

# **NATIONAL EDUCATION POLICY-2020**

**Syllabus Major Elective Subject**

**Geology**

**DEPARTMENT OF GEOLOGY  
FACULTY OF SCIENCE  
KUMAUN UNIVERSITY, NAINITAL**

List of Semester-wise Titles of the Papers in Geology (Major Elective Subject)					
Year	Sem.	Course Code	Paper Title	Theory/ Practical	Credits
<b>CERTIFICATE COURSE IN SCIENCE</b>					
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
<b>DIPLOMA COURSE IN SCIENCE</b>					
SECOND YEAR	III		Petrology	Theory	04
			Petrology + Field work	Practical	02
	IV		Palaeontology	Theory	04
			Practical (Palaeontology)	Practical	02
<b>BACHELOR OF SCIENCE</b>					
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
<b>BACHELOR (RESEARCH) OF SCIENCE</b>					
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
<b>MASTER OF SCIENCE (GEOLOGY)</b>					
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 recognized 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 proceed 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:

<b>PO1</b>	Enabling the students to understand the age, composition, structure, processes, and Evolutionary history of the Earth.
<b>PO2</b>	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.
<b>PO3</b>	Enabling the students to understand and assess the potential of natural processes in causing hazards and disasters.
<b>PO4</b>	Enabling the students to understand such geological conditions that make the terrain prone to natural and anthropogenic hazards.
<b>PO5</b>	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.
<b>PO6</b>	Enabling the students to formulate and execute guidelines for safe developmental activities in diverse geological terrains.
<b>PO7</b>	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 identify 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 geo-scientific 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 Specific Prerequisites:** 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 geo-hazards. It will also instill in them the quest for better understanding of the subject through incessant pursuance and research.

## COURSE STRUCTURE

Year	Semester	Course type	Credits	Teaching hours
First	I	Physical & Structural Geology	04	60
		Practical (Physical & Structural Geology + Fieldwork)	02	60
	II	Elements of Mineralogy & Gemology	04	60
		Practical (Mineralogy & Gemology)	02	60
Second	III	Petrology	04	60
		Practical (Petrology + Fieldwork)	02	60
	IV	Paleontology	04	60
		Practical (Paleontology)	02	60
Third	V	Economic Geology & Mineral Exploration	04	60
		Geohydrology & Environment Geology	04	60
		Practical (Economic & Exploration Geology + Fieldwork)	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
		Micropaleontology & Oceanography	04	60
		Field & Laboratory techniques in Geology (Field training)	04	60
		Practical	04	60
	X	Applied Ground water Hydrology	04	60
		Advanced Remote Sensing & GIS	04	60
		Project/ Research Oriented Dissertation	08	120
		Practical	04	60

**Semester I**  
**Paper: Physical & Structural Geology**

<b>Course outcome:</b> After successful completion of this course students will understand the origin of solar system, and dynamics of earth's surface and interiors, plate tectonic processes, seismicity, and volcanism. 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 be able to recognize and interpret the geological structures formed as a result of deformation.		
Course type, paper & Credits	Content	Teaching hours
Theory  Physical & Structural Geology  (04)	Unit I: Introduction to geology and its geological time scale. 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

**Suggested Reading:**

- Arthur Holmes (1992). Principles of Physical Geology. Chapman and Hall, London.
- Miller (1949). An Introduction to Physical Geology. East West Press Ltd.
- Spencer, E.V. (1962). Basic concepts of Physical Geology. Oxford & IBH.
- Billings, M.P. (1972). Structural Geology. Prentice Hall.
- Davis, G.R. (1984). Structural Geology of Rocks and Region. John Wiley
- Hills, E. S. (1963). Elements of Structural Geology. Farrold and Sons, London.
- R.J Park (1998) Foundation of Structural Geology, III Edition, Routledge

- Singh,R.P.(1995).Structural Geology, A Practical Approach.Ganga Kaveri Publ.,Varanasi.

**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-lifecoursera>
- <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>

**Practical**

Practical & Field training  (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 field work in a suitable geological area to study the elementary aspects of field geology and submit a report there on.	

