Learning Outcomes based Curriculum Framework (LOCF)

for

Undergraduate Programme
B.Sc. (Geology)

2019

UNIVERSITY GRANTS COMMISSION

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CONTENTS

Preamble

The role of higher education is very important in securing the gainful employment and / or providing further access to higher education comparable to the best available in the world class institutions elsewhere. The improvement in the quality of higher education, therefore, 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 all undergraduate programs in science, humanities, commerce and professional streams of higher education. One of the significant reforms in the undergraduate education is to introduce the Learning Outcomes-based Curriculum Framework (LOCF) which makes it student -centric, interactive and outcome-oriented with well-defined aims, objectives and goals to achieve. The University Grants Commission (UGC) took the initiative of implementing the LOCF in the Colleges and the Universities of the country and Prof. D. P. Singh, the honourable chairman constituted a Core Expert Committee (CEC) which formulated the modalities for developing the LOCF in various subjects being taught in the undergraduate courses in sciences, humanities and commerce. The honourable chairman also constituted the Subject Expert Committees (SEC) in various subjects to prepare detailed guidelines for the LOCF in subjects concerned. The following Committee was constituted in Geology.

1. Prof. Nitin R. Karmalkar, Vice-Chancellor, Savitribai Phule Pune University, Pune – Chairman
2. Prof. Rajesh Kumar Srivastava, CAS Department of Geology, Banaras Hindu University, Varanasi - Member
3. Prof. Anand Mohan, Registrar, Dayalbagh Educational Institute, Agra - Member
4. Prof. S.P. Mohan, Head, DSA, Department of Geology, University of Madras, Chennai - Member

A meeting of the members of the CEC and all the Chairmen of SEC was held on 18.06.2018which was chaired by Prof. D. P. Singh and attended by Prof R. Jain, Secretary UGC, Dr. R. Batra, Additional Secretary, UGC and Ms. M. Kaushik, The Education Officer, UGC, Prof. K. Ramachandran, a member of the CEC made a presentation on the essential features of the LOCF which was formulated on the basis of a set of learning outcomes projected to be achieved for enhancing the employability and providing further opportunities for higher education and research. These Learning Outcomes (LO) determine the structure of the under graduate programs to be offered by the Higher Educational Institutions (HEI) of our country. The key component of the planning and development of LOCF are given in terms of clear and unambiguous description of the Graduate Attributes, Qualification descriptors, Program Learning Outcomes (PLO) and Course Learning Outcomes(CLO) to be achieved at the end of the successful completion of each undergraduate program to be offered by the HEI.

In the undergraduate education in Geology there are two undergraduate programs leading to the degree of B. Sc. with Geology and B. Sc. (Honours) Geology. The Course Learning Outcomes (CLO) is defined separately for both programs.

In order to formulate the LOCF in Geology, the first meeting of the Committee was held on Monday, 20thAugust 2018 at Savitribai Phule Pune University, Pune. Dr. P. Krishnamurthy, Formerly Atomic Minerals Directorate for Exploration and Research, Department of Atomic Energy, Government of India, Dr. M. S. Bodas, Director, Geological Survey of India, Pune and Dr. R. A. Duraiswami, Assistant Professor, SPPU and Former Geologist at Groundwater Surveys and Development Agency, Government of Maharashtra were co-opted as member to the committee to utilize their professional expertise in the field of applied geology. The Chairman briefed the members about the decisions taken in the meeting of all the chairmen of SEC with the members of CEC and officers of UGC held on 18.06.2018 and appraised them the task at hand and the modalities to prepare the report were elucidated. The topics were allocated to each member keeping in mind the member's expertise and interests. It was proposed that the prepared notes shall be circulated among all members for feedback in the first instance.

The second meeting of the Committee was held on 24thSeptember at UGC, New Delhi. Prof. Karmalkar, Chairperson, briefed about the UGC meeting he attended along with Chairmen of all subject LOCF Committees, Prof. D P Singh, Chairman UGC,

R. Subramaniam, Secretary, MHRD and other officers of UGC and MHRD on 18.09.2018. The committee reviewed the progress made in the preparation of LOCF. It was resolved that all the inputs and the individual contributions be collated and discussed through the exchange of e-mails, telephonic conversions and other means of communications and resolved to finalize the draft report at the earliest possible date. Meanwhile UGC invited suggestions / comments from interested Institutions /and faculty to provide valuable feedback with reference to CBCS / LOCF program. A second meeting of various stakeholders was convened by Prof. Karmalkar, Chairperson, at Pune on 27th March 2019. About a dozen suggestions were received from various teachers, professionals and scientists working in many institutions in India which were made available to the committee and were given serious considerations in preparing the report.

The committee in its meetings deliberated on all the undergraduate programs being offered in Geology that is categorized in two distinct types of programs:

i) B.Sc (Honours) Geology

ii) B.Sc with Geology

The LOCF have been formulated for the above courses as far as the Qualification Descriptors, Program Learning Outcomes (PLO) and the Course Learning Outcomes (CLO) are concerned. Once the LOCF are formulated for the two undergraduate programs, their course structure and detailed contents of the courses regarding the various components like the class room teaching (theory), laboratory (experiments), tutorials, and industrial / field visits and projects can be designed and planned to achieve the stated Learning Objectives (LO).

The LOCF also gives general guidelines for the teaching-learning process (TLP) corresponding to each component of theory, experiment, tutorials, projects and industrial / field visits to be followed in order to achieve the stated outcomes for each component. Finally some suggestions for using various methods in the assessment and evaluation of learning levels of students are also made.

The UGC Committee constituted for Learning Outcomes based Curriculum Framework for B.Sc (Honours) Geology and B.Sc with Geology is pleased to submit its report. The Committee suggests that the following remarks may be taken into account by those faculty

and research members of Departments/Schools, Boards of Studies in Geology, Institutes and Universities, while considering the recommendations for their use:

i. The learning outcomes are designed to help learners understand the objectives of studying B.Sc (Honours) Geology and B.Sc with Geology, that is, to analyze, appreciate, understand and critically engage with tangible, non-tangible, literary and material sources, approaching them from various perspectives.

ii. It is significant to mention here that the B.Sc (Honours) Geology and B.Sc with Geology syllabus under CBCS remains the point of reference for the LOCF recommendations. However, stakeholders (respective departments or Universities or Institutions) may make suitable alternations with justifications while selecting course, finalizing objectives keeping in view global, national and regional contexts of analysis and appreciation.

iii. To this end, the texts mentioned in the LOCF document are indicative. Similarly, the organization of divisions/ themes/ genres/ periods/ authors/ areas, etc. is specific to contexts identified in the course(s) and does not pre-empt further rethinking or selection with clear justification for the choices exercised therein.

iv. The organization of the courses/papers may be worked into semesters keeping in consideration the credit load with the ultimate end of outcomes of the course/programme. Learning outcomes are modifiable with due justification in view of contexts, texts selected in the course and requirements of the stakeholders, which are as diverse as are regions in the country.

v. The overarching concern of the LOCF committee in Geology is to have definite and justifiable course outcomes and their realization by the end of the course/programme.

vi. The Department/Institute/University is expected to encourage its faculty concerned to make suitable pedagogical innovations, in addition to teaching/learning processes suggested in the LOCF Recommendations, so that the Course/Programme learning outcomes can be achieved

Learning Outcomes-Based Curriculum Framework for undergraduate education in Geology

1. Introduction

Outcome based learning is the principal end of pedagogical transactions in higher education in today's world in the light of exponential changes brought about in science and technology, and the prevalent utilitarian world view of the society. Geology as a discipline falls within the special category of science with a multidisciplinary approach.

Academic model of Indian higher education has remained more or less the same for the past century and more. The entire higher education spectrum was divided into streams like Arts, Commerce, Science, Engineering, Medicine, Law, Agriculture etc. Each stream will select the student after the secondary education and provide three or four to five years of education so as to award a degree. The silos created are so strong that now we have even institutes of "this and that" based on the stream. In fact, the comprehensive university concept was thrown out in the window. Now, we are seeing the drawbacks of such unitary higher education process.

The academic world is increasingly a global village now. Academic institutions from Singapore, Japan, Korea and China are marching ahead very fast in the international scenario. The Americans and Europeans are reforming many aspects of the academic world. India will have to look at reforms of the academic world as well. In fact, Indian graduates will have to seek placements not at the national level but at the international level in future. The number of graduates will be far more than the number of jobs. However, the Indian graduates will be able to grab the international placements only when their academic background and skills will be suitable at the international level.

Many surveys and reviews have indicated that a large number of Indian graduates are not employable since they do not possess the skills that are needed in today's world. Neither the knowledge nor the skills are adequately provided through the current academic model of higher education.

In the Solar System amongst the terrestrial planet the Earth is the only living planet which has Lithosphere, oxygenated Atmosphere, Hydrosphere and the Biosphere. There is seamless interaction among these spheres. The Earth has hot interior and this very heat acts as the fuel to run the Earth engine. To understand how our planet works, at depth and at the surface, the ideas and principles of Biology, Chemistry, Physics, Mathematics and Geography are integrated in the exciting and stimulating studies which make up Earth Sciences. It is a fast-moving, diversifying, multidisciplinary field that ranges from understanding the Earths origin in the solar system, the evolution of hydrosphere and atmosphere as well as the earth's materials at the atomic level, through the geological processes that drive volcanoes and earthquakes, surface processes that shape landscapes and create the geological record, biological processes that build diversity and bring extinction, up to planetary-scale systems, such as plate tectonics, climate and the origins of life and ecosystems. The Earth Science takes you very close to the nature as this is basically a filed Science. The geology program integrates field trips with classroom learning to give you the hands-on experience you need to succeed. These opportunities develop your technical skills using measuring instruments and laboratory equipment.

2. Learning outcomes-based approach to curricular planning:

2.1 Nature and extent of UG program in Geology:

The UG program in Geology builds on the basic Geosciences if taught at the +2 level in all the schools in the country. Ideally, the +2 senior secondary school education should aim and achieve a sound grounding in understanding the basic concepts in Geosciences with sufficient content of topics from modern Geology and contemporary areas of exciting developments in geosciences to ignite the young minds. The curricula and syllabi should be framed and implemented in such a way that the basic connection between theory and experiment and its importance in understanding Geology should be apparent to the student. This is very critical in developing a scientific temperament and urge to innovate, create and discover in Geology. Unfortunately the condition of our school system in most parts of the country lacks the facilities to achieve the above goal and it is incumbent upon the college/university system to fill the gaps in the knowledge creation of our young minds created by the lack of infrastructural and academic resources of our school system and strengthen their

understanding in all the subjects through the UG programs specially in Geology and other science subjects.

The undergraduate program in Geology is presently being offered though the courses designed for granting the following degrees by various colleges and universities in India. All the courses are of three year duration spread over six semesters after the higher secondary (+2) level Science course.

i. B.Sc (Honours) Geology

ii. B.Sc with Geology

2.2 Aims of UG program in Geology

The aims and objectives of our UG educational programs in sciences in general and Geology in particular should be structured to

- Create the facilities and environment in all the educational institutions to introduce and consolidate the knowledge acquired at +2 level and to motivate and inspire the students to create deep interest in Geology, to develop broad and balanced knowledge and understanding of geological concepts, principles and theories of stratigraphy, geological mapping, exploration of natural resources and understand Earth evolution.
- Learn, design and perform experiments in the labs to demonstrate the concepts, principles and theories learned in the classrooms.
- Develop the ability to apply the knowledge acquired in the classroom and laboratories to specific problems in theoretical and applied Geology.
- 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 spanning from disaster management, watershed management, water pollution, oil exploration and mining, etc.
- Emphasize the need for integrating Geosciences as one of the most important branch of science for pursuing the interdisciplinary and multidisciplinary higher education and/or research in interdisciplinary and multidisciplinary areas.
- To emphasize the importance of Geology as the most important discipline for sustaining the existing industries and establishing new ones to create job opportunities at all levels of employment.

In view of opening the new windows in higher education and research and opening job opportunities at all levels from technicians to innovator scientists and engineers, two undergraduate programs are offered in our universities and other higher education institutions (HEI) at the entry level of our higher education system.

