogeography, paleoclimate, and paleoenvironment study
3. Explain evolution of vertebrate and microfossils

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9
CLO1	3	2	2		1	1	2		
CLO2	3	2	2		2	3	3	1	3
CLO3	2	3	2		3	2	1	2	1

(ii) Broad contents of the course:

Paleontologists study the fossils which have been preserved in the earth's crust by natural processes and are used to fingerprint a large chunk of the age of the earth in terms of time. Paleontology encompasses study of micro-fossils, plant fossils, vertebrate and invertebrate fossils and their evolution. These aspects are fundamental not only to geology and stratigraphy but to inter-disciplinary fields of paleobotany, paleozoology and evolutionary biology.

(iii) Skills to be learned:

The students will acquire skills of discovering and describing fossils and their taxonomic classification. They will also be introduced to interpreting paleoclimate and paleoenvironment conditions. The students will also acquire skills in identification of invertebrate, vertebrate and plant fossils and in identification of microfossils.

(iv) The detail contents of this course and references and suggested books:

Unit 1: (10 hours)

Fossilization and fossil record. Nature and importance of fossil record; Fossilization processes and modes of preservation; Taxonomy and Species concept Species concept with special reference to paleontology, Taxonomic hierarchy Theory of organic evolution interpreted from fossil record

Unit 2: (10 hours)

Geological Time scale. Concept of Eon, Era, Period, Epoch, Origin of life, Evolution of life with time, Index Fossils though time

Unit 3: (10 hours)

Morphological description of Invertebrates such as Bivalvia, Gastropoda, Brachiopoda, Nautiloids, Ammonites, Belemnites, Trilobites, and Echinoids

Unit 4: (10 hours)

Vertebrate Palaeontology: Brief introduction to various vertebrate groups. Origin and Morphological description of vertebrates. Mesozoic reptiles with special reference to origin, diversity and extinction of dinosaurs, Evolution of horse and intercontinental migrations. Human evolution; vertebrate fossil record from India (Gondwana formations, Deccan volcanic Province, Palaeogene and Neogene sequences of India)

Unit 5: (10 hours)

Palaeoecology – Principles and methods; application of fossils in the study of palaeoecology, palaeobiogeography and palaeoclimate. Ichnology-classification of trace fossils and their utility in palaeoenvironmental reconstructions. Palaeobotany: Early plant life, colonization of land, important stages in plant evolution; Gondwana flora and role of climate in its evolution. Introduction to palynology

Unit 6: (10 hours)

Introduction to Microfossils. Morphological descriptions of Foraminifera, Ostracoda, Radiolaria, Coccolith and diatoms

Books Recommended:

1. Atlas of Benthic Foraminifera by Ann Holbourn, Andrew S. Henderson, Norman MacLeod
2. Atlas of Benthic Shelf Foraminifera of the Southwest Atlantic by Esteban Boltovskoy, Graciela Giussani, Silvia Watanabe, Ramil Wright
3. Benton, M. (2009). Vertebrate paleontology. John Wiley & Sons. 4. Shukla, A. C.
4. Benton, M. 1997. Basic Palaeontology: An introductory text D.Harker Addision Wisely Longman.
5. Brechley, P. J., and Harper, D. A. T. 1998. Palaeoecology: Ecosystems, Environments and Evolution. By Chapman and Hall:
6. Clare Milsom and Sue Rigby (2010). Fossils at a Glance. Wiley-Blackwell. (Second Edition).
7. Clarkson, E. N. K. (2012) Invertebrate paleontology and evolution 4th Edition by Blackwell Publishing.
8. Colbert, E.H. and Minkoff, Eli C. (2001) Evolution of vertebrates, Wiley Liss
9. Cowen, R. (2000) History of Life, Blackwell Science.
10. E. N. K. Clarkson (2013) Invertebrate paleontology and Evolution, Blackwell Science
11. Johansson, C. Z., Underwood, M. Richter, (2019) Evolution and development of Fishes, Cambridge University Press.
12. Michael Benton, (2005) Vertebrate Paleontology, Blackwell Publishing
13. Michael Benton, David A. T. Harper, (2009) Introduction to Paleobiology and the Fossil Record, Wiley-Blackwell.
14. Micropaleontology – Bilal Ulla haq. 1998. Elsevier
15. Misra, S. P. (1975). Essentials of paleobotany. Vikas Publisher 5. Armstrong, H. A., & 23.Brasier, M.D. (2005) Microfossils. Blackwell Publishing
16. Morley Davies (2008) An Introduction to Palaeontology, Read Books.

17. Patrick Wyse Jackson, (2019) Introducing Paleontology: A Guide to Ancient Life, Dunedin Academic Press Ltd.
18. Peter Doyle, Understanding Fossils: An Introduction to Invertebrate Palaeontology.
19. Pratul Kumar Saraswati, M.S. Srinivasan, (2016) Micropaleontology: Principles and Applications, Springer International Publishing Switzerland.
20. Principles of paleontology (2nd edition) – Roop and stanely. 1978. W. H. Freeman
21. Principles of paleontology (3rd edition)-Michael Foote& Arnold I. Miller. 2006. W.H. Freeman
22. Prothero, D.R. 1998. Bringing fossils to life - An introduction to PaJaeobiology, McGraw Hill.
23. Raup, D. M., Stanley, S. M., Freeman, W. H. (1971) Principles of Paleontology 2.
24. Raymond Enay (2012) Paleontology of Invertebrates, Springer-Verlag.
25. Rhona M. Black, (1989) The Elements of Paleontology, Cambridge University Press
26. Roland Goldring, (2014) Field Palaeontology, Routledge
27. S.K. Shah (2013). Elements of Palaeontology. Text-book Series in Geological Sciences for Graduate Students, Geological Society of India.
28. Sreepat Jain (2017) Fundamentals of Invertebrate Palaeontology: Macrofossils, Springer India
29. Willis, K.J. &McElwain, J.C. 2002. The evolution of plants Oxford University Press.

Discipline Specific Core Course 11 (P): Practical: Paleontology (Credits: 2, Practical: 2)

1. Study of diagnostic morphological characters, systematic position, stratigraphic position and age of various invertebrate, vertebrate and plant fossils.
2. Identification of Mega fossils.
3. Identification of Microfossils.
4. Preliminary laboratory analysis of sediments for microfossils study.

Discipline Specific Elective Course 2 (DSE 2): Marine Geology (Credits: 03, Theory-03)

(i) Course learning outcome:

1. Students will understand about the concepts of Marine Geology.

2. Students will understand and learn about the basic concepts of marine geology with respect to geology as to enable them to work as a marine researcher.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9
CLO1	2	1	1	2	3		2	3	2
CLO2	2	2	2		2	3	3	1	3

(ii) Broad contents of the course:

To provide essential concepts of oceanography and to study the tectonics, geology, economic resources with respect to the oceans.

(iii) Skills to be learned:

The students will equip himself with knowledge and skills related to dealing with the physical and chemical components and phenomena related to oceanography and marine geology.

(iv) The detail contents of this course and references and suggested books:

Unit 1: (15 hours)

Introduction to Marine Geology: Definition of Beach, Configuration of beach and various types of Beaches; Definition of Coasts, Different types of coasts, Coastal Processes, Coastal Protection measures, Coastal erosion, Coastal deposition, Coastal landforms (erosion and deposition) and conservation methods; Coastal Regulatory Zones and Its types - Ocean margins and their significance; Continental Margins and its types; Mid Ocean Ridges, Subduction Zones, Marine Sediments, Deep sea sedimentation; Physical oceanography, ocean salinity, ocean currents; Principles behind echo sounder and side scan sonar systems and seismic methods

Unit 2: (15 hours)

Physiographic divisions of oceans; Marine Mineral Resources: Phosphatic nodules, Ferro-Manganese noudules and copper crust, Gas Hydrates; Instruments used in marine geology and sampling techniques; Different types of sediments in the ocean basins and on their margins; Placers - formations, mode of occurrence, mineral composition and distribution; Placer mineral deposits along the Indian coast Estuaries, Deltas, Tidal flats, Marine Tarrace.

Unit 3: (15 hours)

Mineralization due to plate tectonics; Exclusive economic zones and their economic potential; Past historical impact of sea level changes; Hydrothermal vents, Hydrothermal Sulphides, their location, formation and occurrence; Occurrence of hydrothermal activities at different regimes; Application of clay minerals in paleoclimate and paleoenvironmental studies

Books Recommended:

1. Ahmed, E. (1972). Coastal Geomorphology of India. Orient Longman. New Delhi, 222.Tuscot, D.L. and Schubert, G (1992) Geodynamics, Wiley and Sons.
2. Bender, M. (2013) Paleoclimate, Princeton Premiers in Climate
3. Bradley R. S., (1999), Paleoclimatology: Reconstructing climates of the quaternary. Academic Press v. 64 of International Geophysical series.
4. Dronkers J. (2005) Dynamics of coastal systems, World Scientific
5. Einsele, G. (1982) Sedimentary basins-evolution, facies and sediment budget. Springer-Verlag. Ruddiman, W.F. (2008) Earth's Climate, Past and Future, WH Freeman & Co. Shepherd, Submarine Geology.
6. Eugen Seibold (Author), Wolfgang H. Berger (Author); 1996. The Sea Floor: An Introduction to Marine Geology, Springer; 3rd ed. 1996 edition
7. Fowler, C.M.R. (1993) The Solid Earth, Cambridge Press University.
8. James P. Kennett, Marine Geology. Published November 11th 1981 by Prentice Hal
9. Jon Erickson, (1996). Marine Geology: Under Landforms and Life Forms (Changing Earth S.). Facts On File Inc (25 April 1996)
10. Kenneth, J. (1982) Marine Geology and Geophysics.
11. Marine Geology by John Wiley & Sons (1950),
12. Nittrouer, C.A., Austin, J. A., Field M. E., Kravitz J. H., SyvitskiJ. P. M., Wiberg P.L. (2007) Continental margin, sedimentation from sediment transport to sequence stratigraphy, Wiley Blackwell.
13. Physical Geology Earth Revealed (Sixth Edition). 2006. Carlson-Plummer-McGeary. McGraw-Hill
14. The Open University (1989) Ocean chemistry and deep sea sediments.