**Semester II**  
**Paper: Elements of Mineralogy & Gemology**

<b>Course outcome:</b> 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 symmetry elements and notation 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 these precious and semi-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; Silicate structure and classification of silicates. 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 nicolls. 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

**Suggested Reading:**

- Berry, L.G., Mason, B. and Dietrich, R.V.(1982). Mineralogy. CBS Publ.
- Nesse, D.W.(1986). Optical Mineralogy. Mc Graw Hill.
- Deer, W. A., Howie, R. A., and Zussman, J. (1996). An Introduction to Rock-Forming Minerals. Prentice Hall.
- Kerr, P. F. (1977) Optical Mineralogy. IV Edition. McGraw Hill
- Read, H.H.(1968). Rutley's Element of Mineralogy (Rev.Ed.). Thomas Murby and Co.
- 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; NewYork.
- 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. 2<sup>nd</sup> ed. Butterworth-Heinemann, London.
- Anderson, Basil, W (1990). GemTesting.Rev.byE.A.Jobbins.10<sup>th</sup> ed.,Butterworth, London.
- Verma, P.K. (2010) Optical Mineralogy. CRC Press.
- Demanje, M. A. (2012) Mineralogy for petrologists. CRC Press

**Suggested Online Link:**

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

**Practical**

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, Feldspar Group, Chalcedony, Barite, Augite, Agate, Jasper, Flint. Use of polarizing microscope; Study of optical properties of common rock forming minerals such as Olivine, Pyroxene, Garnet, Muscovite, Biotite, Amphiboles, Feldspars, Augite, Quartz. Calcite, Fe-oxide (magnetite, chromite), Tourmaline.	60
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## Semester III

### Paper: Petrology

<p><b>Course outcome:</b> 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.</p>		
Course type, paper & Credits	Content	Teaching hours
Theory Petrology (04)	Unit I: Introduction to igneous petrology; Magma: definition, origin, composition and properties; Mode of magma emplacement; Forms of igneous rocks; Textures of igneous rocks. Reaction principle; Bowen's reaction series; Magma differentiation and assimilation; Crystallization of magma in unary and binary phase equilibria system. IUGS classification scheme and nomenclature of igneous rocks. Petrography and petrogenesis of Dunite, Gabbro, Diorite, Granodiorite, Granite, Syenite, Basalt, Trachyte, and Rhyolite.	15
	Unit II: Introduction to metamorphic petrology; Process and products of metamorphism; Textures, structures and classification of metamorphic rocks. Types of metamorphism. Factors, zones and grade of metamorphism; Petrographic details of some important metamorphic Rocks, such as foliate, phyllite, schists, gneiss, quartzite, and marble.	15
	Unit III: Introduction to sedimentary petrology; Processes of formation of sedimentary rocks. Clastic and non-clastic sedimentary rocks. Classification of sandstone and carbonate rocks. Textures and structures of sedimentary rocks. Paleocurrent 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

**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.
- Moor house, W.W.(1969).The study of rocks in thin sections. Harper and sons.

- Pettijohn, F.J. (1975). Sedimentary rocks, Harper & Bros. III Edition
- Prasad, C.(1980). A text book of Sedimentology.
- Turner, F.J.(1980). Metamorphic petrology. Mc Graw Hill.
- Blatt, H. and Tracy, R.J.(1996). Petrology (Igneous, Sedimentary, Metamorphic), W.H. Freeman & Co., New York.
- Tucker, M. E. (1991) Sedimentary petrology: An introduction to the origin of sedimentary rocks. Blackwell Science
- Boggs Jr., S. (2009) Petrology of sedimentary rocks. II Edition, The Blackburn Press.
- Best, M.G. (2002) Igneous and Metamorphic Petrology. II Edition, Wiley-Blackwell
- Hibbard, M. J. (1995) Petrography to petrogenesis. MacMillan USA
- Haldhar, S. K., Tišljarić, J. (2014) Introduction to Mineralogy and Petrology, Elsevier

**Suggested Online Links:**

- <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/>

**Practical**

<b>Practical &amp; Field training (02)</b>	Section A: Petrology : Study of common structures and textures of igneous, metamorphic and sedimentary rocks in hand specimen and thin sections.	<b>60</b>
	Section B: Geological Field Training: Students will be required to carry out one week field work in a suitable geological area to study the elementary aspects of field geology and submit a report there on.	

