NATIONAL EDUCATION POLICY-2020

Common Minimum Syllabus for all Uttarakhand State Universities and Colleges for Five Years of Higher Education

PROPOSED STRUCTURE OF
UG & PG - GEOLOGY
SYLLABUS

2021

Curriculum Design Committee, Uttarakhand

Sr.No.	Name & Designation	
1.	Prof. N.K. Joshi Vice-Chancellor , Kumaun University Nainital	Chairman
2.	Prof. O.P.S. Negi Vice-Chancellor , Uttarakhand Open University	Member
3.	Prof. P. P. Dhyani Vice-Chancellor , Sri Dev Suman Uttarakhand University	Member
4.	Prof. N.S. Bhandari Vice-Chancellor, Soban Singh Jeena University Almora	Member
5.	Prof. Surekha Dangwal Vice-Chancellor, Doon University, Dehradun	Member
6.	Prof. M.S.M. Rawat Advisor, Rashtriya Uchchatar Shiksha Abhiyan, Uttarakhand	Member
7.	Prof. K. D. Purohit Advisor, Rashtriya Uchchatar Shiksha Abhiyan, Uttarakhand	Member

Expert Committee

S.N.	Name	Designation	Department	Affiliation
1.	Dr. Pradeep Goswami	Professor & Head	Center of Advanced Study, Department of Geology	Kumaun University, Nainital
2.	Dr. Santosh Kumar	Professor	Center of Advanced Study, Department of Geology	Kumaun University, Nainital
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4.	Dr. SrikrishnaNautiyal	Assistant Professor	Department of Geology	Pt. Lalit Mohan Sharma Campus Sri Dev Suman Uttarakhand University, Chamba, Tehri Garhwal
5.	Dr. Manish Sanguri	Guest Faculty	Center of Advanced Study, Department of Geology	Kumaun University, Nainital

Syllabus Preparation Committee

S.N.	Name	Designation	Department	Affiliation
1.	Dr. Pradeep Goswami	Professor & Head	Center of Advanced Study, Department of Geology	Kumaun University, Nainital
2.	Dr. Santosh Kumar	Professor	Center of Advanced Study, Department of Geology	Kumaun University, Nainital
3.	Dr. G. K. Sharma	Professor	Center of Advanced Study, Department of Geology	Kumaun University, Nainital
4.	Dr. Rajeev Upadhyay	Professor	Center of Advanced Study, Department of Geology	Kumaun University, Nainital
5.	Dr. Deepa Arya	Assistant Professor	Center of Advanced Study, Department of Geology	Kumaun University, Nainital
6.	Dr. Ashok Kumar	Guest Faculty	Center of Advanced Study, Department of Geology	Kumaun University, Nainital
7.	Dr. Manish Sanguri	Guest Faculty	Center of Advanced Study, Department of Geology	Kumaun University, Nainital

List of Semester-wise Titles of the Papers in Geology (Ten Semester)					
Year	**Sem.**	**Course Code**	**Paper Title**	**Theory/ Practical**	**Credits**
CERTIFICATE COURSE IN SCIENCE					
FIRST YEAR	I		Physical & Structural Geology	Theory	04
			Physical & Structural Geology + Field work)	Practical	02
	II		Elements of Mineralogy & Gemology	Theory	04
			Mineralogy & Gemology	Practical	02
DIPLOMA COURSE IN SCIENCE					
SECOND YEAR	III		Petrology	Theory	04
			Petrology + Field work	Practical	02
	IV		Palaeontology	Theory	04
			Practical (Palaeontology)	Practical	02
BACHELOR OF SCIENCE					
THIRD YEAR	V		Economic Geology & Mineral Exploration	Theory	04
			Geohydrology & Environment Geology	Theory	04
			Economic & Exploration Geology + Field work	Practical	02
	VI		Remote Sensing & Elementary Engineering Geology	Theory	04
			Stratigraphy	Theory	04
			Remote Sensing + Stratigraphy	Practical	02
BACHELOR (RESEARCH) OF SCIENCE					
FOURTH YEAR	VII		Advanced Structural Geology	Theory	04
			Advanced Mineralogy	Theory	04
			Geochemistry & Geochronology	Theory	04
			Geological Mapping	Field Training	04
			Practical	Practical	04
	VIII		Igneous Petrology	Theory	04
			Metamorphic Petrology	Theory	04
			Sedimentology	Theory	04
			Fuel Geology	Theory	04
			Practical	Practical	04
MASTER OF SCIENCE (GEOLOGY)					
FIFTH YEAR	IX		Geodynamics	Theory	04
			Tectonic Geomorphology	Theory	04
			Micropalaeontology& Oceanography	Theory	04
			Field & Laboratory techniques in Geology	Field Training	04
			Practical	Practical	04
	X		Applied Groundwater Hydrology	Theory	04
			Advanced Remote Sensing & GIS	Theory	04
			Project/Research Oriented Dissertation	Dissertation	08
			Practical	Practical	04

PROGRAMME PREREQUISITES

Any student who has passed intermediate Science with Mathematics/Biology group or equivalent examination can opt for geology in **Six Semester B.Sc. programme** (undergraduate level). He/she should have keen interest in understanding the earth forming processes through time and aptitude for geoscientific study and research.

Candidates who have passed the three-year B.Sc. examination from any recognised university including Kumaun University or equivalent examination of other universities with Geology as one of the major subjects in all the three years can apply for admission to the **Four Semester M.Sc. Programme**in Geology.

PROGRAMME INTRODUCTION

Geology is an ever advancing and most popular branch of pure and applied science amongst the students having keen interest and curiosity in understanding the origin, evolution, nature, composition, structure and processes of the Earth and its environs through time. The identification of minerals, rocks, and fossils provide insights into the age, composition, structure, and paleoenvironment of the Earth, and life that thrived on it through the geological ages. This leads to understanding the physical processes of the Earth's spatio-temporal evolution and the availability of its natural resources and reserves. A thorough knowledge on various domains of geology is, thus, immensely useful in not only enriching our knowledge about various physical and historical aspects of the Earth's evolution and dynamics, but also in judiciously utilizing its precious natural resources as well as efficiently preventing or mitigating disasters that could be caused as a result of the Earth's powerful endogenic and exogenic processes.

The programme offers essentially the fundamental and advanced knowledge and technical skills on various domains of geology. Students would study core and applied aspects of, and recent technological advances in the subject field. The curriculum of the programme is designed in such a stepwise manner that the student can derive benefit at any stage of the programme even if the entire course is not completed; it begins with basic essential knowledge and gradually covers advanced aspects of the subject. At the end of every academic year, the student would have good knowledge of some basic and applied aspects of the subject, and this will keep on growing as the students proceeds further with the subject course. At a later stage of the course, the curriculum provides the student with an opportunity of carrying out field and/or laboratory based project work leading to a dissertation in a specialized domain of geology, which is actually a training of making a professional geologist competent in generating, analyzing, and synthesizing the data, to resolve geoscientific problems.

Candidates desirous to pursue their career in the fields of geoscience, disaster management, natural resource assessment and management, civil engineering construction projects, natural environment conservation, and allied fields can choose the offered courses in geology.

PROGRAMME OUTCOMES (POs)

The curricula of the subject of geology are designed keeping in view the following programme outcomes:

PO 1	Enabling the students to understand the age, composition, structure, processes, and evolutionary history of the Earth.
PO2	Enabling the students to identify, locate, explore, judiciously exploit, and manage various Earth resources like minerals, fossil fuel and natural gas, coal, building stones, weathered crust and soils, underground and surface water etc.
PO 3	Enabling the students to understand and assess the potential of natural processes in causing hazards and disasters.
PO 4	Enabling the students to understand such geological conditions that make the terrain prone to natural and anthropogenic hazards.
PO 5	Enabling the students to assess the suitability of terrain for various civil engineering constructions such as dams, reservoirs, bridges, tunnels, roads, railway lines, cable cars, and buildings etc.
PO 6	Enabling the students to formulate and execute guidelines for safe developmental activities in diverse geological terrains.
PO7	Motivating the students to take up higher studies and research to bringing out new knowledge yet to be understood the geological aspects of the Earth.

Programme specific outcomes (PSOs):

UG I Year / ***Certificate Course in Science***

Programme Specific Prerequisites: To acquire a *Certificate in Science*, with geology as one of the major subjects, a student should have passed 10+2 with science background having either Mathematics/Biology group or equivalent subjects. The candidate may have keen interest in understanding the earth forming processes and its evolution through time.

PSOs: This programme pertains to basic and applied knowledge on the essential components of geology, in which the students will know the broad physical aspects of the earth, and learn to identify different minerals and gemstones. This programme will impart knowledge on diverse branches of the subject, as well as endogenic and exogenic processes, and geomorphic features of the earth.

At the end of the programme the student will have basic knowledge about the rock forming minerals, characteristics properties of gemstones, and the subject domain of geology that are required for further academic progression as well as preparation for competitive examinations.

Programme specific outcomes (PSOs):

UG II Year/ ***Diploma Course in Science***

Programme Specific Prerequisites: To acquire *Diploma in Science*, with geology as one of the major subjects, a student should have obtained Certificate Course in Science from any recognized university.

PSOs: This programme provides broad understanding on various physical and historical aspects of the earth. Having understood the broad physical aspects of the Earth, its constituents, and rock-forming minerals in the two semester *Certificate of Science*programme, the students will gain knowledge on rock forming processes in one semester, and faunal and floral life of the geological past in another

semester.

The programme will enable the students to identifying different rocks and rock forming processes (petrogenesis) on the basis of minerals, structure, composition, megascopic, and microscopic characters by observing rocks at outcrops, in hand specimens and thin sections. It will also enable them to identify different types of animal and plant fossils, and to understand the origin and evolution of life on the earth.

Programme specific outcomes (PSOs):

UG III Year/ ***Bachelor of Science***

Programme Specific Prerequisites: To acquire a *Bachelor of Science* degree, with geology as one of the major subjects, a student should have obtained Diploma Course in Science from any recognized university. Student should have a learning aptitude towards rocks and ores.