3 Graduate Attributes in Geology

Some of the characteristic attributes of a graduate in Geology are

3.1 Education and Training

a) Provide training of the highest academic quality in Geosciences in a challenging and supportive learning environment.
b) Develop a systematic understanding of both core areas and advanced topics in the study of the Earth, its materials and structure, its history over 4600 million years, and the processes that have controlled its evolution as a planet by viewing Earth from new and challenging perspectives of time, space, process and pattern.
c) Develop the ability to evaluate primary evidence critically; and the conceptual understanding to present arguments and solutions based on primary data and theory.
d) Promote an appreciation of the limits to our present understanding of the Earth, its processes and the interactions between them.
e) 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.
f) Provide for student interaction with high-level scientific expertise and advanced equipment in an environment committed to scientific advance.
g) Develop skills in gathering and interpreting the geological and geophysical data used to gain this understanding and thereby equip students with the foundations for their professional careers or additional study.
h) 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.

i) Provide, through a strong transferable skills strand, graduates for non-Earth-science industries, commerce, public service and education, particularly those needing to be informed by the methodology of a broad range of physical and natural science.

3.2 Communication Skills:

a) Skills to communicate in written, numerical, graphical and verbal forms, in ways that are appropriate to different audiences and indifferent situations, ranging from scientific and industry reports, to group and individual oral presentations, and from blogs and outreach articles, to news articles and essays.

b) Formulate a coherent written, electronic or oral presentation on the basis of material gathered (e.g. textual, numerical, verbal, graphical) and organised independently on a given topic.

c) Express clearly ideas and arguments, both orally and in writing and in electronic media.

d) Use group discussions and joint seminar presentations to research and present work collaboratively; and Develop oral presentation and participation skills during seminars and group-work, and in written form through online e- learning tools, dissertations and essays.

3.3 Critical Thinking:

a) Acquire an understanding of the concept in geology and related disciplines and an ability to understand, integrate, and extend it so that all fundamental geological concepts are accessible.

b) Acquire, digest and critically evaluate scholarly arguments, the assumptions behind them, and their theoretical and empirical components.

3.4 Problem Solving:

a) Skills to recognise and articulate a problem and then apply appropriate conceptual frameworks and methods to solve it.

b) 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. This provides the foundation for student-led independent, but academically directed, project work.

3.5 Analytical Reasoning:

a) A broad knowledge base in geology and related disciplines and an ability to understand, integrate, and extend it so that all fundamental geological concepts are accessible. Knowledge of the fundamentals of chemistry, physics, biology and mathematics needed to provide insight into these Earth processes (with levels of expertise varying according to choices of more generalist or more specialist courses at honours level).

b) 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.

3.6 Research-Related Skills:

a) Develop a research design, which has an appropriate problem related to earth sciences but may incorporate some scientific methods, ability to plan and write a research paper.

b) Ability to process and interpret large, complex, datasets, to hypothesis set and test, and to function as a numerate, literate scientist able to prove insight and guidance related to real-world problems and issues.

c) Ability to apply knowledge and understanding to address familiar, unresolved and more open-ended problems.

d) Ability to collect, analyse, synthesise, summarise and inter-relate diverse processes and facts, to formulate and test hypotheses and reach conclusions.

3.7 Self and Time Management:

a) Time management skills are developed through interaction with the assessment process in all years: students must learn how to meet deadlines for submission of continuous assessment material and how to set aside appropriate time to prepare for end of year examinations.

b) Time management is integral to the student's independent mapping project.

3.8 Team Work:

a) Ability to contribute effectively to team objectives and interact productively with others both in project-related settings and in meetings.

b) This is addressed through group exercises in all years of the Geology programme, including in-class presentations, group lab-sessions where students use research

equipment, mock-industry presentations to panels of outside industry experts, and group fieldwork mini-projects.

3.9 Scientific Reasoning:

a) View the Earth from new and challenging perspectives of time, space, process and pattern.
b) Develop a systematic understanding of both core areas and advanced topics in the study of the Earth, its materials and structure, its history over 4600 million years, and the processes that have controlled its evolution as a planet.
c) Provide for student interaction with high-level scientific expertise and advanced equipment in an environment committed to scientific advance.
d) Develop the ability to evaluate primary evidence critically; and the conceptual understanding to present arguments and solutions based on primary data and theory.
e) Promote an appreciation of the limits to our present understanding of the Earth, its processes and the interactions between them.

3.10 Digital Literacy:

a) ability of advanced Word skills and advanced GIS, statistics, databases, spreadsheets, digital drawing through online workbooks and workshops
b) ability to use digital resources for presentations

3.11 Moral and Ethical Values:

a) The degree to which every student engages with these themes will vary but it is important that all think especially about ethical issues
b) 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.

3.12 Leadership Readiness:

a) Provide training of the highest academic quality in Earth Sciences in a challenging and supportive learning environment
b) Be accessible to those qualified at intake in a broad and diverse range of sciences.

c) Provide an excellent preparation for a career in professional practice in industrial or environmental Earth Sciences, research in Earth Sciences, and specialist areas of other physical and natural sciences.

d) Provide, through a strong transferable skills strand, graduates for non-Earth-science industries, commerce, public service and education, particularly those needing to be informed by the methodology of a broad range of physical and natural science.

3.13 Life-long Learning:

a) ability to blend academic and practical skills

b) ability to transfer such skills to other domains of one's life and work

3.14 Global Competency:

a) 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.

b) He/She will be ready to accept challenges and stand in competition at a national and global level.

4. Qualification descriptors for a UG programs in Geology

4.1 Qualification descriptors for a B.Sc. Geology

The qualification descriptors for the B.Sc. programme in Geology shall be five learning attributes such as understanding, use, communication, expansion, and application of subject knowledge with a clear understanding of one's location. This also involves an awareness on the students' part of differences pertaining to class, caste, gender, community, region, etc. in order that they can transcend these differences with transparency of purpose and thought. The key qualification descriptor for B.Sc. Geology shall be clarity of communication as well as critical thinking and ethical awareness. Each Graduate in Geology should be able to:

- Demonstrate a coherent and systematic knowledge and understanding of the field of Geology making intelligible Geoscientific research frontiers and theoretical developments in this field in the global context. This would also include the student's

ability to collect, analyse, synthesise, summarise and inter-relate diverse processes and facts, to formulate and test hypotheses and reach conclusions.

- Demonstrate the ability to identify and differentiate rocks, minerals, fossils, other Earth materials and Earth structures in the field, as hand specimens and using laboratory techniques including microscopy and spectroscopic analysis. Skill to observe and record original field and laboratory data and then apply these to evaluate and resolve geological and geotechnical problems.

- Demonstrate the ability to assemble and analyse incomplete and varied observational data and develop testable hypotheses, predictions or explanations from them. Skills to recognise associations between geological observations and then integrate them into their 3D and 4D (space-time) frameworks.

- Demonstrate the ability to share the results of academic and disciplinary learning through different forms of communication such as essays, dissertations, reports, findings, notes, etc. on different platforms of communication such as the classroom, conferences, seminars, workshops, the media and the internet

- Ability to devise and carry out an independent field-based project, including the formulation and testing of hypotheses whilst in the process of carrying out the project. The integration of field-based, experimental and theoretical principles needed for the Earth Sciences.

The goal of the Geology undergraduate program is to equip students with the fundamental knowledge of the diverse fields of Geology (encompassing Geomorphology and Surface Processes, Hydrology & Low-Temperature Geochemistry, Sedimentology and Paleoecology, and Tectonics and Solid-Earth Processes). In addition, it is critical that students learn to think like a scientist and to apply the scientific method in their coursework and in their lives. The geology program integrates field trips with classroom learning to give you the hands-on experience you need to succeed. These opportunities develop your technical skills using measuring instruments and laboratory equipment. The skills have been split into two groups:

skills needed by any science professional and skills specifically needed by geosciences professionals.

Critical Geosciences Skills

1. Make inferences about Earth systems from observations of the natural world
2. Readily solve problems, especially those requiring spatial and temporal interpretation
3. Work with uncertainty, non-uniqueness, incompleteness, ambiguity, and indirect observations
4. Integrate information from different disciplines and apply systems thinking
5. Have strong field skills
6. Have strong computational skills for managing and analysing multi-component datasets
7. Be able to collect, illustrate, and analyse spatial data

Critical Professional Scientist Skills

8. Think critically and problem-solve
9. Communicate effectively to scientists and non-scientists
10. Integrate information from different sources and continue to learn

4.2 Qualification descriptors for B. Sc. (Honours) Geology

The qualification descriptors for a B.Sc. (Honours) Geology Program may include the following. The graduates should be able to:

- 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;

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

- 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.

- Demonstrate comprehensive knowledge about materials, including current research, scholarly, and/or professional literature, relating to essential and advanced learning areas pertaining to various subfields in Geology, and techniques and skills required for identifying problems and issues in their area of specialization.

- Demonstrate skills in identifying information needs, collection of relevant quantitative and/or qualitative geostatistical 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.

- 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 like mineralogy, petrology, hydrogeology, disasters, etc., etc.

- 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;

- 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.

- Apply one's knowledge and understandings relating to Geology and skills to new/unfamiliar contexts and to identify and analyse problems and issues and seek solutions to real-life problems.

- 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.

5. Programme Learning Outcomes relating to B. Sc. Courses in Geology

5.1 Program Learning Outcomes in B.Sc. Geology

The student graduating with the Degree B.Sc. Geology should:

- Acquire a solid base of knowledge in the science of geology as a whole as well as earth materials, earth history, sedimentation and stratigraphy, deformational processes and structural features, and geomorphic processes and landforms.
- Know the geologic time scale and place important geologic events in a temporal framework
- Use compasses, survey instruments, and images in geological investigations
- Understand the pathways, fluxes, and influence of water and other fluids at Earth's surface and in the subsurface
- Interpret topographic maps and terrain models and create profiles
- Interpret geologic maps and construct cross sections from them
- Interpret geophysical measurements of subsurface properties
- Distinguish between various structural features and determine the types of stress responsible for their formation
- Describe and interpret types of surfacial deposits and landforms
- Apply principles of mathematics, chemistry, and physics to geologic problems
- Develop proficiency in conveying complex geologic concepts in clear, technically correct writing.
- Develop proficiency in oral communication of complex geologic concepts.
- Develop the aptitudes and dispositions necessary to help democratize society by obtaining and maintaining employment as a professional geologist.

5.2 Program Learning Outcomes in B. Sc. (Honours) Geology

The student graduating with the Degree B. Sc. (Honours) Geology should be able to

- Acquire

a) 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, Palaeontology, Economic geology, Hydrogeology, etc. and its linkages with related interdisciplinary areas/subjects like Geography, Environmental

sciences, Physics, Chemistry, Mathematics, Life sciences, Atmospheric sciences, Remote Sensing, Computer science, Information Technology;

b) 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;

c) 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.

- Demonstrate the ability to use skills in Geology and its related areas of technology for formulating and tackling geosciences-related problems and identifying and applying appropriate geological principles and methodologies to solve a wide range of problems associated with geosciences.

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

- 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.