## Semester IV

### Paper : Paleontology

<b>Course outcome:</b> 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 the basic concept of paleontology using mode and methods of fossil preservation and species identification, thereafter suggesting the organic evolutionary path and paleo-environment. Also they will know the causes of major events of mass extinctions in geological past including the glaciation 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 timescale. 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, 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

#### Suggested Readings:

- Raup, D.M., Stanley, S.M., Freeman, W.H.(1971).Principles of Paleontology.
- Clarkson,E.N.K.(2012).Invertebrate paleontology and evolution 4<sup>th</sup> Edition by Black well 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 Paleontology. CBS, Delhi
- Bilal U. Haq andA. Boersome, Introduction to Marine Micropaleontology
- Wood, F. (1961) Invertebrate paleontology. Cambridge University Press.

**Suggested Online Link:**

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

**Practical**

Practical (02)	Study of fossils showing various modes of preservation. Study of diagnostic morphological characters, systematic position, stratigraphic position and age of various invertebrate and plant fossils.	<b>60</b>
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## Semester V

### Paper I: Economic Geology & Mineral Exploration

<b>Course outcome:</b> 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 in deed 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  Economic Geology & Mineral Exploration  (04)	Unit I: Concept of ore and ore deposits, ore minerals and gangue minerals. Ore forming processes: magmatic, metamorphic and sedimentary.	15
	Unit II: Study of important metallic (Cu, Pb, Zn, Mn, Fe, Au, Al) and non-metallic(industrial) minerals (gypsum, magnesite, mica, silica, phosphorite, talc, clay minerals, limestone, halite, Baryte). Distribution of iron, copper, zinc, lead, gold, diamond, uranium, bauxite, phosphorite, magnesite, mica, coal, and oil and natural gas in India.	15
	Unit III: Mineral exploration: Surface and subsurface exploration methods. Elementary idea of geological, geophysical, geochemical and geo-botanical prospecting and mining methods. Drilling, sampling and assaying.	15
	Unit IV: Basic knowledge about the genesis, exploration, distribution and reserves of oil and natural gas, and coal. Petroliferous basins of India. Metallogenic epochs and provinces.	15

#### Suggested Reading:

- Robb, L (2020). Introduction to ore forming processes. Wiley
- Moon, C.J., Whateley, M.E.G. and Evans, A.M (2006) Introduction to mineral exploration. 2<sup>nd</sup> edition, Blackwell Publishing
- Evans,A.M (2013) Ore Geology and Industrial Minerals, An Introduction. Wiley-Blackwell (3<sup>rd</sup> edition)
- 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.
- Jensen, 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 distributors.
- Sharma, N.L. and Ram, K.V.S.(1972).Introduction to India’s Economic Minerals, Dhanbad.
- McKinsty, H.E.(1962). Mining Geology. IIEd. Asia Publishing House.
- Clark, G.B.(1967). Elements of Mining. IIIEd. John Wiley
- Arogyaswami, R.P.N.(1996). Courses in Mining Geology. IV Ed. Oxford IBH.
- Haldar, S. K. (2018) Mineral Exploration: Principles and Applications. II Edition, Elsevier

**Suggested Online Links:**

- <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

<p><b>Course outcome:</b> 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 water resources, and their utilization in more scientific and sustainable manner and further managing geo-hazards.</p>		
Course type, paper & Credits	Content	Teaching hours
Theory  Geohydrology & Environment Geology  (04)	Unit I: Introduction and scope of hydrology. Hydrologic cycle and its components: precipitation, evapo-transpiration, runoff, infiltration and sub-surface movement of water. Vertical distribution of sub-surface water. Water bearing and yielding bodies.	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.	15
	Unit III: Scope and aims of environmental geology. Biosphere and man. Geohazards: Earthquakes, volcanism, landslides, floods, flashfloods, and snow avalanches. Concepts of geo hazard management. Climatology and global environment- Coastal, riverine, desertic, tropical, cold and polar. Greenhouse effect and global warming.	15
	Unit IV: Elementary idea about pedogenesis and pedotypes. Soil erosion and conservation. Preliminary idea of environmental implications of mining activities and their remedies. Elementary concept of watershed management. Land reclamation	15

### Suggested Reading:

- Valdiya, K.S.(2013).Environmental Geology 2<sup>nd</sup> Edition. McGraw Hill Education
- 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
- Rangunath,N.M.(1982):GroundWater-Wiley Eastern
- Karanth,K.R.(1987).Groundwater Assessment-Development and Management-Tata McGraw Hill
- 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>

**Practical**

Practical & Field training (02)	Section A: Economic Geology & Mineral Exploration: Study of common ores in hand specimen. Study of copper, lead, zinc, iron, gold, phosphorite, magnesite, oil and gas, and coal deposits of India. Ore microscopy. Laboratory exercises in solving exploration related problems.	60
	Section B: Geohydrology: Estimation of hydrologic components, Assessment of different aquifer parameters.	
	Section C: Geological Field Training: Students will be required to carry out one week field work in a suitable geological area to study the elementary aspects of field geology and submit a report there on.	

