



St. Xavier's College

Mumbai

Syllabus

for B.Sc Ist Semester Courses in Geology

(June 2016 onwards)

Contents:

- Theory Syllabus for Courses:
 - S.Geo.1.01 - Introduction to Mineralogy and Crystallography
 - S.Geo.1.02 - Introduction To Earth Science, Cartography and Structural Geology.
- Practical Course Syllabus for: S.Geo.1.PR.
- Evaluation and Assessment guidelines.

F.Y. B.Sc. Geology

Course: S.Geo.1.01

Title: Introduction To Mineralogy and Crystallography

Learning Objectives:

This is among the first exposure that a learner has to the subject of geology at the undergraduate level. The aim of this course is to develop in the learner ability to understand and identify various minerals along with their characteristic crystallographic properties, as this forms one of the fundamental requirements in the later profession.

Number of lectures: 45

Unit 1

Mineralogy:

(15 Lectures)

Chemical bonds and formation of compounds.

Minerals: definition, chemical compositions and classification.

Physical properties of minerals: colour, streak, luster, diaphaneity, form, habit, cleavage, fracture, hardness, specific gravity, and electrical and magnetic properties.

Isomorphism, polymorphism and pseudomorphism.

Unit 2

Elementary Crystallography:

(15 Lectures)

States of matter: crystalline state.

Elementary ideas about the crystal structure.

External characteristics of crystals: face, form, edge, solid angle, interfacial angle and its measurement, zone.

Crystal symmetry: planes, axes and center of symmetry.

Crystallographic axes and axial angles, parameters, indices and rational indices.

Classification of crystals into seven systems.

Study of the normal classes belonging to following systems:

Isometric, Tetragonal, Hexagonal, Trigonal, Orthorhombic, Monoclinic and Triclinic.

Unit 3

Descriptive Mineralogy of Rock forming minerals:

(15 Lectures)

Structural classification of silicates.

Feldspars, Silica, Pyroxene, Amphibole, Mica, Olivine.

List Of Recommended Reference Books

1. Dana J.D. and Ford W.E. (rev. ed.) (2010), Dana's Manual of Mineralogy, J. Wiley & Sons.
 2. Read H.H. (Rev. ed. C.D. Gribble) (1988), Rutley's Elements of Mineralogy" (27TH Edition), CBS Publications.
 3. Perkins D (2010). Mineralogy (3rd Edition), Prentice-Hall of India.
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Practical Course:

- I. Study of crystal models representing forms of seven normal classes of symmetry.

- II. Identification and description of the physical properties, composition, occurrences and uses of 30 rock forming minerals.

F.Y. B.Sc. Geology

Course: S.Geo.1.02

Title: Introduction to Earth Science, Cartography And Structural Geology

Learning Objectives:

The primary platform for any learner attempting to understand geology, is our planet earth. As this course is among the introductory courses at the undergraduate level, it needs to communicate and also attempt at the learner becoming acquainted to the various theories about the origin of the universe and our solar system. After that the learner needs to know the theories that lead to the understanding about the planets interior and the energy systems that drive the various internal (sub-surface and deep interior) systems along with the linkages between the interior and the atmospheric circulation. This leads to an understanding about the internal and external processes on our planet and how various structures within rocks form due to earth's internal forces.

Number of lectures: 45

Unit-1:

15 Lectures

Earth in the Solar System:

Geology and its perspectives.

Earth in the Solar System: Earth's Origin, size, shape, mass, density, rotational parameters.

Earth's Internal structure: core, mantle, and crust.

Hydrosphere, Atmosphere and Biosphere: characteristics and elemental abundance in each constituent. Convection in the earth's core and production of its magnetic field.

Age of the earth.

Unit-2:

15 Lectures

Atmospheric circulation and Global climatic changes:

Atmospheric circulation, weather and climate changes.

Land-air-sea interaction.

Earth's heat budget and global climatic changes.

Ocean currents:

Generation of oceanic currents, surface currents and global ocean conveyor system.

Ocean as a thermostat for the earth's surface heat balance.

Cartography:

Maps and Topographical maps; latitude – longitude concepts, Datum, map projections, types of maps, SOI map index, Contours and contour reading: Scales and Compass bearings, map grids (UTM).