PSOs: Having understood basic physical and historical aspects of the earth as *Diploma in Science*programme, the students of this programme will gain added knowledge on earth resources, environment, geological controls on the safety of civil engineering construction, and evolution of the earth through time. They will also learn the basics of the fast growing remote sensing technology, and its application potential in geological investigations.

The programme will enable the students to understand such aspects of the earth as its composition, structure, natural resources, terrain and life evolution through time and space, geological process leading to environmental degradation and hazards, and endangering the safety of civil engineering constructions, as also the techniques of earth resource exploration and using remote sensing technique in geological investigations.

Programme specific outcomes (PSOs):

PG I Year/ ***Bachelor (Research) of Science***

Programme Specific Prerequisites: To acquire *Bachelor (Research) of Science* degree, in Geology, a student should have obtained three year *Bachelor of Science* degree from any recognized university.

PSOs: Under this programme, the students will gain in-depth knowledge on successive advancements in the subject of geology. Particular focus of this programme is to inculcate in the students the spirit of researching, identifying the knowledge-gaps in the specific core branches of geology, and motivating them to take up and address such geoscientific problems in future.

The programme will enable the students to understand the intricacies of various mineral, rock, and terrain forming processes resulting from spatio-temporal variations under the prevailing physico-chemical conditions. Such a knowledge will make them able to locate, explore, and judiciously utilize the Earth's resources, solving the complex geological problems, providing the geo-engineering solutions to sundry geo-environmental problems, including the hazard vulnerability, and safety and stability of civil engineering structures, as well as fill-up the knowledge-gaps pertaining to core branches of geology.

Programme specific outcomes (PSOs):

PG II Year/ ***Master of Science (Geology)***

Programme SpecificPrerequisites: To acquire *Master of Science*, in Geology, a student should have obtained three year*Bachelor of Science* and *one year Bachelor (research) of Science* from any recognized university. Student should have research oriented aptitude for gaining the advanced knowledge in the subject field so that he/she can apply the gained knowledge to resolve related research and professional issues.

PSOs: Under this programme, the students will gain in-depth, advanced knowledge on core branches of geology, as well as newly developed branches and techniques in the subject field, with particular focus on the applied aspects of it.

After completing this programme the students will have wide-spectrum, in-depth knowledge in the subject of geology, covering basic principles, gradual advancements, and classical and recent concepts. The students will be able to identify, analyze, and solve different types of geological problems, to ensure developmental activities and optimum harnessing of the earth resources without adversely affecting the geo-environment or endangering the terrain stability, and to analyze the vulnerability of any terrain to various types of geohazards. It will also instill in them the quest for better understanding of the subject through incessant pursuance and research.

COURSE STRUCTURE (Year wise Structure of X semesters)

CBCS pattern

Year	Semester	Course type	Credits	Teaching hrs
First	I	Physical & Structural Geology	04	60
		Practical (Physical & Structural Geology + Field work	02	60
	II	Elements of Mineralogy & Gemology	*04*	60
		Practical (Mineralogy &Gemology)	02	60
Second	III	Petrology	*04*	60
		Practical (Petrology + Field work)	02	60
	IV	Palaeontology	*04*	60
		Practical (Palaeontology)	02	60
Third	V	Economic Geology & Mineral Exploration	*04*	60
		Geohydrology & Environment Geology	*04*	60
		Practical (Economic & Exploration Geology + Field work	02	60
	VI	Remote Sensing & Elementary Engineering Geology	*04*	60
		Stratigraphy	*04*	60
		Practical (Remote Sensing + Stratigraphy	02	60
Fourth	VII	Advanced Structural Geology	04	60
		Advanced Mineralogy	04	60
		Geochemistry & Geochronology	04	60
		Geological Mapping (Field training)	04	60
		Practical	04	60
	VIII	Igneous Petrology	04	60
		Metamorphic Petrology	04	60
		Sedimentology	04	60
		Fuel Geology	04	60
		Practical	04	60
Fifth	IX	Geodynamics	04	60
		Tectonic Geomorphology	04	60
		Micropalaeontology& Oceanography	04	60
		Field & Laboratory techniques in Geology (Field training)	04	60
		Practical	04	60
	X	Applied Groundwater Hydrology	04	60
		Advanced Remote Sensing & GIS	04	60
		Project/Research Oriented Dissertation	08	120
		Practical	04	60

Semester I

Paper: Physical & Structural Geology

Course outcome: After successful completion of this course students will understandthe origin of solar system, and dynamicsof earth's surface and interiors,platetectonicprocesses,seismicity, andvolcanism. They will be enhanced by the knowledge regarding formation of different landforms and the physical, chemical and biological processes operating upon the earth. After completing this course they will able to recognize and interpret the geological structures formed as a result of deformation.		
Course type, paper & Credits, paper & credit	**Content**	**Teaching hours**
Theory Physical & Structural Geology (04)	Unit I: Introduction to geology and its scope, Earth and solar system: origin, size, shape, mass, density and its atmosphere. A brief account of various theories regarding the origin of the earth; Internal structure of the earth and its composition. Earth's gravity and magnetic fields, and thermal structure. Law of uniformitarianism.	15
	Unit II: Earth's internal and external processes: The rock cycle. Earthquakes: nature of seismic waves, their intensity and magnitude; Volcanoes: types, products and causes of volcanism. Weathering and its types; Erosion, transportation and deposition by rivers, wind, glaciers, and waves and underground water, and their related landforms	15
	Unit III: Introduction to Structural Geology; basic concept of stress and strain. Elementary idea of bed, dip and strike; Outcrop, effects of various structures on outcrop. Clinometer/Brunton compass and its use. Elementary idea of types of deformation; Folds: nomenclature and types of folds.	15
	Unit IV: Faults: nomenclature, geometrical and genetic classifications, normal, thrust and slip faults; Definition, kinds and significance of joints and unconformity.	15
Practical (02)	Section A: Physical Geology: Study of important geomorphological models; Reading topographical maps of the Survey of India; Identification of geomorphic features.	60
	Section B: Structural Geology: Identification of different types of folds/faults from block models; Exercises on structural problems: preparation of cross section profile from a geological map.	
	Section C: Geological Field Training: Students will be required to carry out one week fieldwork in a suitable geological area to study the elementary aspects of field geology and submit a report thereon.	

Suggested Reading:

- Arthur Holmes (1992). Principles of Physical Geology. Chapman and Hall,London.
- Miller (1949). An Introduction to Physical Geology. East West PressLtd.
- Spencer, E.V. (1962). Basic concepts of Physical Geology. Oxford &IBH.
- Mahapatra, G.B. (1994). A text book of Physical geology. CBSPublishers.
- Billings, M.P. (1972). Structural Geology. PrenticeHall.
- Davis, G.R. (1984). Structural Geology of Rocks and Region. JohnWiley
- Hills, E.S. (1963). Elements of Structural Geology. Farrold and Sons,London.
- Singh, R. P. (1995). Structural Geology, A Practical Approach. Ganga Kaveri Publ., Varanasi.

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Suggested Online Link:

- https://www.futurelearn.com/courses/extinctions-past-present/19/steps/1312906.
- https://www.mooc-list.com/course/mountains-101-coursera
- https://www.mooc-list.com/course/origins-formation-universe-solar-system-earth-and-life coursera
- https://www.mooc-list.com/course/science-solar-system-coursera
- https://www.mooc-list.com/course/planet-earth-and-you-coursera
- https://www.mooc-list.com/course/dynamic-earth-course-educators-coursera
- https://www.classcentral.com/course/swayam-structural-geology-14312

Semester II

Paper: Elements of Mineralogy & Gemology

Course outcome: After completing this course, student will gain basic and fundamental knowledge about the various mineral groups with regard to their physical and optical properties along with an idea about crystal systems, their symmetryelements andnotation systems. Apart from this, basic knowledge about the instruments such as physical tools and polarizing microscope etc. will also be imparted. Basic knowledge about gemstones will be given to train the students in recognizing and using the semiprecious and precious minerals and gemstones, which make them a professional in geology and newly emerging medicinal gemology field of therapy.		
Course type, paper & Credits	**Content**	**Teaching hours**
Theory Elements of Mineralogy & Gemology (04)	Unit I: Crystals and their characters: Crystal form, face, edge, solid angle; Interfacial angle and their measurements; Crystallographic axes and angles. Crystal parameters, Weiss and Miller system of notations. Symmetry elements and description of normal class of Isometric, Tetragonal, Hexagonal, Orthorhombic, Monoclinic and Triclinic systems. Twinning and twin laws.	15
	Unit II: Definition and characters of mineral; Chemical composition and diagnostic physical properties of common rock forming minerals: quartz, feldspar, pyroxene, amphibole, garnet, olivine and mica families.	15
	Unit III: Polarizing microscope, its parts and functioning; Ordinary and polarized lights; Common optical properties of minerals observed under ordinary, polarized lights and crossed nicols. Optical properties of some common rock forming minerals (Quartz, Orthoclase, Microcline, Olivine, Augite, Hornblende, Muscovite, Biotite, Garnet).	15
	Unit IV: Definition and scope of Gemology. Basic qualities of a gem, Physical properties, Optical properties & optical effects in gemstones. Theory of gem cutting techniques, & application crystallography in Gemology. Instruments used in gem identification. Techniques, limitation and precautions of gem identification.	15
Practical (02)	Study of physical properties of minerals such as Olivine, Garnet, Muscovite, Biotite, Beryl, Tourmaline, Hornblende, Gypsum, and its varieties, Quartz and its varieties, Orthoclase, Microcline, Plagioclase, Chalcedony, Barite, Augite, Chalcedony, Agate, Jasper, Flint. Use of polarizing microscope; Study of optical properties of common rock forming minerals such as Olivine, Garnet, Muscovite, Biotite, Hornblende, Tourmaline, Augite, Quartz, orthoclase, Microcline, Plagioclase etc.	60

Suggested Reading:

- Berry, L.G., Mason, B. and Dietrich, R.V. (1982). Mineralogy. CBS Publ.
- Nesse, D.W. (1986). Optical Mineralogy. McGrawHill.
- Read, H.H. (1968). Rutley's Element of Mineralogy (Rev. Ed.). Thomas MurbyandCo.
- Berry and Mason (1961). Mineralogy. W.H. Freeman &Co.
- Sharma, R.S. and Sharma A. (2013). Crystallography and Mineralogy (Concepts and Methods). Geological Society of India, Bangalore.
- Hall, Cally (2000) Gemstones. Dorling Kindersley, London; New York.
- Liddicoat, Richard T. (1989) Handbook of Gem Identification. 12th ed., rev., Gemological Institute of America, Santa Monica, CA.
- Nassau, Kurt (1994) Gemstone Enhancement: History, Science and State of the Art. 2nd ed. Butterworth-Heinemann, London.
- Anderson, Basil W (1990) Gem Testing. Rev. by E. A. Jobbins. 10th ed., Butterworth, London.