## Semester VI

### Paper I: Remote sensing & Elementary Engineering Geology

<p><b>Course outcome:</b> 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.</p>		
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 interactions with atmosphere and earth surface features. Film and digital aerial photography. Types of aerial photographs. Aerial photography mission and stereo-pair 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. Dams and their types. Geological conditions controlling the safety of dams. Causes of dam failure. Geological problem of reservoirs. Bridges and their types.	15
	Unit IV: Tunnels and their types. Geological conditions controlling the safety of tunnels. Seepage problem in tunnels and role of watertable. Landslides: classification, Causes and preventative measures.	15

**Suggested Reading:**

- Valdiya, K.S.(2013). Environmental Geology 2<sup>nd</sup> 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 textbook of engineering geology. Macmillan 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.
- Campbell, J.B. and Wynne R.H. (2011). Introduction to Remote Sensing. The Guilford Press, New York/London.
- Pandey, S.N.(1987). Principles and Application of Photo geology. 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-gongchengdezixue-edx>
- <https://www.classcentral.com/course/swayam-photogeology-remote-sensing-45165>

## Paper II: Stratigraphy

<b>Course outcome:</b> After completion of this course students will be able to understand fundamentals of stratigraphy 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. Precambrian-Cambrian, Permian-Triassic, and Cretaceous-Tertiary boundaries	15
	Unit II: Study of following Precambrian succession: Dharwar, Aravalli, Cuddappah, Vindhyan and Delhi Supergroups; Precambrian-Cambrian successions of NW Himalaya.	15
	Unit III: Brief idea about Palaeozoic succession of north western Himalaya; Mesozoic of Spiti; Mesozoic type succession of Kachcha and Rajasthan; Cretaceous of Tiruchirapalli	15
	Unit IV: Stratigraphy of the Indian Gondwana, and Deccan Trap. Paleogene-Neogene sequences of northwest Himalaya.	15

### Suggested Reading:

- Wadia, D. (1973). Geology of India. Mc Graw Hill Book Co.
- Krishnan, M.S. (1982). Geology of India and Burma, 6<sup>th</sup> 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.

## Practical

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 landuse / landcover classes.	<b>60</b>
	Section B: Stratigraphy: Preparation of litho-stratigraphic maps of India showing distribution of important geological formations and Gondwana flora.	

**Semester VII**  
**Paper I: Advanced Structural Geology**

<b>Course outcome:</b> 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 ellipsoids; their properties and significance. Mechanical properties of rocks and their controlling factors. Theories of rock failure.	15
	Unit II: Mechanics of folding and buckling. Folds geometry and classification. Superimposed folds and their interference patterns. Causes and dynamics of faulting. Normal faults and strike – slip faults, thrust faults. Thin skinned deformation and decollement. Salt domes and diapirs. Concept of balanced cross-sections.	15
	Unit III: Joints, rock cleavage and foliations; their origin, domain character, relationship with major structures and geological significance. Lineations and linear structures; their origin, relationship with major structures and significance.	15
	Unit IV: Brittle and ductile shear zones; their geometry, strain pattern, kinematics, products 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.(2012).Structural Analysis of Metamorphic Tectonites. Literary Licensing, LLC.
- Ramsay, J.G.(1967). Folding and Fracturing of Rocks. Mc Graw Hill.
- Davis, G.H.(1984). Structural Geology of Rocks and Region. John Wiley.
- Ramsay, J.G. and Huber, M.I. (1983 and 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 (2<sup>nd</sup> 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.
- 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, Springer.
- RichardH.Groshong(2008).3D 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.andWilliams,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<sup>nd</sup> 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<sup>rd</sup> edition, Wiley-Blackwell.