15. Weisberg J., and Parish,H., Introductory Oceanography. McGraw Hill, 1974.
16. Woodroffe, C.D. (2013) Coast: Form, process and evolution, Cambridge University Press.
17. Wright J. and Colling A. (1995) Seawater: its Composition, Properties and Behaviour, The Open University

OR

Discipline Specific Elective Course 2 (DSE 2): Marine Mineral Resources (Credits: 03, Theory: 03)

(i) Course learning outcome:

1. Students will understand and learn about the basic concepts of Marine Mineral Resources and their importance in terms of a country's growth.
2. Students will understand and learn about the basic concepts of how minerals have been deposited in the marine environment, their formation, processes and their geology as to enable them to work as a marine researcher.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9
CLO1	2	1	1	2	3		2	3	2
CLO2	2	2	2		2	3	3	1	3

(ii) Broad contents of the course:

To provide essential concepts of mineral resources, economic resources with respect to the oceans.

(iii) Skills to be learned:

The students will equip himself/herself with knowledge and skills related with marine mineral resources, and their importance in the world and Indian Economics.

(iv) The detail contents of this course and references and suggested books:

Unit 1: (15 hours)

Introduction and classification of mineral resources; Sources and modes of formation of minerals in the ocean; Chemical and mechanical weathering of rocks on land; Heavy minerals, Placers - formations, mode of occurrence, mineral composition and distribution; Hydrodynamics of Heavy mineral deposits; Placer mineral deposits along the Indian coast

Unit 2: (15 hours)

Phosphorite deposits, formation, distribution, Glauconite, Barium Sulphate concretions, etc.; Petroleum deposits underlying the sedimentary carpet of the shelves; Mineralisation due to plate tectonics; Mineralisation along the continental margin; Exclusive economic zones and their importance with reference to mineral wealth; Mineral wealth of Indian Ocean

Unit 3: (15 hours)

Polymetallic nodules, Physical and chemical aspects of polymetallic nodules, and their formation, Distribution and concentration; Ferromanganese crust, their occurrence and composition; Cobalt crust; Hydrocarbon

deposits; Gas hydrates and their economic potential; Hydrothermal Sulphides, their location, formation and occurrence; Marine mineral laws

Books Recommended:

1. Fowler, C.M.R. (1993) The Solid Earth, Cambridge Press University.
2. Bradley R. S., (1999), Paleoclimatology: Reconstructing climates of the quaternary. Academic Press v. 64 of International Geophysical series.
3. Einsele, G. (1982) Sedimentary basins-evolution, facies and sediment budget. Springer-Verlag. Ruddiman, W.F. (2008) Earth's Climate, Past and Future, WH Freeman & Co. Shepherd, Submarine Geology.
4. Jon Erickson, (1996). Marine Geology: Under Landforms and Life Forms (Changing Earth S.). Facts On File Inc (25 April 1996)
5. Eugen Seibold (Author), Wolfgang H. Berger (Author); 1996. The Sea Floor: An Introduction to Marine Geology, Springer; 3rd ed. 1996 edition
6. James P. Kennett, Marine Geology. Published November 11th 1981 by Prentice Hal
7. Physical Geology Earth Revealed (Sixth Edition). 2006. Carlson-Plummer-McGeary. McGraw-Hill
8. Marine Geology by John Wiley & Sons (1950),
9. Weisberg J., and Parish,H. (1974) Introductory Oceanography. McGraw Hill
10. Ahamed,E. Coastal geomorphology of India. Orient long man, New Delhi
11. Tuscot, D.L. and Schubert, G (1992) Geodynamics, Wiley and Sons.
12. Ghosh, A. K., & Mukhopadhyay, R. (1999) Mineral wealth of the Ocean: A treatise on distribution, origin, exploration, mining and management of sea floor non-living resources. Oxford & IBH, New Delhi.
13. P. Kennett (1981) Marine Geology. Pearson Education (US)
14. Mero, John L. (1965) The mineral resources of the sea. Elsevier oceanography series – 1
15. Shepard, Francis P. (1971) The Earth Beneath the Sea. John Hopkins
16. Shepard, Francis Parker (1967) Submarine geology (2nd. edition). Harper
17. Edmund A Gullian (Ed). (1968) Use of the seas. Englewood Cliffs, N.J., Prentice-Hall
18. Trask, P.D. (1955) Recent Marine Sediments.
19. Kenneth, J. (1982) Marine Geology and Geophysics.
20. Wright J. and Colling A. (1995) Seawater: its Composition, Properties and Behaviour, The Open UniversityThe Open University (1989) Ocean chemistry and deep sea sediments.
21. Dronkers J. (2005) Dynamics of coastal systems, World Scientific
22. Woodroffe, C.D. (2013) Coast: Form, process and evolution, Cambridge University Press.
23. Nittrouer, C.A., Austin, J. A., Field M. E., Kravitz J. H., SyvitskiJ. P. M., Wiberg P.L. (2007) Continental margin, sedimentation from sediment transport to sequence stratigraphy, Wiley Blackwell.
24. Bender, M. (2013) Paleoclimate, Princeton Premiers in Climate

OR

Discipline Specific Elective Course 2 (DSE 2): Coal and Petroleum Geology (Credits: 03, Theory: 03)

(i) Course learning outcome:

Students will be able to

1. Understand the basic concepts of petroleum geology, which will enable them to work as a petroleum geologist
2. Gain knowledge on physical and chemical properties of petroleum

3. Acquire acquaintance on prospecting, drilling, and logging techniques of petroleum
4. Know fundamental aspects of coal such as origin, formation, types, physical properties and depositional environments
5. Distinguish between different types of coal based on physical, chemical and petrographical and other properties

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9
CLO1	3	2	3	2	2	3	3	3	2
CLO2	3	2	2			3	2	3	1
CLO3	2		2			2	2	2	1
CLO4	3	2	3	2	2	3	3	3	2
CLO5	3	2	2			3	3	3	1

(ii) Broad contents of the course:

To provide the student essential and basic concepts of coal and petroleum geology and to study the process and the operations involved in it.

(iii) Skills to be learned:

Students will be appraised about the origin, migration and accumulation of coal and petroleum. It will also provide basic skills in prospecting, drilling and logging operation in oil exploration. Students will acquire the concept of coal and their classification, broad knowledge of tertiary and Gondwana coalfields of India and application of the coal in various industries.

(iv) The detail contents of this course and references and suggested books:

Unit 1: (15 hours)

Occurrence of petroleum, nature of source rock; Classification and composition of petroleum products; Physical properties of petroleum, composition of biomass; Classification of reservoir rocks; Hydrocarbon traps - structural, stratigraphic and combination; Migration of oil and gas: primary and secondary migration, geologic factors controlling hydrocarbon migration; Oil field waters

Unit 2: (15 hours)

Kerogen- Composition and types; Prospecting, Drilling and Logging, and subsurface correlation; Geophysical prospecting for petroleum; Oil bearing basins of India and world; Introduction to petroleum geology of Assam, Bengal, Cauvery, Krishna-Godavari, Cambay and Bombay offshore basins; India's position with regard to petroleum and natural gas future prospects

Unit 3: (15 hours)

Coal and its properties: Coal Classification and ranks of coal; Coal bed methane – definition, origin of coal bed methane, Coalification process and its causes; Geological controls of methane generation from coal; Lithotypes, microlithotypes and macerals: their physical, chemical and optical properties; Introduction to geology of different Tertiary and Gondwana coalfields of India; Industrial evaluation of coal; Application of coal petrography; Proximate and ultimate analyses; Uses of coal for various industries, e.g., carbonization, liquefaction power generation, gasification, and coalbed methane production

Books Recommended:

1. Chandra, D., Singh, R.M. Singh, M. P. (2000): Textbook of Coal (Indian context), Tara Book Agency.

2. Gayer, R. and Harris, I. (1996): Coal Bed Methane and Coal Geology, Geological Soc. Special Publ., London.
3. Hunt, J.M. (1996) Petroleum Geochemistry and Geology, W.H. Freeman
4. Levorsen, A.I, (2004) Geology of Petroleum, CBS Publishers and Distributors
5. North, F.K. (1986) Petroleum Geology, Allen & Unwin, London. 607p
6. Selley, R.C., 1998, Elements of Petroleum Geology: W.H. Freeman & Company, New York.
7. Singh, M.P. (Ed.) (1998): Coal and Organic Petrology, Hindustan Publ. Co.
8. Stach, E., Mackowsky, M-Th., Taylor, G.H., Chandra, D., Teichumullelr, M. and Teichmuller R. (1982): Stach Texbook of Coal Petrology, Gebruder Borntraeger, Stuttgart.
9. Taylor, G.H., Teichmüller, M., Davis, A., Diessel, C.F.K., Littke, R., Robert, P., 1998. Org. Petrol. Gerbrüder Borntraeger, Berlin.16, 704. 2. vanKrevelen, D.W., 1993. Coal: Typology-chemistry-physics-constitution. Elsevier Science, Amsterdam, 963. 10.
10. Thomas, Larry (2002): Coal Geology, John Wiley and Sons. Van Krevelen, D. W. (1993): Coal (typology-physics-chemistry-constitution), Elsevier Science.
11. Tissot, B.P. and Welte, D.H. (1984) Petroleum Formation and Occurrence, Springer- Verlag, Berlin.

OR

Discipline Specific Elective Course 2 (DSE 2): Isotope Geochemistry (Credits: 03, Theory: 03)

(i) Course learning outcome (CLOs):

On successful completion of the course the student will be able to

1. Understand the basic principles of isotope systematics used in geoscience
2. Understand different analytical methods to measure elemental and isotopic concentrations
3. Acquire basic knowledge of geochronology
4. Develop knowledge on the application of isotope geochemistry in petrogenetic interpretations

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9
CLO1	3	1	1		3		2	2	2
CLO2	3	1	1		3		2	2	2
CLO3	2	2	1		2		1		1
CLO4	3	2	1		2		1		2

(ii) Broad contents of the course:

The course aims to allow the student to use stable and radiogenic isotopes to track different processes in the different reservoirs of the earth. The course also aims to allow the student to understand and apply the most used techniques for the geochronology.

(iii) Skills to be learned:

The students will acquire skills required for using isotope geochemistry in unrevealing the geological processes.