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Suggested Online Link:

- https://www.classcentral.com/course/swayam-subject-geology-paper-crystallography-mineralogy-17820

Semester III

Paper Petrology

Course outcome: The prime aim of this course is to characterize, classify, and deduce the genesis of individual rock, and rocks in association making a rock suite or complex or succession. Students will characterize, identify and name different types of rocks in the field and in hand-specimens, and rock-thin sections, and finally they will propose the rock-forming processes (petrogenesis). The most common criteria are structure, texture, mineral assemblage and modes present in a particular rock that are examined at megascopic and microscopic levels.		
Course type, paper & Credits	**Content**	**Teaching hours**
Theory Petrology (04)	Unit I: Introduction to igneous petrology; Magma: definition, composition, properties, types and origin; Plutonic, hypabyssal, and volcanic magma emplacement; Forms of igneous rocks; textures of igneous rocks. Reaction principle; Bowen's reaction series, Differentiation and Assimilation; Crystallization of uni-component and bi-component (mixed-crystals).Basic classification of igneous rocks; IUGS classification of igneous rocks. Detailed petrographic description of Granite, Granodiorite, Syenite, Diorite, Rhyolite and Basalt.	15
	Unit II: Introduction to metamorphic petrology; Process and products of metamorphism; Type of metamorphism. Factors, zones and grade of metamorphism; Textures, structures and classification of metamorphic rocks. Petrographic details of some important metamorphic rocks, such as slate, schists, gneiss, quartzite, and marble.	15
	Unit III: Introduction to sedimentary petrology; Processes of formation of sedimentary rocks. Clastic and non-clastic sedimentary rocks. Textures and structures of sedimentary rocks. Palaeocurrent and sediment dispersal.	15
	Unit IV: Concept of provenance and basins. Elementary knowledge about continental and oceanic sedimentary basins. Concept of sedimentary environments and facies. Petrographic details of important siliciclastic and carbonate rocks such as-conglomerate, breccia, sandstone, shale, and limestone.	15
Practical (02)	Section A: Petrology: Study of common igneous, metamorphic and sedimentary rocks in hand specimen and thin sections. Study of common structures in igneous, metamorphic and sedimentary rocks.	60
	Section B: Geological Field Training : Students will be required to carry out one week fieldwork in a suitable geological area to study the elementary aspects of field geology and submit a report thereon.	

Suggested Reading:

- Bose, M.K. (1997). Igneous petrology. World press.
- Ehlers, W.G. and Blatt, H. (1987). Petrology, Igneous, Sedimentary and Metamorphic rocks, CBS Publishers.
- Friedman and Sanders, (1978).Principles of Sedimentology. John Wiley and sons.
- Mason, R. (1978). Petrology of Metamorphic Rocks. CBS Publ.
- Moorhouse, W.W. (1969). The study of rocks in thin sections. Harper and sons.
- Pettijohn, F.J. (1975).Sedimentary rocks, Harper & Bros.3rd Ed.
- Prasad, C. (1980).A text book of Sedimentology.
- Sengupta, S. (1997).Introduction to Sedimentology. Oxford-IBH.
- Turner, F.J. and Verhoogen, J. (1960). Igneous & Metamorphic petrology. McGraw Hill Co.
- Turner, F.J. (1980). Metamorphic petrology. McGraw Hill.
- Tyrell, G. W. (1989). Principles of Petrology. Methuren and Co (Students ed.).
- Winkler, H.G.C. (1967). Petrogenesis of Metamorphic Rocks. Narosa Publ.
- Blatt, H. and Tracy, R.J. (1996). Petrology (Igneous, Sedimentary, Metamorphic), W.H. Freeman & Co., New York

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Suggested Online Link:

- https://www.classcentral.com/course/swayam-petrology-14084
- https://www.mooc-list.com/course/myths-and-facts-about-rocks-iversity.
- E- pathshala. https://epgp.inflibnet.ac.in/

Semester IV

Paper: Paleontology

Course outcome: This course intends to acquaint the students about origin and evolution of life through geological time and the major evolutionary breakthroughs, and to correlate the evolutionary history with other synchronous geological events. It would add to their knowledge regarding thebasicconceptofpaleontology using mode and methods of fossil preservation and species identification,thereafter suggesting theorganicevolutionary path and paleoenvironment. Also they will know the causes of major events of mass extinctions in geological past including the glaciations periods		
Course type, paper & Credits	**Content**	**Teaching hours**
Theory Paleontology (04)	Unit I: Origin of life. Organic evolution- Macro and Micro evolution, Punctuated Equilibrium and Phyletic Gradualism. Taxonomy and Species concept. Taphonomy. Mass extinctions and their causes. Ediacaran. Gondwana fauna and flora and their significance.	15
	Unit II: Fossils, condition, modes of fossilization and its significance in geological time scale. Trace fossils and Ichno-fossils. Binomial nomenclature. Biozones-significance and correlation, Index fossils.	15
	Unit III: Invertebrate Paleontology- Morphology, classification, evolutionary trends, and geological distribution of Brachiopods, Lamellibranchs, Gastropods and Cephalopods, Trilobites, Graptolites, Echinoids and Corals.	15
	Unit IV: Vertebrate Paleontology- Origin of vertebrates and evolution of vertebrate. Evolutionary history of Equidae, Proboscidea and Hominidae. Origin, diversity and extinction of dinosaurs.	15
Practical (02)	Study of fossils showing various modes of preservation. Study of diagnostic morphological characters, systematic position, stratigraphic position and age of various invertebrate, vertebrate and plant fossils.	60

Suggested Reading:

- Raup, D. M., Stanley, S. M., Freeman, W. H. (1971). Principles of Paleontology.
- Clarkson, E. N. K. (2012). Invertebrate paleontology and evolution 4th Edition by Blackwell Publishing.
- Benton, M. (2009). Vertebrate paleontology. John Wiley & Sons.
- Shukla, A. C. and Misra, S. P. (1975). Essentials of paleobotany. Vikas Publisher.
- Moore, R.C. Lalliker, C.G. and Fischer, A.G. (1952). Text book of Invertebrate Palaeontology.
- Schrock, Twenhofel and Williams (1953). Principles of Invertebrate Palaeontology. CBS, Delhi Bilal U. Haq and A. Boersome, Introduction to Marine Micropalaeontology

Suggested Online Link:

- https://www.futurelearn.com/courses/extinctions-past-present/19/steps/1312906.

Semester V

Paper I: Economic Geology & Mineral Exploration

Course outcome: The course is intended to impart basic knowledge about the occurrence and distribution of metallic and non-metallic ores and energy resources in India, and to understand ore-forming processes. The acquired knowledge of ore-formation indeed paved the way of developing methods of ore prospecting, exploration, mining, and beneficiation of economic deposits.. This course will surely help the students for opting carrier in the field of mineral prospection, exploration, and mining industry.		
Course type, paper & Credits	**Content**	**Teaching hours**
Theory Paper I Economic Geology & Mineral Exploration (04)	Unit I: Concept of ore and ore deposits, ore minerals and gangue minerals; Tenor of ores; Metallic and non-metallic ore minerals; Strategic, Critical and essential minerals. Ore forming processes: magmatic, contact metasomatic, hydrothermal, sedimentary.	15
	Unit II: Study of important metallic (Cu, Pb, Zn Mn, Fe, Au, Al) and non-metallic (industrial) minerals (gypsum, magnesite, mica). Basic knowledge about the genesis of oil and natural gas, and coal. Metallogenic epochs and provinces. Distribution of iron, copper, zinc, lead, gold, diamond, uranium, bauxite, phospherite, magnesite, mica, coal, and oil and natural gas in India.	15
	Unit III: Mineral exploration: Surface and sub surface exploration methods including use of remote sensing techniques, Elementary idea of geological, geophysical and geo-botanical prospecting and mining methods. Drilling, sampling and assaying.	15
	Unit IV: Elementary knowledge of geological and geophysical prospecting. Gravity, electrical, magnetic airborne and seismic methods of exploration. Geo-botanical and geochemical methods of exploration. Elementary idea of mining and environmental considerations.	15

Suggested Reading:

- Brown, C. and Dey, A.K. (1955). Indian Mineral Wealth. Oxford University
- Gokhale, K.V.G.K. and Rao, T.C. (1983). Ore Deposits of India. East West Press Pvt.Ltd.
- Jense, M.L. and Bateman A.M. (1981). Economic Mineral Deposits. John Wiley and Sons.
- Krishnnaswamy, S., 1979. India's Minerals Resources. Oxford and IBH Publ.
- Deb, S. (1980). Industrial minerals and Rocks of India. Allied Publishers Pvt.Ltd.
- Umeshwar Prasad (2003). Economic Geology. CBS Publishers and distributers.
- Sharma, N.L. and Ram, K.V.S. (1972). Introduction to India's Economic Minerals, Dhanbad.

- McKinstry, H.E. (1962). Mining Geology. II Ed. Asia Publishing House.
- Clark, G.B. (1967). Elements of Mining. III Ed. John Wiley
- Arogyaswami, R.P.N. (1996). Courses in Mining Geology. IV Ed. Oxford IBH.
- Umathi, Exploration Geology.