Unit-3:

15 Lectures

Structural Geology:

Stratification; Dip and Strike; Clinometer compass its use.

Outcrop pattern of horizontal, dipping and vertical strata on various types of topography.

Outliers, Inliers.

Folds: Definition, Morphology, anticline and syncline.

Types of folds: symmetrical, asymmetrical, recumbent, overturned, isoclinal, plunging, doubly plunging, structural dome and basin, monocline, structural terrace, chevron, fan, anticlinorium, synclinorium, Importance of folds.

Joints: Definition, geometric classification and importance.

Faults: morphology; geometric classification based on relation to affected rocks, angle of dip, apparent movement and relative movement; distributive faulting: horst, graben and step faults; nappes.

Unconformities: nature, types and importance; overlap and off-lap.

List Of Recommended Reference Books

1. Compton R.R. (1985), Geology in The Field., J. Wiley& Sons
2. Skinner B.J., Porter S.C. and Botkin D.B. (1999), The Blue Planet., 2nd edn. J. Wiley & Sons.
3. Holmes A. (1993), Principles of Physical Geology.,ed by David Duff, Nelson Thornes Ltd
4. Billings M.P. (1987), Structural Geology., 3rd edn, Prentice-Hall, India Pvt. Ltd
5. Robinson. A, Morrison. J, Muehrcke. P, Kimerling. A, Guptill. S (1995),Elements of Cartography, 6 ed, J. Wiley & Sons.
6. Siddhartha K., (1999), Oceanography - A Brief Introduction., KosalayaPubln., India
7. Butz S. (2007) Science of Earth Systems., 2nd edn., Thomas Delmar.

Practical Course:

- I. Use of Clinometer and Brunton compasses
- II. Description and drawing of vertical cross section of simple geological maps involving horizontal or dipping strata with vertical faults, folded (non-plunging and non-faulted) strata and strata involving angular unconformity.
- III. Graphical solution of structural geology problems involving
 - a. Strike, true dip and apparent dip
 - b. Thickness and width of outcrop.



St. Xavier's College
Mumbai
Syllabus
for BScIInd Semester Courses in Geology
(November 2016 onwards)

Contents:

- Theory Syllabus for Courses:
 - S.Geo.2.01-Introduction to Petrology, Geotectonics and Economic Geology.
 - S.Geo.2.02-Introduction to Physical Geology, Principles of Stratigraphy and Paleontology.
- Practical Course Syllabus for: S.Geo.2.PR.
- Evaluation and Assessment guidelines.

F.Y. B.Sc. Geology

Course: S.Geo.2.01

Title: Introduction to Petrology, Geotectonics and Economic Geology

Learning Objectives: As a part of the four formative courses which introduce the learner to the basics of geology, this module incorporates the necessary topics to appreciate and understand the processes which lead to the formation of various rock types and mineral deposits along with their relationship to tectonism. A brief understanding of the methods of exploration and exploitation of earth's natural resources is also discussed.

Number of lectures: 45

Unit 1

(15 lectures)

Igneous Petrology

Rocks: definition, their classification.

Magma: definition, composition, origin, Bowen's Reaction Series, magmatic differentiation and assimilation.

Mode of occurrences, Intrusive and Extrusive forms.

Textures and structures.

Classification based on grain size and mineral composition.

Metamorphic Petrology

Metamorphism: definition, agents and types of metamorphism.

Metamorphic minerals: stress and anti-stress minerals, textures and structures.

Metamorphic facies and isograds, Relationship between metamorphism and deformation.

Rock cycle.

Unit 2

(15 lectures)

Sedimentary Petrology

Sediments: weathering, transport, deposition, consolidation, diagenesis.

Textures and structures.

Classification: Terrigenous and Chemical sedimentary rocks.

Mineral Deposits

Classification and brief study of following mineral deposits: Hydrothermal, Magmatic, Sedimentary (evaporites, strata-bound, bedded iron formations), Placer, Residual.

Unit 3

(15 lectures)

Introduction to Mineral Exploration and Mining:

Methods of mineral exploration: Surface methods – grid sampling. Sub-surface methods – Seismic, Electrical, Magnetic and Electrical.