(iv) The detail contents of this course:

Unit 1: (15 hours)

Geochemical classification of elements; Analytical techniques and Mass spectrometers; Geochemical data – Major elements, Trace elements, Radiogenic and Stable isotopes – and their uses; Radioactive decay and basic principles of geochronology; Isochron calculations, Model ages, Closure temperature; Interpretation of geologic age; Whole rock and mineral age method

Unit 2: (15 hours)

Different isotopic systems used in Geochronology; Principles of K–Ar, Ar–Ar, Rb-Sr, U–Th–Pb, Sm–Nd, Lu–Hf and Re–Os methods; Plotting and interpreting isochron using software; Radiogenic isotopes and Petrogenesis

Unit 3: **(15 hours)**

Principles of Stable isotope geochemistry, Isotopic fractionation; Different notations used in stable isotope geochemistry; Traditional stable isotopes – H, C, N, O and S – and their uses; A brief introduction to some non-traditional stable isotopes - Li, Mg, Si, Cr and Fe

Books Recommended:

1. Albarède, F. (2003). Geochemistry: an introduction. Cambridge University Press
2. Dickin, A. P., Radiogenic Isotope Geology. Cambridge University Press, 1995
3. Faure, G. and Mensing, T. M., Isotopes: Principles and Applications, 3rd Edn. John Wiley & Sons, 2005
4. Geyh, M. A. and Schleicher, H., Absolute age determination. Springer,1990
5. Hoefs, J., Stable Isotope Geochemistry, 3rd Edn. Springer-Verlag, 1987
6. Longman U.K. Faure, G., Principles of Isotope Geology, 2nd Edn. John Wiley & Sons, 1986
7. Mason, B. (1986) Principles of Geochemistry. 3rd Edition, Wiley New York.
8. Rollinson, H. (2007) Using geochemical data – evaluation, presentation and interpretation. 2nd Edition. Publisher Longman Scientific & Technical.
9. Sharp Zachary (2006). Principles of Stable Isotope Geochemistry. Prentice Hall
10. Walther, J. V. (2009). Essentials of geochemistry. Jones & Bartlett Publishers
11. White, M. William (2014). Isotope Geochemistry. Wiley – Blackwell

Value Addition Courses 3 (VAC 3): Fieldwork: Geological Field Methods and Mapping (Credits: 02)

(i) Course learning outcome:

1. This course is devised to provide basic knowledge of geological mapping and surveying techniques.
2. It also will upgrade and relate the theoretical knowledge of geological aspects to field observations.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9
CLO1	3	1	1	2	3		2	3	2
CLO2	2	2	1		2	2	3	1	3

(ii) Broad contents of the course:

Students will be expected to understand how preliminary surveys are carried out especially in mining and natural resource bearing areas. They would be trained to work independently in the field of geological mapping and sampling.

(iii) Skills to be learned:

Skill of using of Brunton Compass and GPS is only taught and learnt in the field. Hence, these are imperative to geological mapping and preparation of cross sections.

(iv) The detail contents of this course and references and suggested books:

Students will make geological observations in the field, record data in field notes, and prepare geological maps (equivalent to 30 lectures or at least 05 days).

An introduction to geological field methods and mapping and use of Brunton Compass and GPS.

Topics include: field safety, logistics, navigation, field mapping techniques and data collection, toposheet reading, interpretation of geological data and maps, and communicating geological information.

Books Recommended:

1. Compton Robert R. (1962) Manual of Field Geology John Wiley & Sons.
2. Field Geology McGraw – Hill Book Company, Inc. 6thed.
3. Gokhale N.W. (2001) A Guide to Field Geology. CBS Publishers & Distributors 1st ed.
4. Lahee Fredrick H. (1961) Geology in the field by Robert R. Compton, John Wiley &Sons.
5. Mathur S.M. (2004) Guide to Field Geology, PHI.

SEMESTER – VI

Discipline Specific Core Course 12: Mineral Exploration and Mining (Credits: 06, Theory-06)

(i) Course learning outcome:

By the end of this course, the student will be able to

1. Understand the basic concepts of mineral exploration.
2. Understand the geological methods of mineral exploration.
3. Understand the geochemical methods of mineral exploration
4. Understand different mining methods
5. To understand environmental impact of mining, and the importance conservation of mineral resources

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9
CLO1	3	3	2				2		2
CLO2	3	1	1	2	3		2	3	2
CLO3	3	1	1	2	3		2	3	2
CLO4	3	1	1		2		2	3	2
CLO5	3	1	2		3	1	2		1

(ii) Broad contents of the course:

The course covers introductory aspects, classification of mineral deposits, basic and advanced methods in geological exploration for mineral deposits and geochemical methods of mineral exploration. Mining being a key source of revenue generation for the Central as well as State governments, and an important job provider for Geologists, this course is designed to equip the students with basic knowledge of key concepts of mining processes right from exploration to exploitation, together with an acquaintance of government regulations that control the mining and mineral conservation processes.

(iii) Skills to be learned:

Students will be exposed to the skills of geological and structural mapping, sampling of different geological media, core-logging and geochemical sampling programs and identifying anomalies. In addition, students will acquire knowledge and skills required for himself/herself becoming a mining geologist.

(iv) The detail contents of this course and references and suggested books

Unit 1: (10 hours)

Introduction to mineral exploration: Definition and objective; Principles of mineral exploration – The rationale of mineral exploration, Basic principles of mineral exploration; Different activities included in a mineral exploration program (geological and structural mapping at different scales, sampling of geological media, geochemical analysis, drilling, ore reserve estimation, feasibility study etc.), Different phases of activities included in a mineral exploration program; Resource-Reserve definitions; Measured, Indicated and Inferred Resources; United Nations Framework Classification (UNFC) for Mineral Reserves and Resources

Unit 2: (15 hours)

Stages in Mineral Exploration: Different stages in mineral exploration viz. G4-Reconnaisance Stage, G3-Prospecting Stage, G2-General exploration stage, and G1-Detailed exploration stage; Geological methods of mineral exploration: Geological and structural mapping as part of a mineral exploration program, Techniques and Scales of geological and structural mapping, Measuring and recording structures; Sampling as a part of mineral exploration – Random sampling, Chip sampling, Channel/Groove sampling, Bulk sampling and Coning-and-Quartering, Subsurface sampling through pitting and trenching; Drilling as part of a mineral exploration program – Purpose and importance of drilling; Factors controlling choice of drilling type, Simple drilling techniques like hand auger and screw auger, Introduction to Drilling types for hard rocks, Technique of core preservation, sampling and logging.

Unit 3: (20 hours)

Geochemical exploration: Introduction; Geochemical anomaly and its types; Geochemical cycle, Principles of geochemical exploration, Geochemical environment, Dispersion, Mobility of elements and tracers, Patterns of atmochemical distribution and atmochemical anomalies; Primary and Secondary dispersions and classifications, Geochemical soil surveys, Soil profiles in drainage sediments, Geochemical drainage survey, Biogeochemical anomalies, Biogeochemical survey techniques; Geobotanical indicators in mineral exploration

Unit 4: (15 hours)

Introduction, Terminologies used in mining, Scope and aim of mining, Life cycle of a mine, Factors controlling the availability of mineral deposit for mining; Methods of Surface/open pit mining/quarrying; Alluvial/placer deposits mining

Unit 5: (15 hours)

Introduction to underground mining, terminologies used in underground mining, Stoping and types of stoping: open and closed; Methods of underground mining: room and pillar method, vein mining, shrinkage stoping, sublevel stoping, LDH stoping, vertical carter retreating, cut and fill, long wall mining; Caving: block caving and sublevel caving

Unit 6: (15 hours)

Coal mining methods: Surface and underground mining, Methods of drilling and interpretation of drill core data; Environmental hazards due to mining and mine safety; Brief outline of the mining acts and regulations in India

Books Recommended:

1. Arogyaswamy R.N.P. (1973) Courses in Mining Geology, Oxford and IBH Publishers Co. Ltd., 916 pages
2. Babu S. K. and Sinha D. K. (1988) Practical Manual of Exploration and Prospecting, CBS Publishers and Distributors, New Delhi
3. Dobrin, M. B. (1960) Geophysical prospecting, McGrath Hill.
4. Gandhi, S. M. and Sarkar B. C. (2016) Essentials of Mineral Exploration and Evaluation. Elsevier
5. Halder, S. K. (2018) Mineral Exploration: Principles and Applications. Second edition. Elsevier
6. Krieter, V. M. (2004) Geological prospecting and exploration, University Press of Pacific.
7. Majoribanks Roger (2010) Geological Methods in Mineral Exploration and Mining. Second edition, Springer
8. McKinstry H. E. (1980) Mining Geology, Prentice Hill Inc., 667 pages.
9. Moon, Charles J., Whateley, Michael K.G. and Evans, Anthony M. (Editors) (2006) Introduction to Mineral Exploration. Second edition, Blackwell Publishing

10. Roonwal, G. S. (2018) Mineral Exploration: Practical Application. Springer
11. Rose, Howkes and Webb (1979) Geochemistry in mineral exploration, Academic Press.
12. Sharma J. P.(2009) Environmental Studies, Laxmi Publications (P) Ltd, New Delhi, Indian Bureau of Mines publications
13. Sinha R. K. and Sharma N. L. (1989) Mineral Economics, Oxford and IBH Publishers Co. Ltd, 4th Edition

Discipline Specific Core Course 13 (T): Hydrogeology
(Credits: 04, Theory-04)

(i) Course learning outcome:

On completion of the course, the student will able to

1. Understand the Hydrological cycle and its components in detail
2. Know the occurrence of water in the subsurface and its vertical distribution in the subsurface
3. Understand the inter-relationship between properties of earth materials and water occurrence in them
4. Acquire knowledge on groundwater flow dynamics in the subsurface
5. Understand the physico-chemical composition of water and basic concepts of water management

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9
CLO1	3	2	2	1	1	1	2	2	
CLO2	3	1	1	1	3	2	2	3	2
CLO3	3	1	1	1	3	2	2	3	2
CLO4	2	2	3	3	2	2	1	1	
CLO5	3	2	3	2	2	1			2

(ii) Broad contents of the course:

This course starts with introductory aspects of hydrogeology and covers various topics ranging from hydrological cycle, vertical distribution of water in the subsurface, relation between properties of earth materials and occurrence of water to groundwater flow, composition of natural waters and basic aspects of water management.