Suggested Online Link:

- https://www.mooc-list.com/course/minerals-and-mining-business-edx
- https://www.classcentral.com/course/swayam-drilling-and-blasting-technology-58442
- https://www.classcentral.com/course/swayam-underground-mining-of-metalliferous-deposits-43673

Paper II: Geohydrology & Environment Geology

Course outcome: This course has a direct implication on understanding and resolving the societal issues particularly dealing with groundwater and environment. The students will gain a better knowledge regarding groundwater occurring in the form of aquifers and surface waters, and the laws governing the recharge, storage, movement and exploitation. They will be enlightened as to how we the humans are part of our surrounding natural environment and how we should work for its preservation and sustainable development. This course will help making a responsible citizen and professional with regard to understanding our valuable land and water resources, and their utilization in more scientific and sustainable manner and further managing geohazards

Course type, paper & Credits	Content	Teaching hours
Theory Paper II Geohydrology & Environment Geology (04)	Unit I: Introduction and scope of hydrology. Hydrologic cycle and its components: precipitation, evapo-transpiration, run-off, infiltration and sub-surface movement of water. Vertical distribution of sub-surface water. Types of aquifers, aquifer parameters.	15
	Unit II: Aquifers and their types. Darcy's Law and its validity, Dupuit's assumptions, Base flow equation. Surface and sub-surface water interaction. Drinking water quality parameters: Physical and Chemical properties of water. Hydrological provinces in India.	15
	Unit III: Scope and aims of environmental geology. Biosphere and man. Geohazards: Earthquakes, volcanism, landslides, floods, flash floods, and snow avalanches. Concepts of geohazard management. Climatology and global environment- Coastal, riverine, desertic, tropical, cold and polar. Green-house effect and global warming.	15
	Unit IV: Elementary idea of soil types. Soil erosion and conservation. Preliminary idea of environmental implications of mining activities and their remedies.	15

	Elementary concept of watershed management. Land reclamation.	
Practical 02	Section A: Economic Geology & Mineral Exploration: Study of common ores in handspecimen. Study of copper, lead, zinc, iron, gold, phosphorite, magnesite, oil and gas, and coal deposits of India. Laboratory exercises in solving exploration related problems.	60
	Section B: Geohydrology: Estimation of hydrologic components, Assessment of different aquifer parameters, Plotting of hydrological provinces in India.	

Suggested Reading:

- Valdiya, K.S. (2013). Environmental Geology 2nd Edition. McGraw Hill Education
- Todd, D.K. (1980). Groundwater Hydrology- John Wiley
- Davis, S.N. and De Wiest, R.J.M. (1966): Hydrogeology- JohnWiley
- Freeze, R.A. and Cherry, J.A. (1979): Ground Water- PrenticeHall
- Fetter, C.W. (1990). Applied Hydrogeology- Merill Publishing
- Ragunath, N.M. (1982): Ground Water- Wiley Eastern
- Karanth, K.R. (1987). Groundwater Assessment- Development and Management- Tata McGrawHill
- Alley, W.M. (1993). Regional Ground Water Quality- VNR, NewYork

Suggested Online Link:

- https://www.mooc-list.com/course/natural-resources-sustainable-development-edx
- https://www.mooc-list.com/course/extreme-geological-events-futurelearn
- https://www.mooc-list.com/course/history-ancient-environments-climate-and-life-edx

Semester VI

Paper I: Remote sensing & Elementary Engineering Geology

Course outcome: This course introduces recent technique of remote sensing that has wide application potential in several fields of surveying such as geological, geographical, agricultural, forestry etc. In the present programme, the students will know about the interpretation of aerial remote sensing and its application potential in geological investigations. The students will also be introduced to geological aspects that must be taken care of for any safe and stable geo-engineering activity such as construction, mining, and environmental conservation.		
Course type, paper & Credits	**Content**	**Teaching hours**
Theory Remote sensing & Elementary Engineering Geology (04)	Unit I: Definition and scope of remote sensing. EM energy and its interaction interactions with atmosphere and earth surface features. Film and digital aerial photography. Types of aerial photographs. Aerial photography mission and stereopair aerial photographs. Tilt in aerial photographs. Scale of aerial photographs. Relief distortions and vertical exaggeration in aerial photographs. Ortho photographs.	15
	Unit II: Aerial photo mosaics, their types and utility. Stereoscopic vision in aerial photographs. Pocket and Mirror Stereoscopes. Photo-technical and geotechnical elements of photo-interpretation. Application potential of aerial photographs in land cover, landform, rock type and structure recognition.	15
	Unit III: Engineering properties of rocks and Soils. Soil and Soil groups of India. Dams and their types. Geological conditions controlling the safety of dams. Causes of dam failure. Geological problem of reservoirs. Bridges and their types. Geological conditions controlling the safety of dams.	15
	Unit IV: Tunnels and their types. Geological conditions controlling the safety of tunnels. Seepage problem in tunnels and role of water table. Landslides: classification, causes and preventative measures.	15

Suggested Reading:

- Valdiya, K.S. (2013). Environmental Geology 2nd Edition. McGraw Hill Education
- Krynine D.P. and Judd W.R. (1957). Principles of Engineering Geology & Geotechnics. McGraw-Hill Book
- Kesavulu, N.C. (2009). A text book of engineering geology. Macmillan P publishing India Ltd.
- Crozier. M.J. (1989). Landslides: causes, consequences and environment. Academic Press.
- Bell, F.G. (1983). Fundamentals of Engineering Geology. Butterworth and Co.
- Lillesand, T.M., Kiefer, R.W., and Chipman (2015). Remote Sensing and Image Interpretation. Wiley.

- Pandey, S.N. (1987). Principles and Application of Photogeology. Wiley Eastern, New Delhi.

Suggested Online Link:

- https://www.classcentral.com/course/swayam-rock-mechanics-and-tunneling-43654
- https://www.classcentral.com/course/swayam-introduction-to-engineering-seismology-43605
- https://www.mooc-list.com/course/reservoir-geomechanics-edx
- https://www.mooc-list.com/course/geology-and-engineering-geology-gongchengdezhixue-edx
- https://www.classcentral.com/course/swayam-photogeology-remote-sensing-45165

Paper II: Stratigraphy

Course outcome: After completion of this course students will be able to understand fundamentalsofstratigraphy and the geological time scale. They will now be able to correlate and understand about the various age group rocks occurring in India and the boundaries separating them. It will enable them to understand the evolution of terranes through time and space.		
Course type, paper & Credits	**Content**	**Teaching hrs**
Theory Stratigraphy (04)	Unit I: Principle of stratigraphy; fundamentals of litho-, bio-, chrono-, and magneto-stratigraphy; Code of stratigraphic nomenclature; Concepts of palaeogeographic reconstructions. Geological Time Scale. Precambrian-Cambrian, Permian-Triassic, and Cretaceous-Tertiary boundaries	15
	Unit II: Study of following Precambrian succession: Dharwar, Aravalli, Cuddappa, Vindhyan and Delhi Supergroups; Precambrian-Cambrian successions of Uttarakhand;	15
	Unit III: Brief idea about Palaeozoic succession of northwestern Himalaya; Triassic of Spiti; Mesozoic type succession of Kutch and Rajasthan; Cretaceous of Tiruchirapalli	15
	Unit IV: Stratigraphy of the Indian Gondwana, and Deccan Trap. Paleogene-Neogene sequences of northwest Himalaya.	15
Practical (02)	Section A: Remote sensing: Studying stereopair aerial photographs and using stereoscopes for identifying the photo-technical and geotechnical elements of different landforms, and land use/ land cover classes.	60
	Section B: Stratigraphy: Preparation of litho-stratigraphic maps of India showing distribution of important geological formations and Gondwana flora.	

Suggested Reading:

- Wadia, D. (1973). Geology of India. Mc Graw Hill Bookco.

- Krishnan, M.S. (1982). Geology of India and Burma, 6th Edition. CBS Publ.
- Ravindra Kumar (1985). Fundamentals of Historical Geology & Stratigraphy of India. Wiley Eastern.
- Valdiya K.S. (2010). The making of India, McMillan India Pvt ltd.

Semester VII

Paper I: Advanced Structural Geology

Course outcome: Deformation is a continuous process occurring within the rocks in different range so this course will provide a better concept regarding such processes by providing indepth information about stress and strain. It will also give a better understanding towards the mechanisms responsible for the formation of different geological structures.		
Course type, paper & Credits	**Content**	**Teaching hours**
Theory Advanced Structural Geology (04)	Unit I: Concept of stress and strain. Stress-strain relationships of elastic, plastic and viscous materials. Two dimensional strain and stress analyses. Types of strain ellipses and ellipsoids; their properties and significance. Mechanical principles and properties of rocks and their controlling factors. Theory of rock failure; brittle and ductile deformation.	15
	Unit II: Mechanics of folding and buckling. Folds geometry and classification. Superimposed folds and their interference patterns. Analytical methods of determining fold style. Causes and dynamics of faulting. Normal faults and strike – slip faults. Overthrust and nappe with implications to thrust tectonics. Thin skinned deformation and decollement. Salt domes and diapers. Concept of balanced cross sections.	15
	Unit III: Joints, rock cleavage and foliations; their origin, domain character, relationship with major structures and geological significance. Transposed foliations. Linear structures and boudinage; their origin, relationship with major structures and significance. Deformation of linear structures.	15
	Unit IV: Brittle and ductile shear zones; their geometry, strain pattern, kinematics and significance. Rotation of structural elements. Concept of petrofabric analysis. Use of stereographic and equal area projections for representing different types of fabric.	15

Suggested Reading:

- Turner, F.J. and Weiss, L.E. (1963). Structural Analysis of Metamorphic Tectonites. McGraw Hill.
- Ramsay, J. G. (1967). Folding and Fracturing of Rocks. McGraw Hill.
- Davis, G. R. (1984). Structural Geology of Rocks and Region. John Wiley.
- Ramsay, J.G. and Huber, M.I. (1987). Techniques of Modern Structural Geology, Vol. I & II. Academic Press.
- Price, N. J. and Cosgrove, J. W. (1990). Analysis of Geological Structures. Cambridge Univ.Press.
- Bayle, B. (1992). Mechanics in Structural Geology. Springer Verlag

- Robert, D. Hatcher (1994). Structural Geology: Principles Concepts and Problems (2nd Edition)
- Ghosh, S. K. (1995). Structural Geology: Fundamentals of Modern Development. Pergamon.
- Pollard, D.D. and Fletcher R.C. (2005). Fundamentals of Structural Geology Cambridge University Press.
- Moores, E. and Twiss, R.J. (1995). Tectonics. Freeman.
- Valdiya, K.S. (1998). Dynamic Himalaya. University Press.
- Twiss, R.J. and Moores, E.M. (2006). Structural Geology Second Edition, W. H. Freeman.
- Passchier C. w. and Treuw R. a. J. (2005). Microtectonics, Springr.
- Richard H. Groshong (2008). 3-D Structural Geology: A Practical Guide to Quantitative Surface and Subsurface Map Interpretation. Springer
- Ragan, D.M (2009). Structural Geology: An introduction to Geometrical Techniques. Cambridge, University Press.
- Fossen, H. 2010: Structural Geology, Cambridge University Press
- Lisle, R.J.2004: Geological Structures and Maps: A Practical Guide, Third edition. Elsevier
- Marshak S and Mitra, G (1988) : Basic Methods of Structural Geology, Printice Hall.
- Hobbs, B.E., Means, W.D. and Williams, P.F. (1976): An outline of Structural Geology. John Wiley and Sons. New York.
- Lisle R.J. and Leyshon, P.R (2004): Stereographic Projection Techniques for Geologists and Civil Engineers, 2 edition, Cambridge University Press.
- Rowland, S.M. Duebendorfer, E.M. and Schiefelbein, I.M. (2007) Structural Analysis and Synthesis: A Laboratory Course in Structural Geology 3 edition, Wiley-Blackwell.

