

Sons.

Morrison, D.F. (1967) Multivariate statistical methods, McGraw-Hill. **Five years Integrated**

Course in M. Sc Tech. Applied Geology

Semester	Paper-I	Paper-II	Paper-III	Paper-IV	Practical-I	Practical-II	Field Training/ Dissertation
Semester -I	English: Communication Skills	Earth Processes and Dynamics	Fundamental Chemistry	Botany	Paper III	Paper IV	Seminar
Semester -II	English: Application of the Language	Crystallography, Mineralogy and Petrology	Inorganic Chemistry	Zoology	Paper II	Paper III/IV	Field Visit/Seminar
Semester -III	Environmental Science	Indian Stratigraphy and Paleontology	Physical Chemistry	Physics	Paper I & II	Paper III/IV	Seminar
Semester -IV	Information Technology	Structural and Economic Geology	Analytical Chemistry	Mathematics	Paper II	Paper III/IV	Field Visit/Seminar
Semester -V	Mineralogy and Crystallography	Igneous Petrology	Sedimentology	Paleontology and Applied Paleobiology	Paper I & II	Paper III/IV	Seminar
Semester -VI	Metamorphic Petrology	Structural Geology, Geodynamics and Tectonics	Stratigraphy and Indian Geology	Precambrian Geology, Geodesy and Mapping	Paper I & II	Paper III/IV	Seminar
Semester -VII	Geochemistry	Instrumentation Techniques, Geostatistics and Computer Application in Geology	Ore Geology	Mining Geology & Valuation of Mineral Property	Paper I & II	Paper III/IV	Seminar
Semester -VIII	Indian Mineral Deposits and Mineral Economics	Mineral Exploration	Elements of Mining and Drilling Techniques	Geomorphology, Remote Sensing and GIS	Paper I & II	Paper III/IV	Mine/ Industrial Training
Semester -IX	Fuel Geology (Coal, Petroleum and Nuclear)	Ore Microscopy and Ore Dressing	Hydrogeology & Watershed Management	Optional Subject (Any one) 1. Engineering and Environmental Geology 2. Exploration Geochemistry 3. Applied & Industrial Micropaleontology 4. Petroleum Exploration	Paper I & II	Paper III/IV	Seminar
Semester -X	Project						Seminar

1st Semester (Credits: 25)

Theory Paper/ Practical	Title	Teaching Scheme (Hrs/ week)			Credits	Examination Scheme					
		Th	Pr.	Total		Duration (Hrs)	Max. Marks		Total Marks	Min. Passing Marks	
							External	Internal		Th	Pr.
Paper-I	English: Communication Skills	4		4	4	3	100		100	40	
Paper-II	Earth Processes and Dynamics	4		4	4	3	100		100	40	
Paper-III	Fundamental Chemistry	4		4	4	3	100		100	40	
Paper-IV	Botany	4		4	4	3	100		100	40	
Practical I	Fundamental Chemistry (Marks: 75 Pract. Exam. + 05 Viva-voce + 20 Internal Assessment and Class Records)		8	8	4	3	80	20	100		40
Practical II	Botany (Marks: 75 Pract. Exam. + 05 Viva-voce + 20 Internal Assessment and Class Records)		8	8	4	3	80	20	100		40
	Seminar	2		2	1	---		25	25	10	
	Total	18	16	34	25				625	170	80

2nd Semester (Credits: 25)

Theory Paper/ Practical	Title	Teaching Scheme (Hrs/ week)			Credits	Examination Scheme					
		Th	Pr.	Total		Duration (Hrs)	Max. Marks		Total Marks	Min. Passing Marks	
							External	Internal		Th	Pr.
Paper-I	English: Application of the Language	4		4	4	3	100		100	40	
Paper-II	Crystallography, Mineralogy and Petrology	4		4	4	3	100		100	40	
Paper-III	Inorganic Chemistry	4		4	4	3	100		100	40	
Paper-IV	Zoology	4		4	4	3	100		100	40	
Practical I	Crystallography, Mineralogy and Petrology + Geological Field Work & Mapping (Marks: 75 Pract. Exam. + 05 Viva-voce + 20 Internal Assessment and Class Records)		8	8	4	3	80	20	100		40
Practical II	Inorganic Chemistry + Zoology (Marks: 75 Pract. Exam. + 05 Viva-voce + 20 Internal Assessment and Class Records)		8	8	4	3	80	20	100		40
	Seminar	2		2	1	---		25	25	10	
	Total	18	16	34	25				625	170	80

FIELD WORK: Each candidate must carry out field work of three to four days duration in igneous / sedimentary / metamorphic (including structurally deformed) terrain. The field report must be submitted to the field excursion In-charge. The field work should be treated as a part of **practical I examination of semester II**.

3rd Semester (Credits: 25)

Theory Paper/ Practical	Title	Teaching Scheme (Hrs/ week)			Credits	Examination Scheme					
		Th	Pr.	Total		Duration (Hrs)	Max. Marks		Total Marks	Min. Passing Marks	
							External	Internal		Th	Pr.
Paper-I	Environmental Science	4		4	4	3	100		100	40	
Paper-II	Indian Stratigraphy and Paleontology	4		4	4	3	100		100	40	
Paper-III	Physical Chemistry	4		4	4	3	100		100	40	
Paper-IV	Physics	4		4	4	3	100		100	40	
Practical I	Environmental Science and Indian Stratigraphy and Paleontology (Marks: 75 Pract. Exam. + 05 Viva-voce + 20 Internal Assessment and Class Records)		8	8	4	3	80	20	100		40
Practical II	Physical Chemistry and Physics (Marks: 75 Pract. Exam. + 05 Viva-voce + 20 Internal Assessment and Class Records)		8	8	4	3	80	20	100		40
	Seminar	2		2	1	---		25	25	10	
	Total	18	16	34	25				625	170	80

4th Semester (Credits: 25)

Theory Paper/ Practical	Title	Teaching Scheme (Hrs/ week)			Credits	Examination Scheme					
		Th	Pr.	Total		Duration (Hrs)	Max. Marks		Total Marks	Min. Passing Marks	
							External	Internal		Th	Pr.
Paper-I	Information Technology	4		4	4	3	100		100	40	
Paper-II	Structural and Economic Geology	4		4	4	3	100		100	40	
Paper-III	Analytical Chemistry	4		4	4	3	100		100	40	
Paper-IV	Mathematics	4		4	4	3	100		100	40	
Practical I	Structural & Economic Geology and Field work & Mapping (Marks: 75 Pract. Exam. + 05 Viva-voce + 20 Internal Assessment and Class Records)		8	8	4	3	80	20	100		40
Practical II	Information Technology and Analytical Chemistry (Marks: 75 Pract. Exam. + 05 Viva-voce + 20 Internal Assessment and Class Records)		8	8	4	3	80	20	100		40
	Seminar	2		2	1	---		25	25	10	
	Total	18	16	34	25				625	170	80

FIELD WORK: Each candidate must carry out field work of three to four days duration in igneous / sedimentary / metamorphic (including structurally deformed) terrain. The field report must be submitted to the field excursion In-charge. The field work is a part of **Practical I of Semester IV**.

5th Semester (Credits: 25)

Theory Paper/ Practical	Title	Teaching Scheme (Hrs/ week)			Credits	Examination Scheme					
		Th	Pr.	Total		Duration (Hrs)	Max. Marks		Total Marks	Min. Passing Marks	
							External	Internal		Th	Pr.
Paper-I	Mineralogy and Crystallography (3+1)	4		4	4	3	100		100	40	
Paper-II	Igneous Petrology (4)	4		4	4	3	100		100	40	
Paper-III	Sedimentology (4)	4		4	4	3	100		100	40	
Paper-IV	Paleontology and Applied Paleobiology (3+1)	4		4	4	3	100		100	40	
Practical I	Mineralogy, Crystallography, and Igneous Petrology (Marks: 75 Pract. Exam. + 05 Viva-voce + 20 Internal Assessment and Class Records)		8	8	4	3	80	20	100		40
Practical II	Sedimentology, Paleontology and Applied Paleobiology (Marks: 75 Pract. + 05 viva-voce + 20 Internal Assessment and Class Records)		8	8	4	3	80	20	100		40
	Seminar	2		2	1	---		25	25	10	
	Total	18	16	34	25				625	170	80

6th Semester (Credits: 25)

Theory Paper/ Practical	Title	Teaching Scheme (Hrs/ week)			Credits	Examination Scheme					
		Th	Pr.	Total		Duration (Hrs)	Max. Marks		Total Marks	Min. Passing Marks	
							External	Internal		Th	Pr.
Paper-I	Metamorphic Petrology (4)	4		4	4	3	100		100	40	
Paper-II	Structural Geology, Geodynamics and Tectonics	4		4	4	3	100		100	40	
Paper-III	Stratigraphy and Indian Geology	4		4	4	3	100		100	40	
Paper-IV	Precambrian Geology, Geodesy and Mapping	4		4	4	3	100		100	40	
Practical I	Metamorphic Petrology and Structural Geology (Marks: 75 Pract. + 05 Viva-voce + 20 Internal Assessment and Class Record)		8	8	4	3	80	20	100		40
Practical II	Stratigraphy, Indian Geology, Geodesy, Geological Field Work and Mapping (Marks: 55 Pract. + 05 Viva-voce + 20 Field Work and Mapping + 20 Internal Assessment and Class Record)		8	8	4	3	80	20	100		40
	Seminar	2		2	1	---		25	25	10	
	Total	18	16	34	25				625	170	80

FIELD WORK: Each candidate must carry out field work of two to three weeks duration in igneous / sedimentary / metamorphic (including structurally deformed) terrain. The field report should be based on the mapping as well as laboratory work on the rock samples collected during the field work. The field work should be treated as a part of practical II examination of semester II and the field report shall be assessed by field excursion In-charge.

7th Semester (Credits: 25)

Theory Paper/ Practical	Title	Teaching Scheme (Hrs/ week)			Credits	Examination Scheme					
		Th	Pr.	Total		Duration (Hrs)	Max. Marks		Total Marks	Min. Passing Marks	
							External	Internal		Th	Pr.
Paper-I	Geochemistry	4		4	4	3	100		100	40	
Paper-II	Instrumentation Techniques, Geostatistics and Computer Application in Geology	4		4	4	3	100		100	40	
Paper-III	Ore Geology	4		4	4	3	100		100	40	
Paper-IV	Mining Geology & Valuation of Mineral Property	4		4	4	3	100		100	40	
Practical I	Geochemistry, Instrumentation Techniques, Geostatistics, Computer Application in Geology (GIGCA) (Marks: 75 Pract. + 05 Viva-voce + 20 Internal Assessment and Class Record)		8	8	4	3	80	20	100		40
Practical II	Ore Geology, Mining Geology and Valuation of Mineral Property (Marks: 75 Pract. + 05 Viva-voce + 20 Internal Assessment and Class Records)		8	8	4	3	80	20	100		40
	Seminar	2		2	1	---		25	25	10	
	Total	18	16	34	25				625	170	80

8th Semester (Credits: 25)

Theory Paper/ Practical	Title	Teaching Scheme (Hrs/ week)			Credits	Examination Scheme					
		Th	Pr.	Total		Duration (Hrs)	Max. Marks		Total Marks	Min. Passing Marks	
							External	Internal		Th	Pr.
Paper-I	Indian Mineral Deposits and Mineral Economics	4		4	4	3	100		100	40	
Paper-II	Mineral Exploration	4		4	4	3	100		100	40	
Paper-III	Elements of Mining and Drilling Techniques	4		4	4	3	100		100	40	
Paper-IV	Geomorphology, Remote Sensing and GIS	4		4	4	3	100		100	40	
Practical I	Mineral Exploration and Mine/ Industrial Training (Marks: 55 Pract. + 05 Viva-voce + 20 Mine/ Industrial Training + 20 Internal Assessment and Class Record)		8	8	4	3	80	20	100		40
Practical II	Geomorphology, Remote Sensing and GIS (Marks: 75 Pract. + 05 Viva-voce + 20 Internal Assessment and Class record)		8	8	4	3	80	20	100		40
	Seminar	2		2	1	---		25	25	10	
	Total	18	16	34	25				625	170	80

Mine/ Industrial Training:

Each candidate shall undergo Mine / Industrial Training of Two to Four weeks duration in any working mine or industry or organization related to earth science and submit Mine / Industrial Training report to the Head of the Department. This training shall be treated as a part of practical I examination of semester IV and the field report shall be assessed by the Head of the Department.

9th Semester (Credits: 25)

Theory Paper/ Practical	Title	Teaching Scheme (Hrs/ week)			Credits	Examination Scheme					
		Th	Pr.	Total		Duration (Hrs)	Max. Marks		Total Marks	Min. Passing Marks	
							External	Internal		Th	Pr.
Paper-I	Fuel Geology (Coal, Petroleum and Nuclear) (2+1+1)	4		4	4	3	100		100	40	
Paper-II	Ore Microscopy and Ore Dressing (1+3)	4		4	4	3	100		100	40	
Paper-III	Hydrogeology and Watershed Management (3+1)	4		4	4	3	100		100	40	
Paper-IV	Optional (Any one) 1 Engineering and Environmental geology (2+2) 2 Exploration Geochemistry (4) 3 Applied and Industrial Micropaleontology (4) 4 Petroleum Exploration (4)	4		4	4	3	100		100	40	
Practical I	Fuel Geology, Ore Microscopy and Ore Dressing (Marks: 75 Pract. + 05 Viva-voce + 20 Internal Assessment and Class Record)		8	8	4	3	80	20	100		40
Practical II	Hydrogeology, Watershed Management and Optional (Marks: 75 Pract. + 05 Viva-voce + 20 Internal Assessment and Class Records)		8	8	4	3	80	20	100		40
	Seminar	2		2	1	---		25	25	10	
	Total	18	16	34	25				625	170	80

10th Semester: (Credits: 25)

Sr. No	Title	Credit	Maximum Marks		Total Marks	Minimum Passing Marks	
			External Marks	Internal Marks		External Marks	Internal Marks
1	Project work	24	400	200	600	200	100
2	Seminar	1		25	25	10	
	Total	25			625	210	100

Paper-I
(English: Communication Skills)
(Full Marks: 80)

Text prescribed: RADIANCE
(Published by Orient Blackswan)

Internal Assessment (20 marks)

Unit- I General Essay (20 marks)

Unit -II Prose (30 marks)

1. Mother Teresa
2. The Cabuliwallah
3. Uncle Podger Hangs a Picture
4. Education: Indian and American

Unit -III Poetry (10 marks)

1. The Phenomenal Woman
2. Psalm of Life
3. Night and Death
4. Money Madness

Unit- IV Grammar (20 marks)

1. Tenses (05 marks)
2. Subject-Verb Agreement (04 marks)
3. Voice (03 marks)
4. Transformation (08 marks)

Paper –II

(Earth Processes and Dynamics)

Unit-I

Geology and its perspectives. Earth in Solar System: size, shape, mass, density, rotational and revolution parameters. Formation of core, mantle, crust, hydrosphere, atmosphere, biosphere and elemental abundance in each constituent. Convection in Earth's core and production of its magnetic field. Earthquakes and earthquake belts, measurement of earthquakes. Volcanoes: types and distribution.

Unit-II

Rock weathering: Erosion and transportation by wind, river, glaciers and oceanic currents. Soil formation, soil profile and soil types.

Unit-III

Origin of the earth. Radiometric methods of determination of age of the earth. Interior of Earth : Internal structure and chemical composition of various layers. Application of geophysics in understanding the dynamics of Earth. Concept and theories of isostasy. Palaeoclimates: Indicators, glacial periods – causes of glacial ages and glacio-eustasy.

Unit-IV

Earth movements: orogeny and epeirogeny. Definition and types of geosynclines. Evolution of continents and oceans, evidences of continental drift. Evolution of plate tectonic theory : nature and types of plate margins, sea floor spreading, origin and significance of mid-oceanic ridges and trenches, origin and distribution of island arc.

Books Recommended:

- 1) Arthur Holmes (1978) Principles of Physical Geology, E.L.B.S. Nelson, Great Britain
- 2) Emmons, Thiel, Staffer and Allison : Geology Principles and Processes
- 3) Gulluly, Water and Woodford : Principles of Geology
- 4) Robinson, E.S.(1982) : Basic Physical Geology, John Wiley and Sons
- 5) Judson, Deffeyws and Hargrave, R. : Physical Geology
- 6) Sanders, J.E., Anderson (Jr), A.Z., Caroloa : Physical Geology
- 7) Cazen, Hatcher and Siemekowski : Physical Geology
- 8) Borges, S.M., Gwalani, L.G. and Veena Rao, G. (2000-2002) Fundamentals of Geology, Volume I and II. Himalaya Publishing House.
- 9) Patwardhan, A.M. (1999) The Dynamic Earth System, Prentice-Hall, New Delhi
- 10) Howell : Introduction to Geophysics
- 11) Hamblin, W. Kenneth (1992) The Earths Dynamic System. MacMillan
- 12) Sawkins, F.J., Chase, C.G., Darby, D.G. and Rapp, G. (1978) The Evolving Earth : A Text Book in Physical Geology. Collier MacMillan.
- 13) Mallory, B.F. and Cargo, D.N. (1979) Physical Geology. McGraw-Hill Book Co.
- 14) Judson, S., Kauffman, M.E. and Leet, L. Don (1987) Physical Geology. Prentice-Hall

- 15) Skinner, B.J. and Porter, S.C. (1989) The Dynamic Earth: An introduction to Physical Geology. John Wiley and Sons.
- 16) Tarbuck, E.J. and Lutgens, F.K. (1990) The Earth: An introduction to Physical Geology. MacMillan.
- 17) Monroe, J.S. and Wicander, R. (2001) Physical Geology: Exploring the Earth. Books/Cole, Thomson Learning.

Paper –III (Fundamental Chemistry)

Unit-I

Atomic Structure: Atomic orbital's, Quantum numbers, Heisenberg uncertainty principle, shapes of s, p, d orbital's. Aufbau and Pauli exclusion principles. Hund's multiplicity rule. Electronic configurations of the elements, Bohr's atomic model (Qualitative aspect only).

Elements in environment. Origin of elements in the universe; elements in lithosphere and its chemistry.

Periodic Properties: Atomic and Ionic radii, Ionization Energy, Electron affinity and Electro negativity. Trends in periodic table and application in predicting and explaining the chemical behavior.

Unit -II

Mathematics used in chemistry:

Logarithmic relations, curve sketching, linear graphs and calculation of slopes, differentiation of functions like kx , e^x , x^n , $\sin x$, $\log x$; maxima and minima, partial differentiation.

States of Matter:

Gases: Kinetic theory of gases and derivation of gas laws. Non-ideal behavior of gases; van der Waals equation, the critical temperature and liquefaction of gases. Heat capacities of gases, law of equipartition of energy. Mean free path, collision diameter and collision number. Liquids: Vapor pressure, viscosity, surface tension, refractive index, dipole moment and their measurements. Postulates of kinetic theory of gases, kinetic gas equation, Deduction of Gas Laws : Boyles Law, Charles Law, Grahams Law of diffusion, Avogadro's hypothesis, deviation from ideal behavior, van der Waals equation of state. Critical Phenomena: PV isotherms of real gases.

Solutions: Ideal solutions (Raoult's Law), Non-ideal solutions. Henry law, Colligative properties such as relative lowering of vapor pressure, elevation of boiling point, depression of freezing point. Osmotic pressure. (With reference to their thermodynamic treatment). Solubility and heat of solution.

Unit-III

Calibration of volumetric apparatus, Primary and Secondary standards, Principles of volumetric analysis, Acid – base titration. Titration in non-aqueous solvents, Complexometric titrations, Precipitation titrations, Redox titrations, Theoretical aspects of titration curves and end point evaluation, Choice and suitability of indicators in each case.