Basic ideas about the methods of mining.

Geotectonics:

Earthquakes: causes, effects, tsunamis, measurement of earthquakes, seismic belts, seismic zonation in India.

Volcanoes: types, causes and distribution.

Origin of Mountains, Oceans and Continents.

General relief features of the ocean floor.

List Of Recommended Reference Books

1. Ehlers, E.G. and H. Blatt (1982), Petrology, Igneous, Sedimentary and Metamorphic, W.H Freeman, San Francisco
2. Tyrell G.W. (1980), Principles of Petrology: An Introduction to the Science of Rocks., 1st Indian Edn., B.I. Publ. India.
3. Ramam P.K. (1989), Principles and Practices of Mineral Exploration., Publ. Geol. Soc. Ind.
4. Arogyaswami R.N.P. (1973), Courses in Mining Geology., Oxford & IBH
5. Agoskhov M., Borisov S., Layansky V. (1888), Mining of Ores and Non-metallic Minerals., Mir Publishers

Practicals

- I. Identification of group characteristics of 25 common rocks and their classification into major rock groups. Identification and systematic description of the megascopic features of these rocks.
- II. Identification and description of the physical properties, composition, occurrences of 10 commonly occurring economic ore minerals.

F.Y. B.Sc. Geology

Course: S.Geo.2.02

Title:

Introduction to Physical Geology, Principles of Stratigraphy and Paleontology

Learning Objectives:

As the fourth module in the introductory courses in geology, the learner is exposed to the now accepted modern day concept of plate tectonics, which also explains the various surface features on our planet. The learner develops an understanding about the various surface phenomenon that lead to the development of soil and the breakdown of landforms. The last unit in this module introduces the learner to the basics of stratigraphy, whereby the concept of age related geological activities which shaped our planet are explained. Also explained is the basis of formation of fossils.

Number of lectures: 45

Unit 1 Introduction to Plate Tectonics and Physical Geology (15 Lectures)

Theory of Plate Tectonics and its proofs .

Introduction to Weathering and Erosion; Exogenic and endogenic geomorphic processes; Evolution of landscape.

Soil: definition, formation and functions; soil profile.

Unit 2 Landforms (15 Lectures)

Wind: erosion, transport and deposition; Aeolian landforms.

Rivers: development of a typical river system; erosion, transportation and deposition; Fluvial landforms

Glaciers: types, formation and morphology; erosion, transport and deposition; Glacial landforms.

Oceans: marine erosion and deposition; Coastal landforms.

Unit 3 Introduction to Principles of Stratigraphy and Paleontology (15 Lectures)

Definition of stratigraphy. Nature of stratigraphic records.

Principles of Stratigraphy- superposition, initial horizontality, lateral continuity, floral and faunal succession, cross-cutting relationship, and uniformitarianism.

Concept of time in geology. Geological time scale. Unconformities- types, formation and applications.

Introduction to paleontology. Fossils- definition, types of fossils, modes of preservation. Applications of fossils in geology.

List Of Recommended Reference Books

1. Benton M.J. and Harper D.A.T. (2009), Introduction to Paleobiology and Fossil Record, Wiley-Blackwell Publication.
2. Ray Anis. K, (2008), Fossils in Earth Sciences, Prentice Hall of India
3. Butz S. (2007) Science of Earth Systems., (2nd Edition), Thomas Delmar.
4. Dasgupta, A.,(2005), Introduction to Palaeontology, (1st Edition), World Press
5. Skinner B.J., Porter S.C. and Botkin D.B. (1999), The Blue Planet.,(2nd Edition) J. Wiley & Sons.
6. Holmes A. (1993), Principles of Physical Geology.,ed by David Duff, Nelson Thornes Ltd
7. Emiliani C. (1992), Planet Earth: cosmology, geology and evolution of life and environment, Cambridge University Press.
8. Weller J.M. (1960), Stratigraphic Principles and Practice, Harper.

Practicals

1. Study of 3D models of the various landforms formed due to the geomorphic processes.
2. Correlation of the lithologs and their interpretations.