(iii) Skills to be learned:

Students will gain skills of calculating different components of hydrological cycle, quantifying properties such as porosity and effective porosity, calculating multiple components of groundwater flow and determining flow direction of groundwater, etc.

(iv) The detail contents of this course and references and suggested books:

Unit 1: (5 hours)

Introduction to hydrogeology: Terminology viz. hydrogeology, Importance and uses of water, Distribution of water resource on planet Earth; Global Hydrological Cycle: Background Information (Concept of a System, Types of a System with examples, States of Matter, Phase Transformations and Phase Transformations, Definition of a Cycle with examples); Introduction of the hydrological cycle: Definition and description of the hydrological cycle and, Hydrologic Equation

Unit 2: (17 hours)

Definition and detailed study of the components of the hydrological cycle viz. Precipitation (definition, formation, global precipitation, types of precipitation, types and classification of rain gauges and, measurement of precipitation), Hydrologic Equation, Evaporation and Evapotranspiration (definition and physics of evaporation – latent heat, humidity and its types, various controls on evaporation, measurement of evaporation), Transpiration – Definition, Evapotranspiration (Definition, types and measurement), Streamflow and Runoff (Terminology – Interception, infiltration, Overland flow, Streamflow, Stream Network, Drainage Basin and related terms; Streamflow measurement), Infiltration and its measurement

Unit 3: (18 hours)

Vertical distribution of water in the sub-surface: Major divisions and their definitions (Zones of Aeration and Saturation, their vertical extent, Forces at work in the zone of aeration, pressure differentials in the two zones and the effect on groundwater withdrawal, Water Table and its identification, Difference between Water Table and Static Water Level), Minor divisions within the Zone of Aeration and their characters (Soil Water Zone, Intermediate Vadose Zone and the Zone of Capillary Water); Hydrological Properties of Rocks (Terminology – Pervious and impervious earth materials, properties of storativity and transmitivity, Porosity – Definition and its mathematical expression, Kinds of porosity on the basis of the time of their formation viz. primary and secondary porosity, Kinds of porosity on the basis of their origin i.e. Genetic classification viz. Intergranular porosity, fracture porosity, micro-porosity, vugular porosity and intragranular porosity; Factors affecting porosity, Examples of porosity of different earth materials, Effective porosity – Definition, mathematical expression and examples; Permeability – Definition and examples)

Unit 4: (20 hours)

Water bearing earth formations: Aquifer, Aquitard, Aquiclude and Aquifuge. Examples for each of these earth formations; Types of aquifers: Unconfined-, Perched-Confined- and Semi-confined aquifers and their examples;

Groundwater Flow: Darcy's Law and related terminology like manometer/piezometer, hydraulic head, hydraulic conductivity, hydraulic gradient, specific discharge; Applicability of Darcy's Law; Bernoulli Equation; Flow Nets – Determination of groundwater flow direction and hydraulic gradient; Types of groundwater flow (viz. laminar flow and turbulent flow) and their mathematical expression and Reynold's Number;

Physical and chemical properties of water: Nature of water, Solutes in water – the dissolved solids, units of solute concentration, physico-chemical characters of natural waters including physical parameters like temperature, odour, taste, clarity and turbidity, TDS, TSS, Electrical conductivity; chemical composition of natural waters (rain water, sea water, groundwater) including major, secondary and trace constituents and their sources; Suitability of water for drinking and, global and Indian drinking water standards;

Introduction to Water Management: Need for management of water resources, Basic concepts of groundwater management (i.e. concepts of safe yield and sustainable yield); Groundwater balance and its equation; Rainwater harvesting and artificial groundwater recharge practices as part of water management plan

Books Recommended:

1. A Glossary of Hydrogeological Terms by John M. Sharp, Jr. Department of Geological Sciences, The University of Texas, 2007.

2. Applied Hydrogeology by C. W. Fetter Jr. Pearson Education Limited, 2014, Fourth edition.
3. Applied hydrogeology of fractured rocks by B. B. S. Singhal and R. K. Gupta, 2010, Second edition.
4. Fundamentals of Hydrology by Tim Davie. Routledge, 2008, Second edition.
5. Ground Water Assessment: Development and Management by K. R. Karanth. Tata McGraw-Hill Publishing Company Limited, 1987.
6. Groundwater Hydrology by David K. Todd and Larry W. Mays. John Wiley and Sons Inc., 2005, Third edition.
7. Groundwater Resources of the World and Their Use by Igor S. Zektser and Lorne G. Everett (Editors). UNESCO, 2004.
8. Hydrogeology: Principles and Practice by Kevin M. Hiscock and Victor F. Bense. Wiley Blackwell, 2014, Second edition.
9. Hydrology: Principles, Analysis, and Design by H. M. Raghunath. New Age International Publishers, 2006, Revised Second edition.
10. Introduction to Hydrology by Warren Viessman Jr. and Gary Lewis. Printice Hall, 2003, Fifth edition.

Discipline Specific Core Course 13 (P): Practical: Hydrogeology (Credits: 02, Parctical-02)

1. Numerical problems related to porosity and permeability
2. Preparation and interpretation of water level contour maps and depth to water level maps study, preparation and analysis of hydrographs. Water potential zones of India (map study), Groundwater flow

Discipline Specific Core Course 14 (T): Engineering Geology (Credits: 04, Theory-04)

(i) Course learning outcome:

1. Upon completion of the course the student will become aware of the importance of geological studies
2. And its applicability to various engineering problems.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9
CLO1	3	1	1				2	3	2
CLO2	3	2	2	2	2		1	1	

(ii) Broad contents of the course:

To impart sufficient knowledge of engineering geology so as to be able to anticipate the technical problems related to geology of various engineering sites and suggest possible remedial measures.

(iii) Skills to be learned:

The student will be educated on geological site investigations for engineering structures and will provide skills in geological mapping and making geotechnical measurements.

(iv) The detail contents of this course and references and suggested books:

Unit 1: (10 hours)

Engineering Geology: Introduction, importance, stages of engineering projects, and role of engineering geology

Unit 2: (15 hours)

Engineering properties of rocks: Introduction, physical and geomechanical properties; Building stones, cladding stones, flooring stones, roofing stones, pavement stones, decorative stones; Road metal and concrete aggregates

Unit 3: (15 hours)

Geological investigation: Stages of engineering geological investigation for civil engineering projects; Geological consideration for evaluation of dams, reservoir sites, bridges, highways and tunnels

Unit 4: (20 hours)

Rock mechanics: Introduction, Rock mass and rock mass classification - RQD, RSR, RMR, Tunneling quality index; Grout and grouting; Ground improvement and support; Earthquakes and buildings – Introduction, seismic zones of India, aseismic design of buildings and geological considerations in aseismic design; Case history of Indian civil engineering projects

Books Recommended:

1. Blyth, F.G.H. and M. H. de Freitas (1984) Geology for Engineers, Butterworth- Heinemann Title
2. Chenna Keshvallu (2018) Text book of Engineering Geology, Laxmi Publications.
3. Gokhale, K.V.G. (2006) Principles of engineering geology, BS publications.
4. Krynine, D.P and Judd, W.R (2005) Principles of Engineering Geology and Geotechniques, CBS Publishers & Distributors
5. Ries, H. and T. L. Watson, (1949) Elements of Engineering Geology, New York, John Wiley & Sons, Inc.
6. Tony Waltham (2009) Foundations of Engineering Geology, Taylor and Francis.

Discipline Specific Core Course 14 (P): Practical: Engineering Geology (Credits: 02, Parctical-02)

1. Problems related to foundations, dam, tunnel, road and bridge and mines.
2. Problems related to Geotechnical Engineering.
3. Problems related investigation of slope and building stones.

Discipline Specific Elective Course 3 (DSE 3): Geogenic disasters (Credits: 03, Theory-03)

(i) Course learning outcome:

1. Students will be able to understand the basic concept of geogenic disasters, cause and type of geogenic disasters
2. Able to differentiate between hazards and disasters
3. Able to learn the disaster management strategies

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9
CLO1	3	2	3	3	2	3	3	3	2
CLO2	3	3	3			2	2	3	1
CLO3	2		2			2	3	2	2

(ii) Broad contents of the course:

This course covers topics on Geogenic disasters such as Earthquake, Volcanoes, Cyclones, Floods, Landslides, Coastal Hazards (Tsunami) and Mining Hazards with their impact and management.

(iii) Skills to be learned:

Students will acquire skills related to different type of disasters and management strategies.

(iv) The detail contents of this course and references and suggested books:

Unit 1: (15 hours)

Earth and atmospheric processes; Basics of plate-tectonics; Distinction between hazard and disaster, Definition and type of disaster; Introduction to Geogenic disasters: Earthquakes, Volcanoes, Cyclones, Floods, Landslides, Coastal Hazards (Tsunami), Mining Hazards; Natural hazard zones

Unit 2: (15 hours)

Earthquakes: Origin of earthquakes, seismic waves, hazards associated with earthquakes, response to earthquake hazards; Volcanoes: Causes and types of volcanoes; Cyclones: Genesis, tropical cyclones- formation, frequency and trajectory, impact of cyclones, mitigation and adaptation; Floods: Causes and factors of flooding, effects/hazards associated with flooding

Unit 3: (15 hours)

Tsunami: Cause and impact, types of tsunamis, response to hazards- mitigation and adaptation; Landslides: Genesis (slope failure mechanism), causes of landslides, prevention and correction methods; Mining hazards; Disaster management: causes, immediate effects and management

Books Recommended:

1. Bell, F.G. (1999) Geological Hazards, Routledge, London.
2. Bird, Eric (2000) Coastal Geomorphology: An Introduction. John Wiley & Sons, Ltd. Singapore.
3. Blyth, F.G.H. and M. H. de Freitas (1984) Geology for Engineers, Butterworth-Heinemann Title
4. Bryant, E. (1985) Natural Hazards, Cambridge University Press.
5. Keller, E. A., (2000) Environmental Geology. Shales E. Merril Publishing Co., Columbus, Ohio.
6. Krynine, D.P and Judd, W.R (2005) Principles of Engineering Geology and Geotechniques, CBS Publishers & Distributors
7. Liu, B.C. (1981) Earthquake Risk and Damage, Westview.
8. Montgomery, C. (1984) Environmental Geology. John Wiley and Sons, London.
9. Ries, H. and Watson, T. L. (1949) Elements of Engineering Geology, New York, John Wiley & Sons, Inc.
10. Selby, M.J. (1996) Earths Changing Surface. Oxford University Press UK.
11. Sharma, J. P. (2009) Environmental Studies, Laxmi Publications (P) Ltd, New Delhi
12. Smith, K. (1992) Environmental Hazards. Routledge, London.
13. Subramaniam, V. (2001) Textbook in Environmental Science, Narosa International
14. Thornbury W. D. (1997) Principles of Geomorphology Wiley Eastern Ltd., New Delhi.
15. Valdiya, K. S. (1987) Environmental Geology - Indian Context. Tata McGraw Hill New Delhi.