Unit- IV

Polymer Chemistry: Introduction, classification & properties of polymers, types of polymerization reactions, preparation of commercially important polymers: Polyethylene, polypropylene, polystyrene, polyvinyl chloride, polyacrylonitrile and polymethylmethacrylate.

Explosives: Classification; organic and inorganic explosives; commercial explosives used in mineral industries.

Coal Chemistry: Origin of coal formation, composition of coal, peat, lignite, bituminous, anthracite, Rank of coal; Indian coals, Grading; Analysis- proximate and ultimate, storage and spontaneous combustion; Carbonization and pyrolysis, manufacturing of metallurgical coke- Beehives ovens and Otto Hoffmann's method.

Petroleum Chemistry: origin, mining and refining; thermal and catalytic processes- cracking and reforming; Requisites of an ideal gasoline, Knocking, Octane and Cetane number; additives to improve the quality of petro and disel.

Water Treatment: Hard and Soft water, determination of Hardness, Alkalinity, physical, chemical and biological characteristics of waste water, primary treatment- sedimentation, coagulation, equalization, neutralization; Secondary treatment- activated sludge process, oxidation ditch process, anaerobic sludge digestion; Tertiary treatment- Evaporation, Ion exchange, Adsorption; Reverse osmosis.

PRACTICALS

1. Preparation of standard solution: 0.1N, 0.01N, 0.001N Potassium dichromate solution by weighing and dilution method.
2. Acid base titration.
3. Redox titration.
4. Complexometric titration.
5. Preparation of polymer:
 1. Preparation of urea-formaldehyde polymer.
 2. Preparation of phenol- formaldehyde polymer.
 3. Preparation of polymethylmethacrylate.
 4. Preparation of polystyrene.
 5. Preparation of Nylon.
6. Physical Experiments:
 1. To determine relative viscosity of given liquid using Ostwald's viscometer.
 2. To determine percentage composition of given ethanol-water mixture by viscosity method.
 3. To determine surface tension of a given liquid using stalagmometer.
 4. To determine molecular weight of solute by Rast's method.

Paper –IV (Botany)

Unit- I

Five Kingdom Classification:Virus- General Characters; Bacteria and Cyanobacteria- General characters, Cell structure and Economic Importance: Algae and Fungi- General Characters and Classification: Lichens- General Characters:Bryophytes, Pteridophytes and Gymnosperms- General Characters and Classification.

Unit- II

Morphology of Angiosperms : Root, Stem, and Leaves - Types, Functions, Modifications : Inflorescence -Types : Flower- Symmetry, Thalamus, Calyx, Corolla: Androecium – Stamens, Structure of Anther ; Gynoecium – Carpel, Structure of Ovule; Pollination- Types, Double Fertilization, Types of Fruits and Seeds.

Unit -III

Origin and Evolution of Angiosperms; Bentham and Hookers system of classification, Study of Families: Dicots – Brassicaceae, Malvaceae, and Asteraceae; Monocots-Liliaceae and Poaceae.

Ecosystems, abiotic and biotic components, foodchain, foodweb, energy pyramids. Phytogeographical regions of India

Unit -IV

Plant fossils-Types, preparation and age determination, geological column and time scale Fossil record, Systematics, reconstruction and nomenclature:Diversification of fossil Fungi, Algae and Bryophytes, Vascular primitive plants, seed ferns,pteridosperms,progymnosperms,cycades;Diversification of angiosperms. Tertiary and Gondwana fossil flora.

PRACTICALS

Unit- I

1. Study of bacterial and Cyanobacteria forms permanent slides.
2. Study of Cyanobacteria.(*Nostoc*)
3. Study of Algae(*Chara*,*Spirogyra*)
4. Study of Fungi (*Mucor*,*Penicillium*)
5. Study of Lichen thallus (Fruticose)
6. Study of Bryophytes (*Riccia*),Pteridophytes (*Nephrolepis*,*Marsilea*)
7. Study of Gymnosperms (*Cycas*-Leaf,Corolloid root,Mega and Microsporophyll)

Unit- II

1. Study of Stem-Monopodial and Sympodial
2. Study of Root (Taproot,Adventitious roots)
3. Study of Leaves (Simple,Compound,Phyllotaxy)
4. Study of inflorescence (Recemose,Cymose)
5. Study of Flowers:
 - A) Thalamus-Hypo,peri,epigyny

- B) Calyx-Gamo and poly
- C) Carolla-Gamo and Poly
- D) Androecium-Stamen,T.S.Anther
- E) Gynoecium-Carpel,L.S.Ovule
- F) Fruit- Simple Dry, fleshy ,aggregate and Composite

Unit- III

Study of Families-Brassicaceae, Malvaceae, Asteraceae, Liliaceae, Poaceae.

Unit -IV

Fossils-Types-Impression, Compression, Coal bed, Petrification.

Specimens of Pteridophytes (Ex: *Psilophyton*, *Asteroxylon*) and Gymnosperms (Ex: *Rachiopteris aspera*, *Kaloxylon hookeri*).

Specimens of Tertiary and Gondwana fossils.

Books Recommended:

1. Dubey,RC, DK Maheshwari (1999): Text book of Microbiology (S.Chand & Co.)
2. Bold, H.C, C.J. Alexopoulos and T.Delevoryas (1980):Morphology of Plants and Fungi(Harper and Row Publishers, NY)
3. Ganguly, Kar, College Botany ,Vol: II (New Central Book Agency,Calcutta)
4. Sharma,O.P.(1992): Text book of Thallophytes (McGraw Hill Publishing Co.)
5. Smith,G.M.(1971) : CryptogamicBotany,Vol I Algae and Fungi (TMH)
6. Vasistha,B.R.(1990) : Algae (S.Chand&Co)
7. Vasistha,B.R.(1990) : Fungi (S.Chand&Co)
8. Vasistha,B.R.(1992) :Bryophyta (S.Chand&Co)
9. Vasistha,B.R.(1990) : Pteridophyta (S.Chand&Co)
10. Smith,G.M.(1971) : CryptogamicBotany,Vol II Bryophyta and Pteridophyta (THM)
11. Bhatnaga,S.P. and Moitra A.(1996):Gymnosperm(New age International Ltd., New Delhi)
12. Stewart,W.N. and G.W.Rothwell (1993):Paleobotany and Evolution of Plants (2nd Ed.), Cambridge University Press)
13. Singh,G. Plant Systematics(1999): Theory and Practice (Oxford and IBH Pvt.Ltd. New Delhi)
14. Dutta,S.C. Plant Systematics(1989):(Wiley Eastern Co)
15. Naik,V.N.Taxonomy of Angiosperm
16. Sharma, P.D. 1992. Ecology and Environment. Rastogi Publications, Meerut.

Paper- I
(English: Application of the Language)
(Full Marks 80)

Text prescribed: RADIANCE
 (Published by Orient Blackswan)

Internal Assessment (20 marks)

- Unit- I** i. Paragraph writing
 ii. Letter writing
- Unit -II** i. Report writing
 ii. Writing Notices, Agendas and Minutes
- Unit -III** i. Comprehension
 ii. Curriculum Vitae
- Unit- IV** i. Electronic Correspondence
 ii. One word substitute
 iii. Synonyms
 iv. Antonyms

Paper-II
(Crystallography, Mineralogy and Petrology)

Unit-I

Laws of crystallography, constancy of interfacial angles, rationality of indices and symmetry. Elementary ideas about crystal structure, crystal faces, edges, solid angles and zone, crystallographic axes and axial angles. Crystal notations, Miller Indices and Weiss Parameters. Crystal symmetry and classification of crystals into seven systems. Study of Galena, Zircon, Beryl, Barytes, Gypsum and Axinite classes of symmetry.

Chemical bonding and compound formation. Mineral composition of the earth's crust, chemistry of minerals (Polymorphism, Isomorphism and Pseudomorphism). Various physical properties of minerals. Properties dependent on magnetism, electricity and radioactivity. Silicate structures.

Unit-II

Rock forming minerals- silicates, oxides and sulphides. Chemical and physical properties and geological occurrence of the following rock forming mineral groups:

Quartz, feldspars, feldspathoids, zeolites, pyroxenes, amphiboles, micas, olivine, garnet, aluminous silicates.

Petrological microscope: its parts and functioning. Elementary mineral optics. Critical angle, refractive index, twinkling, birefringence, pleochroism, interference colours, extinction and extinction

angle, twinning, isotrophism and anisotrophism. Phenomenon of double refraction and Nicol prism. Optical characters of common rock forming minerals.

Unit-III

Classification of rocks. Rock cycle.

Igneous Rocks: Forms, textures and structures of igneous rocks. Classification of igneous rocks. Rock associations in time and space. Concept of rock series. Mineralogical characteristics of acid, alkaline, basic and ultrabasic igneous rocks.

Magma: Definition, composition and origin. Bowen's reaction series. Magmatic differentiation and assimilation. Phase rule and phase equilibria : Concept of system, phase and component. Chemical potential and phase rule. Basic principles of Phase equilibria in uni and bi component silicate systems. Phase equilibria and their applications in petrology.

Unit-IV

Sediments-Weathering, transportation, deposition, consolidation, lithification and diagenesis. Sedimentary fabrics and textures. Primary features and mineralogy of sedimentary rocks. Classification of sedimentary rocks. Residual, clastic, chemical and organic sedimentary deposits. Aeolian, glacial, fluvial, lacustrine, near shore and deep-sea environmental deposits. Concept of sedimentary facies.

Agents, kinds and products of metamorphism. Textures, structures and classification of metamorphic rocks. Basic concepts about grade, zones and facies of metamorphism. Reactions in metamorphic processes. Metamorphism of pelitic, acidic, basic and calcareous rocks. Metasomatism, granitisation and migmatitisation. Suitable Indian examples.

PRACTICALS:

Study of elements of symmetry and description of various forms of crystals from normal classes of seven crystal systems.

Study of physical properties in hand specimen of common rock forming minerals. Study of the optical characters of common rock forming minerals using polarising microscope.

Megascope and microscopic study of common igneous, sedimentary and metamorphic rocks.

Books Recommended:

Crystallography and Mineralogy:

- 1) H.F. Read : Rutley's Elements of Mineralogy
- 2) Berry, L.G., Mason, Brian and Dietrich, R.V. (1985) Mineralogy. CBS Publishers
- 3) Dana, E.S. and Ford, W.E. (1949) A Text Book of Mineralogy. Wiley Eastern Ltd.
- 4) Deer, W.A., Howie, R.A. and Zussman J. (1992): An Introduction to the Rock-Forming Minerals, Longman Scientific and Technical
- 5) Smith : Minerals and Microscopes
- 6) Roger and Kerr : Optical Mineralogy

Petrology:

- 1) Tyrell, G.W. (1998) Principles of Petrology B.I. Publications Pvt. Ltd., New Delhi
- 2) Hatch, F.H., Wells, A.K. and Wells, M.K. (1984) Petrology of Igneous Rocks. CBS Publishers, New Delhi.
- 3) Hall, A. (1987) Igneous Petrology. Longman ELBS.
- 4) Nockolds, S.R., Knox, R.W.O.B., Chinner, G.A. (1978) Petrology for Students. Cambridge University Press, London.
- 5) Turner, F.J. and Verhoogen, J. (1987) Igneous and Metamorphic Petrology. CBS.
- 6) Philipotts, A. (1992) Igneous and Metamorphic Petrology. Prentice Hall.
- 7) Ehlers, E.G. and Blatt, H. (1981) Petrology: Igneous, Sedimentary and Metamorphic. CBS Publishers, New Delhi.
- 8) Pettijohn, F.J. (1957) Sedimentary Rocks. Oxford and IBH Pub. Co., New Delhi.
- 9) Tucker, M.E. (1988) Sedimentary Petrology : An Introduction. ELBS.
- 10) Gokhale, N.W. (1998) Fundamentals of Sedimentary Rocks. CBS Publishers.
- 11) Collinson, J.D. and Thompson, D.B. (1994) Sedimentary Structures. CBS Pub.
- 12) Yardley, B.W.D. (1989) An Introduction to Metamorphic Petrology. Longman ELBS.
- 13) Turner, F.J. (1980) Metamorphic Petrology. McGraw Hill, New York.
- 14) Moorhouse, W.W. (1985) The study of Rocks in Thin Sections. CBS Publishers.
- 15) Williams, H., Turner, F.J. and Gilbert, C.M. (1985) Petrography: An Introduction to the Study of Rocks in Thin Sections. CBS Publishers.

Geological Field Work:

Students will be required to carry out field work of a short duration in an area of geological interest to study the elementary aspects of field Geology (study of topographic features, reading topographical maps, use of compass clinometer, marking location on the toposheet) and submit a report thereon.

Books Recommended:

- 1) Mathur, S.M. (2001) Guide to Field Geology, Prentice-Hall, New Delhi
- 2) Compton, R.R. (1962) Manual of Field Geology. John Wiley and Sons, Inc.
- 3) Lahi, F.H. (1987) Field Geology, CBS Publishers
- 4) Gokhale, N.W. (2001) A Guide to Field Geology. CBS Publishers

Paper-III (Inorganic Chemistry)

Unit-I

Chemical Bonding:

Covalent Bond-Valence theory and its limitations, directional characteristic of covalent bond, various types of hybridization and shapes of simple inorganic molecules and ions. MO theory, homonuclear (He, N₂ and O₂) and heteronuclear (CO and NO) diatomic molecules. Valence shell electron pair repulsion (VSEPR) theory of NH₃, SF₄, ClF₃, ICl₂ and H₂O. bond strength and bond energy, percentage ionic character from dipole moment and electro negativity difference.

Ionic Bonds - Definitions, Energetic of ionic bond formation and Born Haber's cycle. Factors affecting ionic bond formation.

Hydrogen bonding, Van-der-Waals forces, Metallic bond and its free electron concept.

Unit -II

Elements

s-Block Elements: Comparative study, diagonal relationship, salient features of hydrides, solvation and complexation tendencies including their functions in biosystems.

p - Block Elements: Comparative Study (including diagonal relationship) of groups 13-17 elements, compounds like hydrides oxides of groups 13-16. Interhalogen compounds and its types.

d and f-Block Elements: General comparison of 3d, 4d and 5d elements in term of electronic configuration, elemental forms, metallic nature, atomization energy, oxidation states, redox properties, coordination chemistry, spectral and magnetic properties. f-block elements: electronic configuration, ionization energies, oxidation states, variation in atomic and ionic (3+) radii, magnetic and spectral properties of lanthanides, comparison between lanthanide and actinides, separation of lanthanides (by ion-exchange method).

Unit-III

Coordination Chemistry

Werner's theory, application of werner's theory, Coordination no., EAN rule, Nomenclature of complexes (IUPAC), Isomerism and stereochemistry in Coordination compounds. Factors affecting stability of complexes, chelation, theories of chemical bonding for complexes with special reference to valance bond and crystal field theory.

Unit-IV

Nuclear Chemistry

Nuclear stability and nuclear binding energy. Nuclear forces: meson exchange theory. Nuclear models (elementary idea): Concept of nuclear quantum number, magic numbers. Nuclear Reactions: Artificial radioactivity, transmutation of elements, fission, fusion and spallation. Nuclear energy and power generation. Separation and uses of isotopes. Radio chemical methods: principles of determination of age of rocks and minerals, radio carbon dating, hazards of radiation and safety measures.

PRACTICALS

1. Qualitative inorganic analysis; To determine two acidic, one interfering and two basic radicals from the given inorganic mixture.
2. Inorganic preparations ;
 1. To prepare Nickel- DMG complex.
 2. To prepare tetrammine copper (II) Sulphate dihydrate.
 3. To prepare potassium trioxalato ferrate (III) complex.
 4. To prepare hexammine nickel (II) chloride.

Paper-IV (Zoology)

Unit-I

Introduction to Animal Kingdom:

Non-Chordates: General characters and classification up to the classes with examples showing distinctive features of Protozoans (locomotion), Poriferans (Skeleton- spicules and spongin), Coelenterates (Polymorphism), Platyhelminthes and Nematodes (Parasitic adaptations), Annelids (Metamerism), Arthropods (Mouth parts), Molluscs (Modification of foot), Echinoderms (Water vascular system), Hemichordates (Phylogeny).

Unit-II

Chordates: General characters of Protochordates (Urochordates, Cephalochordates), Cyclostomes , Fishes (General Characters, accessory respiratory organs, migration, electric organs), Amphibians (General characters ,parental care), Reptilians (General characters, poisonous and non poisonous snakes in India, biting mechanism of snake), Aves (General characters, migration, flight muscles and mechanism and types of flight), Mammals (General characters, structural peculiarities and distribution of prototheria and metatheria, Brief outline of evolution of man).

Unit-III

Cell Biology and Genetics: Pro and eukaryotic cell, Animal and plant cell, Structure and functions of plasma membrane, golgi complex, endoplasmic reticulum, ribosomes, mitochondrion, chromosomes and nucleus lysosomes and cytoskeleton. Cell reproduction: Cell division – Mitosis and Meiosis. Concept of Gene, Structure of DNA and RNA, Pro and eukaryote gene structure, Genetic code, Genotypic sex determination, Human genetics, Genetic counselling, Gene therapy. DNA fingerprinting, Mutation, Brief outline of protein synthesis.

Unit-IV:

Environmental Biology: Basic components. Atmosphere: Major zones and importance. Ecosystem: structure, functions and types of ecosystems, food chain, food web, ecological pyramids and energy flow and biogeochemical cycles, Biodiversity: Definition, significance and conservation of biodiversity, Present status of biodiversity in India, Brief introduction to National Parks and Sanctuaries. Sources, types, effects and control measures of air, water, noise pesticide and thermal

pollution, Global warming, Green house effect, Ozone depletion, eutrophication, Toxic effects of heavy metals lead, cadmium and mercury, Bioaccumulation and biotransformation.

PRACTICALS:

1. Study of museum specimens (Identification and classification of animals upto orders)

Non-Chordates:

- a. **Protozoa:** Paramecium, Plasmodium *vivax*
- b. **Porifera:** Sycon, Leucosolenia
- c. **Coelenterata:** Obelia, Aurelia, Adamsia
- d. **Platyhelminthes:** Planaria, Fasciola, Taenia
- e. **Aschelminthes:** Ascaris, Ancylostoma, Wuchereria
- f. **Annelida:** Nereis, Leech, Pheretima
- g. **Arthropoda:** Cockroach, Prawn, Dragonfly
- h. **Mollusca:** Pila, Chiton, Octopus
- i. **Echinodermata:** Asterias, Antedon, Echinus
- j. **Hemichordata:** Balanoglossus

Chordates:

- a. **Urochordata:** Herdmania
- b. **Cephalochordata:** Amphioxus
- c. **Cyclostomata:** Petromyzon, Myxine
- d. **Pisces:** Claries, Catla, Rohu, Mrigal
- e. **Amphibia:** Bufo, Ichthyophis
- f. **Reptilia:** Varanus, Chameleon, Cobra
- g. **Aves:** Woodpecker, Pigeon, Parrot
- h. **Mammals:** Squirrel, Bat, Rabbit

2. Study of permanent slides:

Non-Chordates:- Entamoeba, Plasmodium, Paramecium, Sponge spicules, T.S. of Sycon, Obelia medusa, Miracidium & Cercaria larva of Fasciola, T.S. of male and female Ascaris, Glochidium larva, T.S. of arm of Starfish, Bipinnaria and Auricularia larva, Trochophore and Tornaria larva, T.S. of Balanoglossus through collar and proboscis.

Chordates:-T.S. of Amphioxus-through pharynx, intestine, gonad and caudal region, V.S. skin of Frog and Mammal.

3. Dissection:

Non- Chordate:- Cockroach- Digestive system, Reproductive system

Chordate:- Locally available Fish- Digestive system, Reproductive system

4. Mounting/ permanent stained micro preparation:

Non Chordates:- Available invertebrate material

Chordates:- Fish scales- Placoid, Cycloid, Ctenoid

Study of Skeleton of Fowl (loose bones of skull not to be studied)

5. Cytology/ Genetics experiments:

- a. Study of polytene chromosome in chironomous larva.
- b. Study of human barr body.
- c. Preparation of various stages of mitosis in Onion root tip.