St. Xavier's College

Mumbai

Syllabus

for B.Sc IIIrd Semester Courses in Geology

(June 2016 onwards)

Contents:

- Theory Syllabus for Courses:
 - S.Geo.3.01 –Stratigraphy, General and Invertebrate Paleontology
 - S.Geo.3.02 - Crystallography
 - S.Geo.3.03 - Geomorphology and Cartographic Analysis
- Practical Course Syllabus for: S.Geo.3. PR
- Evaluation and Assessment guidelines.

S.Y. B.Sc. Geology

Course: S.Geo.3.01

Title: Stratigraphy, General and Invertebrate Palaeontology

Learning Objectives: Among the first of the core courses, developed keeping in mind the needs of a professional geologist and a learner who is likely to pursue his career in the subject, this course communicates the basis of stratigraphy and correlation of strata among rock sequences. The correlation between the rocks and the evolving life on our planet is dealt with in two units. They specifically deal with the characteristic features, origin, evolution and preservation of life in sedimentary rocks.

Number of lectures: 45

Unit 1 Stratigraphy

(15 lectures)

Stratigraphic classification & nomenclature, study of stratigraphic elements, Stratigraphic Units: lithostratigraphic, geochronologic, chronostratigraphic and biostratigraphic.
Concept of biozones and applications of biostratigraphic units.
Walther's law of facies and its application in the field.
Introduction to sequence stratigraphic.

Unit 2 Paleontology - I

(15 lectures)

Modern concept of origin of life, principles and theories of evolution, mechanism & pattern of evolution; causes of migration, dispersal and extinction of organisms, Mass extinctions
Introduction to paleontology, Potential and preservation of fossils, Types and applications of fossils
Taphonomy
Study of functional morphology and evolutionary trends of:
-Trilobite
-Brachiopoda

Unit 3 Paleontology-II

(15 lectures)

Study of functional morphology and evolutionary trends of:
-Mollusca: Pelecypoda, Gastropoda, and Cephalopods
-Corals
-Echinoidea
-Graptololoidea
Ichnofossils: introduction, types and applications in paleoenvironmental interpretation.

List Of Recommended Reference Books

1. Benton M.J. and Harper D.A.T. (2009), Introduction to Paleobiology and Fossil Record, Wiley-Blackwell Publication.
2. Nichols G. (2009), Sedimentology and Stratigraphy, Wiley-Blackwell.
3. Ray Anis. K, (2008), Fossils in Earth Sciences, Prentice Hall of India.
4. Catuneanu O. (2006), Principles of Sequence Stratigraphy, Elsevier.
5. Dasgupta, A., (2005), Introduction to Palaeontology, (1st Edition), World Press.
6. Kumar R. (1996), Fundamentals of Historical Geology and Stratigraphy of India, 4th ed., New Age International Limited.
7. Clarkson E. (1993), Invertebrate Paleontology and Evolution, Chapman and Hall.
8. Raup D. and Stanley S.M. (1971), Principles of Paleontology, W.H. Freeman.
9. Shrock Robert R. and Twenhofel William H. (1953), Principles of Invertebrate Paleontology, McGraw Hill Co., New York.
10. Spencer E.W. (1962), Basic Concepts of Historical Geology, Thomas Y. Crowell, New York.
11. Weller J.M. (1960), Stratigraphic Principles and Practice, Harper.
12. Woods H (1958), Paleontology-Invertebrate, University Press London.

Practicals

1. Identification (morphology, classification, and geological distribution) and study of evolutionary trends of: trilobite, brachiopods, lamellibranches, gastropods, cephalopods, echinoids, and graptolites.
2. Identification and interpretation of biozones in stratigraphy.

S.Y. B.Sc. Geology
Title: Crystallography

Course: S.Geo.3.02

Learning Objectives:

The aim of the course is to communicate and facilitate the understanding of concepts of crystal structures, symmetry and point groups. The course is also aimed to relate the application of crystallography in various fields with special emphasis on mineralogy. This course becomes the prerequisite to advanced level (S.Geo.5.0 courses) in petrology and gemology.

Number of lectures: 45

Unit 1:

Characteristic of Crystals:

(15 lectures)

Atomic arrangement in crystals, Bravais Lattices, Crystal symmetry, Elements of symmetry: Planes, Axes and Centre, Axis of inversion symmetry, Crystallographic axes, Miller Indices, Axial ratios, Classification of crystals, Stereographic projections of symmetry, Graphical symbols used in stereographic illustrations.