Suggested Online Link:

- https://www.classcentral.com/course/swayam-structural-geology-14312.

Paper II: Advanced Mineralogy

Course outcome: Minerals are essential constituents of rocks and hence mineral science plays prime and vital role in the study of geology and material science. They may be valuable if occurring in form of precious and semi-precious minerals and gemstones, and are commonly used in the industries and other fields. This course will provide a better understanding on natural occurrence, identification, structure, and genesis of silicate and non-silicate minerals, and their applications in different fields.		
Course type, paper & Credits	**Content**	**Teaching hours**
	Unit I: Structural classification of silicates; Study of following group of minerals with reference to chemical and structural formula, classification, atomic structure, chemistry, physical and optical properties, occurrences:	15

Advanced Mineralogy (04)	Olivine, Garnet, Pyroxene, Amphibole, Mica, Feldspars, Feldspathoids, Silica and Al silicates.	
	Unit II: Formation of Uni-axial and Bi-axial interference figures, Interference colors, Pleochroism and determination of pleochroic scheme, Interference figures and determination of optic sign; Extinction; Uniaxial and Biaxial indicatrix and dispersion in minerals.	15
	Unit III: Petrographical microscope; Mica, Gypsum and Quartz plates; Universal stage and their uses in the determination of optical properties of minerals.	15
	Unit IV: Application of spectroscopic techniques in mineralogy-Raman and Mossbauer spectroscopy, An overview of environmental and radiation mineralogy; biomineralization and gemology.	15

Suggested Reading:

- Battey, M.H. (1981). Mineralogy for students, London, New York :Longman.
- Berry, L.G. and Mason, B (1959). Mineralogy: concepts, descriptions, determinations, London Publication.
- Dana, E.S. and Ford, W.E. (2002) A text book of Mineralogy (Reprint)
- Deer, W.A., Howie, R.A., and Zussman, J. (1992) An Introduction to the rock forming minerals, Harlow, Essex, England : New York, NY : Longman Scientific & Technical .
- Sharma, R. S. and Sharma, A. (2014) Crystallography and mineralogy. Graduate Text Book Series, Geological Society of India, Bangalore.
- Gribble, C.D. (2005) Rutley's elements of Mineralogy, Springer.
- Klein, C. and Hurlbut, Jr., C.S. (1993) Manual of Mineralogy, JohnWiley.
- Nesse, D.W (1986). Optical Mineralogy, McGraw Hill
- Kerr, P.F. (1977). Optical Mineralogy, 4th Edition McGraw-Hill
- Putnis, Andrew (1992) Introduction to Mineral Sciences, Cambridge UniversityPress.
- Winchell, A.N. (1962) Elements of Optical Mineralogy, John Wiley.

Suggested Online Link:

- https://www.classcentral.com/course/swayam-subject-geology-paper-crystallography-mineralogy-17820.

Paper III: Geochemistry & Geochronology

Course outcome: This course is designed to understand high-T and low-T geochemical processes that operate in the earth's deeper and near-surface environments. The major task of geochemists is to know the physical and chemical laws governing the abundance, distribution and migration of chemical elements from one sphere to another sphere of the Earth i.e. chemical differentiation of the Earth. Dating the geological materials are utmost important for arranging the geological events in chronological order.		
Course type, paper & Credits	**Content**	**Teaching hours**
Geochemistry & Geochronology (04)	Unit I: Composition of Earth and its constituents (Crust, mantle and core); Ionic and co-ordination number; Rules of ionic substitution, coupled substitution; Distribution coefficient: Capture admission and camouflage, Geochemical classification of elements; Behaviour of major and trace including rare earth elements during magmatic crystallization.	15
	Unit II: Near-Earth surface geochemical environment: Eh-pH diagram; Principle of chemical mass balance and rock-cycle; Chemical weathering of minerals and rocks.	15
	Unit III: Radiogenic isotopes in geochronology and petrogenesis: Rb-Sr, Sm-Nd, U-Pb isotopic system.	15
	Unit IV: Stable isotopes geochemistry, Fission Track (FT) and OSL dating techniques; Dendrochronology and Lichenometry.	15

Suggested Reading:

- Allegre, C.J. and Michard, G. (1974) Introduction to Geochemistry, Reidel,Holland.
- Evans, R.C. (1964) Introduction to Crystal Chemistry, Cambridge Univ.Press.
- Faure, G. (1998) Principles and applications of geochemistry, 2nd Edn., PrenticeHall, New Jersy,593p.
- Faure, G. (1986) Principles of Isotope Geology, 2nd Edn., JohnWiley.
- Albarde Francis (2003). Geochemistry- Introduction. Cambridge University Press.
- Misra, K. C. (2012). Introduction to Geochemistry: Principles and Applications, Wiley-Blackwell.
- Alan P. Dickins (2005). Radiogenic Isotope Geology,. Cambridge University Press
- Hoefs, J. (1980). Stable Isotope Geochemistry, Springer and Verlag.
- Gunter Faure (1977). Principles of Isotope Geology by John Wiley & Sons Ltd.
- Krauskopf, K.B. (1967) Introduction to Geochemistry, McGrawHill.
- Mason, B. and Moore, C.B. (1991) Introduction to Geochemistry, WileyEastern.
- Rollinson, H.R. (1993) Using geochemical data: Evaluation, Presentation, Interpretation, Longman,U.K.

Suggested Online Link:

- https://www.classcentral.com/course/swayam-geology-geochemistry-14083

Paper IV: Geological Mapping

Course outcome: Geology is field and observational science. Geoscientific hypothesis is framed in the field that can be tested through field data and laboratory investigations.This course will enable the students to explore practical aspect of geology such as preparation of geological maps, cross section, and reconnaissance and detailed surveys for georesource exploration and environmental purposes etc.		
Course type, paper & Credits	**Content**	**Teaching hours**
Theory Geological Mapping (04)	The paper will be based on geological field training, in which the students will be trained on the following aspects: 1. Studying the geologic maps, understanding the interaction between topography and geologic structures. 2. Basics of field data collection, analyses, interpretation, and geological report writing, 3. Various type of geological mapping, (Note: Marks will be evaluated on the basis of student's field training report.)	120
Practical (04)	Section A: Advanced Structural Geology: Study of naturally deformed rocks in hand specimens, Geometrical analysis of folds and faults. Preparation and interpretation of geological maps, Applications of stereographic and equal area projections, Strain analysis using software and manually.	120
	Section B: Advanced Mineralogy: Study of physical and optical properties of important rock forming minerals; Determination ofan content of plagioclase feldspars; Determination of elongation and optic sign of minerals; Determination of Pleochroism and absorption schemes.	
	Section C: Geochemistry & Geochronology: Construction of geochemical variation diagrams (Spider diagrams; Harker's variation diagrams; addition- substraction diagrams); Calculation of stoichriometric formula from chemical analysis of minerals.	

Semester VIII

Paper I: Igneous Petrology

Course outcome: This course will provide in-depth knowledge about the origin and evolution of igneous rocks in diverse tectonic environments through a number of major and subsidiary magmatic processes. The petrogenesis of igneous rocks can be very well demonstrated in the light of modern phase equilibria experimental works. Igneous rocks, also called primary rocks, are most abundant and were formed throughout the Earth's evolutionary history that essentially make-up the continents as a stable platform to live on it. Students will come to know about the igneous processes and world class examples of igneous provinces, complexes and suites of India.

Course type, paper & Credits	Content	Teaching hours
Theory Igneous Petrology (04)	Unit-I: Magma generation in the mantle, their nature and evolution; Magmatic processes: Partial melting, fractional crystallization, assimilation, and liquid immiscibility.	15
	Unit-II: Petrography and interpretation of igneous textures in terms of rate of nucleation and crystal growth; IUGS classification schemes of igneous rocks: Ultramafic, mafic and felsic igneous rocks; total- alkali-silica (TAS) classification of volcanic igneous rocks.	15
	Unit-III: Study of phase equilibria in binary (Diopside-Anorthite, Forsterite- Silica, Leucite-Silica, Albite-Anorthite, Orthoclase-Albite) and ternary silicate systems (Orthoclase-Albite-Silica, Diopside-Albite-Anorthite, Diopside-Forsterite-Silica, Fayalite-Leucite-Silica) in the light of modern experimental works.	15
	Unit-IV: Petrogenesis and tectonic setting of major igneous rock types and suites: Ultramafic rocks, komatiite, lamprophyres, kimberlite, ophiolite, flood basalt, anorthosite, Tonalite-Trondhjemite- Granodiorite (TTG), granitoids, alkaline rocks and carbonatites with special reference to Indian examples.	15

Suggested Reading:

- Phillpotts, A.R. (1994) Principles of Igneous and Metamorphic Petrology, Prentice Hall of India.
- Best, M. G. (2003) Igneous and Metamorphic Petrology, 2nd Edn.,Blackwell.
- Bose, M. K. (1997) Igneous Petrology, World Press,Kolkata.
- Cox, K. G., Bell, J. D. and Pankhurst, R. J. (1979) The Interpretation of IgneousRocks, UnwinHyman.
- Frost, B.R. and Frost, C.D. 2014, Essentials of Igneous and Metamorphic Petrology, Cambridge University Press
- McBirney, A. R. (1993) Igneous petrology. Jones &BartletPublication.
- LeMaitre R. W. (2002) Igneous Rocks: A Classification and Glossary of Terms, Cambridge

UniversityPress.