- d. Study of the genetic traits (Hardy – Weinberg's law) in human being (Tongue rolling, earlobe, PTC taster/ non taster).

6. Environmental Biology:

- a. Estimation of DO in water.
- b. Estimation of CO₂ in water.
- c. Detection of p^H of the nearby water body.
- d. Study of pond ecosystem.
- e. Identification of zooplankton.

Recommended books:

1. Kotpal, Agrawal and Khetarpal – Modern Text Book of Zoology (Invertebrates).
2. Nigam – Biology of Non Chordates.
3. Kotpal, Agrawal and Khetarpal – Modern Text Book of Zoology (Vertebrates).
4. Nigam – Biology of Chordates.
5. De Roberties – Cell Biology
6. C.B.Powar – Cell Biology
7. Gardner - Genetics
8. Verma and Agrawal- Cell Biology, Genetics, Molecular Biology, Evolution and Ecology
9. Asthana D.K.- Environmental Problem and Solution.
10. Sharma- Ecology and Environmental Biology
11. Verma and Agrawal- Vertebrate- Practical Manual
12. Verma and Agrawal – Invertebrate- Practical Manual

**Paper-I
(Environmental Science)**

Unit-I

Definition, Scope and importance of environmental Science. Man and Environmental Relation, components of environment, definitions and their inter dependence. Environment and Ecology: Ecology definition, concept of ecosystem and types, Forest, water, agroecosystem etc and their structure and functions. Concept of environmental education- formal and non formal. Environmental organizations and agencies- National and International. Natural resources: Renewable and non renewable resources. Natural resources and associated problems: Forest, water, mineral, food, energy and land. Biodiversity: Definition, importance and types. Threats to biodiversity and its conservation.

Unit-II

Environmental Pollution: Definition, the climate, present, past and future projections. Air Pollution: Causes- types of air pollutants and their sources (Industrial, Vehicular, Agriculture, Pollen etc), their effects- climate change. Effects on crops (Temperature, increased CO₂, Ozone, UV and other radiation). Air Pollution and its effect on agro-ecosystems productivity and implications, plants response to air pollutants. Global warming- causes, scales and characteristics, sea level rise, role of plants in pollution prevention and mitigation. Water Pollution: causes- types of water pollutants and their sources (point sources- industries and domestic effluents, non-point sources agricultural ecosystem). Effects on ground/surface waters, eutrophication of lakes and ponds, fauna and flora and health. Marine pollution. Impact of polluted water on crops and soil (physical, chemical and biological properties). Methods of control of water pollution. Soil Pollution: Causes, types of soil pollutants, role of fertilizers, pesticides, solid wastes, heavy metals, organics and irrigation management. Effects on soil health, productivity and quality of produce. Measures to control soil pollution- using bio-remediation including phyto-remediation. Management of solid waste: composting, rapid composting, enrichment, concept 3 R's (Reduce, Recycle and Reuse). Pesticide pollution- air, water and soil and its impact on crops. An introduction to thermal, nuclear and noise pollution- causes effects and control.

Unit-III

Disaster Management: Floods, earthquakes, cyclones and landslides. Social issues and environmental legislations. Sustainable development. Resettlement and rehabilitation of people: Its problems and concerns. Wasteland reclamation, consumerism and waste products. Environmental protection acts on Air, Water, Wildlife protection, Forest conservation (Prevention and Control of Pollution related acts). Issues involved in enforcement of environmental legislations, public awareness, environmental impact assessment and management plan. Human population and the environment: Environment and human health, human rights, value education.

Unit-IV

Environmental Impact Assessment: Definition, Basic Concepts and Principles of EIA. Nexus between Development and Environment, Need for EIA, Elements of EIA, Environmental Attributes, Nature of Impacts- Primary, Secondary, Tertiary, Short Term, Long Term, Reversible and Irreversible Impacts. Overview of Impacts, Directly and Indirectly Measurable Impacts of Air, Noise, Water, Land, Biological and Socio-Economic Elements. EIA Procedure: Screening and Scoping in EIA, Methodologies of EIA, Checklist, Matrices, Overlays, Cost Benefit Analysis, Computer Aided EIA, Role of Statutory Agencies in EIA Clearance. Environmental Protection Acts: The Air Act, The Water Act, The Wildlife Protection Act, Forest Conservation Act, Environmental Management Act and Bio-safety Acts etc. Role of I.T In environment management. Introduction to Environmental Audit.

PRACTICALS:

1. Determination of pH & EC of polluted and non polluted samples(water and sewage)
2. Determination of Dissolved Oxygen in polluted samples
3. Determination of COD and BOD of polluted samples
4. Determination of Total Dissolved Solids in effluent samples
5. Analysis of Temporary and Permanent Hardness of water samples
6. Determination of Phosphates and Sulphates in polluted water
7. Determination of Fluorides and Chlorides in polluted water
8. Estimation of Particulate matter/Dust in Air
9. Determination of Noise pollution using Sound Level Meter
10. Pesticide residue analysis- soil/grain/water/air

Paper-II (Indian Stratigraphy and Palaeontology)

Unit-I

Geological time scale. Methods of collecting stratigraphic data. Principles of stratigraphy. Stratigraphic classification: Lithostratigraphic, chronostratigraphic and biostratigraphic units. Stratigraphic correlation. Physical and structural subdivisions of Indian subcontinent and their characteristics. Classification, geographic distribution, lithological characteristics, fossil content and economic importance of the following:

Archaean Supergroup of Peninsular India, Dharwar Supergroup and associated granitic rocks, Sausar Group, Sakoli Group, Dongargarh Supergroup, Aravalli Supergroup and associated gneissic rocks, Iron Ore Group. Cuddapah Supergroup of Cuddapah basin, Kaladgis, Pakhals, Penganga Formation, Delhi Supergroup, Shimla Formation. Vindhyan Supergroup of Vindhyan basin, Kurnool Supergroup, Chattisgarh Supergroup.

Unit-II

Classification, geographic distribution, lithological characteristics, fossil content and economic importance of the following:

Palaeozoic succession of Spiti valley. Gondwana Supergroup. Triassic of Spiti. Jurassic of Kutch, Rajasthan and Spiti. Cretaceous of Narmada valley, Trichinopoly, Spiti, and Lameta Formation. Deccan traps. Tertiary of Assam and Western India. Siwalik Group. Karewa Formation of Kashmir. Stratigraphy of Maharashtra.

Unit-III

Definition and scope of palaeontology. Processes of fossilization. Preservation potential of organisms. Elementary ideas about origin of life, evolution and fossil record. Ontogeny and variation in fossil assemblages. Methods of description and illustration, taxonomic categories and codes of systematic nomenclature. Applications of palaeontological data in economic geology, palaeoecology, evolution, stratigraphy, paleogeographic and palaeoclimatic reconstructions. Basic ideas about micro-palaeontology and microfossils.

Classification, diagnostic morphological characters, environment and geological distribution of Brachiopoda, Mollusca (bivalvia, gastropoda and cephalopoda)

Unit-IV

Classification, diagnostic morphological characters, environment and geological distribution of Foraminifera, Graptoloidea, Anthozoa, Echinodermata (Echinoidea and Crinoidea), Trilobita and Plants of Gondwana period.

PRACTICALS:

Palaeontology:

Morphological characters, identification, age and sketches of the following fossils:

Nummulite, Rhynchonella, Terebratula, Productus, Spirifer, Pecten, Ostrea, Trigonina, Cerithium, Conus, Turritella, Physa, Ceratites, Orthoceras, Nautilus, Belemnites, Monograptus, Cidaris, Hemiaster, Paradoxide, Calymene, Zaphrentis, Cyathophyllum, Calceola.

Alethopteris, Lepidodendron, Calamites, Glossopteris, Gangamopteris, Vertebraria, Cordiales, Ptilophyllum.

Books Recommended:

Indian Stratigraphy:

- 1) Ravindra Kumar (1985) Fundamentals of Historical Geology and Stratigraphy of India. Wiley Eastern Ltd., New Delhi.
- 2) M.S. Krishnan (1982) Geology of India and Burma. CBS Publishers.
- 3) D.N. Wadia (1998) Geology of India. Tata McGraw Hill, India.
- 4) G.G. Deshpande (1998) Geology of Maharashtra. Geological Society of India, Bangalore.

Palaeontology:

- 1) Clarkson, E.N.K. (1986) Invertebrate Palaeontology and Evolution. ELBS Allen and Unwin, London.
- 2) Swinnerton, H.H. (1973) Fossils. William Collins Son's and Co. Ltd.
- 3) Shrock, R.R. & Twenhofel, W.H. (1999) Principles of Palaeontology. CBS Publishers.
- 4) Woods, Henry (1985) Invertebrate Palaeontology. CBS Publishers.

- 5) Moore, R.C., Lalicker, C.G. and Fisher, A.G. (1997) Invertebrate Fossils. CBS Publishers
- 6) Stearn, W.C. and Carroll, R.L. (1989) Palaeontology: The record of life. John Wiley and Sons Inc., New York.
- 7) Arnold, C.A. (1947) An Introduction to Palaeobotany. McGraw Hill, New York.
- 8) Black, R.M. (1970) The Elements of Invertebrate Palaeontology. Cambridge Uni. Press.
- 9) Koregave, M.A. (1998) Fundamentals of Invertebrate Palaeontology. Book World Enterprises, Mumbai.

Paper-III (Physical Chemistry)

Unit-I

Thermodynamics:

Thermodynamics systems and state functions. Work and thermal energy. 1st law of thermodynamics. Isothermal and adiabatic changes. Measurement of enthalpy (H). Relation between E and H. Temperature dependence of H. Reversibility and irreversibility. 2nd Law of thermodynamics. Absolute scale of temperature, Carnot cycle and entropy. Entropy as a state function, Entropy changes in Reversible and irreversible processes, Entropy as a function of V and T, Entropy as a function of P and T, Gibbs free energy, Gibb's Helmholtz's equation, Clausius – Clapeyron equation.

Unit-II

Chemical Kinetics and Catalysis:

Introduction of reaction rate in terms of extent of reaction; rate constants, order and molecularity of reactions. Reactions of zero order, first order, second order and fractional order. Pseudo first order reactions (example using acid catalyzed hydrolysis of methyl acetate). Determination of order of a reaction by half-life and differential method. Rate-determining and steady-state approximation – explanation with suitable examples. Opposing reactions, consecutive reactions and parallel reactions.

Arrhenius equation, concept of activation energy Catalysis : Definition, types, and characteristics of catalysis, homogeneous, heterogeneous catalysis - Enzyme catalysis and its application. Collision theory of uni-and bi-molecular reactions.

Unit-III

Electro – Chemistry

Specific and Equivalent conductance and their measurements, variation of Specific and Equivalent conductance with dilution, migration of ions, Kohlrausch's law and its applications. Determination of degree of dissociation of weak Electrolytes (Ostwald's dilution law). Ionic mobility's and their determination. Transport numbers and their determination (Hittroff and moving boundary methods). Reversible and irreversible cells, various kinds of reversible electrodes. Measurement of e.m.f. of cells. Buffer solutions. Theories of indicators. pH. of a solution and its determination by Buffer and indicators.

Unit-IV

Phase Equilibrium

Phase, Component, Degree of Freedom, Derivation of Phase rule, application of phase rule to one component system- water and sulphur systems, Two component systems- Ag-Pb, application of phase diagram of Ag-Pb system.

Solids State Chemistry: Types of solids, Amorphous, crystalline and difference between them, Miller Indices, Laws of crystallography - (i) Law of constancy of interfacial angles (ii) Law of rationality of indices (iii) Law of symmetry. Symmetry elements in crystals. X-ray diffraction by crystals. Derivation of Bragg equation. Crystal system, the properties of crystal. The Bragg methods of crystal analysis, X-ray analysis of sodium chloride. The powder methods of crystal analysis.

PRACTICALS:

1. To determine heat of solution potassium nitrate.
2. To determine heat of ionization of weak acid.
3. To determine refractive index of a given liquid by Abbe's refractometer.
4. To determine specific reaction rate of hydrolysis of methyl acetate by acid.
5. To determine specific reaction rate of hydrolysis of ethyl acetate by alkali.
6. To determine strength of the given acid (HCl or CH₃COOH) conductometrically.
7. To determine ionization constant of a weak acid conductometrically.
8. To determine strength of the given acid (HCl or CH₃COOH) potentiometrically
9. To determine ionization constant of a weak acid potentiometrically
10. To determine CST of phenol-water system

Paper IV (Physics)

Unit -I

Seismology and Internal structure of the earth: Elasticity theories, Elastic, inelastic and plastic behavior of materials, The stress and strain matrices, Shear strain, The elastic constants, Bulk modulus in terms of Young's modulus and Poisson's ratio, Shear modulus in terms of Young's modulus and Poisson's ratio. Seismic waves, Seismic body waves, Compressional waves, Transverse waves, Seismic surface waves, Rayleigh and Love waves, The dispersion of surface waves, Free oscillations of the Earth. The seismograph, Principle of the seismometer, Long-period, short-period and Broadband seismometers.

Unit- II

Diffraction grating, diffraction at parallel slits, intensity distribution, plane transmission grating, resolving power of grating, comparison with prism, Fabry-Perot etalon, reflection and glazed gratings. Concave grating, different mountings, Rowland and Eagle mounting, Double

refraction,.Electromagnetic theory of refraction in uniaxial crystals, double prism, optical rotation, rotation plane of polarization, origin of optical rotation in liquids and crystals.

Unit-III

Positive rays, properties, determination of e/m of positive rays (Thomson's mass spectrograph), Aston's mass spectrograph, Bainbridge mass spectrograph, applications of mass spectrography, Isotopes, applications, radioactivity, average life, half-life. Standard of activity. Techniques of age determination, uranium-lead dating, radioactive dating methods.

X-rays, production properties, continuous and characteristic x-rays, Mosley's law and its importance.

Unit-IV

Diffraction of x-rays, Bragg's law, Bragg's x-ray spectrometer.

Crystalline arrangement. Elements of symmetry, elementary ideas about 7 crystal systems, 14 Bravais lattices, 32 point groups, 230 space groups. Stereograms for 32 point groups.

Experimental methods of crystal structure determination. Laue method. Debye-Scherrer method, interpretation of powder photographs, analytical indexing, Ito's method.

PRACTICALS:

Any 10 (from the following list)

1. Study of bending of cantilever
2. Study of bending of beam
3. Study of torsion of a wire (static method)
4. Study of torsion of a wire (dynamic method)
5. Modulus of rigidity by Maxwell's needle.
6. Determination of Y and η by flat spiral spring
7. Surface tension by capillary rise
8. Surface tension by Quincke's method
9. Surface tension of a liquid by Jaeger Method
10. Study of viscosity of liquid
11. Determination of resolving power of a grating
12. Study of Wavelength of light using plane transmission grating
13. Verification of Brewster's law
14. Determination of unit cell of a cubic crystal from Debye-Scherrer powder photograph
15. Interpretation of Laue photograph
16. Construction of models for 14 Bravais lattices
17. Determination of refractive indices for ordinary and extraordinary rays
18. Study of seismometer

Books Recommended:

Text book Fundamentals of geophysics –(second edition) William Lowrie , Chapter III

Text book of Optics – N.Subramaniam and Brij Lal

Text books Basic nuclear physics and cosmic rays, B.N. Srivastava

Atomic and Nuclear Physics, N.Subramaniam and Brij Lal

Text book of X-ray crystallography by Cullity

Crystallography for solid state physicist, A.R.Verma and Srivastava

**Paper-I
(Information Technology)**

Unit-I

Introduction to computer: Historical perspectives, history, evolution, characteristics of computer evolution. Definition, characteristics, user, types and classification. Basic anatomy of computers: Block diagram. CPU: Functions of each unit. Memory: Primary, Cache, Flash. Bus: Organization. Number system: Binary, Octal, Decimal, Hexa Decimal, their conversions, Operations; Addition, subtraction. Data Representation: Using ASCII, BCD, EBCDIC.

Input/output peripherals: Tape, Floppy disk, hard disk, mouse, touch screen. Voice input, MICR, OCR, OMR, Barcode reader and Flatbed Scanner. Output Devices: VDU, Dot matrix, Laser and Inkjet Plotter.

Unit-II

Introduction to OS: Its functions and classification. DOS: Warm booting and cold booting. Types of commands, command format, directory, file management, disk management and general commands, path, filters, pipes, DOS editor, Batch files.

Windows OS: Introduction features. Modules: Program, File and Print Managers. Control Panels, icons, Switching between applications, Running MS DOS applications, help and recycle bin. Windows Accessories: Note pad, Paint and Calculators.

Unit-III

C-Language: Introduction, constant, variable and data types- operators and expressions. Input/ Output statements: Decision making and branching, looping, Arrays: User defined functions, structures and unions, Pointers: File managements; Dynamic memory allocation and linked lists. Preprocessors. Introduction to C++.

Unit-IV

Network: Introduction, Network terminology, topologies, types of networks and their characteristics, advantages and disadvantages, Network protocols, Architecture.

Intranet: introduction, characteristics and advantages, Specific applications of Intranet.

Internet: Addressing data transmission, internet access, Protocol.

World Wide Web: Web pages & HTML, web browsers, search engines.

Applications: sending and receiving E-mail, Managing E-mail addresses, Junk mail.

Paper-II

(Structural and Economic Geology)

Unit-I

Scope and aim of structural Geology. Concept of rock deformation: Types of forces, stress and strain. Methods of analysis of simple tectonic structures. Stereographic projections and its use in structural analysis. Compass clinometer and its parts, method of using instrument. Study of outcrops, identification of bedding, data measurement. Dip, strike, rake and plunge, their measurements. Outcrops and their relationship with topography. Overlap (Off lap and on lap). Erosional structures: Inlier and outlier, klippe and fenster, synclinal hill and anticlinal valley. Unconformities: kinds, geological significance and their recognition. Diapirs.

Unit-II

Structural elements- Planer and linear. Diastrophic and non diastrophic features. Folds: definition, style, orientation, morphology, geometric and genetic classifications, mechanics of folding. Effects of folding on outcrops. Faults: definition, geometric and genetic classification of faults. Effects of faulting on outcrops. Recognition of faults in the field. Joints: definition, geometric and genetic classification of joints. Foliation: descriptive terminology, kinds, origin and relation to major structures. Lineation: descriptive terminology, kinds, origin and relation to major structures. Map symbols for above structural features. Shear zones : types, geometry and kinematics of shear zone.

Unit-III

Definition of ore, ore minerals and gangue minerals, grade of ores and non-metallic minerals, assay value and tenor of ore. Broad outline of ideas regarding classification of mineral deposits, Bateman's classification. Principles and processes of formation of mineral deposits in detail: Magmatic concentration deposits, Pegmatitic deposits, Sublimation deposits, Contact metasomatic deposits, Hydrothermal Deposits (Cavity fillings and Replacements), Submarine exhalative volcanogenic deposits, Residual concentration deposits, Mechanical concentration deposits (Placers), Sedimentary deposits, Evaporites, Bacteriogenic deposits, Supergene sulphide enrichment deposits, Metamorphic and Metamorphosed deposits with suitable Indian examples.

Unit-IV

Mineralogy, uses, Geological occurrence, origin and geographical distribution in India of the mineral deposits of- Iron, Manganese, Chromium, Tungsten, Tin, Copper, Lead, Zinc, Gold, Aluminium, radioactive minerals. Fossil fuels: Lignite and Coal, Natural hydrocarbons (Oil and Natural Gas). Nonmetals related to refractory, fertilizer, cement, chemical and gemstone industry like- Asbestos, Barytes, Gypsum, Mica, Graphite, Talc, Magnesite, Kyanite, Sillimanite, Monazite, Pyrite, Diamond.