Unit 2:

The thirty-two crystal classes and possible forms of each class

(15 Lectures)

Forms and crystal morphology, Name of forms, Illustration and description of forms, open forms and closed forms, point groups and crystal systems, Derivation of 32 classes of symmetry with Hermann-Mauguin symbols, Characteristic symmetry, and relationships between crystal axes and symmetry notation of crystal systems.

Unit 3:

X-ray Diffraction and Crystal imperfections

(15 Lectures)

Twin crystals, Twin axis, Twin plane, Composition plane. Types of Twinning: Simple and Multiple contact twins, Simple and Multiple penetration twins, Cyclic twins, Twinning in Feldspars: Carlsbad, Manebech, Baveno, Albite, Albite-Carlsbad.

X-ray Diffraction: Brief introduction of X-rays, Diffraction effects and Bragg equation, Application of X-rays in crystallography and mineralogy.

List Of Recommended Reference Books

1. Read H.H. (Rev. ed. C.D. Gribble) (1988), Rutley's Elements of Mineralogy" (27TH Edition), CBS Publications.
2. Cornelius K. and Hurlbut Jr. S. (1994), Manual of Mineralogy, Twenty first Edition and Minerals and Rocks Exercises in Crystallography, J. Wiley & Sons.
3. Dana J.D. and Ford W.E. (rev. ed.) (2010), Dana's Manual of Mineralogy, J. Wiley & Sons.
4. Rogers A.F. and Kerr P.F. (1942), Optical Mineralogy (2nd Edition), McGraw- Hill Co. Inc., New York.
5. Berry L.G., Mason B.H. and Dietrich R.V. (1983), Mineralogy, concepts, descriptions, determinations, W.F. Freeman and Co.
6. Deer W.A., Howie A.H. and Zussman J. (1992), An introduction to rock forming minerals, Longman Scientific and Technical.
7. Shelly David (1985), Optical Mineralogy (2nd Edition), Elsevier.
8. Nesse W.D. and Schulze D.J. (2004), Introduction to Optical Mineralogy" (Third Edition) and An Atlas of Minerals in Thin Section, Oxford University Press.
9. Perkins Dexter (2011), Mineralogy (International Edition), Pearson Education.
10. Wenk H.R. and Bulakh A. (2004), Minerals: their constitution and origin, Cambridge University Press.

Practicals:

Study of Symmetry: Symmetry elements of 32 classes of symmetry

Stereographic projections of Symmetry elements of 32 classes of symmetry Study of 48 possible forms in crystallography with special emphasis on crystals belonging to the following Fourteen classes of symmetry:

Cubic system: galena, tetrahedrite & pyrite classes

Tetragonal system: zircon, chalcopyrite, nickel sulfate classes

Hexagonal system: beryl, apatite & beta- quartz classes.

Trigonal system: calcite, tourmaline and alpha- quartz classes.

Orthorhombic system: barite class.

Monoclinic system: gypsum class.

Triclinic system: axinite class.

Study of Twin-axis, Twin plane and composition plane of the following types of Twin crystals: Simple contact twinning: Spinel, Rutile, Aragonite, Gypsum, Augite, Orthoclase (Bavano, Manebach, Carlsbad).

Simple penetration twinning: Staurolite, Augite, Orthoclase (Carlsbad-partially penetrant).

Multiple contact twinning: Albite.

Multiple penetration twinning: Fluorite, Diamond (Star), Chrysoberyl (Wheel).

Multiple cyclic twinning: Aragonite, Chrysoberyl (Wheel).

S.Y. B.Sc. Geology
Title: Geomorphology and Cartographic Analysis

Course: S.Geo.3.03

Learning Objectives:

Understanding of -

- **Concepts of Geomorphology & Cartography**
- **Types & Origin of Landforms**
- **Cartographic Techniques, their applications & interpretations**

Number of lectures: 45

Unit 1:

(15 lectures)

Concepts of Geomorphology:

Energy for landform change, methods of dating.

Geomorphic Systems: people as Geomorphic Agents, People as creators of Landforms.