OR

Discipline Specific Elective Course 3 (DSE 3): Disaster Management (Credits: 03, Theory-03)

(i) Course learning outcome:

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

1. Explain various types of disasters, risk assessment and management strategies
2. Understand causative factors, vulnerability, predictability, and technological approaches in disaster managements
3. Illustrate application of remote sensing and GIS in disaster management.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9
CLO1	3	2	3	3	2	3	3	3	2
CLO2	3	2	3			3	2	2	2
CLO3	3		2			2	3	2	2

(ii) Broad contents of the course:

This course covers topics on management of different types of disasters such as Earthquake, Volcanoes, Cyclones, Floods, Mass movements, Tsunami, Mining Hazards with their management.

(iii) Skills to be learned:

Students will acquire skills related to different type of risk and hazards, their management, various aspects of remote sensing and GIS in risk management.

(iv) The detail contents of this course and references and suggested books:

Unit 1: (15 hours)

Definition and causes of disasters, Types of disasters: Earthquakes, Volcanoes, Cyclones, Floods, Mass movements, Tsunamis, Mining Hazards

Unit 2: (15 hours)

Natural hazard zones and impact assessment; Prediction of volcanic eruptions and mitigation of volcanic hazards, risk assessment; Cyclone and flood hazards in India, causative factors, vulnerability, predictability (forecasting) and mitigation measures; Technological approaches (e.g., dams and levees) and land-use planning (floodplain mapping and zoning) approaches to avoid flood damages

Unit 3: (15 hours)

Mitigation of droughts; Identification of landslides zones, control measures, mitigation and concept of safety factor, evaluation of technologies for landslide prevention; Application of remote sensing and GIS in Disaster Management; Role of geologists in disaster management plan; Conservation of natural resources

Books Recommended

1. Bell, F.G. (1999) Geological Hazards, Routledge, London.
2. Bird, Eric (2000) Coastal Geomorphology: An Introduction. John Wiley & Sons, Ltd. Singapore.
3. Blyth, F.G.H. and M. H. de Freitas (1984) Geology for Engineers, Butterworth-Heinemann Title
4. Bryant, E. (1985) Natural Hazards, Cambridge University Press.
5. Keller, E. A. (2000) Environmental Geology. Shales E. Merril Publishing Co., Columbus, Ohio.

6. Krynine, D.P and Judd, W.R (2005) Principles of Engineering Geology and Geotechniques, CBS Publishers & Distributors
7. Liu, B.C. (1981) Earthquake Risk and Damage, Westview.
8. Montgomery, C. (1984) Environmental Geology. John Wiley and Sons, London.
9. Ries, H. and T. L. Watson (1949) Elements of Engineering Geology, New York, John Wiley & Sons, Inc.
10. Selby, M.J. (1996) Earths Changing Surface. Oxford University Press UK.
11. Sharma J. P. (2009) Environmental Studies, Laxmi Publications (P) Ltd, New Delhi
12. Smith, K. (1992) Environmental Hazards. Routledge, London.
13. Subramaniam, V. (2001) Textbook in Environmental Science, Narosa International
14. Thornbury W. D. (1997) Principles of Geomorphology Wiley Eastern Ltd., New Delhi.
15. Valdiya, K. S. (1987) Environmental Geology - Indian Context. Tata McGraw Hill New Delhi.

OR

Discipline Specific Elective Course 3 (DSE 3): Gemmology
(Credits: 03, Theory-03)

(i) Course learning outcome:

The basic idea is to make students well versed with the different terminologies used in the gem industry and to provide skills to become a successful gemologist.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9
CLO1	3	2	1		1		2		2

(ii) Broad contents of the course:

The course covers the various aspects of gem testing using both theoretical as well as lab work by dealing with basics to the advanced techniques of gemstone identification. Further, it deals with the methods employed by diamond industry in cutting a rough diamond into a sparkling gem and how diamonds are graded internationally. Why synthetic gemstones have flooded the market and how they are manufactured is then next topic, including their detection.

(iii) Skills to be learned

The students will acquire skills which will be useful to them in the gem industry.

(iv) The detail contents of this course and references and suggested books

Unit 1: (10 hours)

Gemmology: Introduction to Gems, basic properties of gems, Formation of gem stones, Use of refractometers, Polariscope, Dichroscope, Methods of Specific Gravity determination, Causes of colors in gemstones.

Unit 2: (10 hours)

Introduction to special optical properties like chatoyancy, asterism, luminescence, play of colors, labradorescence, inclusions etc., Distinction between synthetic and natural gem stones.

Unit 3: (15 hours)

Use of Gem Testing Instruments: hand lens (10x), Detection of double refraction, by observing pleochroic colors with the Dichroscope, Identification of gemstones on the basis of pleochroic colors; Detection of double refraction, interference figures and internal strain with the Polariscope

Unit 4: (10 hours)

Study of the fluorescent colors exhibited by various gemstones under Ultraviolet (long wave and short wave) light, Measurement of refractive indices and birefringence tests using a gem-testing Refractometer.

Books Recommended:

1. Babu T.M (1998) Diamonds in India, Geological Society of India
2. Fareeduddin & R. H. Mitchell (2012) Diamonds and their Source rocks in India, Geological society of India
3. Karanth R.V (2000) Gems and Gem Industry in India, Geological society of India
4. Karanth R.V (2008) Gemstones Enchanting Gifts of Nature, Geological society of India
5. Read, P. G. (1991) Gemmology, Butterworth-Heinemann Ltd.
6. Sinkankas, J. (1969) Mineralogy: A First Course, Van Nostrand Reinhold Company.
7. Webster, R. and edited by Anderson, B.W. (1983) Gems: Their Sources, Descriptions and Identification, Butterworth-Heinemann Ltd

Skill Enhancement Courses 4 (SEC 4): Geostatistics
(Credits: 02, SEC-02)

(i) Course learning outcome:

1. To understand basic statistical analysis for geological data

2. To apply statistical analyses for geological database

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9
CLO1	3	3	2		2		1		
CLO2	2	3	3	2	1	2	1		2

(ii) Broad contents of the course:

The course includes introductory aspects of geostatistics, use of graphical representation and statistical management of geological data.

(iii) Skills to be learned:

The students will acquire skills related to statistical representation and analyses of geological data using real datasets.

(iv) The detail contents of this course and references and suggested books:

Unit 1: (15 hours)

Introduction, Need and importance of statistics in the field of geology; Data types; Frequency distribution; Graphical representation of geological data; Measures of Central Tendency, Measures of Dispersion, Skewness and Kurtosis

Unit 2: (15 hours)

Introduction to multivariate analysis: Correlation analysis, Regression analysis, Principal Component Analysis, and Cluster Analysis.

Books Recommended:

1. Introduction to Geostatistics: Applications in Hydrogeology by P. K. Kitanidis. Cambridge University Press, 1997
2. An Introduction to Applied Geostatistics by Edward H. Isaaks and R. Mohan Srivastava. Oxford University Press, 1989
3. Geostatistics for Environmental Scientists by Richard Webster and Margaret A. Oliver. Wiley, 2007
4. Geostatistics for Natural Resource Evaluation by Pierre Goovaerts. Oxford University Press, 1999
5. Geostatistics for Engineers and Earth Scientist by Ricardo A. Olea. Springer, 1999

OR

Skill Enhancement Courses 4 (SEC 4): Fieldwork
(Credits: 02, SEC-02)

(i) Course learning outcome:

1. This course is devised to provide basic knowledge of geological mapping and surveying techniques.
2. It also will upgrade and relate the theoretical knowledge of geological aspects to field observations.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9
CLO1	3	1	1	2	3		2	3	2
CLO2	2	2	1		2	2	3	1	3

(ii) Broad contents of the course:

Students will be expected to understand how preliminary surveys are carried out especially in mining and natural resource bearing areas. They would be trained to work independently in the field of geological mapping and sampling.

(iii) Skills to be learned:

Skill of using of Brunton Compass and GPS is only taught and learnt in the field. Hence, these are imperative to geological mapping and preparation of cross sections.

(iv) The detail contents of this course and references and suggested books:

Students will make geological observations in the field, record data in field notes, and prepare geological maps (equivalent to 30 lectures or at least 05 days).

An introduction to geological field methods and mapping and use of Brunton Compass and GPS.

Topics include: field safety, logistics, navigation, field mapping techniques and data collection, toposheet reading, interpretation of geological data and maps, and communicating geological information.

Books Recommended:

1. Field Geology McGraw – Hill Book Company, Inc. 6thed.

2. Compton Robert R. (1962) Manual of Field Geology John Wiley & Sons.
3. Lahee Fredrick H. (1961) Geology in the field by Robert R. Compton, John Wiley &Sons.
4. Gokhale N.W. (2001) A Guide to Field Geology. CBS Publishers & Distributors 1st ed.
5. Mathur S.M. (2004) Guide to Field Geology, PHI.

YEAR IV- (SEMESTER-VII & VIII)

SEMESTER – VII

Discipline Specific Core Courses 15: Research Methodology and publication ethics (Credits: 04, Theory-04)

(i) Course learning outcome:

1. To understand basic idea about research
2. To know different methods used to find out solution to research problems
3. To acquire knowledge on publication process and the importance of ethics in publication

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9
CLO1	3	3	1		2	2		2	
CLO2	3	2	1	2	3	2	3		2
CLO3	2	2				2	1		2

(ii) Broad contents of the course:

The course includes an introductory approach to research and will help the students to understand various methods used to solve research problems. It will also help students to understand ethics related to research publications.