Brief account of the geological setting and the mineralization of the following:

Kolar gold fields, Singhbhum copper belt, Malanjkhand copper deposit, Lead-Zinc deposit of Zawar, Manganese belt of Maharashtra, Iron ore deposits of Bastar, Bauxite deposits of Maharashtra, Mica

deposits of Bihar and Andhra Pradesh, Gondwana Coal deposits, Neyvelli Lignite deposit, Gypsum deposit of Rajasthan, Beach placers of Kerala.

Books Recommended:

Structural Geology:

- 1) Billings, M.P. (1997) Structural Geology. Prentice-Hall of India Pvt. Ltd., New Delhi.
- 2) Hills, E.S. (1972) Outline of Structural Geology.
- 3) Hobbs, B.E., Means, W.D. and Williams, P.F. (1986) Outline of Structural Geology. John Willey and Sons Inc., New York.
- 4) Suppe, J. (1985) Principles of Structural Geology. Prentice-Hall, New Jersey.
- 5) Park, R.G. (1989) Foundations of Structural Geology. Blackie, New York.
- 6) Gokhale, N.W. (2001) Theory of Structural Geology. CBS Publishers.
- 7) Gokhale, N.W. (1991) A Manual of Problems of Structural Geology. CBS Publishers.
- 8) Mathur, S.M. (2001) Guide to Field Geology, Prentice-Hall, New Delhi.
- 9) Compton, R.R. (1962) Manual of Field Geology. John Wiley and Sons, Inc.
- 10) Lahi, F.H. (1987) Field Geology, CBS Publishers.
- 11) Gokhale, N.W. (2001) A Guide to Field Geology. CBS Publishers.
- 12) Butler, B.C.M. & Bell, J.D. (1988) Interpretation of Geological Maps, Longman Scientific and Technical, Harlow, Essex.
- 13) Phillips, F.C. (1971) The use of Stereographic Projection in Structural Geology, Edward Arnold, London.
- 14) Roberts, J.L. (1982) Introduction to Geological Maps and Structures, Pergamon, Oxford.
- 15) Ragan, D.M. (1973) Structural Geology: an Introduction to Geometrical Techniques (2nd edition), Wiley, New York.
- 16) Bolton, T. (1989) Geological Maps: Their Solution and Interpretation. Cambridge University Press.

Economic Geology:

- 1) Jensen, M.L. and Bateman, A.M. (1981) Economic Mineral Deposits. John Wiley and Sons, New York.
- 2) Sen, A.K. and Guha, P.K. (1993) A Handbook of Economic Geology. Dynamic Printers, Kolkata.
- 3) Banerjee, D.K. (1992) Mineral Resources of India. The World Press Pvt. Ltd., Kolkata
- 4) Sharma, N.L. and Ram, K.S.V. (1964) Introduction to India's Economic Minerals. Dhanbad Publishers.
- 5) Deb, S. (1980) Industrial Minerals and Rocks of India. Allied Publishers, New Delhi.
- 6) Krishnaswamy, S. (1979) India's Mineral Resources. Oxford and IBH Pub. Co., New Delhi.
- 7) Babu, T.M. (1994) Tin in India. Geological Society of India, Bangalore.
- 8) Babu, T.M. (1998) Diamonds in India. Geological Society of India, Bangalore.
- 9) Radhakrishnan, B.P. and Curtis, L.C. (1999) Gold in India. Geological Society of India, Bangalore.
- 10) Deshpande, G.G. (1998) Geology of Maharashtra. Geological Society of India, Bangalore.

Paper-III (Analytical Chemistry)

Unit-I

Statistical methods in chemical analysis

Introduction to chemical analysis: Scientific approach, wet analysis, destructive and non-destructive analysis; Macro and nano analysis; Classical and instrumental analysis.

Errors in chemical analysis: Accuracy and precision of measurements, determinate indeterminate, systematic and random errors in chemical analysis with examples, absolute and relative errors; source, effect and detection of systematic errors; distribution of random errors, normal error curve, standard deviations, standard deviation of calculated results- sum or difference, product or quotient, significant figures, rounding and expressing results of chemical computations.

Unit-II

Spectroscopy UV and IR

UV Spectra: Electronic transition ($\sigma\text{-}\sigma^*$, $n\text{-}\sigma^*$, $\pi\text{-}\pi^*$ and $n\text{-}\pi^*$), relative position of λ_{max} considering conjugative effect, steric effect, solvent effect, red shift (bathochromic shift), blue shift (hypsochromic shift), hyperchromic effect, hypochromic effect (typical examples).

IR Spectra: Modes of molecular vibrations, application of Hooke's law, characteristic stretching frequencies of O-H, N-H, C-H, C-D, C=C, C=N, C=O functions; factors effecting stretching frequencies (H-bonding, mass effect, electronic factors, bond multiplicity, ring size).

Unit-III

Flame emission Spectrometry: Instrumentation. Flame characteristics. Flame processes, Emission Spectra, Quantitative measurements, Interferences, Application.

Atomic absorption Spectrometry: Theory of atomic absorption spectrometry, Instrumentation, interferences.

Turbidimetry and Nephelometry: Theory, Instrumentation, Applications.

Potentiometry: Electrodes, electrode systems, Determination of cell EMF, Potentiometric titrations,

Conductometry: Principles, Instrumentation, Analytical applications.

Unit-IV

Water Analysis: Requirement of water and sources, Water Quality Standards, Physico Chemical parameters and Significance-odor, Temperature, turbidity, Hardness, Acidity, Alkalinity-Dissolved Oxygen-Organic Chemicals and BOD, COD. Principles for determination of BOD, COD, DO, TDS, in water samples. Detection and estimation of As, Hg, Cd, Pb, NH_4^+ , and F^- , NO_3^- , NO_2^- in water sample.

Chemistry of glass and ceramics.

PRACTICALS

1. **Spectroscopy;** 1. To verify Beers- Lambert's law of a given coloured solution
2. To determine concentration of KMnO_4 solution colorimetrically.
3. To determine composition of a Fe- SSA complex colorimetrically.
4. Interpretation of IR spectra.

- 2. Water analysis;** 1. To determine hardness of given water sample.
 2. To determine acidity of given water sample.
 3. To determine alkalinity of given water sample.
 4. To determine TDS of given water sample.
 5. To determine COD of given water sample.
 6. To determine BOD₅ of given water sample.
 7. To determine NO₃⁻ of given water sample.
 8. To determine NO₂⁻ of given water sample.

Paper IV (Mathematics)

Unit-I

Algebra

Some Special Types of Matrices and Elementary Operations. Adjoint and Inverse of a Square Matrix. Rank of a Matrix, Systems of Linear Equation, Eigen values and Eigen Vectors. Cayley Hamilton Theorem

Unit-II

Trigonometry

De-Moivre's Theorem, Applications of De-Moivre's Theorem. Functions of a Complex Variable, Summation of Series.

GEOMETRY: The Sphere, Cones, Cylinders.

VECTOR ANALYSIS: Vectors and Scalars, The Dot and Cross Product, Vector Differentiation Gradient, Divergence and Curl.

Unit-III

Laplace Transforms

The Laplace Transform, The Inverse Laplace Transform, Applications to Differential Equations, Applications to Integral and Difference Equations.

Unit-IV

Successive Differentiation

Higher Order Derivatives, Calculation of the nth Derivative, Some Standard Results.

Determination of the nth Derivative of Rational Functions. The nth Derivatives of the Products of the Powers of Sines and Cosines. Leibnitz's Theorem for the nth Derivative of the Product of Two Functions.

INDETERMINATE FORMS: Indeterminate Forms $0/0$, ∞/∞ , $0 \cdot \infty$, 0^0 , 1^0 , ∞^0

Books Recommended:

Algebra and Geometry: Romesh Kumar {Pradeep Publications, Jalandhar (India)},
 Analytical Solid Geometry: Shanti Narayan,
 Theory and Problems of Vector Analysis {SI (Metric) Edition}: Murray R. Spiegel,
 Laplace Transforms: Murray R. Spiegel,
 Differential Calculus: Shanti Narayan and P.K. Mittal (S.Chand)

Paper-I
Mineralogy and Crystallography

Unit-I

Isotropic and anisotropic substances; Reflection, refraction and refractive index; Relief, birefringence and Becke line effect; Optically uniaxial and biaxial minerals; Determination of optic sign of uniaxial and biaxial minerals; Interference figures; Pleochroism and determination of pleochroic scheme in minerals; X-ray crystallography and Bragg's equation; Application of X-ray diffraction spectrometry in mineral characterization; Application of following techniques in mineralogy: Differential Thermal Analysis (DTA), Thermogravimetric Analysis (TGA), Scanning Electron Microscope (SEM), Transmission Electron Microscope (TEM), Electron Probe Micro Analyser (EPMA); Application of thermal, magnetic and radioactive properties of minerals.

Unit-II

Principle of crystal structure; Bonding in minerals; Coordination and co-ordination numbers; Silicate structures and structural formula; Isomorphism and solid solution; Types of ionic substitution; Polymorphism and types of polymorphic transformations; Pseudomorphism; Conversions of oxide and element weight percentages; Calculation of mineral formulae.

A detailed study of following mineral groups with reference to their general formulae, classification, atomic structure, chemistry, experimental work and paragenesis:

Non-silicates: Carbonates- Calcite Group, Aragonite Group, Dolomite Group; Phosphates- Apatite, Monazite; Sulphates- Gypsum, Anhydrite, Barite, Alunite Group; Halides- Halite, Sylvite, Fluorite; Nitrates- Trona, Soda niter; Oxides and Hydroxides- Spinel Group, Hematite Group, Rutile Group, Bauxite Group, Periclase.

Unit -III

A detailed study of following mineral groups with reference to their general formulae, classification, atomic structure, chemistry, experimental work and paragenesis:

Silicates: Nesosilicates- Olivine Group, Garnet Group and Aluminosilicate Group; Sorosilicates- Epidote Group, Scapolite Group; Cyclosilicates- Beryl, Tourmaline; Inosilicates- Pyroxene Group, Amphibole Group; Phyllosilicate- Mica Group, Chlorite Group, Serpentine Group, Pyrophyllite, Talc; Tectosilicates- Quartz, Feldspars, Feldspathoides and Zeolite Group.

Unit-IV

Crystals, crystalline solids and their formation; Ordered patterns, nets and lattices; Symmetry in crystals; Axial ratio, indices, lettering and order of the crystallographic axes; Crystallographic notation (Weiss and Miller indices and convention in notation); Classification of crystals- introduction to 32 classes of symmetry; The crystal systems and symmetry types; Stereographic representation of

crystal symmetry and their uses; Imperfection of crystals and crystal defects; Twinning- causes, effects and genetic types.

PRACTICALS

Study of rock forming minerals in hand specimen and thin sections: Physical and optical properties of common rock forming minerals; Study of Becke line; Determination of refractive indices and birefringence; An-content of plagioclase; Pleochroism and Dichroism: pleochroic scheme of tourmaline, biotite, hornblende, actinolite, glaucophane, hypersthene, aegirine, andalusite and other silicate minerals; Use of Berek Compensator (and other Compensators), Quartz wedge and gypsum plate; Determination of length-fast and length-slow character of minerals; Study of Interference figures of uniaxial and biaxial minerals and determination of optic sign; Refractive Index determination by immersion method; Interpretation of X-ray diffractograms of common minerals and components of the bulk rocks; Stereographic projection of crystals.

Books Recommended:

Mineralogy and Mineral Optics:

- Batthey, M.H. (1981) Mineralogy for students 2nd Edn. Longmans.
- Berry, L.G. and Mason, B. and Dietrich, R.V. (1983) Mineralogy, 2nd Edn, Freeman.
- Bunn, C.W. (1961) Chemical Crystallography, Clarendon.
- Donald Bloss (1971) Crystallography and Crystal chemistry, Holt, Rinehart and Winston.
- Deer, W.A., Howie, R.A., and Zussman, J. (1992) An Introduction to the rock forming minerals, Longman.
- Hutchinson, C.S. (1974) Laboratory Handbook of Petrographic Techniques, John Wiley.
- Klein, C. and Hurlbut, Jr., C.S. (1993) Manual of Mineralogy, John Wiley.
- Kerr, P.F. (1977) Optical Mineralogy 4thEdn., McGraw-Hill
- Phillips, Wm, R. and Griffen, D.T. (1986) Optical Mineralogy, CBS Edition.
- Putnis, Andrew (1992) Introduction to Mineral Sciences, Cambridge University Press.
- Santosh, M. (1988) Fluid Inclusions, Geological Society of India, Bangalore.
- Spear, F.S. (1993) Mineralogical Phase Equilibria and Pressure -Temperature-Time Paths, Mineralogical Society of America Publication.
- Winchell, A.N. (1962) Elements of Optical Mineralogy, John Wiley.
- Slemmons, D.B. (1962). Determination of Volcanic and Plutonic Plagioclases using a three- or Four-Axis Universal Stage, Geological Society of America.
- Szymanski, A. (1988). Technical Mineralogy and Petrography, Elsevier.
- Hota, R.N. (2011) Practical Approach to Crystallography and Mineralogy, CBS Publisher and Distributors Pvt Ltd., New Delh.i

Paper II

Igneous Petrology

Unit-I

Introduction to rocks and magmas; Internal structure and thermal properties of the earth; The nature of magmas (temperature, viscosity and volatile component); Melting (partial melting, batch melting, dynamic melting) and generation of magmas; Movement and storage of magma (magma chambers and modes of emplacement); A window to the mantle of the earth and its heterogeneity (Study of mantle and crustal xenoliths, xenocrysts and glimmerites).

Unit-II

Introduction to phase petrology; Phase relations of silicates and silicate melts; Binary systems (Ab-An, Ge-Ac, Co-Es, An-Si, Ne-Ab, Ne-Si, Lu-Si and Fo-Si); Ternary systems (Ab-An-Si, Ab-Fy-Si, Fy-Ne-Si, An-Lc-Si); Diversity and evolution of magma; Generation of magmas vis-a-vis plate tectonics.

Unit-III

IUGS classification of igneous rocks; Weight norms and cation norms; Forms, textures and structures of igneous rocks; Petrography and interpretation of igneous textures in terms of rate of nucleation and crystal growth.

Unit-IV

Petrography and petrogenesis of major igneous rock clans with Indian examples and world famous localities: The basalt clan (MORB, OIB, CFB, spillites, komatiites); The anderites, boninites and related rocks. The trachyte-syenite clan; Granites and granitic rocks; The anorthosites and ultramafic rocks; Nephelinites and carbonatites; Lamprophyres, lamproites and kimberlites; The alkaline rocks. LIP's; Lunar basalts; Magmatism on other planets in solar system.

PRACTICALS

Megascopic and microscopic study of different igneous rocks; Calculation of CIPW and molecular norms; Modal analysis; Preparation and description of variation diagrams. Exercises related to various igneous processes such as crystal fractionation, partial melting and magma mixing.

Books Recommended:

- 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 Igneous Rocks*. Unwin Hyman.
- Faure, G. (2001) *Origin of Igneous Rocks*, Springer.
- Hall, A. (1996) *Igneous Petrology*, 2nd Edn., Longman.
- LeMaitre R.W. (2002) *Igneous Rocks: A Classification and Glossary of Terms*, Cambridge University Press.
- McBirney, A.R. (2006) *Igneous Petrology*, 3rd Edn., Jones & Bartlett.
- Middlemost, E.A.K. (1985) *Magmas and Magmatic Rocks*. Longman.

Parfitt, E. and Wilson, L. (2008) Fundamentals of Physical Volcanology. Wiley-Blackwell.

Phillipotts, A.R. (1994) Principles of Igneous and Metamorphic Petrology, Prentice Hall of India.

Sood, M.K. (1982) Modern Igneous Petrology, Wiley-Interscience Publ., New York.

Srivastava, R.K. and Chandra, R. (1995) Magmatism in Relation to Diverse Tectonic Settings, A.A. Balkema, Rotterdam.

Wilson, M. (1993) Igneous Petrogenesis, Chapman and Hall, London.

Winter, J.D. (2001) Introduction to Igneous and Metamorphic Petrology. Prentice-Hall.

Bell, Keith (Ed.) (1989) Carbonatites: Genesis and Evolution. Unwin Hyman, London

Bell, K., Kjarsgaard, B.A. and Simonetti, A. (1998) Carbonatites – Into the twenty-first Century, Journal of Petrology, Spl. Vol.39 (11 & 12)

Carmichael, J., Turner and Verhoogen (1974) Igneous Petrology, McGraw Hill.

Fitton, J.G. Upton, B.J.G. (Eds) (1987) Alkaline Igneous Rocks, Geological Society, London.

LeBas, M.J. (1977) Carbonatite-nephelinite Volcanis, Wiley.

Rock, N.M.S., (1991) Lamprophyres, Blackie, Glasgow

Perchuk, L.L. and Kushiro, I. (Eds.) (1991) Physical Chemistry of Magmas. Springer Verlag.

Gupta, Alok (1998) Igneous Rocks. Allied Publishers Limited.

Allegre, C.J. and Hart, S.R. (1979) Trace elements in Igneous Petrology, Elsevier

Hughes, C.J. (1982) Igneous Petrology, Elsevier

Hota, R.N. (2011) Practical Approach to Petrology, CBS Publisher and Distributors Pvt Ltd., New Delhi

Paper-III

Sedimentology

Unit-I

Liberation and flux of sediments; Rock Cycle; Texture of sedimentary rocks and their significance; Size analysis of sediments and determination of grain size parameters; Analysis of shape and roundness; Paleocurrent, heavy mineral and provenance studies; Processes of sediment transport; Fluid flow mechanics and formation of sedimentary bedforms; Sedimentary structures.

Unit-II

Classification and composition of conglomerate, sandstones, shale and carbonate rocks; Diagenesis - physical and chemical, processes and evidences of diagenesis in sandstones, mud rocks and carbonate rocks; Detailed study of siliceous, phosphatic and ferruginous rocks; Study of evaporites such as gypsum, anhydrite and halite; Dolomites, their petrographic characteristics and models of dolomitization.

Unit-III

Paleo-climate and paleoenvironment analysis; Implication of facies in environmental interpretation and basin analysis; Tectonics and sandstones composition; Study of economic mineral deposits in sedimentary rocks from India; Study of sedimentary basins of India: Precambrian- Proterozoic, Gondwana and post-Gondwana and Quaternary sedimentation.

Unit-IV

Field and laboratory techniques in sedimentology: Recording of sedimentary textures and structures, preparation of lithologs and thin section staining, cathodoluminescence, SEM studies etc; Application of trace element, rare earth element and stable isotope geochemistry to sedimentological problems with examples from India.

PRACTICALS

Detailed study of clastic and non-clastic rocks in hand specimens; Study of assemblages of sedimentary structures in context of their paleoenvironmental significance; Microscopic examination of important rock-types; Heavy mineral separation and their microscopic characters, graphic representation and interpretation; Grain-size analysis by sieving method; Plotting of size-distribution data as frequency and cumulative curves, computation of statistical parameters and interpretation.

Books Recommended:

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.
Hota, R.N. (2011) Practical Approach to Petrology, CBS Publisher and Distributors Pvt Ltd., New Delhi

Paper-IV

Paleontology and Applied Paleobiology

Unit-I

Types of fossils and taphonomy; Origin of life; Modern Concept of systematic of fossils; Biostratigraphy; Concept of species and type specimens; speciation and radiation; Types of growth; Brief morphology and evolutionary trends in Bivalves, Cephalopods, Brachiopods, Echinoids, and Trilobites; Ichnofossils, their modes of preservation and significance.

Unit-II

Vertebrate life through ages; Evolution and Extinction of dinosaurs, Indian dinosaurs; Mammalia-Origin and evolution of the mammals, mammalian characters; Siwalik mammals; Evolutionary changes in Equidae; Evolution of Homo; Major extinction and origination through ages.