**Suggested Online Link:**

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

## Paper II: Advanced Mineralogy

<b>Course outcome:</b> 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
Theory Advanced Mineralogy (04)	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: Olivine, Garnet, Pyroxene, Amphibole, Mica, Feldspars, Feldspathoids, Silica and Al silicates, oxides and sulphides.	15
	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. Longman, London, New York.
- Berry,L.G. and Mason,B(1959). Mineralogy: concepts, descriptions, determinations, London Publication.
- Dana, E.S. and Ford, W.E.(2002). A textbook of Mineralogy (Reprint)
- Deer,W.A.,Howie,R.A.,andZussman,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, John Wiley.
- Kerr, P.F.(1977).Optical Mineralogy, 4<sup>th</sup> Edition McGraw-Hill
- Putnis, Andrew(1992). Introduction to Mineral Sciences, Cambridge University Press.
- Winchell, A.N.(1962). Elements of Optical Mineralogy, John Wiley.

- Nesse, W. D. (2011). Introduction to Optical Mineralogy (Fourth Edition). Oxford University Press.

**Suggested OnlineLink:**

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

## Paper III

### Geochemistry & Geochronology

<b>Course outcome:</b> 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
Theory 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, 2<sup>nd</sup> Edn., Prentice Hall, New Jersey, 593p.
- Faure, G. (1986). Principles of Isotope Geology, 2<sup>nd</sup> Edn., John Wiley.
- 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, Mc Graw Hill.
- Mason, B. and Moore, C.B. (1991). Introduction to Geochemistry, Wiley Eastern.
- Rollinson, H.R. (1993). Using geochemical data : Evaluation, Presentation,

Interpretation, Longman, U.K.

- Gill, R. (2015) Chemical Fundamental of Geology, Wiley Blackwell

**Suggested Online Link:**

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

## Paper IV: Geological Mapping

<p><b>Course outcome:</b> Geology is field and observational science. Geo-scientific 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.</p>		
Course type, paper & Credits	Content	Teaching hours
<p>Field training</p> <p>Geological Mapping (04)</p>	<p>The paper will be based on geological field training, in which the students will be trained on the following aspects:</p> <ol style="list-style-type: none"> <li>1. Geological mapping techniques, understanding the interaction between topography and geologic structures.</li> <li>2. Basics of field data collection, analyses, interpretation, and geological report writing.</li> </ol> <p><b>(Note:</b> Marks will be evaluated on the basis of student's field training report.)</p>	<p>120</p>

### Practical

<p>Practical (04)</p>	<p>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 oriented thin sections.</p>	<p>120</p>
	<p>Section B: Advanced Mineralogy: Study of physical and optical properties of important rock forming minerals; Determination of An content of plagioclase feldspars; Determination of elongation and optic sign of minerals; Determination of Pleochroism and absorption schemes.</p>	
	<p>Section C: Geochemistry &amp; Geochronology: Construction of geochemical variation diagrams (Spiderdiagrams; Harker's variation diagrams; addition-substraction diagrams); Calculation of stoichiometric formula from chemical analysis of minerals.</p>	

**Semester VIII**  
**Paper I: Igneous Petrology**

<b>Course outcome:</b> 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, magma mixing, assimilation, liquid immiscibility, and other subsidiary processes.	15
	Unit II: Petrography and genetic interpretation of igneous textures in terms of rate of nucleation and crystal growth; IUGS classification schemes and nomenclature of igneous rocks: Ultramafic, mafic and felsic igneous rocks; total-alkali-silica(TAS)classification of volcanicigneousrocks.	15
	Unit III: Study of phase equilibria in binary (Diopside-Anorthite, Forsterite-Silica, Nepheline-Silica, Forsterite-Fayalite; Albite-Anorthite; Orthoclase-Albite) and ternary (Diopside-Nepheline-Silica, Diopside-Albite-Anorthite, Anorthite-Forsterite-Silica; Fayalite-Leucite-Silica, Orthoclase-Albite-Silica) silicate systems in the light of modern experimental works.	15
	Unit IV: Petrogenesis and tectonic setting of major igneous rocktypes and suites: Ultramafic rocks, komatiite, lamprophyres, kimberlite, ophiolite, floodbasalt, 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, 2<sup>nd</sup> Edition, Blackwell.
- Bose, M.K.(1997). Igneous Petrology, World Press, Kolkata.
- Cox, K.G., Bell, J.D. and Pankhurst, R.J. (1979). Interpretation of Igneous Rocks, Unwin Hyman, London
- Frost, B.R. and Frost, C.D.(2014). Essentials of Igneous and Metamorphic Petrology, Cambridge University Press