- Demonstrate relevant generic skills and global competencies such as

a) 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;

b) investigative skills, including skills of independent investigation of geoscience-related issues and problems;

c) communication skills involving the ability to listen carefully, to read texts and research papers analytically and to present complex information in a concise manner to different groups/audiences of technical or popular nature;

d) 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;
e) ICT skills;
f) personal skills such as the ability to work both independently and in Teams

- Demonstrate professional behaviour such as

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

Core Course for B.Sc. (Honours) Geology

Sr. no.		CC-I	CC-II	CC-III	CC-IV	CC-V	CC-VI	CC-VII	CC-VIII	CC-IX	CC-X	CC-XI	CC-XII	CC-XIII	CC-XIV
1	Fundamental understanding of the field	X	X	X	X	X	X	X	X	X	X	X	X	X	X
2	Application of basic Geology concepts	X	X	X	X	X	X	X	X	X	X	X	X	X	X
3	Linkages with related disciplines	X	X	X	X	X	X	X	X	X	X	X	X	X	X
4	Procedural knowledge for professional subjects	X	X	X	X	X	X	X	X	X	X	X	X	X	X
5	Skills in related field of specialization	X	X	X	X	X	X	X	X	X	X	X	X	X	X
6	Ability to use in Geological problems	X	X	X	X	X	X	X	X	X	X	X	X	X	X
7	Skills in Mathematical modeling	--	X	X	X	X			X	X	X	X	X	X	X
8	Skills in performing analysis and interpretation of data	X	X	X	X	X	X	X	X	X	X	X	X	X	X
9	Develop investigative Skills	X	X	X	X	X	X	X	X		X	X	X	X	X
10	Skills in problem solving in Geology and related discipline	X	X	X	X	X	X	X	X	X	X	X	X	X	X
11	Develop Technical Communication skills	X	X	X	X	X	X	X	X	X	X	X	X	X	X
12	Developing analytical skills and popular communication	X	X	X	X					X			X	X	X
13	Developing ICT skills	X	X	X	X	X	X	X	X		X	X	X	X	X
14	Demonstrate Professional behaviour with respect to attribute like objectivity, ethical values, selfreading, etc.	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Discipline Specific Electives (DSE) for B.Sc. (Honours) Geology

Sr no.		DSE -I	DSE -II	DSE -III	DSE -IV	DSE -V
1	Fundamental understanding of the field	X	X	X	X	X
2	Application of basic Geological concepts	X	X	X	X	X
3	Linkages with related disciplines	X	X	X	X	X
4	Procedural knowledge for professional subjects	X	X	X	X	X
5	Skills in related field of specialization	X	X	X	X	X
6	Ability to use inGeological problems	X	X	X	X	X
7	Skills in Mathematical modeling	X	X	X	X	X
8	Skills in performing analysis and interpretation of data	X	X	X	X	X
9	Develop investigative Skills	X			X	X
10	Skills in problem solving in Geology and related discipline	X			X	X
11	Develop Technical Communication skills			X	X	
12	Developing analytical skills and popular communication	X			X	
13	Developing ICT skills		X		X	
14	Demonstrate Professional behaviour with respect to attribute like objectivity, ethical values, selfreading, etc.	X	X	X	X	X

Skill Enhancement Course (SEC): B.Sc. (Honours) and B.Sc. Geology

Sr. no.		SEC -I	SEC -II	SEC -III	SEC -IV	SEC -V	SEC - VI	SEC - VII	SEC - VIII
1	Fundamental understanding of the field	X	X	X	X	X	X	X	X
2	Application of basic Geology concepts	X	X	X	X	X	X	X	X
3	Linkages with related disciplines	X	X	X	X	X	X	X	X
4	Procedural knowledge for professional subjects	X	X	X	X	X	-	-	X
5	Skills in related field of specialization		-	-	-	X	-	-	X
6	Ability to use in Geological problem	X	X	X	-	-	X	X	X
7	Skills in Mathematical modeling	-	X	-	-	-	-	-	-
8	Skills in performing analysis and interpretation of data	X	X	X	X	X	X	X	X
9	Develop investigative Skills	X	X	-	-	-	-	-	X
10	Skills in problem solving in Geology and related discipline	-	X	-	X	-	-	-	-
11	Develop Technical Communication skills	-	X	X	X	X	X	X	X
12	Developing analytical skills and popular communication	-	X	X	-	X	X	X	X
13	Developing ICT skills	-	X	-	-	-	-	-	-
14	Demonstrate Professional behaviour with respect to attribute like objectivity, ethical values, self reading, etc.	X	X	X	X	X	X	X	X

Core Course & Generic Elective & Discipline Specific Electives for B. Sc Geology

Sr. no.		CC-I/ GEC-I	CCII/ GECII	CCIII / GEC -III	CCIV / GEC -IV
1	Fundamental understanding of the field	X	X	X	X
2	Application of basic Geology concepts	X	X	X	X
3	Linkages with related disciplines	X	X	X	X
4	Procedural knowledge for professional subjects	X	X	X	X
5	Skills in related field of specialization	X	X	X	X
6	Ability to use in Geological problem	X	X	X	X
7	Skills in Mathematical modeling	X	X	X	X
8	Skills in performing analysis and interpretation of data	X	X	X	X
9	Develop investigative Skills	X	X	X	X
10	Skills in problem solving in Geology and related discipline	X	X	X	X
11	Develop Technical Communication skills	X	X	X	X
12	Developing analytical skills and popular communication	X	X	X	X
13	Developing ICT skills	X	X	X	X
14	Demonstrate Professional behaviour with respect to attribute like objectivity, ethical values, self reading, etc	X	X	X	X

6. Structure of UG Courses in Geology

Distribution of different Courses in each semester with their credits for B.Sc.in Geology

Semester	**Compulsory Core Courses (CC) each with 06 credit (Total no. of Papers 12) 04 Core courses are compulsory to be selected from each subject A B and C**	**Discipline Specific Elective(DSE) Select any 02 courses form each subject A B and C**	**Ability Enhancement Compulsory Courses (AECC) Select any 02 from 03 courses**	**Skill Enhancement Course (SEC) Select any 08 courses choosing (at least 2 and not more than 3) form each subject A B and C**	**Total Credits**
Sem I	CC-1A CC-1B CC-1C	-	AECC-1	-	22
Sem II	CC-2A CC-2B CC-2C	-	AECC-2	-	22
Sem III	CC-3A CC-3B CC-3C	-	-	SEC-1A SEC-2B	22
Sem IV	CC-4A CC-4B CC-4C	-	-	SEC-2A SEC-2C	22
Sem V	-	DSE-1A DSE -1B DSE -1C	-	SEC-2B SEC-2C	22
Sem VI	-	DSE -2A DSE -2B DSE -2C	-	Any 02 SEC courses from discipline A, B & C	22
Total Credits	72	36	8	16	132

Distribution of different Courses in each semester with their credits for B.Sc.(Honours) in Geology

Semester	**Core Courses (CC) each with 06 credit All 14 courses are compulsory**	**Generic Elective(GE)**	**Skill Enhancement Course (SEC) Select any 4 out of 8 courses**	**Discipline Specific Elective (DSE) Select any four out of 5 courses**	**Ability Enhancement Compulsory Courses (AECC) Select any 2 out of 3 courses**	**Total Credit**
Sem I	CC-1 CC-2	GEC-1	SEC-1	-	AECC-1	24
Sem II	CC-3 CC-4	GEC-2	SEC-2	-	AECC-2	24
Sem III	CC-5 CC-6 CC-7	GEC-3	-	-	-	24
Sem IV	CC-8 CC-9 CC-10	GEC-4	-	-	-	24
Sem V	CC-11 CC-12	-	SEC-3	DSE-1 DSE-2	-	24
Sem VI	CC-13 CC-14	-	SEC-4	DSE-3 DSE-4	-	24
Total Credits	84	24	8	24	8	148

6.1 Structure of courses in B.Sc. Geology

The B.Sc. programs with Geology as one of the subjects consists of 132 credits based on the Choice Based Credit System (CBCS) approved by the UGC with 1 hour for each credit for theory/tutorials and 2 hours for each credit of laboratory work. Out of 132 credits, 108 credits are equally divided between Geology and two other subjects (36 credits each) based on the choice of the candidates while the additional 16 credits consist of Skilled Enhancement courses (SEC) and 8 credits of Ability Enhancement Compulsory Courses (AECC) equally divided (4 credits each) between disciplines of the Environmental sciences and Languages/communications. The 132 credit courses comprise of 72 credits of core courses (CC) and 8 credits of AECC which are mandatory as well as 36 credits of Discipline specific courses (DSE) and 16 credits of Skilled Enhancement courses (SEC) which are elective. A student can take more than 132 credits in total (but not more than 148 credits) to qualify for the grant of the B.Sc. Geology degree after completing them successfully as per rules and regulations of the HEI.

6.2 Structure of courses in B.Sc. (Honours)

The B.Sc. (Honours) Geology program is also based on the Choice Based Credit System (CBCS) approved by the UGC with a total of 148 credits. Out of 148 credits, 84 credits of core courses (CC) and 8 credits of Ability Enhancement Compulsory Courses (AECC) are mandatory while 24 credits of Discipline specific course and 24 credits of Generic Elective Courses (GEC) from Interdisciplinary disciplines as well as 16 credits of Skilled Enhancement courses are elective. A student can offer more than 148 credits (but not more than a total of 160 credits) to qualify for the grant of the B.Sc. (Honours) Geology degree after completing them successfully as per rules and regulations of the HEI.

A detailed list of Core Courses, Discipline Specific Courses (DSE) Generic Elective Courses (GEC), Skill Enhancement Courses (SEC) and Ability Enhancement Compulsory Courses (AECC) are given in Section 6.3

6.3 List of Geology Courses

6.3.1 Core Courses (CC)

All the courses have 6 credits with 4 credits of theory and 2 credits of practicals.

B.Sc. Geology	B.Sc. (Honours) Geology
	Fundamentals of Geology and Understanding the Planet Earth
	Mineralogy and Crystallography
Fundamentals of Geology and Understanding the Planet Earth	
	Petrology and Geochemistry
Mineralogy and Crystallography	
	Principles of Stratigraphy and Sedimentation
Petrology and Geochemistry	
	Global Tectonics and Geodynamics of the lithosphere
Principles of Stratigraphy and Sedimentation	
-	Structural Geology
-	Environmental Geology and Geogenic disasters
-	Palaeontology
-	Applied Geophysics
-	Engineering Geology
-	Geology of India
-	Hydrogeology
-	Mineral Resources: mining methods, ore processing, beneficiation
-	Geological Field Methods and Mapping

6.3.2 Discipline Specific Electives (DSE)

All the courses have 6 credits with 4 credits of theory and 2 credits of practicals or 5 credits of theory and 1 credit of Tutorials.

B.Sc. Geology	**B.Sc. (Honours) Geology**
Climate Change: Past, Present, and Future	Climate Change: Past, Present, and Future
Oceanography and Marine Geology	Oceanography and Marine Geology
--	Isotope Geology and Geochemistry
Petroleum Geology	Petroleum Geology
Mining And Mineral Exploration	Mining And Mineral Exploration
Research Project in Geosciences (Dissertation)	Research Project in Geosciences (Dissertation)

6.3.3 Skill Enhancement Courses (SEC)

All courses have 4 credits with 2 credits of theory and 2 credits of Practicals /Tutorials / Projects and Field Work (if applicable) to be decided by HEI.

B.Sc. Geology	**B.Sc. (Honours) Geology**
Earth Science Work Experience	Earth Science Work Experience
Watershed Development	Watershed Development
Water and Sanitation	Water and Sanitation
Geotechnology	Geotechnology
Optics and Optical mineralogy	Optics and Optical mineralogy
Gemology and Gem Testing	Gemology and Gem Testing
Oil Field Services	Oil Field Services
Medical Geology	Medical Geology

6.3.4 Generic Electives (GE) (Minor Geology)

All the courses have 6 credits with 4 for other Departments/Disciplines credits of theory and 2 credits of practicals or 5 credits of theory and 1credit of Tutorials.

Generic Elective papers for other B.Sc. (Honours) Geology program and B.Sc. (Honours) Physics
X-Ray Diffraction and phase identification
Digital Image Processing in Geology
Applications of Remote Sensing in Geosciences
Geographic Information System

6.3.5 Ability Enhancement Compulsory Courses (AECC)

All the courses have 4 credits including Theory / Practicals / Projects

AECC	**B.Sc. Geology/B.Sc. (Honours) Geology**
1	English
2	MIL Communication
3	Environment Science

6.4 Course Learning Outcomes (CLO)

B.Sc. (Honours) Geology Courses

6.4.1. Core Courses (CC)

YEAR I (SEMISTER I & II)

In addition to other courses offered, the following core courses are mandatory: The number of tentative lectures allotted is given in parenthesis.

CC-I: Fundamentals of Geology and Understanding the Planet Earth

(Credits: 06, Theory-04, Practicals-02)

(i) Course learning outcome:

The study of this paper strengthens students knowledge with respect to understanding the essentials of the structural dynamics of the earth.

(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:

This course gives an overall introduction to Geology from topics ranging from the formation of the solar system (6), meteorites (2) minerals and rocks (3), plate tectonics (5), volcanoes and earthquakes (4). An introduction to historical geology (4) and the evolution of the earth's crust (5), oceans (3), atmosphere (3), and life forms (4). Topics like geological time scale (6), stratigraphic layering (3), fossils, geologic age, dating (4), rock deformation and tectonic plate movement, (4) climate change, and mass extinction events etc. (5) are to be covered.