Unit-III

Approach to paleobotany; Classification of fossil plants; Evolutionary trend in angiosperms plants; A brief idea about Indian pre-Gondwana; Gondwana and Paleogene flora; Application of paleobotany in assessing paleoclimate and paleoenvironment; Dendrochronology & its application; Introduction to important animal and plant microfossils.

Unit-IV

Concept of evolution and extinction; Micro and macro-evolution, evolutionary lineages and their application to biochronology; Phylogenetic analysis; Molecular biology and its application Distribution, migration and dispersal of organisms applied to paleobiogeography and plate-tectonics; Fossil record applied to sequence stratigraphy and depositional environment; Paleocological and paleoclimatological significance of fossils; Stable isotope studies in paleoclimatology; Applications of important mega and micro fossils in the exploration of coal and petroleum.

PRACTICALS

Study of modes of preservation of fossils; Study of the morphological characters of important invertebrate fossils belonging to Brachiopoda, Bivalvia, Gastropoda, Ammonoidea, Trilobita, Echinoidea and Corals; Study of some important vertebrate fossils; Study of important trace fossils and microfossils; Study of important Indian Gondwana and Paleogene flora; Shell petrography of bivalves and brachiopods; Measurements of dimensional parameters and preparation of elementary bivariate growth curves and scatter plots; Paleogeographic maps.

Books Recommended:

General Paleontology

- Boardman, R.S., Cheethan, A.M. and Rowell, A.J. (1988) Fossil Invertebrates, Blackwell.
Clarksons, E.N.K. (1998) Invertebrate Paleontology and Evolution, Allen and Unwin, London.
Dobzhansky, Ayala, Stebbins and Valentine (1977) Evolution, Freeman.
Horowitz, A.S. and Potter, E.D. (1971) Introductory Petrography of Fossils, Springer Verlag.
Mayr, E. (1971) Population, Species and Evolution, Harvard.
Prothero, D.R. (2004) Bringing Fossil to Life – An Introduction to Paleontology (2nd Ed.), McGraw Hill.
Raup, D.M. and Stanley, S.M. (1985) Principles of Paleontology, CBS Publishers, New Delhi.
Smith, A.B. (1994) Systematics and Fossil Record – Documenting Evolutionary Patterns, Blackwell.
Stearn, C.W. and Carroll, R.L. (1989) Paleontology – the record of life, John Wiley.

Applicative Paleobiology

- Allison, P.A. and Briggs, D.E.G. (1991) Taphonomy. Releasing the data locked in the fossils record, Plenum Press.
Dord, J.R. and Stanta, R.J. (1981) Palaeoecology concepts and applications, John Wiley and Sons.
Patnaik, R. (2003) Reconstruction of Upper Siwalik palaeoecology and palaeoclimatology using microfossil palaeocommunities, Palaeogeography, Palaeoclimatology, Palaeoecology, Vol. 197.
Bergland, B.E. (1986) Handbook of Holocene paleoecology & paleohydrology, John Wiley, New York.
Jones, T.P. and Rowe, T.P. (1999) Fossil Plants and Spores Modern Techniques, Geological Society of London.
Prothero, D.R. (2004) Bringing Fossil to Life – An Introduction to Paleontology (2nd Ed.), McGraw Hill.
Seaward, A.C. (1991) Plant fossils, Today's and Tomorrow, New Delhi.
Shipad N. Agashe (1995) Paleobotany, Oxford and IBH Publ., New Delhi.
Stewart, Wilson N. and Rothwell Gar W. (1993) Paleobotany and the Evolution of Plants, Cambridge University Press.
Dodd, J. Robert and Stanton, Robert. J. Jr. (2012) Paleoecology: Concepts and Applications. Second Edition (Reprint), Wiley India Pvt. Ltd., New Delhi

Paper-I
Metamorphic Petrology

Unit-I

Metamorphism: Nature and scope; Factors controlling metamorphism (T, P and fluids); Types of metamorphism: Regional, contact, dynamic, hydrothermal, impact, retrograde and ocean floor metamorphism; Transient geotherm, and pressure-temperature regimes; Protolith types and characteristic metamorphic minerals; metamorphic textures.

Unit-II

Metamorphic facies and sub-facies series; metamorphic zones; High grade metamorphism of granulite and eclogite; Metamorphic differentiation, metasomatism and granitization, anatexis and origin of migmatites, granites, charnokites, amphibolites in the light of experimental studies; Ultra high temperature and ultra high pressure (blue schist) metamorphism; Pressure – temperature – time paths and metamorphic terrains in relation to plate tectonics; Regional metamorphism and Paired metamorphic belts; Relationship of metamorphic rocks and associated mineral deposits; Tectonic controls of metamorphism.

Unit-III

Thermodynamic principles of metamorphic reactions, Mineralogical phase rule for closed and open systems; Gibb's free energy, entropy, enthalpy, activity and fugacity of metamorphic reactions (solid-solid and dehydration reactions); Clausius – Clapeyron equation; Isograds and reaction isograds; Role of fluids, Nucleation and growth in solids kinetics of metamorphic reactions, Arrhenius relations, diffusion and interface controlled reactions; Experimental studies on metamorphic reactions; Concepts of geothermometry and geobarometry; Metamorphic projections in positive and negative space; ACF, AKF and AFM diagrams; Schriener's rule and construction of petrogenetic grids.

Unit-IV

Regional Metamorphism of mafic, pelitic and impure calcareous rocks; Geothermometers and geobarometers; Relationship of metamorphic rocks and associated mineral deposits; Tectonic controls of metamorphism.

PRACTICALS

Study of metamorphic rocks of different metamorphic facies in hand specimens; Detailed study of textures in thin sections with reference to time relations between the phases of deformation and recrystallization of minerals; Calculation of ACF, AKF and AFM values from chemical and structural formulation of minerals and their graphical representation; Construction of petrogenetic grid; Estimation of pressure and temperature from important models of geothermobarometry.

Books Recommended:

Harker, Alfred (1964) Metamorphism, Methuen, London.

Turner, F.J. (1980) Metamorphic Petrology, McGraw Hill, New York.

Yardlley, B.W.D. (1989) An introduction to Metamorphic Petrology, Longman Scientific and Technical, New York.

- Philopotts, A.R. (1994) Principles of Igneous and Metamorphic Petrology, Prentice Hall.
- Bhaskar Rao, B. (1986) Metamorphic Petrology, IBH & Oxford.
- Kretz, R. (1994) Metamorphic Crystallization, John Wiley.
- Blatt, H. and Tracy, R.J. (1996) Petrology (Igneous, Sedimentary, Metamorphic), W.H. Freeman and Co., New York.
- 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.
- Spear, F.S. (1993) Mineralogical Phase Equilibria and pressure – temperature – time Paths, Mineralogical Society of America.
- Wood, B.J. and Fraser, D.G. (1976) Elementary Thermodynamics for Geologists, Oxford University Press, London.
- Stuwe, K. (2007) Geodynamics of the Lithosphere. Springer-Verlag.
- Spry, A. (1976) Metamorphic Textures, Pergamon Press.
- Winter, J.D. (2001) An introduction to Igneous and Metamorphic Petrology, Prentice Hall.
- Yardley, B.W.D., Mackenzie, W.S. and Guilford, C. (1995) Atlas of Metamorphic Rocks and their textures, Longman Scientific and Technical, England.

Paper-II

Structural Geology, Geodynamics and Tectonics

Unit-I

Theories of rock failure; Mechanical principles, properties of rocks and their controlling factors; Concept of stress and strain: Classes of stress; Stress ellipsoid; Mohr circle construction; Stress trajectory; Two-dimensional stress analyses; Stress-strain relationship; Strain parameters, Types of strain ellipses and ellipsoids and their properties; Theory of deformation in two and three dimensions; Strain Analysis: Graphical representations of strain (Flinn, Ramsay, and Nadai-Hossack plots), progressive deformation, significance of geological structures in relation to strain, methods of strain measurements in naturally deformed rocks.

Unit-II

Description of folds; Mechanisms of folding (buckling, bending and flow), fold development and distribution of strains in folds; Biot's law - strain within buckled layer, similar fold and shear fold, kink bands, chevron folds and conjugate fold; decollement; Cleavage, Lineation, Boudinage; Deformation of linear structures and planar structures by flexural slip folding and shear folding; Superimposed folding, Type 1, 2, 3 fold interference patterns; Geometric and genetic classification of folds, Ramasay's Classification of folds.

Concept of petrofabrics and symmetry; Types of fabric (planar and linear fabrics in deformed rocks), fabric element, and interpretation of fabric data on microscopic and megascopic scale; field and laboratory techniques, graphical treatment.

Unit -III

Stereographic projections of linear and planar structures, π and β diagrams; Geometrical analysis of simple and complex structures on macroscopic scale.

Thin-skinned deformation; Fractures and joints: Their classification, nomenclature, relationships and significance; Mechanism of rock fracturing; Development of cleavage, lineation, foliation and schistosity in rocks and their mechanism; Faults: Causes, mechanism and dynamics of faulting, strike-slip faults, normal faults, thrust faults and nappe; Unconformities and their significance; Shear Zones: Brittle and ductile shear zones, geometry and products of shear zones; Mylonites and cataclasites, their origin and significance.

Unit -IV

Structure of the earth (crust, mantle and core) , thermal structure of the earth; Concept of continental drift, supercontinents, sea-floor spreading, hot-spots and plumes, diapirs and salt-domes; Cratons and mobile belts; Plate tectonics- recent advances, pros and cons; Geology of plate boundaries, Wilson cycle, plate motions and driving forces; Precambrian tectonics; Phanerozoic plate tectonics; Evolution of Indian subcontinent, Ur to Rodinia to Gondwanaland; Evolution of the Himalayas and Indian Ocean; Seismotectonics and the earthquakes in India; Tectonics of the Indian plate.

PRACTICALS:

Structural Geology

Preparation and interpretation of geological maps and cross sections; Structure contour maps, isopach maps and other facies maps, balanced cross-section, their importance in unraveling the geological history; Structural problems concerning economic deposit based on orthographic and stereographic projections; Recording and plotting of the field data; Study of deformed structures in hand specimens; Strain estimation from the data collected from the field; Study of dip-isogons from the fold profiles; Analysis of stress using Mohr Circle construction.

Books Recommended:

- Ghosh, S.K. (1993) Structural Geology: Fundamental and Modern Developments. Pergamon Press.
- Hobbs, B.E., Means, W.D. and Williams, P.F. (1976) An outline of Structural Geology, John Wiley and Sons, New York.
- Ramsay, J.G. (1967) Folding and fracturing of rocks, McGraw Hill.
- Ramsay, J.G. and Huber, M.I. (1983) Techniques of Modern Structural Geology, Vol. I, Strain Analysis, Academic Press.
- Ramsay, J.G. and Huber, M.I. (1987) Techniques of Modern Structural Geology, Vol. II, Folds and Fractures, Academic Press.
- Ramsay, J.G. and Huber, M.I. (2000) Techniques of Modern Structural Geology, Vol. III (Application of continuum mechanics), Academic Press.
- Turner, F.J. and Weiss, L.E. (1963) Structural analysis of Metamorphic Tectonites, McGraw Hill.
- Marshak, S. and Mitra, G. (1988) Basic methods of Structural Geology, Prentice-Hall, New Jersey.

Geodynamics and Tectonics:

- Condie, K.C. (1989) Plate Tectonics and Crustal Evolution, 3rd Ed., Pergamon, Oxford Press.
- Kearey Phillips and Vine, F.J. (1996) Global Tectonics, Blackwell Science, Oxford.
- Windley, B.F. (1977) The Evolving Continents, John Wiley and Sons, New York.
- Moore, E and Twiss, R.J. (1995) Tectonics. Freeman.
- Keary, P., Klepeis, K.A. and Vine, F.J. (2012) Global Tectonics. Third Edition (Reprint), Wiley-Blackwell, Wiley India Pvt. Ltd.

Storetvedt, K.N. (1997) Our Evolving Planet: Earths History in New Perspective. Bergen (Norway), Alma Mater Forlag.

Summerfield, M.A. (2000) Geomorphology and Global Tectonics. Wiley.

Patwardhan, A.M. (1999) The Dynamic Earth System, Prentice-Hall, New Delhi

Gass, I.G. (1982) Understanding the Earth. Artemis Press (Pvt) Ltd. U.K.

Moore, Eldridge M. and Twiss, Robert J. (1995) Tectonics. Freeman and Company.

Valdiya, K.S. (1984) Aspects of Tectonics -Focus on south central Asia, Tata McGraw- Hill.

Valdiya, K.S. (1998) Dynamic Himalaya. Universities Press, Hyderabad.

Paper-III

Stratigraphy and Indian Geology

Unit-I

Approaches to measurement of geological time; Stratigraphic Principles and concept of Litho, Bio and Chrono Stratigraphy, brief idea about sequence, magneto- seismic- chemo- and event stratigraphy; Stratigraphic correlations; Approaches to paleogeography.

Precambrian geochronology; Precambrian chronostratigraphy of Aravalli craton, Dharwar craton, Eastern Ghats mobile belt, Bastar Craton, Southern Granulite belt and Singhbhum craton; Proterozoic stratigraphy of Cuddapah, Vindhyan, Godavari Supergroup and their equivalents; Precambrian/Cambrian boundary.

Unit-II

Igneous activities and paleogeography during the Palaeozoic era; Stratigraphy, facies, and fossil contents of the Palaeozoic formations of India; Permian/Triassic boundary.

Concept, classification, fauna, flora and age limits of Gondwana Supergroup and related paleogeography, paleoclimate, depositional characteristics and igneous activities.

Unit-III

Classification, depositional characteristics, fauna, and flora of Triassic, Jurassic and Cretaceous systems in major basins of India; Stratigraphy of Deccan Trap, Cretaceous/Tertiary boundary.

Unit-IV

Classification, depositional characteristics, fauna, and flora of the Palaeogene and Neogene systems and their equivalents in India; Epoch boundaries of the Cenozoic in India.

PRACTICALS:

Study of rocks in hand specimens from known Indian stratigraphic horizons; Exercises on stratigraphic classification and correlation, sequence, magneto and seismic stratigraphic interpretations; Study and understanding of plate-movements through important periods during Phanerozoic eon; Evolution of ocean systems during Phanerozoic.

Books Recommended:

Boggs, S. (2001) Principles of Sedimentology and Stratigraphy, Prentice Hall.

Danbar, C.O. and Rodgers, J. (1957) Principles of Stratigraphy, John Wiley and Sons.

Doyle, P. and Bennett.M.R. (1996) Unlocking the Stratigraphic Record, John Wiley and Sons.
Krishnan,M.S. (1982) Geology of India and Burma, C.B.S. Publ. and Distributors, Delhi.
Naqvi, S.M. and Rogers, J.J.W. (1987) Precambrian Geology of India, Oxford University Press.
Pascoe, E.H. (1968) A Manual of the Geology of India and Burma (Vols.I-IV), Govt. of India Press, Delhi.
Pomerol, C. (1982) The Cenozoic Era: Tertiary and Quaternary, Ellis Harwood Ltd., Halsted Press.
Schoch, Robert, M. (1989) Stratigraphy: Principles and Methods, Van Nostrand Reinhold, New York.
Ramakrishnan, M. and Vaidyanadhan, R. (2008) Geology of India, Vol.1, Geological Society of India, Bangalore.
Vaidyanadhan, R. and Ramakrishnan, M. (2008) Geology of India, Vol.2, Geological Society of India, Bangalore.

Paper-IV

Precambrian Geology, Geodesy and Mapping

Unit-I

Age and composition of Archaean crust; Precambrian belts and provinces; Crustal evolution through Precambrian – various models; Archaean cratons: Characteristics of Archaean terranes, high grade terranes and granite-greenstone belts; Precambrian orogeny: Periodicity of orogenesis, dating methods; History, evolution, tectonic frame work, distribution and chemistry of Precambrian mobile belts giving special emphasis to Indian terranes; Precambrian microplates in India; Brief description, evolution, tectonics, geochemistry and mineral resources of Precambrian Belts of India; Proterozoic basins of India: Evolution and tectonics.

Unit-II

Principles of surveying methods; Instrumental methods used in geological mapping and mineral surveys and their usefulness in different conditions; Types of mineral deposit surveys, instruments used- prismatic compass, Brunton compass, theodolite, and plane table with alidade; Method of survey, recording the readings and plotting the traverse, triangulation and establishment of horizontal control points.

Unit-III

Leveling and contouring : Instruments for leveling - hand level, Abney level, Dumpy level, automatic level; Methods of leveling- spot leveling, differential leveling, profile leveling and trigonometric leveling; Plane table survey with telescopic alidade and its use in detailed geological mapping; Astronomical observation of true N-S and latitude.

Fundamentals of mine surveys, surveys in open cast mines and underground mines; Geological mapping in open cast and underground mines.

Unit-IV

Objectives of Geological mapping, precision required in geological mapping; Topographic maps and base maps for geological mapping, topographic maps and their numbering by Survey of India; Types

of geological maps and sections; Geological symbols in maps; General principles of geological mapping; Mapping methods in sedimentary, igneous and metamorphic terrains.

Practical:

Mapping and General Geodesy:

Conducting the following surveys and plotting –

Compass traverse survey using Brunton Compass and Prismatic compass; Theodolite traverse survey and plane table traverse survey with telescopic alidade; Trigonometric surveys; Triangulation; Geological mapping by plane table and telescopic alidade; Profile leveling by Abney level and Dumpy level; Contouring by direct method and indirect method; Stadia survey using theodolite.

Books Recommended:

Precambrian Geology:

Passchier, C.W., Myers, J.S. and Kroner, A. (1990) Field Geology of High-Grade Gneiss Terrains, Springer-Verlag.

Ramakrishnan, M. and Vaidyanadhan, R. (2008) Geology of India, Vol.1, Geological Society of India, Bangalore.

Condie, K.C. (1981) Archaean Greenstone Belts, Developments in Precambrian Geology, 3, Elsevier.

Condie, K.C. (1989) Plate Tectonics and Crustal Evolution, 3rd Ed., Pergamon, Oxford Press.

Goodwin, A.M. (1991) Precambrian Geology: The dynamic evolution of continental crust, Academic Press.

Windley, B.F. (1984) The Evolving Continents, John Wiley and Sons, New York.

Valdiya, K.S. (2010) The making of India Geodynamic Evolution. Macmillan Publishers India Ltd.

Pichamuthu, C.S. (1985) Archaean Geology: An introduction to the early history of the earth, Oxford & IBH Publishing Co., New Delhi.

General Geodesy and Mapping:

Mathur, S.M. (2001) Guide to Field Geology, Prentice-Hall, New Delhi

Compton, R.R. (1962) Manual of Field Geology. John Wiley and Sons, Inc.

Lahi, F.H. (1987) Field Geology, CBS Publishers.

Hosmer, G.L. (1946) Geodesy. Wiley.

Bomford, B.G. (1971) Geodesy. Oxford.

Clark, D. (1962) Plane and Geodetic Surveying (Volume I and II) Asia Publishing House.

Forrester, J.D. (1957) Principles of Field Geology and Mining Geology. John Wiley.

Kanetkar, T.P. and Kulkarni, S.V. (1990) Surveying and Leveling (Vol.I and II). Pune Vidyarthi Griha Prakashan, Pune.

Kissam, P. (1956) Surveying Instruments and Methods for Survey of Limited Extent. McGraw Hill.

Paper-I
Geochemistry

Unit-I

Introduction to geochemistry; Basic principles of chemistry; Major, minor and trace elements and their representation on variation diagrams for presentation of geochemical data (bivariate, multivariate, element ratio variation, enrichment-depletion and vector diagrams); Use of major elements for classification and characterisation of igneous, metamorphic and sedimentary rocks.