(iii) Skills to be learned:

The students will acquire skills related to carrying out geological research and steps involved in writing of thesis as well as research publications.

(iv) The detail contents of this course and references and suggested books:

Unit 1: (10 hours)

Introduction to Research: Meaning, Objectives, Motivation, Utility; Types of Research: Qualitative vs Quantitative Research, Descriptive vs Analytical Research, Applied vs Fundamental Research, Conceptual vs Empirical Research

Unit 2: (20 hours)

Research Formulation and Design: Defining and formulating the research problem, Literature review-primary and secondary sources, Identifying research gaps from literature, Development of working hypothesis, Data sources, Data interpretation; Report writing: Different steps in writing report, Layout of research report, Types of reports, Precautions for writing research reports, Conclusions

Unit 3: (15 hours)

Ethics: Definition, Nature of moral judgements and reactions; Ethics with respect to science and research, Intellectual honesty and research integrity; Scientific misconducts: Falsification, Fabrication, and Plagiarism

(FFP); Redundant publications: Duplicate and overlapping publications, Salami slicing; Selective reporting and Misrepresentation of data

Unit 4: (15 hours)

Publication ethics: Definition, Introduction and Importance; Best practices/standards setting initiatives and guidelines; Conflicts of interest; Publication misconduct: Definition, Concept, Problems leading to unethical behavior and vice versa, Types; Violation of publication ethics, Authorship and Contributorship; Identification of publication misconduct, Complaints and Appeals: Examples and fraud from India and abroad; Predatory publishers and journals

Books Recommended:

1. Beall, J. (2012) Predatory publishers are corrupting open access. Nature, 489(7415), 179-179
2. Bird, A. (2006) Philosophy of Science. Routledge
3. Garg, B.L., Karadia, R., Agarwal, F. and Agarwal, U.K., 2002. An introduction to Research Methodology, RBSA Publishers.
4. Indian National Science Academy (INSA), Ethics in Science Education, Research and Govemance (2019), ISBN:978-8 l-939482- l-7
5. Kothari, C.R., 1990. Research Methodology: Methods and Techniques. New Age International. 418p.
6. Macintyre, Alasdair (1967) A Short History of Ethics. London
7. National Academy of Sciences, National Academy of Engineering and Institute of Medicine. (2009) On Being a Scientist: A Guide to Responsible Conduct in Research: Third Edition. National Academies Press
8. P. Chaddah, (2018) Ethics in Competitive Research: Do not get scooped; do not get plagiarized, ISBN:978-9387480865
9. Resnik, D. B. (2011) What is ethics in research & why is it important. National Institute of Environmental Health Sciences, 1- 10
10. Sinha, S.C. and Dhiman, A.K., 2002. Research Methodology, Ess Publications. 2 volumes.
11. Trochim, W.M.K., 2005. Research Methods: the concise knowledge base, Atomic Dog Publishing. 270p.
12. Wadehra, B.L. 2000. Law relating to patents, trade marks, copyright designs and geographical indications. Universal Law Publishing

Discipline Specific Elective Course 4 (DSE 4): Descriptive Mineralogy and Petrology (Credits: 04, Theory-04)

(i) Course learning outcome:

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

1. Explain systematic descriptions and identifications of minerals in hand specimen and under the microscope
2. Know recent advances technology for the study of minerals and their structures
3. Understand the magmatism in different plate tectonic environment
4. Enhance the knowledge in interpreting metamorphic P-T-t paths with reference to different geodynamic processes

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9
CLO1	3	1	1				2	3	2
CLO2	3	3	2	2	3	2	1	2	1
CLO3	3	2	2	1	2	2	2	2	3
CLO4	2	3	3	1	2	1	2		3

(ii) Broad contents of the course:

The course deals with the study of minerals, their chemistry and identification in hand specimen. Further, it also deals with the study of crystals with respect to their morphology, symmetry and the normal crystal classes. It also deals with the geochemical classification of elements. This course covers topics related to symmetry operations, characteristics of different mineral groups, analytical techniques related to mineral study, isotopes, sediment and water geochemistry. The course also covers topics related to petrology, tracing the evolution of both magmatism and metamorphic processes covering the understanding of melt generation and crystallization mechanism and metamorphism and their link to tectonic settings is vital for the geological assessment of an area.

(iii) Skills to be learned:

The students will be able to identify common rock-forming minerals and hand specimens as well as in thin sections. Besides, they will familiarize themselves with Bravais crystal lattice and crystal systems. They can also identify the behavior of various elements under various geochemical environments. Students will understand the characteristics of silicate structures, understanding the rock-forming mineral thin sections using a polarizing microscope, classification of geochemistry, trace elements and REE. Students will acquire skills related to solving magmatic and metamorphic processes problems by applying concept of thermodynamics.

(iv) The detail contents of this course and references and suggested books:

Unit 1: (15 hours)

Crystallography and Mineral Chemistry: Periodicity and symmetry-concept of space lattice; Introduction to aspects of crystal structure – Hexagonal close packing, Cubic close packing; Pauling's rules; Solid solutions – substitutional solid solution, Coupled substitution, Interstitial solid solution, Omission solid solution; Defects in minerals- point defects, line defects, and planar defects; Applications of XRD, SEM, EPMA in mineralogy

Unit 2: (15 hours)

Descriptive mineralogy: Study of mineral groups based on structure, mineral chemistry, stability, optical properties, and occurrence for the following groups – Silicates: olivine, pyroxene, amphibole, mica, talc, feldspar, quarts, garnet, beryl, epidot, Al_2SiO_5; Oxides: hematite, spinel, rutile; Carbonates: calcite, aragonite, dolomite; Phosphates: Apatite, monazite; Sulphides: Pyrite, chalcopyrite

Unit 3: (10 hours)

Origin and diversification of magma, Layered mafic intrusions, mid-oceanic ridge volcanism, oceanic intraplate volcanism, continental flood basalts, subduction related igneous activity: island arcs and continental arcs; Granitoids, continental alkaline magmatism and anorthosites

Unit 4: (10 hours)

Laws of thermodynamics; Gibbs free energy; Concept of activity, fugacity, ideal and non-ideal solutions; Geothermobarometry; Mineralogical phase rule of close and open system; Concept and classification of metamorphic facies; description of facies of steep geothermal gradient normal geothermal gradient and shallow geothermal gradient; Concept of facies series and paired metamorphic belts; Mineral assemblages, metamorphic

reactions and P-T conditions of metamorphism; P-T time path; Metamorphic differentiation; Anatexis and origin of migmatites; Petrogenesis of Charnockites

Unit 5: (10 hours)

Sedimentary petrology: Sedimentary processes and their products. Classification of sediments. Diagenesis & Lithification. Sedimentary structures. Classification of sedimentary rocks. Mineral composition, structure and textures of Clastic and non-Clastic sediments and Residual deposits. Origin, occurrence and characteristics of common sedimentary rocks - quartz arenites, arkoses and greywacks. Siliceous and calcareous deposits. Sedimentary environments and facies. Palaeocurrents and basin analyses; Clay mineralogy; Provenance studies.

Books Recommended:

1. Berry, L.G., Mason, B. and Dietrich, R.V., (1982) Mineralogy. CBS Publ.
2. Best, M. G. Igneous and Metamorphic Petrology, 2nd Edn., Blackwell, 2003
3. Blatt H., Tracy R.J. and Owens B.E. (2006) Petrology – Igneous, sedimentary and metamorphic rocks (3rd Edition), W.H. Freeman and Company, New York.
4. Bose M.K. (1997) Igneous Petrology. The World Press Pvt. Ltd. 568 p.
5. Buerger M. Elementary Crystallogaphy. The MIT Press (May 15, 1978)
6. Collinson, J., Mountney, N., Thompson, D., Sedimentary Structures, Terra Publishing, 3rd Edn., 2006
7. Cox, K. G., Bell, J. D. and Pankhurst, R. J. The Interpretation of Igneous Rocks. Unwin Hyman, 1979
8. Dana, E.S. and Ford, W.E., (2002) A textbook of Mineralogy (Reprints).
9. Deer, Howie and Zussman (1996) Introduction to Rock forming Minerals, Pearson (3rd Edition)
10. Dexter Perkins, Mineralogy, 3 rd edition, Pearson, 2011
11. Ehlers, WG, and Blatt, H.(1987) Petrology, Igneous, Sedimentary and Metamorphic rocks, CBS Publishers
12. Flint, Y., (1975) Essential of crystallography, Mir Publishers.
13. Francis Albarède Geochemistry: An Introduction, Cambridge, 2009
14. Frye Keith: Modern Mineralogy. Prentice Hall; First Edition edition (May 1974)
15. Gunter Faure Principles and Applications of Geochemistry. Prentice Hall; 2 edition (December 24, 1997)
16. Hall, A. Igneous Petrology, 2nd Edn., Longman, 1996
17. Hatch F.H., Wells A.K and Wells M.K. (1984) Petrology of the igneous rocks. CBS Publishers, 551p.
18. K.C. Misra, Introduction to Geochemistry: Principles and Applications, Wiley-Blackwell, 2012
19. Kerr, B.F., (1995) Optical Mineralogy 5th Ed. McGraw Hill, New York.
20. Mason B, Principles of Geochemistry, J. Willey & Sons, 1982
21. Mason, R., (1978) Petrology of Metamorphic Rocks. CBS Publ.
22. McBirney, A. R. Igneous Petrology, 3rd Edn., Jones & Bartlett, 2006
23. Middlemost, E. A. K. Magmas and Magmatic Rocks. Longman, 1985
24. Moore M. (1982) Principles of Geochemistry, Wiley.
25. Nesse W. D., Introduction to Optical mineralogy. Oxford University Press. 2008
26. Nicholls, G. Sedimentology and Stratigraphy. Wiley-Blackwell, 1999
27. Perkin Dexter. (2017), Mineralogy, (Third Edition). Pearson.
28. Philpotts, A. and Ague, J. (2009). Principles of igneous and metamorphic petrology. Cambridge University Press.
29. Prothero, D.R. and Schwab, F. Sedimentary Geology: An Introduction to Sedimentary Rocks and Stratigraphy, 2nd Edn., W.H. Freeman, 2003
30. Putnis A. Introduction to mineral Sciences, Cambridge publication, 1992
31. Ram S. Sharma (2016) Metamorphic Petrology Concepts and Methods. Text Book Series, Geological Society of India, Bangalore
32. Ram S. Sharma and Anurag Sharma (2013) Crystallography and Mineralogy - Concepts and Methods. Text Book Series, Geological Society of India, Bangalore