Books Recommended:

1. Arthur Holmes, (1992) Principles of Physical Geology. Chapman and Hall, London.
2. Miller, (1949) An Introduction to Physical Geology. East West Press Ltd.
3. Spencer, E.V., (1962) Basic concepts of Physical Geology. Oxford & IBH.
4. Mahapatra, G.B., (1994) A text book of Physical Geology. CBS Publishers.
5. Press and Siever (1998) Understanding Earth, WH Freeman & Co.
6. Emiliani, C. (1992) Planet earth: cosmology, geology, and the evolution of life and environment. Cambridge University Press

CC-II: Principles of Stratigraphy and Sedimentation

(Credits: 06, Theory-04, Practicals-02)

(i) Course learning outcome:

The study of stratigraphy and Palaeontology encompasses the aspects of the age of the earth, chronological arrangement of rocks and appearance and evolution of life through the geologic

time. The knowledge of the concepts in stratigraphy, correlation, and paleontology would enable the students to understand the changes that occurred in the history of the earth and relate them to their field observations and also, in understanding the framework of the stratigraphy of India

(ii) Broad contents of the course: Stratigraphy and Paleontology, the two branches of Geology work together to unearth the secrets of age from rocks of the earth's crust. Stratigraphers study the composition and arrangement of layered or stratified rocks. Palaeontologists study the remains of plants and animals which have been preserved in the earth's crust by natural processes. With these objectives in mind it becomes pertinent to understand the basic concepts of Stratigraphy and Palaeontology.

(iii) Skills to be learned:

The students will be exposed to the principles of stratigraphy including order of superposition. They will also be able to identify primary sedimentary structure and their depositional environments.

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

An introduction to the principles of stratigraphy (10), nature of sediment formation, transport and deposition (10), as well as the use of primary (10) and secondary sedimentary structures (10) in the interpretation and reconstruction of sedimentary facies (10), paleogeography, past climates, and depositional histories (10).

Books Recommended:

1. Wadia, D., (1973) Geology of India. McGraw Hill Book co.
2. Krishnan, M.S., (1982) Geology of India and Burma, 6th Edition. CBS Publ.
3. Ramakrishnan M, and Vaidynadhan, R (1994) Geology of India, Geological Society of India Publication, Bangalore. Vol. I &II.
4. Friedman & Sanders, (1978) Principles of Sedimentology. John Wiley and sons.
5. Pettijohn, F.J., (1975. Sedimentary rocks, Harper & Bros. 3rd Ed.
6. Sengupta. S., (1997) Introduction to sedimentology. Oxford-IBH.
7. Pettijohn F.J. (1984) Sedimentary Rocks (3rd Edition), CBS Publishers and Distributors, New Delhi.

8. Ravindrakumar (2018) Fundamentals of Historical Geology and Stratigraphy of India, Newage Publications.
9. Sengupta S.M. (2007) Introduction to Sedimentology (2nd Edition), CBS Publishers and Distributors, New Delhi.
10. Boggs S., Petrology of Sedimentary rocks (2nd edition), Cambridge University Press.
11. Greensmith J. (1989) Petrology of the Sedimentary rocks (7th Edition), CBS Publishers, New Delhi.
12. Tucker E.M. (2001) Sedimentary Petrology (3rd Edition), Blackwell Science Ltd.
13. H. Blatt, G. Middleton and R. Murray (1980) Origin of sedimentary rocks, Princeton Hall.

CC-III: Mineralogy and Crystallography

(Credits: 06, Theory-04, Practicals-02)

(i) Course learning outcome:

Studying the basics of mineralogy and crystallography helps in understanding and building the overall knowledge in Geology.

(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

(iii) Skills to be learned:

The students will be able to identify common rock-forming minerals n hand specimens as well as in thin sections. Besides, they will familiarise themselves with Bavarias crystal lattice and crystal; systems.

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

Mineralogy: An introduction to the study of minerals (2), definition of minerals (3), mineral groups and silicate structure (5). Topics include the physical mineralogy (5), chemical mineralogy (5) and optical properties of the common rock-forming minerals (5), application

of mineralogical information to geological problems (5). Lab activities include examination and identification of minerals in hand specimen and thin section.

Crystallography: Introduction to Crystals and their characters (4). Crystal form, face, edge, solid angle; Interfacial angle and their measurements (5); Crystallographic axes and angles (1).Introduction to Crystal parameters and Symmetry elements (5), Bavarias crystal lattice: (Isometric, Tetragonal, Hexagonal, Trigonal, Orthorhombic, Monoclinic and Triclinic systems (15).

Books Recommended:

1. Ram S. Sharma and Anurag Sharma (2013) Crystallography and Mineralogy - Concepts and Methods. Text Book Series, Geological Society of India, Bangalore
2. Dana, E.S. and Ford, W.E., (2002) A textbook of Mineralogy (Reprints).
3. Flint, Y., (1975) Essential of crystallography, Mir Publishers.
4. Phillips, F.C., (1963) An introduction to crystallography. Wiley, New York.
5. Berry, L.G., Mason, B. and Dietrich, R.V., (1982) Mineralogy. CBS Publ.
6. Read, H.H., (1968) Rutley's Element of Mineralogy (Rev. Ed.). Thomas Murby and Co.
7. Berry and Mason, (1961) Mineralogy. W.H. Freeman & Co.
8. Kerr, B.F., (1995) Optical Mineralogy 5th Ed. McGraw Hill, New York.
9. Deer, Howie and Zussman (1996) Introduction to Rock forming Minerals, Pearson
10. Wahlstrom E.E. (1971) Optical crystallography, John Wiley and sons.
11. R.N. Hota (2012) Practical approach to Mineralogy and Crystallography, CBS Publications & Distributions.
12. Perkin D. (2010) Mineralogy, Pearson.

CC-IV: Petrology and Geochemistry

(Credits: 06, Theory-04, Practicals-02)

(i) Course learning outcome:

On completion of the course the students will have gained an understanding of the processes involved in the formation of igneous and metamorphic rocks, their textures, structures, classifications and their importance.

(ii) Broad contents of the course:

Petrology is the science of rocks. The course will help the students to exhibit an improved understanding of fundamental petrologic processes and common rock types.

(iii) Skills to be learned:

Students learn to identify, describe and classify rocks using hand specimens. The students will also acquire skills to determine and interpret geochemistry of rocks

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

Petrology: Igneous and metamorphic rocks will be studied in terms of their definition, mineralogical and chemical relationships, classification (TAS, QAPF) (6), field characteristics, and tectonic environments (4). Topics include: phase diagrams (6), melt generation and emplacement (5), metamorphic facies and textures (5), and geochemical processes (4).

Geochemistry: An introduction to geochemistry (4), including geochemical abundances, partitioning coefficients and recycling within the earth (6), geochemistry of igneous/metamorphic rocks and hydrothermal processes (10), average geochemical composition of crust and mantle (6), Radiogenic isotopic end members (4).

Books Recommended:

1. Ram S. Sharma (2016) Metamorphic Petrology Concepts and Methods. Text Book Series, Geological Society of India, Bangalore
2. Bose M.K. (1997) Igneous Petrology. The World Press Pvt. Ltd. 568 p.
3. Ehlers, WG, and Blatt, H.(1987) Petrology, Igneous, Sedimentary and Metamorphic rocks, CBS Publishers
4. Turner, F.J., (1980) Metamorphic petrology. McGraw Hill.
5. Mason, R., (1978) Petrology of Metamorphic Rocks. CBS Publ.
6. Winkler, H.G.C., (1967) Petrogenesis of Metamorphic Rocks. Narosa Publ.
7. Best M.G. Igneous and Metamorphic Petrology, Blackwell Publications
8. Blatt H., Tracy R.J. and Owens B.E. (2006) Petrology – Igneous, sedimentary and Metamorphic rocks (3rdEdition), W.H. Freeman and Company, New York.
9. Collinson J.D and Thompson D.B (1989) Sedimentary Structures (2nd Edition), Unwin Hyman Ltd, Sydney.

10. Hatch F.H., Wells A.K and Wells M.K. (1984) Petrology of the igneous rocks. CBS Publishers, 551 p.
11. Turner F.J and Verhoogen J. (1960) Igneous and Metamorphic Petrology, McGraw-Hill.
12. Winter J. D. (2001) An Introduction to Igneous and Metamorphic Petrology, Prentice Hall, 697p
13. Rollinson, H. (2007) Using geochemical data – evaluation, presentation and interpretation. 2nd Edition. Publisher Longman Scientific & Technical.
14. Philpotts, A. and Ague, J. (2009). Principles of igneous and metamorphic petrology. Cambridge University Press.
15. Raymond, L. A. (2002). Petrology: the study of igneous, sedimentary, and metamorphic rocks. McGraw-Hill Science Engineering

CC-V: Global Tectonics and Geodynamics of the lithosphere

(Credits: 06, Theory-04, Practicals-02)

(i) Course learning outcome:

This course enables the students to appreciate the dynamic nature of the Earth processes. They will also be appraised about the geodynamics of the lithosphere and concept of isostacy, ocean floor spreading, continental drift, plate tectonics.

(ii) Broad contents of the course:

This course develops the concepts of plate tectonics on a global scale and analyses the physical processes responsible for the formation and destruction of the plates.

(iii) Skills to be learned:

The student will be introduced to the structure of the continental crust vs. oceanic crust and their geodynamic. They will also appreciate the modern concept of plate tectonics and its implications.

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

Evolution and structure of the lithosphere (5), lithosphere-asthenospheric interactions (5). LVZ (5), continental crust vs. oceanic crust (6), geotherms-continental crust vs. oceanic crust (6), Concepts of isostacy (3), ocean floor spreading, continental drift, plate tectonics (10).

Definition of plate, platform and shield (5), Different tectonic settings on Earth-MOR, Rift valleys, Island arcs (10), Morphology of Ocean floor (5).

Books Recommended:

1. Patwardhan, A.M. (2012)The dynamic Earth System, PHI Learning Pvt. Ltd.,
2. Moores E.M. and Twiss R.J. (1995) Tectonics, W. H. Freeman
3. Valdiya, K.S.,(1984) Aspects of Tectonics: Focus on Southcentral Asia, Tata-McGraw Hill, New Delhi,
4. Beloussov, V.V. (1980) Geotectonics, Springer-Verlag Berlin Heidelberg
5. Condie, K.C.(1989) Plate Tectonics &Crustal Evolution, Butterworth-Heinemann
6. Billings, M.P. (1942) Structural Geology, Prentice Hall,
7. Badgley, P. C. (1965) Structural & Tectonic Principles, Harper & Row
8. Valdiya K.S. (2014) Making of India, Springer.
9. Valdiya K.S. (1984) Aspects of tectonics, Tata Mcgrath Hill.

YEAR II (SEMISTER III & IV)

CC-VI: Structural Geology

(Credits: 06, Theory-04, Practicals-02)

(i) Course learning outcome:

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

(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:

Concept of strike and dip, Dipping strata (6), unconformities (3), Brunton compass (3), Understanding stress and strain(5), ductile vs. brittle deformation(5), the effects of temperature, time, pressure, pore fluids and strain rate on rock strength (12), and the mechanisms of rock deformation (2). Definition, elements, types and nature of joints(2), fractures(3), shear zones(4), faults(6), and folds(10).

Books Recommended:

1. Ramsay, J.G. (1967) Folding and fracturing of rocks. McGraw-Hill, New York
2. Jain, A.K., (2014) An introduction to structural geology. Text Book series in Geological Sciences for Graduate Students. Geological Society of India, Bangalore.
3. Billings, M.P., (1972) Structural Geology. Prentice Hall.
4. Davis, G.R., (1984) Structural Geology of Rocks and Region. John Wiley
5. Singh, R. P., (1995) Structural Geology: A Practical Approach. Ganga Kaveri Publ., Varanasi
6. Hills, E.S., (1963) Elements of Structural Geology. Farrold and Sons, London.

CC-VII: Environmental Geology and Geogenic disasters

(Credits: 06, Theory-04, Practicals-02)

(i) Course learning outcome:

Know the basic fundamentals of earth science as applied to the interaction between human activity and the natural environment. Understand the occurrence and availability of both surface and subsurface water resources and the role of the hydrologic cycle and pollution. Understand the role of plate tectonics in causing earthquakes and how this understanding can aid the assessment of seismic hazard.

(ii) Broad contents of the course:

This course deals with water and its pollution and geogenic disasters.

(iii) Skills to be learned:

Students will be able to test and evaluate water quality for drinking and agricultural use. They will also have knowledge about various natural disasters.

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

Environmental Geology: Interaction between human activity and the natural environment (5).Surface and subsurface water resources (5), hydrogeologic cycle and pollution, point, line and area sources of pollution (5). Water quality parameters, BIS standards (5), organic and inorganic pollutants, heavy metal pollution (5), remedial measures (5).

Geogenic disasters: Earthquakes and their prediction, Richter scale, seismic hazard zoning map of India (5), Building codes and public education (5). Different types of volcanoes, volcanic hazards and their occurrence in the plate tectonic context (5). Cyclones and Floods, fundamental river processes and the interaction between a river and its floodplain (5). Examine the costs and benefits, to both humans and to ecosystems, of both technological approaches (e.g., dams and levees) and land-use planning approaches (floodplain mapping and zoning) to avoiding flood damages. Droughts, meteorological, agricultural and hydrologic types, mitigation of droughts (5). Landslides, different types and evaluation of technologies for preventing landslides (5).