- Wilson, M. (1993) Igneous Petrogenesis, Chapman and Hall,London.
- Kumar, S, and Singh, R. N. (2014) Modelling of Magmatic and Allied Processes. Springer, Switzerland.
- Kerr, P.F. (1959). Optical Mineralogy, McGraw Hill Book Company Inc., New York.
- Powell, R. (1978). Equilibrium thermodynamics in Petrology: An Introduction, Harper & Row Publishers, London.
- Spear, F. S. 1993 Mineralogical Phase Equilibria and pressure – temperature – time Paths, Mineralogical Society of America.
- Winter, J.D. 2001, An introduction to Igneous and Metamorphic Petrology, Prentice Hall.
- Wood, B.J. and Fraser, D.G. 1976: Elementary Thermodynamics for Geologists, Oxford University Press, London.

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Suggested Online Link:

- https://www.classcentral.com/course/swayam-petrology-14084
- E- pathshala. https://epgp.inflibnet.ac.in/

Paper II Metamorphic Petrology

Course outcome: This course will allow students to gain in-depth knowledge about the origin of metamorphic rocks from different protoliths. The identification of structures, textures and mineral assemblages provide information on involved reactions under different pressures and temperature regimes, and its implication on understanding the metamorphic evolutionary history and geodynamics of mobile belts thorough time. Some noted Indian examples will be demonstrated.

Course type, paper & Credits	Content	Teaching hours
Metamorphic Petrology (04)	Unit I: Mineralogical Phase rule of open and closed systems; Types of metamorphism; Texture of regional & contact metamorphic rocks, deformation and metamorphism; Nature and types of metamorphic reactions; Concept and classification of metamorphic facies; Facies series; Graphical representation of minerals in ACF, AKF, AFM and A'F'M' diagrams; Time relation between phases of deformation and metamorphic crystallization.	15
	Unit II: Description of each facies of low pressure, medium to high pressure and very high pressure with special reference to characteristics minerals, subdivisions into zones/sub facies, mineral assemblages, metamorphic reactions and pressure-temperature conditions of metamorphism. Introduction to Ultra-high temperature and Ultra-high pressure metamorphism. Metamorphism of shale, mafic and calcareous rocks.	15
	Unit III: Isograds and Reaction Isograds; Schreinmakers rule and	15

	construction of Petrogenetic grids; Metamorphic differentiation; Anatexis and origin of migmatites; Paired metamorphic belts	
	Unit IV: Gibb's free energy; Entropy; Enthalpy; Clausius-Clapeyron equation; Geothermobarometry; Pressure-Temperature-Time (P-T-t) paths.	15

Suggested Readings:

- Turner, F.J. (1980) Metamorphic Petrology, McGraw Hill, New York.
- Yardlley, B.W.D. (1989) An introduction to Metamorphic Petrology, Longman Scientific and Technical, NewYork.
- Yardley, B.W.D., Mackenzie, W.S. and Guilford, C. 1995 Atlas of Metamorphic Rocks and their textures, Longman Scientific & Technical, England.
- Philopotts, A.R. (1994) Principles of Igneous and Metamorphic Petrology, Prentice Hall.
- Kretz, R. (1994) Metamorphic Crystallization, John Wiley.
- Bucher, K. and Frey, M. (2002). Petrogenesis of Metamorphic Rocks (7th Rev. Ed.),Springer–Verlag.
- Powell, R. (1978) Equilibrium thermodynamics in Petrology: An Introduction, Harper and Row Publ., London.
- Wood, B.J. and Fraser, D.G. (1976) Elementary Thermodynamics for Geologists, Oxford University Press.
- Rastogy, R.P. and Mishra, R.R. 1993: An Introduction to Chemical Thermodynamics, Vikash Publishing House.
- Spry, A. (1976). Metamorphic Textures, Pergamon Press.
- Sharma, R. S. (2016). Metamorphic Petrology: Concepts and Methods, Geological Society of India
- Winter, J.D. (2001). An introduction to Igneous and Metamorphic Petrology, Prentice Hall.
- Winkler, H.G.F. (2013). Petrogenesis of Metamorphic rocks, Springer New York, Ebook.
- Barker, A. J. (1998). Introduction to Metamorphic textures and Micro-textures,
- Miyashiro, A. (1994). Metamorphic Petrology, Taylor & Francis.

Suggested Online Link:

- https://www.classcentral.com/course/swayam-petrology-14084
- https://www.classcentral.com/course/swayam-geology-metamorphic-petrology-thermodynamics-22994
- E- pathshala. https://epgp.inflibnet.ac.in/

Paper III Sedimentology

Course outcome: The course in-depth knowledge about the types and origin of sedimentary rocks, and source-to-sink sedimentary processes. It emphasizes upon the modern concepts of palaeoenvironmental analysis, as well as provenance determination of sedimentary rocks. The course content deals with all the essential aspects required in exploring oil and natural gas, underground water, mechanically concentrated mineral deposits (placer deposits), and building stones		
Course type, paper & Credits	**Content**	**Teaching hours**
Sedimentology (04)	Unit I: Sedimenatary texture, and textural parameters and their significance. Textural and compositional maturity. Fluid flow concepts, sediment transport, bedforms and sedimentary structures. Allogenic and autogenic controls on sedimentation. Palaeocurrent analysis and its significance.	15
	Unit II: Concept of sedimentary facies, facies associations, and facies model. Characteristics, processes, and facies of fluvial, lacustrine, deltaic, esturine, tidal flat, lagoonal, barrier beach, and deep-sea sedimentary environments. Tectonic classification of sedimentary basins.	15
	Unit III: Types and petrogenesis of conglomerates, sandstones, and argillites. Problem of greywacke. plate tectonics and sandstone composition. Classification and genesis of limestones and dolomites. Evaporites: Gypsum and anhydrite.	15
	Unit IV: Digenesis – Physical and chemical processes. Diagenetic stages and regimes Evidences of diagenesis in sandstones, mud rocks and carbonate rocks. Provenance of sedimentary rocks. Provenance identification of sandstones through petrographic, petrofacies, and heavy mineral analyses.	15

Suggested Reading:

- Blatt, H., Middleton, G.V. and Murray, R.C. (1980). Origin of sedimentary rocks. Prentice Hall Inc.
- Collins, J.D. and Thompson, D.B. (1982). Sedimentary structures. George Allen and Unwin, London.
- Lindholm, R.C. (1987). A practical approach to sedimentology. Allen and Unwin, London.
- Miall, A.D. (2000). Principles of basin analysis, Springer-Verlag.
- Pettijohn, F.J. (1975). Sedimentary rocks (3rd Ed), Harper and Row Publ., New Delhi.
- Reading, H.G. (1997). Sedimentary environments and facies, Blackwell Scientific Publication.
- Reineck, H.E. and Singh, I.B. (1973). Depositional sedimentary Environments, Springer-Verlag.
- Selley, R.C. (2000). Applied Sedimentology, Academic Press.

- Tucker, M.E. (1981). Sedimentary Petrology: An introduction. Wiley and sons, New York.
- Tucker, M.E. (1990). Carbonate Sedimentology, Blackwell Scientific Publication.

Paper IV Fuel Geology

Course outcome: This course will enable students to explore various fossil fuels including coal, petroleum and gas regarding their formation and mode of occurrence. The prospecting and exploration techniques of radioactive minerals will also help students to enhance their knowledge about nuclear energy. All these sources form base for a country's development so it will be beneficial for the students as they can contribute for its development by choosing a carrier related to fuel energy.

Course type, paper & Credits	Content	Teaching hours
Fuel Geology (04)	Unit I: Introduction: Sources of energy, Indian scenario. Grade and Rank of coal, Indian classification, Spatial and temporal distribution of coal, Indian scenario. Petroliferous basins of India.	15
	Unit II: Coal Geology: Introduction, Origin of coal, Biochemical and dynamo-chemical changes in coal formation, Macroscopic and Microscopic constituents, Macerals and micro-lithotypes, Physical and chemical properties.	15
	Unit III: Petroleum Geology: Composition and physical properties of petroleum, Origin of Petroleum; Kerogen and their types. Migration of natural hydrocarbon. Petroleum Reservoir: source rock, reservoir rock, cap rocks. Traps: Structural, stratigraphic and combination traps.	15
	Unit IV: Nuclear Fuel: Minerology, Geochemistry, mode of occurrence; Distribution of radioactive minerals in India; Radiogenic waste disposal — geological constrains. Gas-hydrates.	15
Practical (04)	Section A: Igneous Petrology: Megascopic and microscopic studies of major igneous rock types: CIPW norm calculation: Introduction to software: Newpet, Sinclass, GCD kit.	120
	Section B: Metamorphic Petrology: Study of metamorphic rocks of different metamorphic facies in hand specimens. Calculation of ACF, AKF, AFM and A'F'M values from the given chemical data/structural formula of minerals and their graphical representation. Study of metamorphic rocks in thin sections with reference to texture/structure, time relation between phases of deformation and metamorphic crystallization, mineral association, parent rock, metamorphic facies/sub-facies/zones to which rock can be assigned and	

	representation of assemblage in ACF, AKF, AFM and A'F'M' diagrams. Estimation of pressure and temperature from important models of Geothermobarometry.	
	Section C: Sedimentology: Detailed study of clastic and non-clastic rocks in hand specimen. Study of sedimentary structures hand specimen in form-process context. Petrography of important rock types with emphasis on depositional setting, provenance and diagenesis. Heavy mineral identification with regard to their significance in provenance interpretation. Study of important facies models.	
	Section D: Fuel Geology: Study of hand specimen of coal, Reserve estimation of coal.	