- McBirney, A.R.(1993). Igneous petrology. Jones & Bartlet Publication.
- LeMaitre, R.W.(2002). Igneous Rocks: A Classification and Glossary of Terms, Cambridge University Press.
- Wilson,M.(1993). Igneous Petrogenesis, Chapman and Hall, London.
- Kumar,S, and Singh,R.N.(2014). Modelling of Magmatic and Allied Processes. Springer, Switzerland.
- Powell,R.(1978).Equilibrium thermodynamics in Petrology : An Introduction, Harper & Row Publishers, London.
- 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.
- Gill, R. (2015). Chemical Fundamental of Geology, Wiley Blackwell
- Hibbard, M. J. (1995). Petrography to petrogenesis. MacMillan USA

**Suggested Online Link:**

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

## Paper II

### Metamorphic Petrology

<b>Course outcome:</b> 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
Theory Metamorphic Petrology (04)	Unit I: Mineralogical Phase rule of open and closed systems; Types of metamorphism; Textures of regional and 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 construction of Petrogenetic grids; Metamorphic differentiation; Anatexis and origin of migmatites; Paired metamorphic belts	15
	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, Mc Graw Hill, New York.
- Yardlley, B.W.D.(1989). An introduction to Metamorphic Petrology, Longman Scientific and Technical, New York.
- 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 (7<sup>th</sup> 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

<b>Course outcome:</b> 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
Theory  Sedimentology  (04)	Unit I: Sedimentary texture, 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, estuarine, 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: Diagenesis—Physical and chemical processes. Diagenetic stages and regimes Evidences of diagenesis in sandstones, mud rocks and carbonate rocks. Provenance of sedimentary rocks. Provenance reconstruction 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 (3<sup>rd</sup>Ed),Harper and Row Publ., NewDelhi.
- 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

<b>Course outcome:</b> 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, Coal Geology: Introduction, origin and distribution of coal, Bio-chemical and dynamo-chemical changes in coal formation. Grade and Rank of coal Macroscopic and Microscopic constituents, Macerals and micro-lithotypes, Physical and chemical properties. Indian classification.	15
	Unit II: 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 III: Distribution of Oil and Natural gas, and Coal in India. Coal fields and Petroliferous basins of India.	15
	Unit IV: Nuclear Fuel: Minerology, Geochemistry, mode of occurrence; Distribution of radioactive minerals in India; Radiogenic waste disposal—geological constrains. Gas-hydrates. Elementary idea about non-conventional energy resources	15

#### **Suggested Reading:**

- Barker, C. (1996): Thermal Modeling of Petroleum Generation, Elsevier Science.
- Jahn, F., Cook, M. and Graham, M. (1998): Hydrocarbon Exploration and Production, Elsevier 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, Academic Press.
- Tissot, B.P. and Welte, D.H. (1984): Petroleum formation and occurrence, Springer-Verlag.
- Chandra, D., Singh, R.M. and 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., Teichmüller, M., Davis, A., Diessel, C.F.K., Littke, R. and Robert P., (1998). Organic Petrology, Gebrüder Borntraeger, Stuttgart.
- Singh, M.P. (1998). Coal and organic Petrology. Hindustan Publishing Corporation, New Delhi.
- Stach, E., Mackowsky, M-Th., Taylor, G.H., Chandra, D., Teichmüller, M. and Teichmüller, R. (1982). Stach Textbook of Coal petrology. Gebrüder Borntraeger, 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-Verlag.
- 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 Horwood.
- 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>

## Practical

Practical (04)	Section A : Igneous Petrology: Megascopic and microscopic studies of major igneous rock types. CIPW normative mineral calculation. Introduction to software: Sinclass, GCDkit, MELT, R-Crust.	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 inform-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.	

## Semester IX

### Paper I : Geodynamics

<b>Course outcome:</b> 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-à-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. Isostasy 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-à-vis plate movements. Concept of seismic tomography.	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., NewDelhi.
- KeareyP., 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(2<sup>nd</sup> edition),Wiley–Blackwell publisher.
- Condie,K.C.(1976).PlateTectonics,1<sup>st</sup>edition,ElsevierScience.E-bookavailable.
- Condie, K. (1989) Plate Tectonics and Crustal Evolution. Pergamon Press, Oxford, 476 p.
- Cox,A. and Hart,R.B.(1986). Plate Tectonics, Blackwell Publishing.
- Moores,E. and Twiss, R.J.(1995).Tectonics, Waveland Press Freeman.
- 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, Hyderabad12.
- Summerfield, M.A.,2000:Geomorphology and Global Tectonics-Springer Verlag
- Turcotte,D.L and Schubert,G.(2002). Geodynamics, 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