Books Recommended:

1. Verma, V.K., (1986) Geomorphology Earth surface processes and form. McGraw Hill.
2. Chorley, R. J., (1984) Geomorphology. Methuen.
3. Selby, M.J., (1996) Earths Changing Surface. Oxford University Press UK.
4. Thornbury W. D., (1997) Principles of Geomorphology Wiley Eastern Ltd., New Delhi.
5. Valdiya, K. S., (1987) Environmental Geology - Indian Context. Tata McGraw Hill New Delhi.
6. Keller, E. A., (2000) Environmental Geology. Shales E. Merril Publishing Co., Columbus, Ohio.
7. Montgomery, C., (1984) Environmental Geology. John Wiley and Sons, London.
8. Bird, Eric, (2000) Coastal Geomorphology: An Introduction. John Wiley & Sons, Ltd. Singapore.
9. Liu, B.C., (1981) Earthquake Risk and Damage, Westview.
10. Sharma J. P., Environmental Studies, Laxmi Publications (P) Ltd, New Delhi

11. Blyth, F.G.H. and M. H. de Freitas(1984)Geology for Engineers,Butterworth-Heinemann Title
12. Krynine, D.P and Judd, W.R (2005) Principles of Engineering Geology and Geotechniques, CBS Publishers & Distributors
13. Ries, H. and T. L. Watson, (1949) Elements of Engineering Geology, New York, John Wiley & Sons, Inc.

CC-VIII: Palaeontology

(Credits: 06, Theory-04, Practicals-02)

(i) Course learning outcome:

The study of Palaeontology encompasses the aspects of the age of the earth, chronological arrangement of rocks and appearance and evolution of life through the geologic time. The knowledge of palaeontology would enable the students to understand the changes that occurred in the history of the earth and relate them to their field observations.

(ii) Broad contents of the course:

Palaeontologists 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. Palaeontology 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.

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

This course will introduce the student to the Geological Time scale. Concept of Eon, Era, Period, Epoch, Origin of life, Evolution of life with time, Index fossils though time (10). Lab will include taxonomic classification (5) and morphological descriptions of_- Microfossils

(forams, cocolith and diatoms), Invertebrate (gastropods, nautiloids ammonites and belemnites, vertebrate and plant fossils (15).

Books Recommended:

1. Cowen, R. (2000) History of Life, Blackwell Science.
2. E. N. K. Clarkson (2013) Invertebrate palaeontology and Evolution, Blackwell Science
3. Rhona M. Black, (1989) The Elements of Palaeontology, Cambridge University Press
4. Michael Benton, (2005) Vertebrate Palaeontology, *Blackwell Publishing*
5. Patrick Wyse Jackson, (2019) Introducing Palaeontology: A Guide to Ancient Life, Dunedin Academic Press Ltd.
6. Raymond Enay (2012) Palaeontology of Invertebrates, Springer-Verlag.
7. Peter Doyle, Understanding Fossils: An Introduction to Invertebrate Palaeontology.
8. Morley Davies (2008) An Introduction to Palaeontology, Read Books.
9. Sreepat Jain (2017) Fundamentals of Invertebrate Palaeontology: Macrofossils, Springer India
10. Roland Goldring, (2014) Field Palaeontology, Routledge
11. Johansson, C. Z., Underwood, M. Richter, (2019) Evolution and development of Fishes, Cambridge University Press.
12. Pratul Kumar Saraswati, M.S. Srinivasan, (2016) Micropaleontology: Principles and Applications, Springer International Publishing Switzerland.
13. Michael Benton, David A. T. Harper, (2009) Introduction to Paleobiology and the Fossil Record, Wiley-Blackwell.
14. Colbert, E.H. and Minkoff, Eli C. (2001) Evolution of vertebrates, Wiley Liss

CC-IX: Applied Geophysics

(Credits: 06, Theory-04, Practicals-02)

(i) Course learning outcome:

This course deals with methodologies for extracting geological information out of geophysical datasets generated from different petrophysical properties. In Geophysical

exploration the student will gain first-hand knowledge dealing with the principles and their significance

(ii) Broad contents of the course:

The course is centred on the topics of Applied Geophysics and use of GPS in mapping the subsurface. The geophysical techniques include seismic, gravity, magnetic and electrical resistivity methods and their various applications.

(iii) Skills to be learned:

The students will acquire skills to use GPS, Electrical Resistivity and other methods for exploration. These have wide application in mineral exploration, groundwater studies, petroleum geology, etc.

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

The subject mostly covers potential fields (gravity and magnetic methods) because these datasets are readily available, however it also visits seismic and electrical geophysical methods. Topics covered include elements of maps (5), projection systems (6), datums and GPS (6); theory, acquisition (5), processing and interpretation steps involved for gravity (6) and magnetic (6) methods; electrical geophysical techniques (6) such as Self-potential (5), Electrical profiling (5) and Vertical Electrical Soundings and arrays (10).

Books Recommended:

1. Dobrin, M B and Savit C H. (1988) Introduction to Geophysical Prospecting, McGraw Hill Inc.
2. Ramachandra Rao and Prasaranga, M B. (1975) Outlines of Geophysical Prospecting - A Manual for Geologists by University of Mysore, Mysore.
3. Bhimasarikaram V.L.S., (1990) Exploration Geophysics - An Outline by Association of Exploration Geophysicists, Osmania University, Hyderabad.
4. Telford, W. M., Geldart, L. P., and Sheriff, R. E., (1990) Applied geophysics (vol. 1). Cambridge University Press.
5. Lowrie, W., (2007) Fundamentals of Geophysics. Cambridge University Press.
6. Parasnis D. S. (1986): Well Logging in Oil Fields, In: Principles of Applied Geophysics, Springer.

CC-X: Engineering Geology

(Credits: 06, Theory-04, Practicals-02)

(i) Course learning outcome:

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

(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:

This course includes examination of the physical properties of earth materials in the context of engineering and environmental projects (5). Topics include: engineering properties of soil and rock (10), geological site investigations of slopes (6), foundations (6), tunnels (6), dams (6), mines (6), roads, and other developments (6). Building stones (6) and aggregates (3).

Books Recommended:

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

YEAR III (SEMISTER V & VI)

CC-XI: Geology of India

(Credits: 06, Theory-04, Practicals-02)

(i) Course learning outcome:

The Indian sub-continent exposes a wide range of lithologies that span from 3.6 billion years to present. The geology of India is synonymous with the geology of the world and its ancient rock types from the Indian Peninsula, Cretaceous Deccan volcanism and Tethyian sediments exposed in the mighty Himalayas is noteworthy. 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.

(ii) Broad contents of the course:

The course intends to introduce students to important geological formations of India, from Precambrian to Recent times.

(iii) Skills to be learned:

At the end of the course, the students will acquire skills that will enable to recognise 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:

Precambrian evolution of Peninsular India (5), Stratigraphy and evolution of Dharwar Craton (5), Aravalli craton(5), Singhbhum craton (5), etc. Central Indian Suture Zone(4),Introduction to Proterozoic basins of India(6), Gondwana sedimentation(5), Mesozoic basins of India(5), Deccan Traps volcanic province(4), Introduction to Himalayas: Physiographic divisions and tectono-magmatic evolution(6).Colleges to encourage teaching learning related to their respective state geology(10).

Books Recommended:

1. Wadia, D. (1973) Geology of India. McGraw Hill Book co.

2. Krishnan, M.S. (1982) Geology of India and Burma, 6th Edition. CBS Publ.
3. Ramakrishnan M, and Vaidynadhan, R (1994) Geology of India, Geological Society of India Publication, Bangalore. Vol. I & II.
4. Valdiya K.S.(2010) The Making of India: Geodynamic Evolution, Springer
5. Valdiya K.S. (1984) Aspects of tectonics, Tata Mcgrath Hill.
6. Ravindrakumar (2018) Fundamentals of Historical Geology and Stratigraphy of India, Newage Publications.

CC-XII: Hydrogeology

(Credits: 06, Theory-04, Practicals-02)

(i) Course learning outcome:

On completion of the course, the student will have gained an understanding of hydrogeological concepts, exploration, exploitation and recharge of groundwater and methods of monitoring groundwater quality and sources of pollution

(ii) Broad contents of the course:

To impart knowledge about groundwater, its movement, methods of its exploration, the criteria of its quality, methods of its conservation, recharge of groundwater monitoring of groundwater quantity and quality.

(iii) Skills to be learned:

Students will be able to acquire skills of systematic hydrogeological surveys and water quality monitoring

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

This course will investigate, both qualitatively and quantitatively, the fundamental physical and chemical processes governing groundwater flow and composition, including aquifer properties: porosity, permeability (5), regional geology and hydrology (5), hydrogeology of crystalline rocks (5), water-rock interactions, and subsurface microbial activity (5). Well inventory (5). Field and laboratory methods used to characterize aquifer properties and (5), including well pumping tests (5). Groundwater chemistry: major ion and isotope analyses (5) and chemical tracers will also be covered. Also Groundwater Resources of India (5) with

special reference to each state where the HEI is location should be encouraged (5). Groundwater quality hotspots in India: TDS, F, Ar, U, Fe, etc. (10).

Books Recommended:

1. Todd, D.K. and Mays, L.W. (2004) Groundwater Hydrology, John Wiley & Sons.
2. Karanth, K.R. (1987) Groundwater Assessment Development and Management,Tata McGraw-Hill Education.
3. Raghunath, H.M. (1987) Groundwater,New Age International
4. Davis, S.N. and Dewiest R.J.M. (1966) Hydrogeology, John Wiley & Sons.
5. Freeze, R. A. and Cherry, J. A. (1979) Groundwater, Prentice Hall
6. Hiscock, K. M. (2005) Hydrogeology: Principles and Practice, Blackwell Publishing
7. Kresic, N. (1997) Hydrogeology and Groundwater Modeling, Lewis Publishers
8. Brassington, R. (2017) Field Hydrogeology, Wiley Blackwell
9. Hudak, P. F. (1999) Principles of Hydrogeology, Lewis Publishers
10. Pawar, N.J, Das, S. And Duraiswami R.A (2012) Hydrogeology of Deccan Traps and associated Formations in Peninsular India, Geol. Soc. India, Bangalore.
11. Das Subhajyoti (2011) Groundwater Resources of India. National Book Trust. 1st Edition, 248 p.

CC-XIII- Mineral Resources: mining methods, ore processing, beneficiation

(Credits: 06, Theory-04, Practicals-02)

(i) Course learning outcome:

By the end of this course the student will have learnt about techniques of mineral exploration and exploitation, estimation of ore reserves, environmental impact of mining, and the importance conservation of mineral resources.

(ii) Broad contents of the course:

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 undergraduate student 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:

Upon completion of this course, the student will acquire all knowledge and skills required for himself/herself becoming a mining geologist.

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

An introduction to mineral resources and the methods used to explore for them (5), with particular emphasis on Indian occurrences of metallic (iron, manganese, chromite, copper-lead zinc, gold, etc.) and non-metallic (barite, fire clay, gypsum, bauxite, etc.) deposits (15). Topics include: mineral deposit types (5), ore forming processes (5), mineral exploration techniques (5). Environmental and social issues that relate to mineral resource extraction will also be discussed (10). Colleges to encourage teaching and learning related to State geology (15).

Books Recommended:

1. Tiwari ,S.K. (2010) Ore Geology, Economic Minerals and Mineral Economics, Atlantic Publishers & Distributors (P) Limited
2. Aswathanarayana, U.(2005) Mineral Resources Management and the Environment, Nalkema Publishers
3. Guilbert, John M. and Charles Frederick Park(2007) The Geology of Ore Deposits, Waveland Press
4. Arogyaswamy R.N.P. (2017) Courses in mining geology, Oxford and IBH publishers

CC-XIV: Geological Field Methods and Mapping

(Credits: 06, Theory-04, Practicals-02)

(i) Course learning outcome:

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

(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:

An introduction to geological field methods and mapping (5) and use of Brunton Compass and GPS (5). 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). Topics include: field safety, logistics, navigation (5), field mapping techniques and data collection (5), toposheet reading (5), interpretation of geological data and maps, and communicating geological information (5).

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.