Suggested Reading:

- Barker, C. (1996): Thermal Modeling of Petroleum Generation, ElsevierScience.
- Jahn, F., Cook, M. and Graham, M. (1998):Hydrocarbon Exploration and Production, Eslevier Science. Makhous, M. (2000): The Formation of Hydrocarbon Deposits in North African Basins, Geological and Geochemical Conditions,Springer-Verlag.
- North, F.K. (1985): Petroleum Geology, Allen Unwin. Selley, R.C. (1998): Elements of petroleum geology, AcademicPress.
- Tissot, B.P. and Welte, D.H. (1984): Petroleum formation and occurrence, Springer–Verlag.
- Chandra, D., Singh, R.M., Singh M.P., (2000): Text book of coal (Indian context), Tara Book Agency,Varanasi.
- Scott, A.C., (1987): Coal and coal bearing strata: Recent Advances, Blackwell Scientifics Publications.
- Isabel Suárez-Ruiz John Crelling. (2008). Applied Coal Petrology: The Role of Petrology in Coal Utilization, Academic Press.
- Taylor,G.H., Teichmuller, M., Davis, A., Diessel, C.F.K., Littke, R. and Robert P., (1998). Organic Petrology, GebruderBorntraeger, Stuttgart.
- Singh, M.P. (1998). Coal and organic Petrology. Hindustan Publishing Corporation, New Delhi.
- Stach, E., Mackowsky, M-Th., Taylor, G.H., Chandra, D., Teichumullelr, M. and Teichmuller R. (1982). Stach Textbook of Coal petrology. GebruderBorntraeger, Stuttgart.
- Holson, G.D. and Tiratso, E.N. (1985). Introduction to Petroleum Geology. Gulf Publishing, Houston, Texas.
- Tissot, B.P. and Welte, D.H. (1984).Petroleum Formation and Occurrence, Springer – Verlalg.
- North,F.K. (1985). Petroleum Geology. Allen Unwin.
- Selley, R.C. (1998). Elements of Petroleum Geology. Academic press.
- Durrance, E.M. (1986). Radioactivity in Geology-principles and application. Ellis

Hoorwool.

- Dahlkamp, F.J. (1993). Uranium Ore Deposits. Springer Verlag.
- Boyle, R.W. (1982). Geochemical prospecting for Thorium and Uranium deposits, Elsevier.

Suggested Online Link

- https://www.my-mooc.com/en/mooc/geoscience-earth-its-resources-delftx-geo101x/.
- https://www.mooc-list.com/course/oil-gas-industry-operations-and-markets-coursera

Semester IX

Paper I: Geodynamics

Course outcome: This subject covers the dynamic processes of the solid earth which is responsible for large-scale tectonics and evolution of the earth through deep time. The course introduces advanced topics in Plate Tectonics that have shaped the earth, its deep interior and processes such as earthquakes, volcanoes, lithosphere and asthenosphere interaction vis-á-vis mantle dynamics; Evolution of continental-oceanic crust and orogenic belts and their relationship to continental amalgamation and fragmentation.		
Course type, paper & Credits	**Content**	**Teaching hours**
Theory Geodynamics (04)	Unit-I: Planetary evolution of the earth and its internal structure. Heterogeneity of the earth crust. Major tectonic features of the Oceanic and Continental crust. Isostacy and epeirogeny.	15
	Unit-II: Gravity and magnetic anomalies and heat flow patterns at Mid- Ocean ridges, deep sea trenches, continental shield areas and mountain chains. Continental drift-geological and geophysical evidence, mechanics, objections, present status. Nature of plate margins.	15
	Unit-III: Palaeomagnetism, magnetostratigraphy, seafloor spreading, mechanics of plate motion and Plate Tectonics. Island arcs, oceanic islands, hotspots and plume tectonics. Seismic belts of the earth vis-á-vis plate movements	15
	Unit-IV: Orogeny, geodynamic evolution of Indian cratons and mobile belts. Structure and origin of the Himalaya. Metallogeny in relation to plate tectonics. Neotectonic movements concepts and evidence.	15

Suggested Reading:

- Valdiya, K.S. (1984). Aspects of tectonics ,Tata McGraw-Hill Pub. Co., New Delhi.
- Kearey P., Klepeis, K.A. and Vine F.J. (2009). Global Tectonics, John Wiley & Sons, Ltd., Publication. E-book available
- Valdiya, K.S. (2010). Making of India. Macmillam Publishers, India.
- Windley B.F. (1984). Evolving Continents (2nd edition), Wiley–Blackwell publisher.
- Condie, K.C. (1976). Plate Tectonics, 1st edition, Elsevier Science. E-book available.
- Cox, A. And Hart, R.B. (1986). Plate Tectonics, Blackwell Publishing.
- Moores, E. and Twiss, R.J. (1995). Tectonics, Waveland PressFreeman.
- Keary, P. and Vine, F.J. (1990). Global Tectonics-Balckwell Publishing.
- Storetvedt, K.N. (1997). Our Evolving Planet: Earth's History in New Perspective-Bergen (Norway), Alma Mater Fortag
- Valdiya, K.S. (1998). Dynamic Himalaya-Universal Press, Hyderabad 12.Summerfield, M.A., 2000: Geomorphology and Global Tectonics-Springer Verlag

- Turcotte, D.L and Schubert, G.(2002). Geodyanamics, second edition., Cambridge University Press.

Suggested Online Link:

- https://www.mooc-list.com/course/planet-earth-and-you-coursera
- https://www.mooc-list.com/course/dynamic-earth-course-educators-coursera

Paper II: Tectonic Geomorphology

Course outcome: This course pertains to studying the active terrain deformation in response to activities on structural discontinuities of the earth, and/or climatic fluctuations, and/or isostatic adjustments of the earth. The course will enable the students to indentify active tectonic structures of an area and measure extent of activities of them on the basis of their geomorphic signature. Knowledge on such aspects of an area are quite useful in analyzing the hazard proneness and vulnerability of any area, as well as assessing the safety of any geo-engineering project therein

Course type, paper & Credits	Content	Teaching hours
Theory Tectonic Geomorphology (04)	Unit I: Definition and scope of tectonic geomorphology. Landscape evolution. Davis', Penck's, and Hack's models of landscape evolution. Modern concepts of landscape evolution. Concept of Form-Process relationship in landscape evolution.	15
	Unit II: Geomorphic Markers of active tectonics: Planar and Linear. Landforms of active strike- slip faults, normal faults, reverse faults and folds. River response to active tectonics. Sudden (coseismic) versus gradual modifications in river systems. Tectonic modifications of alluvial and bedrock-channeled rivers: longitudinal profiles, river pattern, sinuosity, drainage patterns and drainage anomalies. Effects of base level.	15
	Unit III: Geomorphic Indices of active tectonics – Morphometric analysis: mountain-front sinuosity, hypsometric curve and hypsometric integral, stream-length gradient index, and valley-floor width to valley height ratio, basin elongation ratio, basin shape, relief ratio, drainage basin asymmetry factor, transverse topography symmetry factor.	15
	Unit IV: Introduction to geodesy. Fundamentals of ground-based and space geodetic techniques of measuring active tectonic deformations: Alignment arrays, Trilateration nets, Dry-tilt nets, electronic distance measurement (EDM) systems, Very long beam interferometry (VLBI), Radar Interferometry, and Global Positioning System (GPS)	15

Suggested Reading:

- Burbank, D.W. and Anderson, R.S. (2011). Tectonic Geomorphology 2nd Edition. Blackwell Science.
- Burbank, D.W. and Anderson, R.S. (2001). Tectonic Geomorphology 1st Edition. Blackwell Science.
- Keller, E.A. and Pinter, N. (1996). Active tectonics: Earthquakes, Uplift, and Landscape. Prentice Hall
- Bull, William. (2009). Tectonically active landscapes.Wiley-Blackwell
- Schumm, S.A, Dumont, J.F. and Holbrook, J.M. (2000). Active tectonics and alluvial rivers. Cambridge University Press.
- Bull, W. (2007).Tectonic Geomorphology of Mountains: A new approach to palaeo-seismology. Blackwell Publishing.
- Small, R.J. (1978). Study of Landforms: A Textbook of geomorphology (2nd Edition), Cambridge University Press.
- Halis, J.R. (1983). Applied Geomorphology.
- Sharma, H.S. (1990). Indian Geomorphology. Concept Publishing Co. New Delhi.
- Thornbury, W.D. (2004). Principles of Geomorphology. 2nd edition CBS Publication.
- Kale V S and Avijit Gupta (2010). Introduction to geomorphology. University Press
- Bloom, A. L. (2011). Geomorphology: A systematic analysis of Late Cenozoic Landforms 3rd Edition. Rawat Publications.
- Condie, Kent. C. (1989). Plate Tectonics and Crustal Evolution. 3rd Edition. Butterworth-Heinemann Ltd.
- Windlley B. (1995). The Evolving Continents. 3rd Edition Wiley-Blackwell.
- Davies, G.F. (1999). Dynamic Earth: Plates, Plumes and Mantle Convection. Cambridge University Press.
- Keller, E.A and Pinter, N (2001). Active Tectonics. 2nd Edition. Pearson Publications.
- Kearey P, Klepeis, K A and Vine, F.J (2009). Global Tectonics 3rd Edition. Wiley-Blackwell.
- Burbank D W and Anderson R S (2016). Tectonic Geomorphology. Wiley India.