<p><b>Course outcome:</b> 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.</p>		
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-channel e drivers: 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-tiltnets, 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 2<sup>nd</sup>Edition. Blackwell Science.
- Burbank,D.W.and Anderson,R.S.(2001). Tectonic Geomorphology 1<sup>st</sup>Edition. Blackwell Science.
- Keller,E.A.and Pinter,N.(1996). Active tectonics : Earthquakes, Uplift, and Landscape. PrenticeHall

- 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 (2ndEdition), Cambridge University Press.
- Halis,J.R.(1983). Applied Geomorphology.
- Sharma, H.S.(1990). Indian Geomorphology. Concept Publishing Co. New Delhi.
- Thornbury,W.D. (2004). PrinciplesofGeomorphology.2<sup>nd</sup> 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 3<sup>rd</sup> Edition. Rawat Publications.
- Condie, Kent. C.(1989).Plate Tectonics and CrustalEvolution.3<sup>rd</sup> Edition. Butterworth-HeinemannLtd.
- Windlley, B.(1995).The Evolving Continents.3<sup>rd</sup> Edition Wiley-Blackwell.
- Davies,G.F.(1999).Dynamic Earth : Plates, Plumes and Mantle Convection. Cambridge University Press.
- Keller,E.A and Pinter,N(2001).ActiveTectonics.2ndEdition.PearsonPublications.
- Kearey, P., Klepeis, KAand Vine,F.J(2009).Global Tectonics 3<sup>rd</sup> Edition.Wiley-Blackwell.
- Burbank, D.W. and Anderson, R.S. (2016).Tectonic Geomorphology. WileyIndia.

### Paper III: Micropalaeontology & Oceanography

<p><b>Course outcome:</b> This course will enable students to develop skills regarding modern techniques and methods employed in micropalaeontology and marine life. It will provide idea about the different Ocean Drilling Programs. 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.</p>		
Course type, paper & Credits	Content	Teaching hours
Theory  Micro-palaeontology & Oceanography  (04)	Unit I: Definition and scope of the subject; Relationship of micropaleontology with ocean sciences; Modern field and laboratory techniques in the study of microfossils (collection, sampling and processing techniques, scanning electron microscopy and mass spectrometry); Concepts of micropaleontological indicators useful in understanding geological evolution, environmental changes and biostratigraphic correlation.	15
	Unit II: Morphology, geological distribution, evolution, significance and applications of organic-walled microfossils (acritarchs, dinoflagellates, spores and pollens) and inorganic walled microfossils (Foraminifers, Ostracoda, Calcareous Nannofossils, Radiolaria, Diatoms, silicoflaglets and Conodonts). Application of Micropaleontology in hydrocarbon exploration, paleoceanography, paleoclimatology and tracing history of marine pollution. Interpretation of seafloor tectonism from micro-paleontological evidence.	15
	Unit III. History and development of Oceanography. Methods of measuring properties of seawater (horizontal and vertical distribution of temperature, salinity, dissolved gases in sea water; density stratification in oceans). Depositional processes and distribution of Calcareous oozes, silicious oozes, and pelagic sediments in oceans. Ocean drilling Programmes (DSDP, ODP, IODP) and its major accomplishments.	15
	Unit IV: Ocean circulation, surface circulation and concept of mixed layers. Coriolis force and Ekman spiral Thermocline and Pycnocline, concept of upwelling and downwelling of ocean water. El Niño, La Niña. Deep Ocean circulation. Formation of bottomwater, water masses of the world ocean and sea sediments.	15

**Suggested Reading:**

- Garrison T and Ellis, R. (2016). Oceanography : An invitation to marine Science. National Geographic Learning.
- Trujillo, A.P and Thurman, H.V. (2011). Essentials of Oceanography. Prentice Hall (10<sup>th</sup> edition)

- Armstrong, and Brasier, M. (2005). Microfossils. Blackwell Publishing (2<sup>nd</sup> edition)
- 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, Elsevier.
- Pinet, P.R.(1992): Oceanography: An introduction to the Planet Oceanus, West Pub,Co
- Bignot,G.,Grahm and Trottman (1985). Elements of Micropaleontology, London.
- DavidTolmazin(1985).Elements of Dyanamic Oceanography, Allen and Unwin
- GrantGross,M.(1977).Oceanography; A view of the Earth, Prentice Hall.
- JohnHoughton(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