6.4.2. Discipline Specific Elective Course (DSE)

DSE-I: Climate Change: Past, Present, and Future

(Credits: 06, Theory-04, Practicals-02)

(i) Course learning outcome:

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

(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:

An interdisciplinary examination of global climate change from past, present, and future perspectives. The course will review the earth's current climate system (5), investigate evidence for past climates(5), and study climate change models(5). The factors affecting the earth's climate will be examined, along with anthropogenic impacts both globally and regionally (5).Milankovich cycle (3), Greenhouse Gases and their effect. El Niño,(5) ocean circulation(2).Climate changes vis-à-vis atmospheric hazards(5), changes in rainfall patterns/intensity vis-à-vis storm surges, cyclone, floods, droughts(5). Evolution of the Indian monsoon system (5), agro-climatic divisions of Indian subcontinent (5), Climate and landscape evolution(5). Use of climate proxies to model and motor past and present climate indicators (5).

Books Recommended:

1. Lowe, J.J. and Walker, M.J.C. (1997) reconstructing Quaternary Environments Longman. ISBN 0-582-100166-2. Pp. 1-16, 148-373.
2. Bradley R. S.(1999) Paleoclimatology: Reconstructing climates of the quaternary. Academic Press v. 64 of International Geophysical series.
3. Peixoto and Oort, (1992) Physics of Climate.
4. Ruddiman, W. F. (2008) Earth's Climate, Past and Future, WH Freeman & Co.
5. Bell, M. and Walker, M.J.C. (1992) Late Quaternary Environmental Change; Physical and human perspective. Longman Scientific and Technical, New York.
6. Bradely, R.S. (1999) Palaeoclimatology; reconstructing climates of the Quaternary. 2nd Edition Harcourt Academic Press: San Diego.
7. Dawson Alastair G. Ice Age Earth: Late Quaternary Geology and Climate (Physical Environment)
8. Bell, Martin. Late Quaternary Environmental change: Physical and Human Perspectives

9. Rudiman, W.F., (2001) Earth's climate: past and future. Edition 2, Freeman Publisher.
10. TERI, (2004) Looking back to change track, PHI
11. U.B. Mathur, (2010) Climate change: Past, present and future, Geol. Soc. India.

DSE-II: Oceanography and Marine Geology

(Credits: 06, Theory-04, Practicals-02)

(i) Course learning outcome:

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

(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:

Physical oceanography, ocean salinity, ocean currents (6), El-Nino-La Nino effect relation between climate and ocean in the Indian context(6), Exclusive economic zones and their economic potential(5), Principles behind echo sounder and side scan sonar systems (5) and seismic methods(6), Physiographic divisions of oceans(5), Origin, stricter and evolution of Indian Ocean shelf and margins (estuaries, deltas, tidal flats)(6). Approach to be interdisciplinary requiring integration of biological, chemical, physical and geological processes (6). Past historical impact of sea level changes (5), coastal erosion and conservation methods (5), Coastal Regulatory Zones(5).

Books Recommended:

1. Fowler, C.M.R. (1993) The Solid Earth, Cambridge Press University.
2. Tuscot, D.L. and Schubert, G (1992) Geodynamics, Wiley and Sons.
3. Kenneth, J. (1982) Marine Geology and Geophysics.

4. Wright J. and Colling A. (1995) Seawater: its Composition, Properties and Behaviour, The Open University
5. The Open University (1989) Ocean chemistry and deep sea sediments.
6. Dronkers J. (2005) Dynamics of coastal systems, World Scientific
7. Woodroffe, C.D. (2013) Coast: Form, process and evolution, Cambridge University Press.
8. 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.
9. Bender, M. (2013) Paleoclimate, Princeton Premiers in Climate
10. Bradley R. S., (1999), Paleoclimatology: Reconstructing climates of the quaternary. Academic Press v. 64 of International Geophysical series.
11. Einsele, G. (1982) Sedimentary basins-evolution, facies and sediment budget. Springer-Verlag.
12. Ruddiman, W.F. (2008) Earth's Climate, Past and Future, WH Freeman & Co.

DSE-III: Isotope Geology and Geochemistry

(Credits: 06, Theory-04, Practicals-02)

(i) Course learning outcome:

The course provides a forum to introduce the concept of isotopes to graduate students and the use of radiogenic and stable isotopes in geosciences.

(ii) Broad contents of the course:

Radiogenic and stable nuclides are a critical tool for dating materials, understanding planetary differentiation, and tracing provenance and process in all spheres of the earth. This course examines the theory and application of isotope geochemistry to a broad range of geologic topics.

(iii) Skills to be learned:

At the end of the course the students will be appraised about the world of isotopes amd their use in dating or geochemical tracing.

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

Radiometric isotope techniques (dating and geochemical tracing) are introduced (5) through a discussion of atoms, isotopes, and radioactive decay systematic(10), followed by systematic discussion of a number of specific systems e.g., Rb-Sr, uranium-lead, etc. (15). Applications of stable isotopes to investigating volcanism (5), metamorphism (5) and meteoric-hydrothermal systems (5) are discussed. Concepts of mass-balance, mixing theory, and open and closed systems are introduced (15).

Books Recommended:

1. Allegre CJ, (2008) Isotope geology, Cambridge university press
2. Dickin Alan P, (2005) Radiogenic isotope geology (2nd edition), Cambridge University Press.
3. Faure G. and Mensing T, (2005) Isotopes: Principles and applications (3rd edition), John Willey
4. Hoefs Jochen, (2015) Stable isotope geochemistry (7th edition), Springer
5. Schaefer Bruce F, (2016) Radiogenic isotope geochemistry, Cambridge University Press.
6. White William M, (2014) Isotope geochemistry, Willey-Blackwell
7. Moore M. (1982) Principles of Geochemistry, Wiley.

DSE-V: Petroleum Geology

(Credits: 06, Theory-04, Practicals-02)

(i) Course learning outcome:

A student will understand and learn about the basic concepts of Petrology Geology with respect to geology as to enable them to work as a Petroleum Geologist.

(ii) Broad contents of the course:

To provide the student essential and basic concepts of Petroleum Geology and to study the process and the operations involved in Petroleum exploration

(iii) Skills to be learned:

The students will be appraised about the origin, migration and accumulation of petroleum; It will also provide basic skills in prospecting, drilling and logging operation in oil exploration.

Further PG studies in this subject will enable tem towards getting employment in the oil industry

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

Occurrence of petroleum, nature of source rock (4), Classification and composition of petroleum products(6), physical properties of petroleum, composition of biomass (5), Kerogen- Composition and types (5), Reservoir, Traps (5), Origin and Migration, pore space and fluids(5), Origin, migration and accumulation of petroleum (5), Prospecting, Drilling and Logging and subsurface correlation (10), Geophysical prospecting for petroleum (5), Oil bearing basins of India and the world, India's position as regards to petroleum and natural gas future prospects(10).

Books Recommended:

1. Tissot, B.P. and Welte, D.H. (1984) Petroleum Formation and Occurrence, Springer-Verlag, Berlin.
2. Levorsen, A.I, (2004) Geology of Petroleum, CBS Publishers and Distributors
3. North, F.K. (1986) Petroleum Geology, Allen & Unwin, London. 607p
4. Hunt, J.M. (1996) Petroleum Geochemistry and Geology, W.H. Freeman
5. Selley, R.C., 1998, Elements of Petroleum Geology: W.H. Freeman & Company, New York.

DSE-VII: MINING AND MINERAL EXPLORATION

(Credits: 06, Theory-04, Practicals-02)

(i) Course learning outcome:

The course provides the student essential and basic concepts of mineral expiration techniques and the art and science of mining mineral resources.

(ii) Broad contents of the course:

The curse envisages to expose the students to the topics such as geology in mining industry, methods of exploration, Sampling Principle, Methods, estimation of reserves, Ore Dressing and Beneficiation.

(iii) Skills to be learned:

This course tries to impart skills related to Geology in mining and enable him/her to perform duties of a geologist at the mining site.

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

Geology in mining industry, Tenor and Grade: definition, meaning and specification(5), mineral exploration: sequence and phases, methods of exploration(5), float ores and In situ ores, Gossan (4), Pits, Trenches and Boreholes, core drilling, equipment and accessories, Core drill sampling, core splitting, logging, storage, sludge, combining Assay returns from sludge and core(10). Calculation of Specific gravity, Porosity, Bulk density, compression factor (5), Sampling Principle, Methods, Size and quantity, Reduction, Errors, Sampling practices in open-cast mining (5). Categories of reserves, estimation of reserves, cross-sectional method, area of influence method, triangular method, and weighted volume estimate method (08), Classification of mining methods, Factors influencing choice of mining method, Open cast mining, Underground mining, Coal mining methods (10) , Ore Dressing or Beneficiation (4), Brief outline of Mining Acts and Regulations in India, Conservation of mineral resources (4),

Books Recommended:

1. Arogyaswamy R.N.P. (1973) Courses in Mining Geology, Oxford and IBH Publishers Co. Ltd., 916 pages
2. Sinha R. K. and Sharma N. L. (1989)Mineral Economics, Oxford and IBH Publishers Co. Ltd, 4th Edition, 410 pages
3. McKinstry H. E.(1980)Mining Geology, Prentice Hill Inc., 667 pages.
4. Babu S. K. and Sinha D. K.(1988)Practical Manual of Exploration and Prospecting, CBS Publishers and Distributors, New Delhi
5. Sharma J. P.(2009) Environmental Studies, Laxmi Publications (P) Ltd, New Delhi, Indian Bureau of Mines publications
6. Krieter, V. M. (2004) Geological prospecting and exploration, University Press of Pacific.
7. Dobrin, M. B. (1960) Geophysical prospecting, McGrath Hill.
8. Rose, Howkes and Webb (1979) Geochemistry in mineral exploration, Academic Press.

DSE-VII: Research Project in Geosciences (Dissertation)

(Credits: 06, Theory-04, Practicals-02)

(i) Course learning outcome:

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

(ii) Broad contents of the course:

This course is designed with great flexibility and involves the topic of interests of the students as well as his Research Supervisor or Institute where he intends to undertake the Dissertation work.

(iii) Skills to be learned:

The basic aim is to expose the students at an early stage to field and laboratory techniques and sophisticated instrumentation.

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

An opportunity to work on a six month-long research project in geosciences under the direct supervision of a faculty member in University/Institute or Government Organisation. 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.

6.4.3. Skill-based Elective Courses (SEC)

SEC-I: Earth Science Work Experience

(Credits: 02)

(i) Course learning outcome:

The learning outcome of this work experience course is to provide the students with a glimpse of the kind of professional ethics and work culture that reputed labs and institutions demand and inculcate.

(ii) Broad contents of the course:

This course is designed with great flexibility and involves the topic of interests of the students as well as his Research Supervisor or Institute.

(iii) Skills to be learned:

After completion of this course, it is expected that the students gains skills and experience with professional ethics and work culture of reputed labs and institutions. This will help the student in his future career and enhance his employability.

(iv)The detail contents of this course:

An opportunity to learn about Earth Science through relevant employment experiences. Students must complete at least 3 weeks in part-time employment in an Earth Science position that has been approved by a faculty member in the department. Interim and final work-experience reports must be submitted.

SEC-II: Watershed Development

(Credits: 02)

(i) Course learning outcome:

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

(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:

Watershed Development: Concept of watershed, watershed characteristics (2), Importance of water resources in watershed, concept of watershed development in relation to water resources (2), salient features of development measures like contour bunding, gully plugs, stream bunds, percolation tank, subsurface dams, afforestation etc. (4) significance of geology in watershed development (2), Assessment of water resources, i.e. surface water and ground water in a watershed: rainfall-runoff and ground water analysis(2). Soil erosion estimation (2). Role of NGO‟s and State Government in watershed development (1).

Watershed Management: Concept of watershed management in relation to water resources (2), water balance equation for watershed (2), sustainability of water resources, conjunctive use of surface and groundwater resources (2), concepts of people's participation in community based watershed management (2), Watershed Modelling(3), Drought assessment and management (2), Integrated watershed management (2).

Books Recommended:

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

SEC-III: Environmental Sanitation

(Credits: 02)

(i) Course learning outcome:

The course helps students learn about sanitary and hygienic aspects in the context of Swacch Bharat programme.

(ii) Broad contents of the course:

This demand-driven and practice orientated programme brings you fundamental understanding and knowledge on urban, peri-urban and rural sanitation, especially in informal settlements.

(iii) Skills to be learned:

The course will yield graduates with fundamental understanding and knowledge, as well as the skills necessary for creating impact in the field of environmental sanitation.