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Paper III: Micropalaeontology& Oceanography

Course outcome: This course will enable students to develop skills regarding modern techniques and methods employed in micropalaeontologyand marine life. It will provide idea about the different Ocean drilling program. The students will gain an advanced knowledge on applications of microfossils and will be able to interpret atmospheric and oceanic circulation systems so as to analyze their driving forces . This all will also help them to evaluate a relationship between ocean chemistry and climate change.		
Course type, paper & Credits	**Content**	**Teaching hours**
Theory Micropalaeontology& Oceanography (04)	Unit I. Definition and scope of the subject, surface and subsurface sampling methods, sample processing and techniques. slide preparation.	15
	Unit II. Morphology, geological distribution, evolution and applications of-Foraminifers, Ostracoda, Calcareous Nannofossils, Radiolaria, Diatoms and Conodonts	15
	Unit III. History and development of Oceanography. Methods of measuring properties of seawater. Ocean drilling Programmes (DSDP, ODP, IODP) and its major accomplishments.	15
	Unit IV. Ocean circulation, surface circulation and concept of mixed layers. Thermocline and Pycnocline, concept of upwelling. El Nino and deep Ocean circulation. Formation of bottom, bottom water, water masses of the world ocean and sea sediments.	15

Suggested Reading:

- Saraswati P. K. and Srinivasan M. S. (2016). Micropaleontology: Principles and Applications,Springer.
- Arnold (2002). Quaternary Environmental Micropaleontology (Ed. Simon K. Haslett), Oxford
- Haq B. U. and Boersma A. (1998). Introduction to Marine Micropaleontology, Elsvier.
- Pinet P. R. (1992): Oceanography: An introduction to the Planet Oceanus, West Pub,Co
- Bignot, G., Grahm and Trottman (1985). Elements of Micropaleontoogy, London.
- David Tolmazin (1985). Elements of Dyanamic Oceanography, Allen and Unwin
- Grant Gross, M. (1977). Oceanography; A view of the Earth, Prentice Hall.
- John Houghton (1997). Global Warming, Cambridge Univ. Press.
- Jones, T.P. and Rowe, T.P. (1999). Fossil plants and spores, Modern Techniques, Geological Soc. Of London.

Paper IV: Field & Laboratory techniques in Geology

Course outcome: Geology is field and observational science. Geoscientific hypothesis is framed in the field that can be tested through field data and laboratory investigations.This course will enable the students to explore practical aspect of geology such as preparation of geological maps, cross section, and reconnaissance and detailed surveys for georesource exploration and environmental purposes etc.		
Course type, paper & Credits	**Content**	**Teaching hours**
Field and Lab training Paper IV Field& Laboratory techniques in Geology (04)	The paper will be based on training on geological field, laboratory techniques, and various instruments used in geological analysis. During fieldwork the students will be exposed to terrains of different geological characteristics, different types of mines, natural resource exploration sites, various types of geohazard sites. Students will prepare geological reports on the basis of their training, which will be evaluated for the marking.	120
Practical (04)	Section A: Tectonic Geomorphology: Exercises on mapping of tectonic geomorphological features and computation of geomorphic indices, using map and remote sensing data.	120
	Section B: Micropalaeontology& Oceanography: Surface and Deep Ocean circulation, Upwelling, Indian Monsoon circulation. Techniques of separation of microfossil from the matrix. Study of representative genera of microfossils, Preparation of bio-zonation charts.	

Course Prerequisites: To study this course, a student must have passed Sem-I to VIII

Semester X

Paper I Applied Groundwater Hydrology

Course outcome: This course has a direct relationship to society as it provides a deep information regarding the most important factor required for a life to sustain i.e water. Groundwater is the purest form of water that can be yielded from rocks. It provides a better knowledge about its origin, prospecting and extraction. It explains the laws governing groundwater flow and various methods of groundwater exploration.		
Course type, paper & Credits	**Content**	**Teaching hours**
Theory Applied Groundwater Hydrology (04)	Unit I: Ground Water origin, type and occurrence, renewable and non-renewable groundwater resources. Subsurface movement and vertical distribution of Ground Water. Concept of depth to water level and water table contour maps. Water table and piezometric surface. Water bearing properties of rocks and aquifer parameters: porosity, permeability, specific yield, specific retention, hydraulic conductivity, transmissivity, intrinsic permeability, storage coefficient, storativity, specific storage. Introduction to hydrogeology of India, and the groundwater provinces of India.	15
	Unit II: Aquifer and their types. Darcy Law, its range and validity. Theory of groundwater flow, numerical solutions for steady state linear groundwater flow in confined and unconfined aquifers and Dupuit's assumption for unconfined flow. Numerical solutions for steady state radial flow to a well in confined (Thiem's equation) and unconfined aquifers (Dupuit's equation). Numerical solutions for unsteady state groundwater water flow condition. Evaluation of aquifer parameters of confined aquifer using Theis and Jacob methods.	15
	Unit III: Quality of Ground water: Chemical characteristics of ground water in relation to various uses- domestic, irrigation and industrial purposes. Groundwater contamination and pollution from natural (geogenic) and anthropogenic sources. Graphical presentation of water quality data. Saline water intrusion in aquifers and its prevention. Groundwater quality in different provinces of India	15
	Unit IV: Geological and geophysical methods of ground water exploration. Geologic and geomorphic controls on groundwater.	15

Suggested Reading:

- Todd, D.K. (1980). Groundwater Hydrology- John Wiley.
- Davis, S.N. and De Wiest, R.J.M. (1966). Hydrogeology- John Wiley.
- Freeze, R.A. and Cherry, J.A. (1979). Ground Water- Prentice Hall.

- Fetter, C.W. (1990). Applied Hydrogeology- Merill Publishing.
- Ragunath, N.M. (1982). Ground Water- Wiley Eastern.
- Karanth, K.R. (1987). Groundwater Assessment- Development and Management- Tata McGrawHill.
- Alley, W.M. (1993). Regional Ground Water Quality- VNR, New York.
- Subramaniam, V. (2000). Water- Kingston Publication, London.
- Hiscock, K.M. and Bense, V.F. (2014). Hydrogeology: Principles and Practice 2nd Edition, Wiley-Blackwell.
- Raghunath,H.M. (1983). Ground Water, Viley Eastern Ltd., Calcutta.
- Driscoll, F.G.(1988). Ground Water and Wells, UOP, Johnson Div. St. Paul. Min. USA.

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Paper II Advanced Remote Sensing & GIS

Course outcome: This course pertains to recent technologies of Remote Sensing and Geographical Information System (GIS). The course introduces various types of remote sensing data in different ranges of the electromagnetic spectrum, and the basic concepts and potential of GIS in geological investigations. It develops skills in students for interpreting visual and digital remote sensing image from different spectral bands, and use them to understand the various physical processes operating on earth's surface through integration of other sources' data in a GIS.		
Course type, paper & Credits	**Content**	**Teaching hours**
Theory Advanced Remote Sensing & GIS (04)	.Unit I: Atmospheric scattering and absorption; Concepts of Optical, NIR, SWIR, TIR and RADAR remote sensing; Satellite and Aerial remote sensing platforms; Spectral reflectance curves of soil, water and vegetation.	15
	Unit II: Types and characteristics of sensors. Concepts of mono-band, multispectral and hyperspectral remote sensing. Basics of optical, thermal and microwave remote sensing. Basic concept of LiDAR. Characteristics of IRS sensors.	15
	Unit III: The structure of Digital Image. Conceptual aspects of Digital Image Processing. Basic processes of image rectification, enhancement and classification. Definition and components of Geographic Information System (GIS). Raster and vector data formats. Basic knowledge about data acquisition, manipulation, analyses and representation in GIS.	15
	Unit IV: Application of remote sensing and GIS in geomorphological investigations, tectonic investigations, lithological mapping, groundwater exploration, mineral exploration, Oil & Gas exploration and geohazard management.	15

Suggested Readings:

- Lillesand, T.M., Kiefer, R. W. and Chapman, J. (2015): Remote Sensing and Image Interpretation, 7th Edition. Wiley
- Gupta, R. P. (2003). Remote Sensing Geology. 2nd Edition.Springer
- Drury, S.A. (1993). Image Interpretation in Geology. 2nd Edition. Chapman &Hall
- Jensen, J.R. (2000). Remote Sensing of the Environment, An earth ResourcePerspective. PearsonEducation.
- DeMers M.N. (2008). Fundamentals of geographic Information System. 4thEdition.Wiley
- Richards, J.A. and Jia, X. (2006). Remote Sensing Digital Image Analysis: AnIntroduction. 4th Edition, Springer
- George Joseph (2005). Fundamentals of Remote Sensing 2nd edition : Universities Press
- Gopi, S, Sathikumar, R and Madhu, N (2006). Advanced Surveying total station GIS and RemoteSensing Pearson Education

- Sabins, F.F. (2007). Remote Sensing Principles and Interpretations 3rd Edition, Waveland Pr Inc.
- Lilles T.M., Kiefer, R.W. and Chipman, J. (2008). Remote Sensing and Image Interpretation. 6thEdition,John Wiley and Sons.
- Bhatia, S. C. (2008). Fundamentals of Remote Sensing Atlantic Publications.
- Bhatta, B. (2011). Remote Sensing and GIS 2nd Edition, Oxford University Press
- Sabins, F.F. (2012). Remote Sensing Principles and Practice 3rd Edition, Levant Books
- Jensen, J R. (2013). Remote Sensing of the Environment : An Earth Resource Perspective 2nd Edition,Pearson India.
- https://www.classcentral.com/course/swayam-photogeology-remote-sensing-45165

Paper III Project Oriented Dissertation

Course outcome: This course will enable students to choose any branch in geology and select a problem for research. During this course student will apply the knowledge gained so far in resolving geological problems by carrying out research work followed by presentation of work. It will help the student to apply all his/her skills and work practically by using different techniques including field and laboratory work.

Course type, paper & Credits	Content	Teaching hours
Research and Dissertation Project Oriented Dissertation (08)	The students will be assigned a minor research topic to write a dissertation, under the supervision of a guide (faculty of the department). The dissertation will be evaluated by combined team of external examiner and internal examiner (guide of the specific dissertation)	240
Practical (04)	Section A: Applied Groundwater Hydrology: Preparation of groundwater flow directions, Estimation of aquifer parameters using different mathematical equations, plotting groundwater quality properties (Hill & piper diagram, Durov plot and SAR plotting), Plot hydrological provinces in India.	120
	Section B: Advanced Remote Sensing & GIS: Determination of the scale of aerial photographs and imageries. Visual interpretation of aerial photographs and imageries for geomorphological, lithological, tectonic and geological mapping.	