33. Raymond, L. A. (2002). Petrology: the study of igneous, sedimentary, and metamorphic rocks. McGraw-Hill Science Engineering
34. Rutley's Elements of Mineralogy. Springer; 27th edition (November 30, 1988)
35. Selley, R.C., Applied sedimentology, 2nd Edn., Academic Press, 2000
36. Tucker, M.E. Sedimentary Petrology, 3rd Edn., Blackwell Science, 2001
37. Turner F.J and Verhoogen J. (1960) Igneous and Metamorphic Petrology, McGraw- Hill.
38. Turner, F.J., (1980) Metamorphic Petrology. McGraw Hill.
39. Verma, P. K. (2010). Optical Mineralogy (Four Colour). Ane Books Pvt Ltd. 4. Deer, W. A., Howie,
40. W. H. Blackburn and W. H. Dennen. Principles of mineralogy. Dubuque, IA: Wm. C. Brown Publishers. 1993)
41. William D Nesse. Introduction to Optical Mineralogy. Oxford University Press, USA; 3 edition (August 21, 2003)
42. Winkler, H.G.C., (1967) Petrogenesis of Metamorphic Rocks. Narosa Publ.
43. Winter, J. D. Introduction to Igneous and Metamorphic Petrology. Prentice Hall India, 2010
44. Yardley, B.W.D. Metamorphic Petrology, Longman, 1989

Discipline Specific Elective Course 5 (DSE 5): Advanced Remote Sensing and Hydrogeology
(Credits: 04, Theory-04)

(i) Course learning outcome:

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

1. Fully equipped with concepts, methodologies and applications of Remote Sensing Technology
2. Acquire skills in handling instruments, tools, techniques and modeling while using Remote Sensing Technology
3. Gain information related to groundwater occurrence in different geological media
4. Acquire knowledge related to groundwater exploration using different methods, and groundwater extraction structures
5. Get to know estimation of aquifer parameters using different tests; and groundwater composition

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9
CLO1	3	2	2	2	1		1	1	
CLO2	2	2	3	3		2	2	3	
CLO3	3	3	1	1				2	
CLO4	3	2	3	2	3	2	3		
CLO5	3	3	2	3	2	1			2

(ii) Broad contents of the course:

The course covers techniques, methods and process in image rectification as well as emerging areas of remote sensing. This course also includes topics related to groundwater-occurrence, -exploration and –wells. It also includes the topics related to estimation of aquifer parameters using pump- and slug-tests; and groundwater chemistry.

(iii) Skills to be learned

The student will be able to learn concept and methodological aspects of advanced remote sensing. The student will be able to learn concept and methodological aspects of advanced remote sensing. In addition, students will gain skills related to groundwater exploration, construction and maintenance of groundwater wells, and estimation of aquifer parameters will be gained by students.

(iv) The detail contents of this course and references and suggested books

Unit 1: (15 hours)

Digital Image Processing: Data reception and data products, Digital data manipulation and analysis; image rectification – Radiometric correction, Atmospheric correction, Geometric correction.

Unit 2: (15 hours)

Advanced Remote Sensing Technologies: Microwave remote sensing, Synthetic Aperture Radar; Hyper spectral Imaging Spectrometer; Thermal Imaging System; Advanced Laser Terrain Mapping.

Unit 3: (15 hours)

Groundwater Occurrence: Types of groundwater on the basis of origin (Meteoric-, connate-, Fossil- and Juvenile-water); Types of geological formations and their hydrogeological characters; Interaction between surface water and groundwater (Gaining- and Losing-type of streams); Groundwater occurrence in hard rocks (Igneous-, Sedimentary-, and metamorphic-rocks), Groundwater occurrence in unconsolidated formations; Topographic/Landform and Structural control over groundwater occurrence.

Groundwater exploration: Factors to be considered before taking-up exploration for groundwater (geological factors and geomorphological factors-including landform features and drainage characters); Remote Sensing (using direct and indirect indicators) and GIS in groundwater exploration; Geophysical (geoelectrical) methods of groundwater exploration.

Groundwater wells: Definition and characters of water wells; Different types of wells and their construction (Dug wells and their characters; Types of dug wells based on their depth, on the basis of their shape, on the basis of their lining; Bore wells and their characters, types of bore wells, horizontal bore wells and their characters, Dug-cum-bore wells and collector wells, Infiltration galleries/Qanat; Well-Design (Well Casing, Well Screening, Gravel Packing, Sand Trap); Well Construction Methods; Well Development Methods (Pumping, Surging, Hydraulic Jetting, Aquifer Development/Simulation Methods including Acidizing, Blasting or Shooting and, Hydrofracturing); Well Maintenance (Purposes of well maintenance, annual maintenance, flow restoring, residential well cleaning and well disinfection).

Unit 4: (15 hours)

Aquifer (Pump) Tests: Purposes of an aquifer test, Terminology (pumping well, observation well, static water level (pre-pumping water well), drawdown, cone of depression, radius of influence), pre-requisites for conducting pumping tests, pumping test design (design of a test well, design of monitoring wells, pumping design, test duration, water discharge control, measurements and disposal), methods, data analysis and interpretation of pump test data, Step Drawdown tests, Recuperation Test, Aquifer and Well Losses, Well Efficiency; Slug Test; Packer Test;

Groundwater chemistry: Solubility of solids, liquids, gasses; Physical properties including specific conductance, total dissolved solids,/salinity, pH, alkalinity; oxidation-reduction potential; Natural groundwater constituents

and their relation to geological media – primary, secondary and trace constituents, radionuclides, and environmental isotopes and groundwater dating; Introduction to groundwater pollution.

Books Recommended:

1. Applied Hydrogeology by C. W. Fetter Jr. Pearson Education Limited, 2014, Fourth edition.
2. Applied hydrogeology of fractured rocks by B. B. S. Singhal and R. K. Gupta, 2010, Second edition.
3. Applied remote sensing for urban planning, governance and sustainability by M. Netzband, W. L. Stefanov, & C. Redman (Eds.), Springer Science & Business Media, 2007. ISBN: 978-3-540-25546-8.
4. Chemical and Isotopic Groundwater Hydrology by Emanuel Mazor. Marcel Deckker, 2004.
5. Fundamentals of Hydrology by Tim Davie. Routledge, 2008, Second edition.
6. Ground Water Assessment: Development and Management by K. R. Karanth. Tata McGraw-Hill Publishing Company Limited, 1987.
7. Groundwater and Wells by Robert J. Sterrett. Johnson Screens, 2007, Third edition.
8. Groundwater Geochemistry and Isotopes by Ian Clark. CRC Press, 2015.
9. Groundwater Hydrology by David K. Todd and Larry W. Mays. John Wiley and Sons Inc., 2005, Third edition.
10. Hydraulics of Wells: Design, Construction, Testing, and Maintenance of Water Well Systems by Nazeer Ahmed, Stewart W. Taylor and Zhuping Sheng. American Society of Civil Engineers, 2014.
11. Hydrogeochemistry Fundamentals and Advances, Volume 1: Groundwater Composition and Chemistry by Viatcheslav V. Tikhomirov. Scrivener Publishing and Wiley, 2016.
12. Hydrogeology: Principles and Practice by Kevin M. Hiscock and Victor F. Bense. Wiley Blackwell, 2014, Second edition.
13. Hydrology: Principles, Analysis, and Design by H. M. Raghunath. New Age International Publishers, 2006, Revised Second edition.
14. Image interpretation in Geology by Steve Drury, Routledge, 2001, Third edition, ISBN: 0-07487-64992.
15. Introduction to Hydrology by Warren Viessman Jr. and Gary Lewis. Printice Hall, 2003, Fifth edition.
16. Remote sensing and geographic information systems for design and operation of water resources systems by M. F. Baumgartner, G. A. Schultz, & A. I. Johnson (Eds.), IAHS (No. 242), 1997.
17. Remote sensing and image interpretation by T. Lillesand, R. W. Kiefer, & J. Chipman, John Wiley & Sons, 2015.
18. Remote Sensing Geology by Ravi P. Gupta, Springer, 2003, Second edition, ISBN: 3-540-43185-3.
19. Remote sensing of forest environments: concepts and case studies by M. A. Wulder, & S. E. Franklin (Eds.), Springer Science & Business Media, 2012.
20. Remote sensing of the environment: An earth resource perspective by J. R. Jensen, Pearson Education India, 2009.
21. Remote Sensing. With Special Reference to Agriculture and Forestry by R. S. Sigafoos, National Research Council Committee on Remote Sensing for Agricultural Purposes. National Academy of Sciences, Washington, DC, 1970.
22. Water Chemistry: An Introduction to the Chemistry of Natural and Engineered Aquatic Systems by Patrick L. Brezonik and William A. Arnold. Oxford University Press, 2011.
23. Water Wells and Boreholes by Bruce Misstear, David Banks, and Lewis Clark. Wiley Blackwell, 2017.

Discipline Specific Elective Course 6 (DSE 6): Exploration Geophysics and Mineral Processing
(Credits: 04, Theory-04)

(i) Course learning outcome:

1. Students will learn about the various geophysical methods of mineral exploration.
2. Students will learn about the aspects of instrumentation, data acquisition and interpretation using different geophysical mineral exploration methods.
3. Students will be exposed to the introductory aspects of mineral processing.
4. Students will learn about different methods involved in mineral processing.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9
CLO1	3	1	1				2	3	2
CLO2	3	2	2	2	2		1	1	
CLO3	3	2	2	1	2		1		
CLO4	3	1	1				2	3	2

(ii) Broad contents of the course:

The course includes topics related to different geophysical methods of exploration including electrical, seismic, magnetic, and gravity methods. The mineral processing part includes introductory aspects and different methods of mineral processing.