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

Introduction to Sanitation, Sanitation Systems and Services, Sanitation and Public Health (3), Epidemiology: Principles of protecting the environmental sanitation measures, Inspect and rodent control (4), Community sanitation measures: sanitation of camps, festivals, schools, swimming pools etc.(2) Food and milk sanitation, hotel management with reference to sanitation, food preservation, pasteurization methods and plants(2). Housing needs: lighting and ventilation, natural and artificial provisions (2) Solid wastes: characteristics, collection, disposal by landfill, composting, incineration and other methods (5). Handling and disposal of Hazardous Wastes (2), Industrial Hygiene: Occupational hazards, various operations in industrial units, Engineering and safety measures. Radiological health: radioactive wastes and disposal (3).Noise Pollution and control: Engineering and medical divisions, various programmes (2). Rural sanitation, various methods of collection and disposal of faecal matter, community toilets, septic tanks and soak pits – biogas plant. Advanced wastewater treatment and reuse (5).

Books Recommended:

1. Ehlers, V. M. and Steel, Ernest W. (1977) Municipal and Rural Sanitation (Sanitary Science & Water Engineering) Tata Mcgraw-hill Education
2. Salvato Joseph A. (2000) Environmental Engineersing and Sanitation. John Wiley & Sons Inc; 5th edition, 1562 pages

3. Chanlett Emil T. (1973) Environmental Protection. Mcgraw –HillInc., US
4. Linda Strande, Mariska Ronteltap, Damir Brdjanovic (2014) Faecal-Sludge-Management. IWA Publishing. https://www.un-ihe.org/faecal-sludge-management-4\
5. Duggal, K.N., (2002)Elements of Environmental Engineering, S.Chand and Co., New Delhi
6. Birdie, G.S. and Birdie, J.S., (1992)Water Supply and Sanitary Engineering, Dhanpat Rai and Sons, New Delhi
7. Metcalf and Eddy, (2005) Waste Water Engineering, Collection, Treatment and Disposal, Tata McGraw Hill Inc., New York
8. CPHEEO, (1999) Manual of Sewage and Sewage Treatment.

SEC-IV: Geotechnology

(Credits: 02)

(i) Course learning outcome:

The student will gain detail knowledge about the concepts, methods and hands on determination of soil and rock properties which will strength their knowledge of Engineering Geology. It also provides basic knowledge of surveying techniques.

(ii) Broad contents of the course:

This course deals with the Geotechnical lab measurements used in Engineering Geology. It also includes surveying and levelling methods.

(iii) Skills to be learned:

The course provides vital skills in geotechnical lab work and skills related to surveying and levelling techniques in the field.

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

Geotechnical Engineering: Core logging, soil sampling (2), Determination of Water content (Oven drying and Calcium Carbide Method) (2), Sieve analysis of Soil (2), Specific Gravity by Pycnometer, Determination of Field Density by Core cutter method and Sand Replacement method (2), Determination of Consistency limit: Liquid Limit by Casagrande's Apparatus (Plastic Limit, Shrinkage Limit (2), Permeability Test (Constant Head and Falling Head

method), Direct Shear Test and Vane Shear Test, Triaxial Test (4), Determination of Compaction properties of Soil by standard proctor Test, Differential Free Swell Test (2).

Surveying and Levelling: Definitions of Surveying and Levelling, Objectives of Survey (2); Measurement of horizontal and vertical angle by 1' Theodolite, Measurement of distance, angle by using Total Station (2).Definitions of Terms used in Levelling, Characteristics of a Dumpy Level and a Levelling Staff, Bench Marks, Change Points (3). Levelling operations and steps in Levelling: Demonstration with an exercise in the field (4). Principles of Levelling: Simple and Differential, Reduction of Levels: The Collimation, and Rise and Fall systems of Computation (3).

Books Recommended:

1. Braja M. Das (2005)Fundamentals of Geotechnical Engineering, Thomson Asia Pvt. Ltd., Singapore
2. Gopal Ranjan and Rao, P. (2002) Basic and Applied Soil Mechanics, New Age International Pvt. Limited, New Delhi
3. Kanetkar T.P. and Kulkarni S.V. (1973) Surveying & Levelling (Part I) 23rded.
4. Duggal, S.K. (2004) Surveying Vol. I and II, Tata McGraw Hill.
5. Punmia, B.C. (1994) Surveying Vol.I and II, Standard Publishers.
6. Arora, K. R. (1996) Surveying Vol. I and II, Standard Book House.

SEC-V: Optics and Optical mineralogy

(Credits: 02)

(i) Course learning outcome:

The course will enable the students not only to differentiate minerals based on their optical properties, but also to understand how they originate and associate with each other in a rock.

(ii) Broad contents of the course:

The course covers the basics of geoscientific studies in mineralogy. The knowledge of optics is applied in understanding the genesis and identification of minerals.

(iii) Skills to be learned

This course will help the students to identify minerals in thin sections- an art and science essential for fundamental research in Geology.

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

Plane polarized and cross polarized light (2), Isotropic and Anisotropic minerals (2) Behavior of minerals in cross polarized light, Birefringence (2), Conoscopic or convergent polarized light(2), Uniaxial and Biaxial minerals - Uniaxial and Biaxial Indicatrises (4),Orientation of indicatrises as per the section (2), Interference of light waves, Passage of light through doubly refracting minerals (2). Optical accessories like mica, gypsum and quartz plates (6), Determination of Optic sign of uniaxial and biaxial minerals (2). True and apparent optic axial angle, 2V and 2E (4), Optical properties and identification of some common rock forming minerals (2).

Books Recommended:

1. Kerr, P.F. (1977) Optical Mineralogy, McGraw-Hill College
2. E.E. Wahlstrom (1979) Optical Crystallography, Wiley, New York
3. Nesse, D.W., (1986) Optical Mineralogy. McGraw Hill.
4. W. S. Amckenzie, Guilford C. (2014) Atlas of minerals in thin section, Routledge.

SEC-VI: Gemmology and Gem Testing

(Credits: 02)

(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.

(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

Gemmology: Introduction to Gems, basic properties of gems, Formation of gem stones (4), Use of refractometers, Polariscope, Dichroscope(4), Methods of Specific Gravity determination (2),Causes of colours in gemstones (1), Introduction to special optical properties like chatoyancy, asterism, luminescence, play of colours, labradorescence, inclusions etc.(5), Distinction between synthetic and natural gem stones (3).

Use of Gem Testing Instruments: hand lens (10x), Detection of double refraction, by observing pleochroic colours with the Dichroscope (4), Identification of gemstones on the basis of pleochroic colours; Detection of double refraction, interference figures and internal strain with the Polariscope (2), study of the fluorescent colours exhibited by various gemstones under Ultraviolet (long wave and short wave) light (3), Measurement of refractive indices and birefringence tests using a gem-testing Refractometer (2),

Books Recommended:

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

SEC-VII: Oil Field Services

(Credits: 02)

(i) Course learning outcome:

This course is to be taken in combination with Petroleum geology. The course focuses on the mud logging component as a supplementary service industry in oil and natural; gas exploration.

(ii) Broad contents of the course:

The course deals with Oil Well Drilling, logging and monitoring. It also deals with techniques for formation evaluation and testing for oil and gas.

(iii) Skills to be learned:

The students who completes this course will have acquired all the skills needed for mud logging job and can be employed with private and public organisations engaged in oil exploration.

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

Introduction to Oil Well Drilling, Types oil wells and geotechnical order (2), Methods of Oil well drilling: Cable tool drilling and rotary drilling (2), Components of rotary drilling system(2), Monitoring of drilling process i.e. depth ROP, WOB, sampling (2), Concept of Subsurface pressure(2), Types of Drilling Rigs: Onshore and offshore rigs,(3) Controlled Directional Rotary Drilling, Horizontal Drilling(2), Drilling Mud: Mud hydraulics, uses and functions of drilling mud (2). Coring-Introduction, Techniques and Applications of Coring in Petroleum Geology (2).

Formation Evaluation: Wire line logs, Basic Principles (2), tools of SP, gamma ray, Neutron, Density, Caliper, Dipmeter, Temperature and Sonic Logs and their interpretation(3). Mud logging: Principle, techniques and tools of mud logging(2).Interpretation of gas, drilling and mud parameters.MWD (Measurement While Drilling)/LWD (Logging While Drilling) (2). Principle and tools of MWD/LWD, data analysis and interpretation (2), Formation (Drillstem) Testing: Introduction, Tools and Techniques of DST (2).

Books Recommended:

Sahay, B., Rai, A. and Ghosh, M. Wellsite (1997) Geological Techniques for Petroleum Exploration, Oxford & IBH, New Delhi,

1. Selley, R.C. (1984) Elements of Petroleum Geology, Academic Press, London.

SEC-VIII: Medical Geology

(Credits: 02)

(i) Course learning outcome:

On completion of the course the student will be able to understand the distribution of trace elements and its cyclic movement through the abiotic-biotic environment and their influence on human health, flora and fauna.

(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

This course introduces students to the basic concepts of Medical Geology (2), interaction between abundances of elements and isotopes and the health of humans and plants (2). The public health effects of Earth materials and geological processes(2), medical impacts of water quality, biogeochemical interactions and nutrient anomalies, anthropogenic degradation of geological environments, application of geochemistry to environmental health issues(8), geospatial analysis as a tool in epidemiology(3), health hazards associated with volcanic eruptions(2), global dust flux and respiratory problems(2), impacts of radon-arsenic-selenium-mercury-iodine, uranium on physiological function(8), carcinogenic associations with coal and fibrous minerals (42), geological effects on animal health, and geophagy (human ingestion of soil materials as a dietary supplement) (3).

Books Recommended:

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

6.4.4. Generic Elective Courses (GEC) for Minor Geology Course in the B.Sc.(Hons.) for other mains and Core Courses (CC) and Discipline Specific Elective Courses (DSEC) for B.Sc. (General) Courses with PCM, PMC and PEM combinations

GEC-1: X-Ray Diffraction and phase identification

(i) Course learning outcome:

Lean and understand the functioning of various analytical techniques using X-ray Diffraction

(ii) Broad contents of the course:

The course deals with X-rays, Instrumentation, X-ray diffraction methods and Mineralogical investigations using X-rays

(iii) Skills to be learned:

On completion of this course the student will be well versed with single crystal and podwer diffraction techniques which will help him in characterising minerals and crystalline material.

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

Introduction to X-rays(2), Instrumentation(2), Braggs equation and derivation (4), X-ray diffraction methods(4), Single crystal diffraction(2), Powder diffraction(2), JCPDS cards(2), Mineralogical investigations using X-rays– Identification of X-ray pattern(12).

Books Recommended:

1. Cracknell ,A.P. (1969) Crystals and their structure. Pergamon Press

2. Cullity, B.D. and Stock,S.R. (2001) Elements of X-Ray Diffraction.Third Edition, AddisonWesley, 664 p.
3. Suryanarayana C. and Grant,M.N. (1998) X-Ray Diffraction: A Practical Approach. Plenum Press, New York.
4. Bish, D.L., and Post, J.E., eds., (1989) Modern Powder Diffraction, Min. Soc. America Reviews in Mineralogy Vol. 20, 369 p.
5. Recommended websites:
   http://www.matter.org.uk/diffraction/
   http://www.ngsir.netfirms.com/englishhtm/Diffraction.htm

GEC-2: Digital Image Processing for Geological applications

(i) Course learning outcome:

Digital Image processing when used to maximise quality and image content for direct or Artificial Intelligence (AI) based interpretations has provided a valuable tool for geological research. Hence, the students who want to venture in the fields of computer applications, RS and GIS, AI, etc. Need to apprise themselves of the basics in Digital Image processing.

(ii) Broad contents of the course:

The course intends to expose the students to the fundamentals of Digital Image processing, terminology, techniques andDigital Image Processing softwares.

(iii) Skills to be learned:

Digital Image Processing is an application-based course where the skills acquired in theory and hands on sessions with suitable softwares will help the student to horn his skills and use the same during his dissertation, research or other geological problems.

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

Introduction to Digital Image Processing and related Terminology (4).Tasks, Classification-Supervised and unsupervised classification (4), Feature extraction (2). Multi-scale signal analyses. Pattern recognition,projection, digital image processing techniques- Anisotropic diffusion, Hidden Markov models, Image editing, Image restoration, Linear filtering, Neural

networks, Pixelation (10), Point feature matching, Principal components analysis (5), Self-organizing maps, Filtering, Digital Image Processing software(5).