Unit-II

Trace and REE, their normalisation and role in petrogenesis of major rock groups; Stable isotopes, their normalisation, fractionation and role in understanding various geological processes; Radiogenic isotopes and their use in geochronology and identification of crustal and mantle reservoirs.

Unit-III

Formation of universe and origin of elements; Cosmic abundance of elements; Primary differentiation and geochemical classification of elements; Geochemical composition of the Solar System, the Sun, Planets, Moon, Comets, Asteroids and meteorites; Geochemical composition of the earth and its constituent parts such as crust, mantle, core; Geochemistry of igneous, metamorphic and sedimentary rocks.

Unit-IV

The composition of atmosphere, biosphere and hydrosphere; The geochemical cycle; Primary and secondary dispersion of elements and their use in geochemical exploration for mineral deposits; Anomalies and various methods of geochemical surveys; Eh-pH diagrams, colloids and colloidal processes and methods of biogeochemical surveys; Primary concepts of Medical Geology; Trace elements and human health; Geological health hazards; Geopharmacy.

PRACTICALS:

Demonstration of sampling methods for geochemical analysis; Preparation of anomaly maps using chemical data; Calculation of important indices related to petrogenesis and weathering; Discriminant diagrams and interpretation of geochemical data; REE and trace elements plotting and interpretation; End member calculations from given EPMA data.

Books Recommended:

- Allegre, C.J. and Michard, G. (1974) Introduction to Geochemistry, Reidel, Holland
Mason, B. (1982) Principles of Geochemistry, Wiley Eastern.
Krauskopf, K.B. (1994) Introduction to Geochemistry, Mc Graw Hill.
Faure, G. (1991) Inorganic Geochemistry, Prentice Hall, 1991.
Mason, B. and Moore, C.B. (1991) Introduction to Geochemistry, Wiley Eastern.

- Faure, G. (1986) Principles of Isotope Geology. John Wiley.
- Hoefs, J. (1980) Stable Isotope Geochemistry. Springer Verlag.
- Marshall, C.P. and Fairbridge, R.W. (1999) Encyclopaedia of Geochemistry. Kluwer Academic.
- Govett, G.J.S. (Ed) (1983) Handbook of Exploration Geochemistry. Elsevier.
- Henderson, P. (1987) Inorganic Geochemistry, Pergamon Press.
- Krauskopf, K.B. and Bird, D.K. (1995) Introduction to Geochemistry, McGraw-Hill International Edn.
- Anderson, G.M. and Crerar, D.A. (1993) Thermodynamics in Geochemistry- the Equilibrium Model, Oxford Univ. Press, New York.
- Wood, B.J. and Fraser, D.G. (1977) Elementary thermodynamics for geologists. Oxford. Nordstrom, D.K. and Munoz, J.L. (1985) Geochemical Thermodynamics, The Benjamin Cummings Publishing Co., Inc.
- Fletcher, P. (1993) Chemical Thermodynamics for Earth Scientists, Longman Scientific and Technical, London.
- Glasstone, S. (1947) Thermodynamics for Chemists, East and West Publishers.
- Powell, R. (1978) Equilibrium Thermodynamics in Petrology, Harper and Row
- Yoder, H.S. (Ed.) (1979) The Evolution of the Igneous Rocks, Princeton University Press.

Paper-II

Instrumentation Techniques, Geostatistics and Computer Application in Geology

Unit-I

Thin section and polished section making; Sample etching, staining and model count techniques; Principle and geological application of Cathodoluminescence, Thermoluminescence, Spectrophotometry, Flame photometry, Atomic absorption spectrophotometry; Inductively coupled plasma – atomic emission spectrometry, optical emission spectrometry and mass spectrometry; X ray fluorescence spectrometry; Scanning and transmission electron microscopy; Instrumental Neutron Activation Analysis (INAA); Isotope dilution technique; Electron Probe Micro Analysis (EPMA), X ray diffractometry; Thermal Ionisation and gas source mass spectrometry.

Unit-II

Introduction to Probability: Random experiments, events, sample space, definition of probability; Conditional probability and independence of events; Baye's theorem; Random variables, discrete and continuous probability distributions, joint probability distributions, conditional probability distributions; Change of variables; Binomial, Poisson, Normal, Gamma, Exponential, Hypergeometric, Multinomial, Chi-square, t and F distributions; Mathematical expectation, moment generating and characteristic functions.

Unit-III

Introduction to statistical inference: sampling distributions, point and interval estimation, hypothesis testing involving one and two univariate populations; Linear models: ANOVA; Linear and multiple regression; Introduction to multivariate techniques; PCA, factor analysis, linear discriminant analysis, classification; Application of geostatistical techniques to Geochemistry, Hydrogeology, Environmental Geochemistry, Paleobiology and Mineral Exploration.

Unit-IV

Introduction to common operating systems; Use of computers and software as tools in the areas of geological problem-solving, report-writing, and presentations; Windows-based software applications, including word-processing, spreadsheets; Graphing, image manipulation and drawing; Brief idea about computer softwares used in earth sciences such as Archinfo, ArcGIS, Elvis, Mapinfo, Autocad, GCD-kit, Rockware, Rockworks, Igpct, Petrograf, Surfer, Aquachem, Statpack, Tilia, Past etc.

PRACTICALS:

Instrumentation Techniques:

Introduction to common analytical instrumental techniques as taught in theory; Rock analyses (rapid method of silicate analysis) and FeO determination by titration method; Determination of loss on ignition (LOI) of rock samples; Presentation of analytical data; Wet assay of Cu, Pb, Zn, Al, Cr, Fe, Mn, Ti, Na, K etc.

Geostatistics and Computer Applications in Geology:

Problems in calculating various statistical parameter for a given data; student test, chi-square test; least square method; Statistical models; Practical training in data analysis using different computer softwares available in the department.

Books Recommended:

Instrumentation Techniques:

Shapiro, L. and Brannock, W.W. (1975) Rapid analysis and silicates, Carbonate and phosphate rocks, USGS Bulletin, 1144 A.

Jeffrey, P.G. (1970) Chemical methods of rock analysis. Pergamon Press.

Perry, D.L. (1990) Instrumental Surface Analysis of Geologic Materials, VCH Pub. Inc., New York.

Hota, R.N. (2011) Geochemical Analysis, CBS Publisher and Distributors Pvt Ltd., New Delhi

Geostatistics/ Statistical Methods in Geology:

Pitman, J. (1993) Probability, Springer Verlag, (also Narosa Publishers).

Creighton, J.H.G. (1994) First course in probability models and statistical inference, Springer Verlag.

Davis, J.G. (1986) Statistics and data analysis in geology, John Wiley.

Walpole, R.E. and Myers, R.H. (1989) Probability and statistics for engineers and scientists, Macmillan Publ. Co.

Johnson, R.A. and Wichern, D.W. (1982) Applied multivariate statistical analysis, Prentice Hall Inc., New Jersey.

Cooley, W.W. and Lohnes, P.R. (1971) Multivariate data analysis, John Wiley and Pandalai, H.S. and Saraswati, P.K. (Eds.) (2000) Geological data analysis: Statistical Methods. Hindusthan Publishing Corporation (India), New Delhi.

Spiegel, M.R. (1982) Probability and Statistics, Schaums Outline Series, McGraw-Hill Int., Singapore, Asian Student Edn.

Kubackova, L., Kubacek, L. and Kukuca, J. (1987) Probability and Statistics in Geodesy and Geophysics, Elsevier.

Journel, A.G. and Huijbregts, Ch. (1978) Mining Geostatistics, Academic Press.

Armstrong, M. (1998) Basic linear geostatistics, Springer Verlag, Berlin.

Isaaks, E.A. and Srivastava, R.M. (1990) An Introduction to Geostatistics, Oxford University Press.

Journel, A.G. and Huijbregts, C. (1978) Mining Geostatistics, Academic Press, London.

Chiles, J.P. and Delfiner, P. (1999) Geostatistics: Modeling Spatial Uncertainty, John Wiley & Sons, New York.

Computer Applications in Geology:

No Textbook - only handouts and web pages

Paper-III

Ore Geology

Unit-I

Modern concept of ore genesis; spatial and temporal distribution of ore deposits -a global perspective; Comparison between Earth's evolutionary history and evolutionary trends in ore deposits; Ore deposits and Plate Tectonics; Mode of occurrence of ore bodies -morphology and relationship of host rocks; Detailed study of all principal ore mineral groups, their textures and structures; Paragenesis and zoning of ores and their significance.

Unit-II

Concept of ore bearing fluids, their origin and migration; Wall-rock alteration; Structural, physico-chemical and stratigraphic control of ore localization; Geochemical modeling of ore deposits; Chemical composition of ores and host rocks -bulk chemistry, trace elements, REE and isotopes (stable and radiogenic); Organic matter in ores and their significance; Geothermometry and geobarometry of ore assemblages; Fluid inclusion in ores: principles, assumptions, limitations and applications.

Unit-III

Petrological ore associations with Indian examples wherever feasible: Orthomagmatic ores of mafic-ultramafic association - diamonds in kimberlites, REE in carbonatites, Ti-V ores, chromite and PGE, Ni

ores, Cyprus type Cu-Zn deposit; Ores of silicic igneous rocks -Kiruna type Fe-P, pegmatoids, greisens, skarns, porphyry associations, Kuroko-type Zn-Pb-Cu.

Unit-IV

Ores of sedimentary affiliation - chemical and clastic sedimentation; Stratiform and stratabound ore deposits (Sedimentary BIF, manganese, non-ferrous ores); Placers and palaeoplacers; Ores of metamorphic affiliations - metamorphism of ores, metamorphogenic ores; Ores related to weathering and weathered surfaces - laterite, bauxite, Ni/Au laterite; Contemporary ore-forming systems (black smokers, mineralized crusts, Mn nodules).

PRACTICALS:

Study of physical properties and identification of ores, non-metallic minerals, industrial rocks and minerals, gemstones and semi-precious minerals in hand specimens.

Books Recommended:

- Edwards, R. and Atkinson, K. (1986) Ore Deposit Geology. Chapman and Hall, London.
- Craig, J.M. and Vaughan, D.J. (1981) Ore Petrography and Mineralogy. John Wiley
- Evans, A.M. (2012) Ore Geology and Industrial Minerals. Third Edition (Reprint), Blackwell Publishing and Wiley India Pvt. Ltd.
- Sawkins, F.J. (1984) Metal Deposits in relation to Plate Tectonics. Springer Verlag.
- Stanton, R.L. (1972) Ore Petrology. McGraw Hill.
- Torling, D.H. (1981) Economic Geology and Geotectonics. Blackwell Sci. Publ.
- Barnes, H.L (1979) Geochemistry of Hydrothermal Ore Deposits. John Wiley.
- Klemm, D.D. and Schneider, H.J. (1977) Time and Strata Bound Ore Deposits. Springer Verlag.
- Guilbert, J.M. and Park, Jr. C.F. (1986) The Geology of Ore Deposits. Freeman.
- Mookherjee, A. (2000) Ore genesis -a Holistic Approach. Allied Publishers.
- Wolf, K.H. (1981) Hand book of Strata Bound and Stratiform Ore Deposits. Elsevier.
- Jensen, M.L. and Bateman, A.M. (1981) Economic Mineral Deposits. John Wiley and Sons, New York.

Paper-IV

Mining Geology and Valuation of Mineral Property

Unit-I

Application of Geology in mining; Geological work at an operating mine; Guides in the location of ore deposits- physiographic, lithologic, stratigraphic, mineralogic and structural guides; Intersecting loci and ringed targets.

Unit-II

Underground exploration methods in mining; Location of extension of ore deposits and dislocated ore bodies; Persistence of ore in depth; Duties of mining geologist; Preparation of mine plans; Geotechnical investigations for mine planning; Geological report writing.

Unit-III

Types of mineral properties for valuation; Objectives of valuation; Stages of mineral exploration and need for valuation; Basic features in valuation of a mineral property; Examination of mineral property and the past records.

Importance of sampling in valuation theory of sampling, bias in sampling; Methods of sampling mineral deposits- types of samples and their collection during trenching, pitting and drilling; logging and storage; Methods of combining the assays of core and sludge samples; methods of collection, recording and presentation of sample data; Salting of samples and safeguards; Reduction of sample for testing; Types of grades of ore, sample weightage and calculation of average grades; Statistical methods in the estimation and use of range of grades, variance, standard deviation, skewness, standard error of mean; Basic concepts about the use of variogram and krigging; Geostatistics for overall grade estimation.

Unit-IV

Use of cut-off grade in outlining ore; Classification of ore reserves and mineral resources; Methods in estimation of ore reserves and limitations; Use of computers in ore reserve estimation; Value of ore based on recoverable value and smelter schedule; Costs in the production of ore- direct costs and indirect costs, depreciation cost and depletion cost; Alternate methods of amortization, pay back period, future costs and future profits, present value of future profits; life of the mine, deferment period and discount for hazards in mining, Hoskold formula; Net value of prospects; Developed mines and working mines; Estimation of profitability of a mineral prospect; Discounted cash flow return on investments; Valuation report.

PRACTICALS:

Preparation of mine plan; Sampling problems: Calculation of average assay value by using sampling data obtained by drilling and by sampling in underground mine workings; Calculation of ore reserves by various methods; Calculation of present value / net value of a prospect, developed mine (non producing) and a developed and producing mine.

Books Recommended:

Mining Geology and Valuation of Mineral Properties:

McKinstry, H.E. (1972) Mining Geology. Prentice-Hall Inc.

Arogyaswamy, R.N.P. (1995) Courses in Mining Geology. Oxford and IBH Publishing Co., New Delhi.

Thomas, L.J. (1978) An Introduction to Mining. Methuen, Brisbane.

Clark, G.B. (1967) Elements of Mining. Asia Publishing House.

Paper-I
Indian Mineral Deposits and Mineral Economics

Unit-I

Study of the following Indian ore deposits with reference to their mineralogy, mode of occurrence, origin, geological association and geographical distribution: Iron, manganese, gold, aluminium, chromium, copper, lead and zinc.

Unit-II

Study of the following Indian ore deposits with reference to their mineralogy, mode of occurrence, origin, geological association and geographical distribution: Tin, tungsten, titanium, nickel and molybdenum; Minerals used in metallurgical, refractory and abrasive industries.

Unit-III

Study of the following Indian mineral deposits with reference to their mineralogy, mode of occurrence, origin, geological association and geographical distribution: Minerals used in ceramics, cosmetic, glass, fertilizers, cement, chemical, paints and pigments, electrical and gemstone industries.

Unit -IV

Concept of mineral economics; Significance of minerals in National economy; Use of various minerals in industries; Production and its effect on prices of minerals; Demand and supply, their effect on prices; International aspects of mineral industries; Cartels and their influence on mineral industry; Mineral resources in India and their present status and future development; Strategic, critical and essential minerals; Conservation and substitution of minerals; Mines and mineral legislation in India, Mineral development fund; Law of sea bed for marine mineral resources; United Nations Framework Classification (UNFC); National Mineral Policy; Statistical modelling for the future requirements and production levels of minerals in India.

Books Recommended:

Indian Mineral Deposits:

- Banerjee, D.K. (1992) Mineral Resources of India, The World Press Pvt. Ltd., Kolkata
Sharma, N.L. and Ram, K.S.V. (1964) Introduction to India's Economic Minerals, Dhanbad Publishers.
Deb, S. (1980) Industrial Minerals and Rocks of India, Allied Publishers, New Delhi.
Krishnaswamy, S. (1979) India's Mineral Resources, Oxford and IBH, New Delhi.
Babu, T.M. (1994) Tin in India, Geological Society of India, Bangalore.
Babu, T.M. (1998) Diamonds in India, Geological Society of India, Bangalore.
Radhakrishnan, B.P. and Curtis, L.C. (1999) Gold in India, Geological Society of India, Bangalore.
Karanth, R.V. (2000) Gems and Gem Industry in India, Geological Society of India, Bangalore.

Mineral Economics:

Sinha, R.K. & Sharma, N.L. (1993) An Introduction to Mineral Economics, Wiley Eastern

Chatterjee, K.K. (1993) An Introduction to Mineral Economics, Wiley Eastern.

Paper-II

Mineral Exploration

Unit-I

Mineral Exploration – its significance, necessity and objectives; Methods in mineral exploration- objectives and limitations of different methods; Stages of mineral exploration; Geological methods of surface and subsurface exploration- evaluation of outcrop, panning, trenching, pitting, drilling etc; Brief idea about drilling methods used in mineral exploration; choice of drilling; Types of drill patterns and density of exploratory drilling; Exploratory mining methods; Methods in outlining the ore body; Geological modeling for mineral exploration with specific examples of Indian mineral deposits.

Unit-II

Fundamentals of geochemical prospecting; Geochemical environments, mobility and distribution in dispersion of elements in primary and secondary environments; Geochemical exploration practices in different environments glacial, desertic and tropical; Methods of geochemical exploration: lithochemical, pedochemical, biogeochemical, hydrogeochemical, atomogeochemical, geobotanical methods; Statistical analysis and interpretation of geochemical prospecting data; Designing exploration models for search of different type of mineral deposits.

Unit-III

Geophysical methods of prospecting of metallic and non-metallic mineral deposits.

Gravity method: Variation of gravity over the surface of the earth; Principle of gravimeters; Gravity field surveys; Various types of corrections applied to gravity data; Preparation of gravity anomaly maps and their interpretation in terms of shape size and depth of the causative body.

Magnetic method: Geomagnetic field of the earth; Magnetic properties of rocks; Working principle of magnetometers; Field surveys and data reductions; Preparation of magnetic anomaly maps and their quantitative interpretation; Magnetic anomalies due to single pole and dipole; Introduction to Aeromagnetic survey; Three dimensional current flow, potential due to a point current source.

Electrical methods: S.P. and I.P. method; Resistivity method: Basic principles, various types of electrode configurations; Field procedure: profiling and sounding; Application of electrical methods in ground water prospecting and civil engineering problems.

Unit-IV

Seismic methods: fundamental principles of wave propagation, refraction and reflection surveys for single interface, horizontal and dipping cases; Concept of seismic channel and multi-channel

recording of seismic data; End-on and split spread shooting techniques CDP method of data acquisition, sorting, gather, stacking and record section seismic velocity and interpretation of seismic data application in mineral and petroleum exploration.

Radioactivity methods: Alpha, beta, gamma radiation sources; Field equipment and procedures.

Description of borehole environment; Brief outline of various well-logging techniques: Principles of electrical logging and its application in petroleum, groundwater and mineral exploration.

PRACTICALS:

Diagrammatic representation of open cast and underground mining; Methods of mine survey; Preparation and interpretation of geochemical anomalies maps; Problems based on statistical analysis of data obtained in geochemical exploration.

Preparation of vertical sections and level plans of ore deposit from bore hole data; Preparation of grade maps of mineral deposits based on sampling data.

Study of gravimeter, magnetometer and seismographs; Resistivity survey; Interpretation of underground structure on the basis of seismic data.

Books Recommended:

McKinstry, H.E. (1972) Mining Geology. Prentice-Hall Inc.

Arogyaswamy, R.N.P. (1995) Courses in Mining Geology. Oxford and IBH Publishing Co., New Delhi.

Thomas, L.J. (1978) An Introduction to Mining. Methuen, Brisbane.

Clark, G.B. (1967) Elements of Mining. Asia Publishing House.

Bagchi, T.C., Sen Gupta, D.K. and Rao, S.V.L.N. (1979) Elements of Prospecting and Exploration. Kalyani Publishers, New Delhi.

Pacal, Z. (Ed.) (1977) Geochemical Prospecting Methods. Ustrendi.

Brooks, A.R. (1972) Geobotany and Biogeochemistry in Mineral Exploration- Harper and Row.

Rose, A.W., Hawkes, H.E. & Webb, J.A. (1979) Geochemistry in Mineral Exploration. Academic Press.