<p><b>Course outcome:</b> Geology is field and observational science. Geo-scientific 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.</p>		
Course type, paper & Credits	Content	Teaching hours
<p>Field and Lab training</p> <p>Field &amp; Laboratory techniques in Geology</p> <p>(04)</p>	<p>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.</p> <p>(Note: Marks will be evaluated on the basis of student's field training report.)</p>	<p>120</p>

### Practical

<p>Practical (04)</p>	<p>Section A: Tectonic Geomorphology: Exercises on mapping of Tectonic geomorphological features and computation of geomorphic indices, using map and remote sensing data.</p>	<p>120</p>
	<p>Section B: Micropaleontology and 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.</p>	

**Semester X**  
**Paper I**  
**Applied Groundwater Hydrology**

<b>Course outcome:</b> 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 ground water flow and various methods of ground water 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 ground water resources. Sub surface movement and 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: 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 flow condition. Evaluation of aquifer parameters of confined Aquifer using Theis and Jacob methods.	15
	Unit III: Quality of Groundwater: 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. Ground water 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).Ground water Hydrology-John Wiley.
- Davis,S.N. and DeWiest, 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.

- Rangunath,N.M.(1982).Ground Water-Wiley Eastern.
- Karanth, K.R.(1987).Groundwater Assessment-DevelopmentandManagement-TataMcGrawHill.
- Alley, W.M.(1993). Regional Ground Water Quality-VNR, NewYork.
- Subramaniam,V.(2000).Water-Kingston Publication, London.
- Hiscock,K.M.andBense,V.F.(2014).Hydrogeology: Principles and Practice 2<sup>nd</sup> Edition, Wiley-Blackwell.
- Raghunath,H.M.(1983).Ground Water, Wiley Eastern Ltd.,Calcutta.
- Driscoll,F.G.(1988).Groundwater and Wells, UOP, Johnson Div.St.Paul.Min.USA.

## Paper II

### Advanced Remote Sensing & GIS

<b>Course outcome:</b> 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, 7<sup>th</sup> Edition. Wiley
- Gupta, R.P. (2003). Remote Sensing Geology. 2<sup>nd</sup> Edition. Springer
- Drury, S.A. (1993). Image Interpretation in Geology. 2<sup>nd</sup> Edition. Chapman & Hall
- Jensen, J.R. (2000). Remote Sensing of the Environment, An earth Resource Perspective. Pearson Education.
- DeMers M.N. (2008). Fundamentals of geographic Information System. 4<sup>th</sup> Edition. Wiley
- Richards, J.A. and Jia, X. (2006). Remote Sensing Digital Image Analysis: An Introduction. 4<sup>th</sup> Edition, Springer
- George Joseph (2005). Fundamentals of Remote Sensing 2<sup>nd</sup> edition: Universities Press

- Gopi,S, Sathikumar,R and Madhu,N(2006). Advanced Surveying total station GIS and Remote Sensing, PearsonEducation
- Sabins,F.F.(2007).Remote Sensing Principles and Interpretations 3<sup>rd</sup> Edition, Waveland Pr Inc.
- LillesT.M.,Kiefer,R.W.and Chipman,J.(2008). Remote Sensing and Image Interpretation. 6<sup>th</sup> Edition, John Wiley and Sons.
- Bhatia,S.C.(2008).Fundamentals of Remote Sensing Atlantic Publications.
- Bhatta,B.(2011).Remote Sensing and GIS 2<sup>nd</sup> Edition, Oxford University Press
- Sabins,F.F.(2012).Remote Sensing Principles and Practice 3<sup>rd</sup> Edition, Levant Books
- Jensen,JR.(2013).Remote Sensing of the Environment: An Earth Resource Perspective 2<sup>nd</sup> Edition, Pearson India.

**Suggested Online Link:**

- <https://www.classcentral.com/course/swayam-photogeology-remote-sensing-45165>

### Paper III

#### Project Oriented Dissertation

<p><b>Course outcome:</b> 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.</p>		
Course type, paper & Credits	Content	Teaching hours
Research and Dissertation  Project Oriented Dissertation (08)	<p>The students will be assigned a minor research topic to write a dissertation, under the supervision of a guide (faculty of The department).</p> <p>The dissertation will be evaluated by combined team of external examiner and internal examiner (guide of the specific dissertation)</p>	240

#### Practical

Practical  (04)	Section A: Applied Groundwater Hydrology : Preparation of ground water 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.	