(iii) Skills to be learned

Students will learn skills about interpretation of geophysical data acquired by different methods. They will also learn about the different mineral processing methods.

(iv) The detail contents of this course and references and suggested books

Unit 1: (20 hours)

A brief review of the introductory aspects of geophysics (basic principles governing geophysics, physical properties of earth materials, geophysical anomaly, earth's physical fields); Classification of geophysical methods of exploration based on different aspects; General principles, instrumentation, types of surveys, field survey procedures, data acquisition, data corrections and interpretation, case studies in respect of the following geophysical exploration methods: Electrical Methods **(**Electrical resistivity and Self-potential methods); Seismic Reflection and Refraction Methods

Unit 2: (10 hours)

General principles, instrumentation, types of surveys, field survey procedures, data acquisition, data corrections and interpretation, case studies in respect of the following geophysical exploration methods: Magnetic and Gravity methods.

Unit 3: (15 hours)

Mineral Processing: Introduction (Definition, its necessity, and objectives), Principles and scope of mineral processing; Properties of ores and minerals applied to mineral beneficiation; Comminution (size reduction) – Crushing, Rittinger's Law and Kick's Law; Crushers and Grinding Mills; Sizing and Screening; Principles of concentration processes; Gravity concentration; Jigging, Wilfley Table, comparison of Jigging and Tabling

Unit 4: (15 hours)

Magnetic separators – primary and secondary magnet types; Flotation – Principles, types, and functions of reagents used; Heavy media separation; Flow sheets for metallic ores (gold, copper, lead and zinc) and non-metalic ores (baryte and coal)

Books Recommended:

1. Applied Geophysics for Geologists and Engineers The Elements of Geophysical Prospecting by D. H. Griffiths and R. F. King. Pergamon Press, 1981, Second edition.
2. Exploration Geophysics: An Introduction by M. Gadallah and R. Fisher. Springer, 2009.
3. Gravity and Magnetic Exploration: Principles, Practices, and Applications by William J. Hinze, Ralph R. B. von Frese, and Afif H. Saad. Cambridge University Press, 2013.
4. Introduction to Mineral Exploration by Charles J. Moon, Michael K.G. Whateley and Anthony M. Evans (Editors). Blackwell Publishing, 2006, Second edition.
5. Mineral Exploration: Principles and Applications by S. K. Halder. Elsevier, 2018, Second edition.
6. Mineral Processing (Including Mineral dressing, Experiments and numerical) by Vandana Rao, Sonam Patel and Avinash Lele.
7. Mineral Processing by S. K. Jain. CBS Publishers, 2001, Second edition.
8. Principles of Mineral Processing by Maurice C. Fuerstenau and Kenneth N. Han (Editors). Society for Mining, Metallurgy, and Exploration (SME), 2003.
9. Principles of the Magnetic Methods in Geophysics by A.A. Kaufman, R.O. Hansenw and Robert L. K. Kleinberg. Elsevier, 2009.
10. Wills' Mineral Processing Technology: An Introduction to the Practical Aspects of Ore Treatment and Mineral Recovery by Barry A. Wills and James Finch. Butterworth-Heinemann, 2015.

Skill Enhancement Courses 5 (SEC 5): Mini Project
(Credits: 04)

(i) Course learning outcome:

1. Students will get exposure to do research in any geological fields
2. They will get a chance to know the applied fields of geology by finding solutions of geological problems
3. They will have an exposure to work on geological equipment/professional software, etc.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9
CLO1	3	2	2	1	3	1			1
CLO2	3	2	2	2	1	3	2	2	1
CLO3	2	3	2	3	2	1	3	2	

(ii) Broad contents of the course:

The students will be able to gain hands-on experience and evaluate geological problems using their theory and practical knowledge.

(iii) Skills to be learned

The main objective of the course is to expose the students to preliminary research and to develop professional skills.

(iv) The detail contents of this course

For Mini Project, the student may carry out a study of geological interest in consultation with the supervisor. After the completion of the work, the student will have to produce a Project Report, duly certified by the supervisor. The student also will have to prepare a presentation in which the completed work has to be presented for evaluation. The project work will be evaluated based on the presentation, viva voce and the report submitted.

There is no financial commitment on the part of the University for the internship/project. However, the University may assist the candidate in locating him/herself and issue letters to concern besides supplying any other documents/references, etc.

Value Addition Courses 4 (VAC 4): Technical Tools for Research (Credits: 02)

(i) Course learning outcome:

1. Students will gain knowledge about various tools used for geological research.
2. Students will get basic idea about various instruments used in analyzing geological samples.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9
CLO1	3	2	1	2	3	2	3		2
CLO2	3	2	1		3		3		

(ii) Broad contents of the course:

Students will be able to understand the working principles of various instruments and their applications in the geological research.

(iii) Skills to be learned

The main objective of the course is to expose the students to various instrument measurement-system used for geological research and their usage in both, field and laboratory.

(iv) The detail contents of this course

Unit 1: (10 hours)

Use of computer applications for geological research; MS Excel Programs useful in geology; Freeware programs/software useful in different branches of geology; Introduction to mineral formulae calculation of important rock forming minerals

Unit 2: (20 hours)

Use of instruments for geological research; Various sample preparation techniques in geology; Classical and rapid methods of analyses; General measurement system; Atomic Absorption Spectrometry (AAS), Inductively Coupled Plasma – Atomic Emission Spectrometry (ICP-AES), Mass Spectrometry (MS), X-Ray Fluorescence

(XRF), X-Ray Diffraction (XRD), Electron Probe Micro Analysis (EPMA), and Scanning Electron Microscopy (SEM) – Principle, application and their utility in Geological analysis

Books Recommended:

1. William Fischer (2016) Excel: Quickstart Guide from Beginner to Expert, Create Space Independent Publishing Platform
2. Cornelis Klein & Barbara Dutrow (2007) Manual of Mineral Science, Wiley
3. Jeffery, P.G. and Hutchinson, D. (1981) Chemical Methods of Rock Analysis, Butterworth-Heinemann
4. Li-ling Ooi (2010) Principles of X-ray Crystallography, Oxford University Press
5. Potts, P.J. (1992) A Handbook of Silicate Rock Analysis, Springer
6. Thompson, M. and Walsh, J.N. (1989) Handbook of Inductively Coupled Plasma Spectrometry, Chapman and Hall
7. Van Loon, J.C. (1980) Analytical Atomic Absorption Spectroscopy, Academic Press
8. Vanhaecke, Frank and Degryse, Patrick (2012) Isotopic Analysis: Fundamentals and Applications Using ICP-MS, CRC Press

SEMESTER – VIII

Discipline Specific Elective Course 7 (DSE 7): Internship
(Credits: 08)

(i) Course learning outcome:

1. Students will gain knowledge about methods of identifying and investigating geological problems and solve them systematically.
2. Students will have an exposure to visit research institutes, industries, mining sectors, etc., where they can get opportunity to gain professional knowledge.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9
CLO1	3	2	2	2	1	3	2	2	1
CLO2	2	3	2	3	2	1	3	2	

(ii) Broad contents of the course:

Students will be able to gain hands-on experience, evaluate career opportunities and begin building a professional network.

(iii) Skills to be learned

The main objective of the course is to expose the students to preliminary research and to develop professional skills.

(iv) The detail contents of this course

During this semester, the students shall undergo institutional or industrial training with prior approval from the concerned faculty and the department. After the completion of the internship students shall submit their report to the department before commencement of the semester examination. The report should be duly certified by the supervisor under whom the student carried out the internship.

Internship in GIS/RS/Geological organizations/institutions based on student's choice to be finalized in consultation with faculty supervisor assigned from the Department.

There is no financial commitment on the part of the University for the internship/project. However, the University may assist the candidate in locating him/herself and issue letters to concern besides supplying any other documents/references, etc.

Discipline Specific Elective Course 8 (DSE 8): Project work
(Credits: 12)

(i) Course learning outcome:

1. Students will get exposure to do research in any geological fields
2. They will get a chance to know the applied fields of geology by finding solutions of geological problems

3. They will have an exposure to work on geological equipment/professional software, etc.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9
CLO1	3	2	2	1	3	1			1
CLO2	3	2	2	2	1	3	2	2	1
CLO3	2	3	2	3	2	1	3	2	

(ii) Broad contents of the course:

The students will be able to gain hands-on experience and evaluate geological problems using their theory and practical knowledge.

(iii) Skills to be learned

The main objective of the course is to expose the students to research and to develop professional skills.

(iv) The detail contents of this course

To inculcate a culture of research and innovation at the undergraduate level so that the students are exposed to the nitty-gritty of the Scientific Research in their fields. Students will develop a research proposal, carry out data collection using field and/or laboratory studies, and complete a final report/presentation. Field studies, Laboratory studies / data processing, reference work and presentation of the thesis are four major components of the course. Students opting for this course should adhere to the following procedure.

1. Precise title and outline of work is to be submitted to the Head of the Department/Exam Coordinator.
2. The student shall spend at least one week in the field. The field work shall be carried out only during vacation or holidays, and in no case, student will be permitted to be absent from regular teaching on account of dissertation. The student shall maintain field diaries and other record relevant to dissertation.
3. If (s)he is working on a laboratory project, the fieldwork component may or may not be essential.
4. Every month the student shall submit the progress report and laboratory work done, through the supervisor to Head of the Department/Exam Coordinator.
5. The student shall do dissertation at his own cost. The department will not spare funds for this purpose.
6. The student shall give a seminar before the submission of the dissertation.
7. The supervisor shall submit the practical sets based on topic of dissertation developed for the students to Head of the Department/Exam Coordinator prior to the commencement of practical examination.
8. Non-compliance of any of the above rules will disqualify students for grant of terms.
9. Three copies neatly typed on thesis size paper or A4, well bound together with maps and illustrations should be submitted.
10. Dissertation, on the basis of the work carried out by the student, will be submitted, through the supervisor concerned, to the Head of the Department//Exam Coordinator before the commencement of the practical examination, for being forwarded to the Board of Examiners.

In case of student receiving help (training and/or participation in ongoing research activities) from other Institution/Organization for their dissertation work, the associated scientist from that Institute/Organization will function as co-supervisor.