Hawkes, H.E. and Webb, J.S. (1980) Geochemistry in Mineral Exploration. Harper and Row.

Dobrin, M.B. (1976) Introduction to Geophysical Prospecting. McGraw Hill.

Howel, B.F. (1959) Introduction to Geophysical Prospecting. McGraw Hill.

Lowrie, W. (1997) Fundamentals of Geophysics. Cambridge University Press.

Mussett, A.E. & Khan, M.A. (2000) Looking into the Earth: An Introduction to Geological Geophysics. Cambridge University Press.

Sharma, P.V. (1986) Geophysical Methods in Geology. Elsevier.

Sharma, P.V. (1997) Environmental and Engineering Geophysics. Cambridge University Press.

Vogelsang, D. (1995) Environmental Geophysics -A Practical Guide. Springer Verlag.

Parasnis, D.S. (1975) Principles of Applied Geophysics. Chapman and Hall.

Stenislave, M. (1984) Introduction to Applied Geophysics. Reidel Publ.

Ramam, P.K. (1989) Principles and Practices of Mineral Exploration. Geological Society of India, Bangalore.

Paper-III

Elements of Mining and Drilling Techniques

Unit-I

Types of mines and the various mine workings; Method of breaking the rocks; Blast holes and their patterns; Blasting practices; Explosives used in mining; Subsidence and supporting of mine opening's; Transportation-haulage and hoisting; Mining machinery; Mine drainage; Ventilation and illumination.

Unit-II

Mine development; Methods of shaft sinking; Underground mining methods for metallic and non-metallic minerals; Underground coal mining methods.

Unit-III

Surface mining methods; Choice of mining method; Alluvial mining methods; Miscellaneous methods including solution methods and leaching methods, Sea bed mining for manganese nodules and coal bed methane; Mine organization; Safety measures in open cast and underground mines; Rescue work, welfare measures.

Unit-IV

Fundamentals of drilling; Purpose and applications of drilling; Brief idea about various common drilling techniques such as rotary, percussive and diamond drilling and their use; Factors influencing drilling; Drilling equipments and their use; Drilling bits: Coring and non-coring, blade bits, roller-cutter bits and diamond bits; Drilling fluids (flushing media); Casing and casing-string design; Coring: rotary and wire line, diamond core drilling, reverse circulation drilling, cable tool drilling, chip coring; Preservation of cores; Problems encountered in drilling (surface and underground) and remedies; Fishing and fishing tools; Deviation in drill holes: their measurements and correction; Directional drilling; Cementing of holes.

Books Recommended:

Elements of Mining and Drilling Techniques:

- McKinstry, H.E. (1972) Mining Geology. Prentice-Hall Inc.
- Arogyaswamy, R.N.P. (1995) Courses in Mining Geology. Oxford and IBH Publishing Co., New Delhi.
- Thomas, L.J. (1978) An Introduction to Mining. Methuen, Brisbane.
- Clark, G.B. (1967) Elements of Mining. Asia Publishing House.
- Young, G.J. (1946) Elements of mining
- Peele, R. and Church, J.A. (1967) Handbook of mining (Vol. I and II) Wiley Eastern Ltd. New Delhi.
- Shevyakov, L.S. (1957) Mining of Mineral Deposits. Foreign Languages Publishing House, Moscow
- Lewis, R.S. (1964) Elements of Mining. John Wiley.
- Scott, J. (1967) Mining. Mir Publishers, Moscow.
- Chugh, C.P. (1983) Manual of Drilling Technology. Oxonian Press Pvt. Ltd.
- Chugh, C.P. (1984) Diamond Drilling. Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi.

Chugh, C.P. (1992) High Technology in Drilling and Exploration. Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi.

Chugh, C.P. (1995) Drilling Technology Handbook. Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi.

Paper-IV

Geomorphology, Remote Sensing and GIS

Unit-I

Geomorphic concepts; Landforms: Role of Lithology, peneplanation, endogenous and exogenous forces responsible, climatic and tectonic factors and rejuvenation of landforms; Denudational processes: Weathering, erosion, transportation, weathering products and soil formation, slope processes; Drainage basin morphometry; Major processes and associated landforms: Tectonic, fluvial, aeolian, coastal, karst and glacial; Geomorphic features and zones of India.

Unit-II

Fundamentals of EMR, radiation laws, black and grey body radiation, atmospheric effect in remote sensing; Interaction of EMR with atmosphere and Earth surface; Interaction of TIR wavelength with terrain feature and vegetation; Interaction of Microwave with Earth surface.

Aerial photography: Sequence involved in the aerial photography: Classification, types, stereoscopy, geometrical characteristic, film and filter; Instrumentation and vertical exaggeration; Calculations of heights and slopes from aerial photographs; Principles of photogrammetry; Aerial photo interpretation – photo recognition elements and Interpretation of different geological features on B/W aerial photographs.

Unit-III

Orbit and Sun-synchronous aspect of satellite; Remote Sensing Sensor: Platforms and sensor resolution and calibration aspects of remotely sensed data, microwave sensor and False Colour Composite (FCC); Fundamentals of digital image processing: Image rectification, Image enhancement and Image classification; TIR remote sensing and its applications; Principle of microwave remote sensing and its applications; Geological applications of remote sensing; LANDSAT, SKYLAB, SPOT, SEASAT, ICONOS and other foreign systems of satellites and their interpretation for geological studies; Space research in India: Bhaskara, IRS series and their applications.

Unit-IV

Principles and components of GIS; Geospatial data, data for GIS application, spatial data models and data structures; Vector and raster based GIS; Spatial data acquisition, Vector overlay analysis; Neighbourhood Operation; Raster spatial analysis; Buffer analysis; Visualization and query of spatial data; Overlay analyses; Terrain analysis (DEM); Line generation; Introduction to GIS and remote sensing software; Geological applications of GIS; Principle and application of GPS.

PRACTICALS:

Geomorphology, Remote Sensing and GIS:

Topographical map interpretation for different landforms; Analysis of weathering trends; Drainage basin morphometry; Relief and slope analyses; Determination of photo scale, aerial photo interpretation for geological and geomorphological applications, parallax measurements for height determination, dip and thickness of beds; Study of landforms and interpretation of lithology and structure from aerial photograph and satellite images; Tracing of lineament and rosettes; Identification of landform on toposheets, aerial photographs and satellite images; Generation of DEM and DTM; FCC interpretation of satellite images; Image processing and GIS software.

Books Recommended:

Geomorphology:

Sharma, H.S. (1990) Indian Geomorphology, Concept Publishing Company, New Delhi

Thornbury, W.D. (1980) Principles of Geomorphology, Wiley Easton Ltd., New York

Remote Sensing and GIS:

Lattman, L.H. and Ray, R.G. (1965) Aerial photographs in field geology, McGraw Hill.

Pande, S.N. (1987) Principles and Applications of Photogeology, Wiley Eastern Limited.

Drury, S.A. (1997, 2001) Image Interpretation in Geology, Chapman and Hall, London.

Gupta, R.P. (1991) Remote Sensing Geology, Springer-Verlag.

Lillesand, T.M. and Kiefer, R.W. (2000) Remote Sensing and Image Interpretation, John Wiley and Sons Inc., New York.

Siegal, B.S. and Gillespie, A.R. (1980) Remote Sensing in Geology, John Wiley.

Miller, V.C. (1961) Photogeology, McGraw Hill

Sabins, F.F.Jr. (2000) Remote Sensing Principles and Interpretations, W.H. Freeman & Company, USA.

Berhardsen, T. (1999) Geographic Information System: an introduction, Wiley, New York

Curran, P.J. (1985) Principles of Remote Sensing, Longman Scientific & Tech. Group, Essex, England

Richards, J.A. (1986) Remote Sensing Digital Analysis: an introduction, Springer-Verlag, Berlin.

Burrough, P.P. and MacDonnel, R.A. (1998) Principles of GIS, Oxford University Press.

Ray, R.G. (1969) Aerial Photographs in Geologic Interpretations, USGS Proc Paper 373

Mikhail, E.M. (1980) Photogrammetry, Harper and Row

Paine, D.P. (1981) Aerial photography & Image Interpretation for Resource Management, John Wiley.

Jensen, J.R. (1986) Introductory Digital Image Processing: A Remote Perspective. Prentice Hall, New Jersey.

Jain, A.K. (1989) Fundamentals of digital image processing, Prentice Hall India.

Bonham-Carter, G.F. (1994) Geographic Information System for Geoscientists: Modelling with GIS, Pergamon.

Maguire, D.J., Goodchild, M.F. and Rhind, D.W. (1991) GIS - Principles and Applications, Longman Scientific and Technical.

Burrough, P.A. (1986) Principles of Geographical Information Systems for land resources assessment. Clarendon Press, Oxford.

Paper-I

Fuel Geology (Coal, Petroleum and Nuclear)

Unit-I

Origin of coal; Sedimentology of coal bearing strata; Structures associated with coal seams; Proximate and Ultimate analysis of coal; Rank, grades and types of coal; Indian and International classification for coking and non-coking coals; Coal preparation: coal carbonization, coal gasification, underground coal gasification (UCG), coal hydrogenation and coal combustion.

Unit-II

Coal Petrology – concept of ‘lithotype’, ‘maceral’ and ‘microlithotype; Classification and optical properties of macerals and microlithotypes; Techniques and methods of coal microscopy; Reflectance and fluorescence microscopy; Application of coal petrology for different industrial purposes; Geological and geographical distribution of coal and lignite deposits in India; Coal exploration and estimation of coal reserves; Indian coal reserves and production of coal in India; Coal Bed Methane (CBM); Generation, retention and exploration of methane from coal beds.

Unit-III

Petroleum: Different states, natural occurrences, chemical composition and physical properties of different fractions; Origin of Petroleum: Transformation of organic matter into kerogen, organic maturation, thermal cracking of kerogen; Migration of oil and gas; Reservoir rocks: General attributes and petrophysical properties; Classification of reservoir rocks- fragmental reservoir rocks and chemical reservoir rocks; Reservoir fluids- water, oil and gas; Hydrocarbon traps: Structural, stratigraphic and combination traps; Cap rock: Definition and general properties; Petroliferous basins of India; Elements of petroleum exploration; Hydrocarbons: Present status and future prospects.

Unit-IV

Mineralogy and geochemistry of radioactive minerals; Mode of occurrence, origin, association and distribution of atomic minerals in nature (U, Th, Be, rare metals and REE etc); Atomic minerals as source of energy; Metallogenic epochs and provinces of uranium mineralisation; Principles and methods of exploration for radioactive mineral deposits; Radiometric surveys: Methods of detection and measurement of radioactivity; Geiger Muller Counters and Scintillation Counters; Gamma ray logging of bore holes; Application of radioactivity in geochronometry; Uranium and thorium exploration in India; Productive geological horizons in India; Atomic fuels and environment; Nuclear power stations of India and future prospects.

PRACTICALS:

Macroscopic characterization of banded coals; Completion of outcrop in the given maps and calculation of coal reserve; Preparation of polished particulate mounts of coal; Microscopic

examination of polished particulate mounts (identification of macerals); Proximate analysis of coal; Laboratory analysis related to coal bed methane studies.

Study of geological maps and sections of important oil fields of India; Calculation of petroleum reserves; Problems on classification of oil field water based on chemical composition.

Megascope identification of common minerals used in atomic industry.

Books Recommended:

Coal Geology

Taylor, G.H., Teichmuller, M., Davis, A., Diessel, G.F.K., Littke, R. and Robert, P. (1998) Organic Petrology, Gebruder Borntraeger, Stuttgart.

Chandra, D., Singh, R.M. and Singh, M.P. (2000) Textbook of Coal (Indian Context), Tara Book Agency, Varanasi.

Singh, M.P. (Ed.) (1998) Coal and Organic Petrology, Hindustan Publ. Corp., New Delhi.

Stach, E., Mackowsky, M.T.H., Taylor G.H., Ghandra, D., Telchmuller, M. and Telchmuller, R. (1982) Stach's Text Book of Coal Petrology, Gebruder Borntraeger, Stuttgart.

Acharyya, S.K. (2000) Coal and Lignite Resources of India: An overview, Geological Society of India, Bangalore.

Francis, W. (1961) Coal, Edward Arnold Ltd.

Scott, A.C. (1987) Coal and Coal-bearing strata: Recent Advances, Blackwell Scientific Publications.

Thomas, Larry (2002) Coal Geology, John Wiley and Sons Ltd., England.

Van Krevelen, D.W. (1993) Coal: Typology-Physics-Chemistry-Constitution, Elsevier Science, Netherlands.

Stach, E. et al. (1975) Stach's textbook of coal petrology. Berlin: Gebruder Borntraeger.

Taylor, G.H., Teichmüller, M. and Davis, C. (1998) Organic Petrology: A new handbook incorporating some revised parts of Stach's Textbook of Coal Petrology.

Petroleum Geology:

Levenson, A.L. (1970) Geology of Petroleum, Freeman and Company.

North, F.K. (1985) Petroleum Geology, Allen and Unwin.

Holson, G.D. and Tiratsoo, E.N. (1985) Introduction to Petroleum Geology, Gulf Publ. Houston, Texas.

Tissot, B.P. and Welte, D.H. (1984) Petroleum Formation and Occurrence, Springer- Verlag.

Selley, R.G. (1998) Elements of Petroleum Geology, Academic Press.

Nuclear Geology:

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.

Aswathanarayana, U. (1985) Principles of Nuclear Geology, Oxford Press.

Paper-II

Ore Microscopy and Ore Dressing

Unit-I

The ore microscope; Preparation of polished section of ores; Physical and optical properties of ore minerals under reflected light; quantitative measurement of reflectivity and microhardness; Microchemical techniques- etch test and microchemical elemental test, contact chromatography of polished section of ores and its uses; Structures and textures of ores, their interpretation and paragenesis; Application of ore microscopy in mineral dressing.

Unit-II

Natural and Scope of mineral dressing; Relation of ore dressing to smelting and utility; Properties of minerals in relation to their dressing; Liberation: Practice of crushing and grading and grinding; Working principles of Jaw, Gyratory, Cone and roll crusher; Stamp, Rod and Ball Mills.

Unit-III

Concentration, screening and sizing: Concentration processes such as preliminary washing and sorting; Heavy fluid separation; Use of Classifiers (Hydraulic and Pneumatic); Jigging; Tabling, Floatation and agglomeration; Electrostatic, centrifugal and magnetic separation; Amalgamation and heat treatment methods; Concentration of ores by chemical leaching; Process of dewatering, filtration, drying and thickening methods, dressing systems and plants.

Unit-IV

Flow sheets of common types of ores; Methods of dressing of coal, clays, fluorspar, graphite, micas, gypsum, talc, diamond, barite and common ores of copper, manganese, chromium, gold, lead, zinc, titanium, tin, zirconium, thorium and uranium; Flow sheets of important concentration plants of India.

PRACTICALS:

Ore Microscopy:

Preparation of polished sections of ores and mounting. Description of optical properties and identification of ore minerals in polished sections under incident light and determination of paragenetic sequence. Exercises in the determination of reflectivity and microhardness of common ore minerals. Microchemical tests for ore minerals.

Ore Dressing:

Mechanical analysis by sieving, size analysis under microscope. Separation of minerals by panning and tabling. Preparation of flow sheets of the important concentration plants of India and flow sheets of common types of ores.

Books Recommended:**Ore Microscopy:**

Ramdohr, P. (1969) The Ore Minerals and their Intergrowths. Pergamon Press.

Picot, P. and Johan, Z. (1982) Atlas of Ore Minerals. Elsevier Publishers.

Craig, J.R. and Vaughan, D.J. (1981) Ore Petrography and Mineralogy. John Wiley.

Craig, J.R. and Vaughan, D.J. (1994) Ore Microscopy and Ore Petrology. John Wiley.

Ineson, P.R. (1989) Introduction to Practical Ore Microscopy. Longman Publishers.

Stanton, R.L. (1972) Ore Petrology, McGraw Hill.

Galopin, R. And Henry, N.F.M. (1972) Microscopic study of opaque minerals. McCrone Research Associates Ltd. London.

Sahoo, R.K. (2011) Atlas of oxide ores of India and their textures. SSDN Publishers and Distributors, New Delhi.

Ore Dressing:

Wills, B.A. (1992) Mineral processing technology. Pergamon Press.

Kelly, E.G. and Spottiswood, D.J. (1982) Introduction to mineral processing. John Wiley.

Gaudin, A.M. (1974) Principles of mineral dressing. Tata McGraw Hill.

Taggart, A.F. () Hand book of mineral dressing.

Paper-III**Hydrogeology and Watershed Management****Unit-I**

Hydrological cycle; Controls of geology on groundwater occurrence, movement and distribution; Classification of aquifers and aquifer systems; Mode of occurrence of groundwater in different geological formations and groundwater provinces of India; Darcy's law and Reynolds number; Aquifer parameters; Water table contour maps and flow net analysis; Seepages and springs.

Unit-II

Groundwater quality and environmental aspects; Chemical characteristics of groundwater in relation to various uses – domestic, industrial and irrigation; Saline water intrusion in coastal and other aquifers and its preventive measures; Environmental effects of over-exploitation of groundwater; Water logging problems; Causative factors of groundwater level fluctuations and environmental influences; Radioisotopes in hydrogeological studies.

Unit-III

Surface and subsurface methods of groundwater exploration; Application of remote sensing in groundwater exploration; Collection of hydrogeological data and preparation of hydrographs; Selection of suitable site for well construction; Type and design of wells, methods of well construction, well completion and well development; Pump tests and evaluation of hydrologic properties through various methods for steady and unsteady flow.

Unit-IV:

Artificial recharge to groundwater and rainwater harvesting; Management of groundwater resources; Conjunctive use of groundwater and surface water; Concept of watershed: Watershed characters, importance of water resources; Technical aspects of artificial recharge structures; Groundwater legislation; Role of NGOs and government policies in watershed development.

PRACTICALS:

Delineation of hydrological boundaries on water-table contour maps and estimation of permeability; Determination of groundwater flow direction; Problems in calculating transmissivity, specific retention and specific yield; Interpretation of well inventory data; Analysis of hydrographs and estimation of infiltration capacity; Pumping test: time-drawdown and time-recovery tests and evaluation of aquifer parameters; Step drawdown tests, Electric resistivity sounding for delineation of fresh aquifers; Study of geophysical well logs; Estimation of TDS using resistivity and SP logs; Exercises on groundwater exploration using remote sensing techniques; Water budgeting problems.

Books Recommended:

Davies, S.N. and De Wiest, R.J.N. (1966) Hydrogeology, John Wiley and Sons, New York.
Driscoll, F.G. (1988) Groundwater and Wells, UOP, Johnson Div. St. Paul. Min. USA.
Karanth, K. R. (1989) Hydrogeology, Tata McGraw Hill Publishers.
Nagabhushaniah, H.S. (2001) Groundwater in Hydrosphere (Groundwater hydrology), CBS Publ.
Raghunath, H.M. (1990) Groundwater, Wiley Eastern Ltd.,
Todd, D.K. (1995) Groundwater Hydrology, John Wiley and Sons.
Tolman, C.F. (1937) Groundwater, McGraw Hill, New York and London.

Paper-IV (Optional)

1. Engineering and Environmental Geology

Unit-I

Scope of geology in civil engineering and mining industry; various stages of engineering geological investigations for civil engineering projects; Engineering properties of rocks and soils: soil classification, rock discontinuities; Physical characters of building stones, metal and concrete aggregates; Use of remote sensing in engineering geology. Preliminary geological investigations for the various engineering projects: dams, reservoirs, tunnels, highways, bridges, hydroelectric power projects, shoreline and airfield engineering; Case history of engineering projects and geological causes for mishaps and failure of engineering structures.