Books Recommended:

1. Solomon, C.J.and Breckon, T.P. (2010). Fundamentals of Digital Image Processing: A Practical Approach with Examples in Matlab. Wiley-Blackwell.
2. Wilhelm Burger; Mark J. Burge (2007). Digital Image Processing: An Algorithmic Approach Using Java. Springer.
3. R. Fisher; K Dawson-Howe; A. Fitzgibbon; C. Robertson; E. Trucco (2005). Dictionary of Computer Vision and Image Processing. John Wiley.
4. Rafael C. Gonzalez; Richard E. Woods; Steven L. Eddins (2004). Digital Image Processing using MATLAB. Pearson Education.
5. Tim Morris (2004). Computer Vision and Image Processing. Palgrave Macmillan.
6. Milan Sonka; Vaclav Hlavac; Roger Boyle (1999). Image Processing, Analysis, and Machine Vision. PWS Publishing

GEC-3: Applications of Remote Sensing in Geosciences

(Credits: 02)

(i) Course learning outcome:

The course is meant to address the fundamental techniques used for remote sensing. At the end of this course, the student will be appraised with all the theoretical knowledge, information and skills to use Remotely Sensed data for geological applications.

(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:

Basic concepts in remote sensing, electro-magnetic spectrum(3), Energy sources, energy interaction in the atmosphere, atmospheric windows, atmospheric effects on remotely sensed data(4), signatures in remote sensing, sensors and sensor platforms (3). Introduction to aerial photographs, history of aerial photography, aerial camera, types of aerial photographs, classification, principles of stereoscopic viewing, conditions and cause for stereovision (2). Aerial photography missions. Use of pocket and mirror stereoscope, scale of aerial photographs, stereoscopic parallax, relief displacement, measurement of height of objects(3).Aerial photo interpretation, photo-recognition elements, methods of photo-interpretation, advantages and limitations of aerial photographs(5).Remote Sensing from space:space crafts and sensors. Visual image interpretation of satellite imagery, image enhancement, digital analysis, preparation of thematic maps (5).Thermal Infrared remote sensing and microwave remote sensing for geological applications. Remote sensing satellites, Indian Remote Sensing Satellite programme (5).

Books Recommended:

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

GEC-4: Geographic Information System in Geology

(i) Course learning outcome:

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

(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 softwares for visualization, query, mapping, and analytical purposes.

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

Introduction to GIS, Components of GIS (2), Hardware & Software Requirements (2), Spatial databases and GIS, GIS and the art of digitizing, Geographic phenomena, Geographic object(4), Regular vs. Irregular tessellations, Triangulated Irregular Network (2), Topology and spatial relationships (2), Data input, Data output and visualization(2), Data storage, Query maintenance and spatial analyses, etc. (2). Different types of vector data: point, line, polygon, Concept of topology. Raster data model and comparison with vector(2), Sourcing satellite data, Non-spatial data and their types (2), Georeferencing, Map projections(4) Applications of GIS, Limitations of GIS(4), Components of GPS (2).

Books Recommended:

1. Rolf, A. de (2001) Principles of Geographic Information Systems-An introductory textbook. ITC Educational Textbook Series. Enschede, The Netherlands.
2. Lo C.P. and Albert K. W. Yeung,(2002) Concepts and Techniques of Geographic Information System, Prentice –Hall, India.

3. Heywood I, el. (2011) An Introduction to Geographical Information Systems , Pearson Education Pvt. Ltd., New Delhi.
4. Kang – tsung – Chang, (2002) Introduction to Geographical Information System, , McGraw Hill.
5. Lillesand T.M. and Kiefer R.W. (2002) Remote Sensing and Image Interpretation, John Wiley and Sons, New Delhi.
6. George Joseph (2005) Fundamentals of Remote Sensing, University press Private Ltd, Hyderabad.
7. P. A. Burrough and R. A. McDonnell, (2000) Principles of Geographical Information System, Oxford University Press.
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. E-resource http://download.osgeo.org/qgis/doc/manual/qgis-1.0.0_a-gentle-gis-introduction_en.pdf
9. Pande, J and Pathak D. (2016) GIS, TERI

6.4.5. Ability Enhancement Compulsory Courses (AECC)

- AECC-1 English
- AECC-II MIL Communications
- AECC-III Environment Science

The learning outcomes, broad contents, skills to be learned and detail contents of thecourse would be designed by the concerned departments.

6.5. Detail Contents of various Courses, the suggested references and books:

The department / university can change / modify the Course Content to the extent of 20% according to the expertise available in the institution after following proper procedures described in the statutes and ordinances.

7. The Teaching Learning Process:

Learning is a challenging, engaging, and enjoyable activity. Learners should be encouraged to engage in a rigorous process of learning and self-discovery by adopting a highly focused and

yet flexible approach to education as opposed to rote learning. Each day learners should be encouraged to focus on key areas of the course and spend time on learning the course fundamentals and their application in life and society. In teaching and learning pedagogy, there should be a shift from domain or conclusions-based approach to the experiential or processes-based approach.

The faculty should promote learning on a proportionate scale of 20:30:50 principle, where lectures (listening/hearing) constitute 20 percent of the delivery; laboratory (scientific analysis and experiments) 30 percent of the learning methods and field-based (collecting/participating) 50 percent. This ratio is subject to change as per institutional needs. In order to achieve its objective of focused process based learning and holistic development, the Institution/University may use a variety of knowledge delivery methods:

7.1 Lectures

Lectures should be designed to provide the learners with interesting and fresh perspectives on the subject matter. Lectures should be interactive in a way that students work with their teachers to get new insights in the subject area, on which they can build their own bridges to higher learning and not spoon feeding.

7.2 Discussions

Discussions are critical components of learning, and can be used as a platform for students to be creative and critical with old and new ideas. Besides developing critiquing skills, arriving at consensus on various issues and discussion groups lead to innovative problem solving and, ultimately to success.

7.3 Simulations

Simulations provide students opportunities to understand real life situations and scenarios, and solve challenges in a controlled environment or make use of them in simulating cultural experiences by locating/transposing them in new (local, regional, national and international) situations.

7.4 Case Studies

Real case studies, wherever possible, should be encouraged in order to challenge students to find creative solutions to complex problems of individual, community, society and various aspects of knowledge domain concerned.

7.5 Team Work

Intended results can be achieved in subjects like Geology only by collective efforts. Positive collaboration in the form of team work is critical, for which, it is necessary to transcend one's prejudices and predilections so as to achieve the desired outcomes. In the process of team work, leaners will acquire the skills of managing knowledge acquisition and other collaborative learners, thereby understanding, how to incorporate and balance personalities.

7.6 Study Tours/Field Visits

Majority of the primary sources in Geology are collected through field survey and excavations. Study Tours/ Field trips provide opportunities to the learners to test their in-class learning in real life situations as well as to understand the functional diversity in the learning spaces. These may include visits to sites of knowledge creation, preservation, dissemination and application. Institutions may devise their own methods to substitute/modify this aspect.

- Students will greatly strengthen your observational accuracy in the field, and this skill will translate into other aspects of data description and interpretation.
- Students will gain new field experience, perspective, competence, and confidence as a field geologist.
- Students will develop the capability to produce geologic maps and cross sections of unknown terrains working individually and/or in groups.
- Production of geologic maps will allow students to demonstrate the capacity for synthesizing and interpreting field data and compiling that information into a working understanding of the assigned field area.

8. Assessment Methods:

In the undergraduate education of Geology leading to the Degree of B. Sc with Geology and B. Sc (Honours) Geology, the assessment and evaluation methods focus on testing the conceptual understanding of the basic ideas, development of geological skills and experimental techniques retention and ability to apply the knowledge acquired to explain with analyses and reason what has been learnt and to solve new problems and communicate the results and findings effectively. Since the Learning Objectives are defined clearly for each course in detail, it is easier to design methods to monitor the progress in achieving the Learning Objectives during the course and test the level of achievement at the end of the course.

- The courses offered in the undergraduate Geology are the first courses at the college/university level, the priority should be given to Formative Assessment for monitoring the progress towards achieving the Learning Objectives while keeping its weightages lower than Summative Assessments. This is to assure that the students know their strengths and weaknesses periodically through the results of Formative Assessments and make amends for the gaps in their knowledge without affecting their final grades in any significant way. In this context it is suggested that 25-30% weightage be given Formative Assessments in case of theory components while 30-40% weightage be given to the Laboratory/Field work/Projects/Case Study/Dissertation components of the various courses. Moreover use of more than one method of Assessment in each course is highly recommended.

- Some of the methods suggested for Theory Component with regard to Formative Assessment are:
  a) Regular Tutorial assignments
  b) seminar presentations
  c) Performance in group discussions
  d) Problem based longer assignments (other than tutorials)
  e) True/False Tests
  f) Multiple Choice Tests
  g) Short Answer Tests
  h) Viva-voce tests

i) Any other innovative tests in the context of the course.

- In the case of substantive Summative Assessment for the theory papers, can be a combination of the following:

a) Mid-Semester test
b) Seminar Report
c) Individual/Team Project report
d) Oral Presentations of Seminar/Projects
e) Viva –Voce Examination on the above reports
f) End Semester closed book examination in the pattern of i) Multiple Choice ii) Short Answer iii) Long Answer
g) End Semester Open Book Examination
h) Peer examination by a group of experts i) Written ii) Oral
i) Any other innovative method depending upon the nature of the course.

- Laboratory Experiments / Field work / Projects / Case Study / Dissertation can be assessed for Formative Assessment through

a) Regular evaluation of Lab. Experiments regarding i) written report of each experiment ii) Viva-Voce on each experiment
b) Test through setting experiments by assembling components
c) Mid semester re-examination
d) Design innovative kits to test the comprehension and analysis of the experiment done by the students

- At the end, the main purpose of Geology teaching should be to impart objective knowledge to students in concrete, comprehensive and effective way. Here, effectiveness implies gaining knowledge and skill which can be applied to solve practical problems as well as attaining capability of logical thinking and imagination which are conducive to new knowledge and new discoveries. Once the student learns, “why is it worth learning?” and “how does it connect to the real world?” the student shall embrace the curriculum in away which would incite imagination and imbibe a spirit of enquiry in them, so that in future they will opt for further investigations or research. Needless to say, there should be a continuous evaluation system for the

students. This will enable the teachers not only to ascertain the overall progress of learning by the students, but also to identify the students who are slow learner and for whom special care should be taken. An appropriate grading system is the "relative grading system" can also be envisaged for certain papers, introducing a competitive element among the students. All in all, the teacher should act as a facilitator and guide and not as a guardian of curriculum.

- HEI can design their own ways and methods to quantify the assessment and evaluation base on the above methods. It would then be converted to the letter grades by the procedure described by the template given by the UGC. Once the letter grade for a course is obtained for a course; it should be done for all the courses offered by the student. Once the letter grades for all the grades are accumulated then a CGPA should be calculated by quantifying the letter grades as described by the template provided by the UGC.

9. Key Words

Ability Enhancement Compulsory Course (AECC)
Course Learning Outcomes (CLO)
Discipline Specific Electives (DSE)
Formative Assessment (FA)
Generic Elective Courses (GEC)
Learning Outcome based on Curriculum Frame work (LOCF)
Learning Outcomes, Program Learning Outcomes (PLO)
Skill Enhancement Courses (SEC)
Higher Education Institute (HEI)
Student Centric, Teacher Centric
Teaching Learning Methodology

List of Potential Recruiters for employing Geologist

- Geological Survey of India
- Oil and Natural Gas Corporation & Oil India Ltd
- Central & State Governments Ground Water Boards or Agencies
- National Mineral Development Corporation
- Atomic Minerals Division, BARC, Uranium Corporation
- Indian Bureau of Mines
- Mines and Geology Directorates of the State Governments
- Coal & Lignite Producers
- Mineral Exploration Corporation
- Private and Public Sector Steel Plants
- National Aluminium Company
- State Government Mining Companies like Odisha Mining Co., Mysore Minerals Ltd. etc.
- Private & Public Sector Mines operated for Ferrous & Non - Ferrous Metals
- Private & Public Sector Mines operated for Industrial Raw Materials like Rock Phosphate, Lime stone, Dolomite, Magnesite, Gypsum, Beach Sand Minerals (Garnet, Rutile & Ilmenite), Barytes, Bauxite, Bentonite, Graphite, Talc, Fireclay, Kaolin, Vermiculite, Wollastonte & Mica etc.
- Private & Public Sectors Mines / Quarries operated for Building / Decorative dimensional stones (Granites, Marbles, Slates, Sand stone etc.) as well as Diamond & Precious- Gem Stones
- Ferro-alloy producers