Unit-II

Mass movements with special emphasis on landslides and cause of hill slope instability; Earthquake and seismicity, seismic zones of India, aseismic design of building; Influence of geological conditions on foundation and design of buildings. Geophysical methods for the selection of engineering sites;

Exploratory drilling, study and construction of subsurface sections based upon drilling data; Core logging: core recovery, preservation of cores, R.Q.D. analyses; Preparation and presentation of geotechnical reports.

Unit III

Components of environmental geology; Time scales of global changes in the ecosystem and climate; Major icehouse and greenhouse periods; Impact of oceanic and atmospheric circulation on climate and rain fall; Methodologies for estimation of present and past atmospheric carbon-dioxides; CO₂ increase and global warming in the present and past atmospheres. Physical, chemical and biological domains of environment; Air, water and noise pollution, their causes and remedial measures; Surface weathering, development of soil and soil pollution; Pollution in the mining areas.

Unit IV

Problems of urbanization, human population and their impact on environment; Alternative sources of energy; Waste disposal and related problems; Environmental legislations. Earthquake and tsunami – causes of occurrence and their impact as natural hazard; Seismic hazard zones; Neotectonics in seismic hazard assessment; Landslide and volcanic hazards their causes and control; Coastal erosion, its causes and control; Major river belts of India, flood hazards and their mitigation.

PRACTICALS:

Engineering Geology

Study of engineering properties of rocks/ soil with reference to their use in engineering projects; Study of models and maps of important engineering structures such as tunnels and dams; Interpretation of geological maps for various engineering geology projects; Preparation of subsurface sections based on drilling data; RQD analysis.

Environmental Geology

Preparation of seismic zonation maps of India and world; Demarcation of landslide prone areas in the Himalaya; Demarcation of flood prone areas in the outline map of India; Preparation of volcanic hazard zonation map; Presentation of chemical analysis data and plotting chemical classification diagrams; Preparation of oceanic and atmospheric circulation maps.

Books Recommended:

Engineering Geology

Bell, F.G. (1981). Engineering properties of Soils and Rocks, Butterworths Publication, London.
Bell, F.G. (1993). Fundamentals of Engineering geology, Butterworths Publication, London.
Garg, S.K. (2009). Physical and Engineering Geology, (6th Ed.), Khanna Publishers, New Delhi.
GSI (1975). Engineering Geology Case Histories, Geological Survey of India, Misc. Publ., No. 29.
Gupte, R.B. (2002). Text Book of Engineering Geology. Vidyarthi Griha Prakashan, Pune.

- Keary, P., Brooks, M. and Hill, I. (2002), An introduction to geophysical exploration, (3rd Ed.), Blackwell.
- Kesavulu, N.C. (2009). Textbook of engineering geology, (2nd Ed.), Macmillan Publishers India Ltd.
- Krynine, D.P. and Judd, W.R. (1998). Principles of Engineering Geology and Geotechnics. CBS Publishers & Distributors, New Delhi.
- Reddy, D.V. (1998). Engineering Geology for Civil Engineering—Oxford & IBH Pub.Co. Pvt. Ltd., Delhi.
- Rider, M.H. (1986). The Geological Interpretation of Well Logs. (Rev. Ed.) Whittles Publishing, Caithness.
- Ries, H. and Watson, T.L. (1947). Elements of Engineering geology (2nd Ed.), John Wiley & Sons, New York.
- Schultz, J.R. and Cleaves, A.B. (1951), Geology in Engineering, John Willey and Sons, New York.
- Singh, P. (1994), Engineering and General Geology. S.K. Kataria and Sons, Delhi.
- Telford, W.M., Geldart, L.P., Sherrif, R.E. and Keys, D.A. (1976). Applied Geophysics, Cambridge Univ. Press.
- Verma, B.P. (1997). Rock Mechanics for Engineers (3rd Ed.), Khanna Publishers, New Delhi.
- Wittke, Walter (1990). Rock Mechanics: Theory and Applications with case Histories, Springer –Verlag Publication.

Environmental Geology

- Bell, F.G. (1999) Geological Hazards, Routledge, London.
- Bryant, E. (1985) Natural Hazards, Cambridge Univ. Press.
- Keller, E.A. (1978) Environmental Geology, Bell and Howell, USA.
- Lal, D. S. (2007) Climatology, Sharda Pustak Bhawan, Allahabad.
- Perry, C.T. and Taylor, K.G. (2006) Environmental Sedimentology, Blackwell Publ.
- Patwardhan, A.M. (1999) The Dynamic Earth System, Prentice Hall.
- Smith, K. (1992) Environmental Hazards, Routledge, London.
- Subramaniam, V. (2001) Textbook in Environmental Science, Narosa International.
- Valdiya, K.S. (1987) Environmental Geology – Indian Context, Tata McGraw Hill.

(Optional)

2. Exploration Geochemistry

Unit-I

Geochemical concepts – terminology and their definitions in geochemical exploration; Back ground, threshold, anomaly; Primary and secondary environments and dispersion, additive, leakage and diffused halos; Zoning, mobility, migration, indicator and pathfinder elements; Mineral pathfinders.

Unit -II

Sampling techniques – pitting, trenching, augering, core sampling, bulk sampling, chip sampling, channel sampling, grid sampling, reconnaissance and detailed sampling, composite and selective sampling, logarithmic sampling (mine scale), ridge and spur sampling; Contamination, Pacing in the field.

Unit-III

Geochemical techniques in exploration – lithochemical, pedochemical, hydrochemical, biogeochemical, atmochemical and stream sediment surveys; Regional and detailed surveys.

Unit-IV

Area selection and sequential exploration model; General geochemical survey procedure; Geochemical conceptual models; Geochemical, metallogenic and biogeochemical provinces, geochemical associations, geochemical relief, productive plutons; Vegetation anomaly; Precision and accuracy.

PRACTICALS:

Geochemical isoconcentration contour maps; Geochemical exploration problems with type areas; Identification of Fluorescent minerals; Interpretation of Geochemical data using probability graphs; Geochemical modelling problems.

Books Recommended:

Govett, G.J.S. (1983). Rock Geochemistry in mineral exploration, Vol.3. Elsevier Scientific Publishing Company.

Govett, W.K., Hoffman, S.J., Merthens, M.B., Sinclair, A.J. and Thomson, I. (1987). Exploration Geochemistry, Design and Interpretation of Soil Survey. Reviews in Economic Geology, Vol.4.

Hale, M. and Plant, J.A. (1994) Handbook of Exploration Geochemistry – Drainage Geochemistry, vol 6, Elsevier Scientific Publishing Company.

Levinson, A.A. (1974) Introduction to Exploration Geochemistry, Applied Publishing Ltd. USA.

Reedman, J. H. (1979) Techniques in mineral exploration. Applied Science Publishers.

Rose, Arthur W., Herbert, E. Hawkes and Webb, John S. (1979) Geochemistry in Mineral Exploration. 2nd edition, Academic Press.

Solov, A.P. (1987) Geochemical Prospecting. Mir Publishers, Moscow.

(Optional)

3. Applied and Industrial Micropalaeontology

Unit-I

Definition and scope of the Applied and environmental Micropaleontology; Modern field and laboratory techniques in the study of microfossils (collection, sampling and processing techniques); Diatoms: Outline of morphology and classification, significance in paleolimnology/limnology, paleoceanographic and biostratigraphic interpretations; Applications of diatoms in environmental, climate and forensic science studies; Brief introduction of Cyanobacteria and Calcareous nannofossils and their geological significance; Brief introduction of Ostracoda, Radiolaria and Conodonts and their geological significance.

Unit-II

Foraminifera: planktic foraminifera, outline of morphology, significance in Cenozoic oceanic biostratigraphy and paleoceanographic, paleoclimatic interpretations; Benthic foraminifera - their brief morphology and application in bottom water paleoceanography and paleobathymetric reconstructions.

Calcareous algae (Rhodophyta and Chlorophyta): Broad classification, morphology and internal structure; Paleoenvironmental, paleogeographical, paleobathymetric, biostratigraphic significance of calcareous algae; Petroleum exploration using calcareous algae.

Spores/pollen: Morphology and classification; Production, dispersal and sedimentation of palynomorphs; Applications of pollens in environmental, climate and forensic science studies; Types of organic matters, concept of palynofacies and their application in paleoenvironment interpretation; Brief introduction of phytoliths and acritarchs and their significance.

Unit-III

Geochemical study of microfossil tests (stable isotopes, radiocarbon isotopes and elemental composition) and its application in Paleolimnology, Paleoceanography, Paleoclimatology and tracing history of marine and lake pollution; Microfossils and Earth's orbital cycles (Milankovitch Cycles).

Paleoclimatic importance of microfossils; Forecasting of monsoon using microfossils; Delineation of Oxygen Minimum Zones (OMZ) using microfossils; Freshwater and Marine pollution and interpreting pollution with the help of microfossils; Utility of microfossils in Paleoceanography and interpretation of sea floor tectonism from microfossils.

Unit-IV

Adaptation of academic micropalaeontology to industry and its future prospects; Samples derived from drilling wells and their reliability for micropaleontological analysis; Traditional uses of micropalaeontology in hydrocarbon exploration; High resolution applications and new approaches to applied micropalaeontology including biosteering and reservoir characterisation by detailed morphological analysis of microfauna / microflora with examples; Unconventional uses of micropalaeontology; Carbonate production in present-day oceans; Larger foraminifera and calcareous algae as carbonate reservoirs; Recognizing foraminiferal and calcareous algal reservoirs; Practical case study in India; Significance of palynology in source rock evaluation and organic matter

maturation; Application of palynology in identifying ancient coast lines for petroleum exploration; Increasing Biostratigraphic resolution with Molecular Biology; Role of Micropaleontology in Economic Geology.

Practicals:

Applied Micropaleontology

Techniques of separation of microfossils from matrix; Microscopic study of the selected taxa of Foraminifera, Ostracodes, Calcareous Algae, Diatoms, Pollens and Spores, dinoflagellates; SEM applications in micropaleontology: Study of surface ultra structures of foraminifera, Calcareous Algae, Diatoms and Pollens and Spores; Preparation of diatom slides from the sediments of the polluted freshwater environments and identification of indicator Diatoms to assess urban stream health and water quality; Techniques in Diatom studies and palynology.

Industrial Micropaleontology

Checking the characteristics of sample; Processing and analyzing ditch cutting samples; Real time well site micropalaeontology: analysis simulation.

From exploration to production - from theory to practice

Exploration: Seismic stratigraphy (including pitfalls), Seismic stratigraphy exercise.

Exploration/Discovery: Bio-Sequence stratigraphy, exercise: well to seismic, identification of surfaces.

Appraisal exercise: second well, tie to first well seismic and exercise: third well, log correlation, compare result with biostratigraphy.

Graphic correlation as a tool: exercise; Building a reservoir zonation- exercise: horizontal drilling.

Books Recommended:

Traverse Alfred (1988) Paleopalynology, Unwin Hyman, USA.

Arnold (2002) Quaternary Environmental Micropaleontology (Ed. Simon K. Haslett), Oxford University Press, New York.

Bergland, B.E. (1986) Handbook of Holocene paleoecology and paleohydrology, John Wiley, New York.

Bignot, G., Grahm and Trotman (1985) Elements of Micropaleontology, London.

Jones, T.P. and Rowe, T.P. (1999) Fossil Plants and Spores Modern Techniques, Geological Society of London.

Kathal, P.K. (2011). Applied Geological Micropaleontology, Scientific Publishers, Jodhpur.

Kundal, P. (2003). Recent Developments in Indian Micropaleontology, Gondwana Geological Society, Sp. Vol. 6.

Kundal, P. and Humane, S.K. (Eds.) (2010) Applied Micropaleontology, Gondwana Geological Society, V. 24 (1).

Pipero, Doluges, R. (1988) Phytolith analysis: An Archaeobiological and Geological perspective, Academic Press.

Prothero, D.R. (2004) Bringing Fossil to Life – An Introduction to Paleontology (2nd Ed.), McGraw Hill.

Seaward, A.C. (1991) Plant fossils, Today's and Tomorrow, New Delhi.

Agashe, Shipad N. (1995) Paleobotany, Oxford and IBH Publ., New Delhi.

Stewart, Wilson N. and Rothwell, Gar W. (1993) Paleobotany and the Evolution of Plants, Cambridge Univ. Press.

Wray, J.L. (1977) Calcareous Algae, Elsevier.

(Optional)

4. Petroleum Exploration

Unit-I

Introduction to Petroleum geology, types of petroliferous basins and their relation to hydrocarbon potential; Global geographic and stratigraphic distributions of oil and gas; Classification and stratigraphy of petroliferous basins of India. Estimation of oil and gas reserves and resources; Basin mapping – structure and isopach contouring, lithofacies and biofacies maps; Petrophysics- rock fluid system and interaction, reservoir characteristics, reservoir heterogeneity and drive mechanisms of carbonate and clastic reservoirs.

Unit-II

Methods and techniques for petroleum exploration, surface indications and direct detection of hydrocarbons; Geochemical methods of Petroleum exploration; Sniffer surveys; Introduction to different biomarkers used in oil exploration; Significance of major microfossil groups such as foraminifers, calcareous algae, ostracods, dinoflagellates, pollen and spores in hydrocarbon exploration; Case studies of Indian sedimentary basins; Sub-surface exploration techniques: concept of potential, magnetic, gravity and seismic methods of geophysical exploration; Seismic data acquisition, processing and interpretation; Synthetic seismograms; Gas hydrates and CBM exploration.

Unit-III

Oil well Drilling methods, drilling equipments, drilling rig - its components and functions, rig sizing and selection, drilling fluids, wellheads, casing and cementing operations, principles of kick control, fishing jobs, drill stem test (DST); Types of offshore and onshore drilling operations; Well completion; Well logging: Formation evaluation, Archie's formulae, principles, methods and application of logging tools including Spontaneous polarization, resistivity, microresistivity, induction, sonic, density, neutron techniques, hingle, pickett, MID, M-N cross plots, saturation estimation, natural gamma ray, gamma ray spectrometry, cement bond, variable density, caliper, dipmeter, formation microscanner and imager; Well log interpretation - quick lithology, porosity and permeability determination; Log interpretation case studies.

Unit-IV

Duties of a well-site geologist; Geotechnical order (GTO), coring and core analysis; Examination of well cuttings; Preparation of lithologs and composite logs; Principles of formation testing; Development geology, production and enhanced oil recovery (EOR) methods; Principles of petroleum economics.

PRACTICALS:

Map projections of different oil horizons in Indian sedimentary basins, their stratigraphic order, and study of microfossils like foraminifers, calcareous algae, ostracods, dinoflagellates, pollen and spores in hydrocarbon exploration; Granulometric analysis, seismic facies analysis, seismic profile

interpretation, preparation of different lithologs; Interpretation of different well log data from different sedimentary environment with the use of Electro-logging (SP, GR, resistivity, Neutron, Density, Dipmeter etc); Core sample studies (identifications of sedimentary structures, lithology, facies and paleoenvironment from core data); Time corrections applied to seismic data; Preparation of synthetic seismograms and calibration of well data; Laboratory analysis related to coal bed methane studies.

Books Recommended:

- Amadei, B. (1997) *Rock Stress and its Measurement*, Chapman & Hall, London.
- Baker, R.A (2001) *Primer of Oil well Drilling: A basic text of oil and gas drilling*, Petroleum Extension Service, University of Texas at Austin.
- Barwis, J.H. (1990) *Sandstone Petroleum Reservoir*, Springer-Verlag, Berlin.
- Berg, R.R. (1986) *Reservoir Sandstones*, Prentice Hall, New Jersey.
- Bhandari, L.L., Venkatachala, B.S., Kumar, R., Swamy, S.N., Garga, P. and Srivastava, D.C. (Eds.) (1983) *Petroliferous Basins of India*, Petroleum Asia Journal, Himachal Times Group.
- Biswas, S.K., Dave, A., Garg, P., Pandey, J., Maithani, A. and Thomas, N.J. (Eds.) (1993) *Proceedings of 2nd Seminar on Petroliferous Basins of India*, Dehra Dun, Dec.18-20, 1991, Vol. 1, 2 and 3, Indian Petroleum Publishers, Dehra Dun.
- Bordenave, M.L. (Ed.) (1993) *Applied Petroleum Geochemistry*, Editions Technip, Paris.
- Chilinger, G.V. and Vorabutr, P. (1981) *Drilling and Drilling Fluids*, Elsevier Science, Amsterdam.
- Deutsch, C.V. (2002) *Geostatistical Reservoir Modelling*, Oxford University Press, Oxford.
- Durable, O. (1998) *Geostatistics in Petroleum Geology*, AAPG Cont. Education Course Note Series 38.
- Asquith, G. and Gibson, C. (1982) *Basic Well Log Analysis for Geologists*, Academic Press, London.
- Goovaerts, P. (1997) *Geostatistics for Natural Resources Modelling*, Oxford University Press, Oxford.
- Guegen, Y. and Palciauskas, V. (1994) *Introduction to Physics of Rocks*, Princeton University Press.
- Gupta, P.K. and Nandi, P.K. (1995) *Well Site Geological Techniques and Formation Evaluation: A User's Manual*, Vol. I, Oil and Natural Gas Corporation, Dehra Dun.
- Hyne, N.J. (2001) *Nontechnical Guide to Petroleum Geology, Exploration, Drilling and Production*, 2nd edition, Pennwell Corporation, Tulsa, Oklahoma.
- Jaeger, J.C. and Cook, N.G.W. (1979) *Fundamentals of Rock Mechanics*, Chapman & Hall, London.
- Levenson, A.L. (1970) *Geology of Petroleum*. Freeman and Company.
- Rider, M.H. (1985) *The Geological Interpretation of Well Logs*, Blackie, London.
- Mallet, J.L. (2002) *Geomodelling*, Oxford Univ. Press, Oxford.
- Moore, C.H. (2001) *Carbonate Reservoirs*, Elsevier, Amsterdam.
- Serra, O. (2003) *Well Logging and Geology*, Editions Technip, Paris.
- Serra, O. (1984) *Fundamentals of Well Log Interpretation*, Vol.1 and 2.Elsevier.
- Peters, K.E., Walters, C.C., Moldowan, J.M. (2005) *The Biomarker Guide (Vol. 1 & 2)*, Cambridge University Press, Cambridge.
- Bateman, R.M. (1985) *Open Hole Log Analysis and Formation Evaluation*, Reidel, Dordrecht.
- Ransom, R.C. (1995) *Practical Formation Evaluation*, John Wiley & Sons, New York.
- Sahay, B., Rai, A. and Ghosh, M. (1984) *Wellsite Geological Techniques for Petroleum Exploration*,

Oxford & IBH, New Delhi.

Schlumberger Manual Log Interpretation Principles/Applications, Vol. 1 & 2,
Schlumberger Education Services, New York, 1989.

Selley, R.C. (1998) Elements of Petroleum Geology, II Edition. Academic Press.

Singh, L. (2000) Oil and Gas Field of India, Indian Petroleum Publishers, Dehra Dun.

Tiab, D. and Donaldson, E.C. (1996) Petrophysics: Theory and Practice of Measuring Reservoir Rock
and Fluid Transport Properties, Gulf Publishing Company, Houston, Texas.

Tissot, B.P., Welte, D.H. (1984) Petroleum Formation and Occurrence, Springer-Verlag, Berlin.

Welte, D.H., Horsfield, B., Baker, R. (Eds.) (1997) Petroleum and Basin Evolution: Insights from
Petroleum Geochemistry, Geology and Basin Modeling, Springer-Verlag, Berlin.

Whittaker, A. (1991) Mud Logging Handbook, Prentice-Hall, Englewood Cliffs.

Yarus, J.M. and Chambers, R.L. (Ed) (1994) Stochastic Modelling and Geostatistics, Principles,
Methods and Case Studies, AAPG Computer Applications in Geology, No 3.

Zimmerle, W. (1995) Petroleum Sedimentology, Kluwer Academic Publishers, Dordrecht.

10th Semester

Project work