Structure controlled Landforms:

Landforms controlled by various structures like faults and folds and resulting peculiarities of drainage patterns

Volcanogenic landforms :

Energy of volcanic eruptions, Products of Volcano, Types of Volcanoes, Types of Eruptions, Landforms produced by Erosion of Volcanic features

Landforms controlled by predominantly Weathering process:

Landforms produced by weathering and the various processes that lead to the formation of Corestones, Tors, Pits, Pans, Caverns, Rills, Duricrust.

Landforms resulting from fluvial processes:

Concept of Fluvial Transport and Deposition, Formation of Alluvial Fans, Floodplains and Terraces, Alluvial river channels, Alluvial Bars, Braided Channels, Straight and Meandering Channels.

Unit 2:

(15 lectures)

Eolian Processes and Landforms:

Landforms resulting from Eolian Erosion, Transport and Deposition.

Coastal Processes and resulting Landforms:

Erosional landforms of the coast. Depositional landforms of the coast.

Influence of Current rates of Erosion, Climatic influences past and present, Sea level changes.

Karst Processes and resulting Landforms:

Limestone Solution and erosion rates.

Surface landforms in karst terrain, Minor solution Sculpture, Enclosed Depressions.

Karst landforms of fluvial erosion, Underground water, caves and springs.

Glaciers and resulting Landforms:

Ice Movement, Flow patterns, Forms of Glacier surfaces, Erosional and depositional landforms.

Unit 3:

(15 lectures)

Topographic Analysis:

Topographical profiles, Projected profiles, Superimposed profiles, Spur Profiles, Cross Valley Profiles, Geomorphological Mapping Using I.G.U symbols.

Slope Analysis:

Morphological Mapping by Savigear's Method. Average Slope Map, Generalized Contour Map.

Drainage Basin Analysis:

Drainage Basin as a Unit of Study. Discharge of Water from a Watershed, Hydrograph Shapes, Flood Frequency, Patterns of Discharge. Drainage basin morphometry – Linear and areal aspects.

References:

1. Wilson J.P. and Gallant J.C. (ed) (2000), Terrain Analysis Principles and Applications, John Wiley.
2. Saha P. and Basu P. (2004), Advanced Practical Geography - A laboratory Manual., Books and Allied (P) Ltd. Kolkata, India
3. King .C.A.M., (1967) Techniques in Geomorphology., Edward Arnold, London.
4. Misra R.P. and Ramesh A. (1989), Fundamentals of Cartography, Concept Publ. India.
5. Morisawa M. (1985), Rivers - Form and Process, Longman Publ.
6. Doornkamp J.C. and King C.A.M. (1971), Numerical Analysis in Geomorphology - an Introduction, Butler and Tanner, London.
7. Selby M.J. (1985), Earth's Changing Surface - An Introduction to Geomorphology, Oxford University Press.
8. Zavoianu I. (1985), Morphometry of Drainage Basins, Elsevier.
9. Mitchell C.W (1973), Terrain Evaluation, Longman
10. Judson S. and Kauffman M.E. (1990), Physical Geology, 8th edn. Prentice Hall
11. Robinson A. H, Sale R.D. and Morrison J.L. (1978), Elements of Cartography, 4th ed. John Wiley.

Practicals:

1. Measurement of lengths, and areas enclosed within curves. (1 session)
2. Projected Profiles, Superimposed Profiles and interpretation (1 session)
3. Longitudinal, Cross valley Profiles and interpretation (1 session)
4. Generalised contours, Altimetric frequency and interpretation (1 Session)

5. Drainage basin delineation on topographical map, Ordering streams using Strahlers scheme. (1 session)
6. Linear Aspects (Stream number, bifurcation ratios, weighted mean bifurcation ratios, regression of stream numbers vs. order) (1 session).
7. Linear aspects(stream lengths, length ratios and regression of stream lengths vs. order) (1 session)
8. Areal aspects – (delineating lower order basins and measuring the area of each, order wise and regression of basin areas vs. order) (1 session)
9. Hypsometric analysis (2 session)
10. Hypsometric analysis
11. Geomorphic mapping using IGU symbols (2 sessions)
12. Geomorphic mapping using IGU symbols



St. Xavier's College Mumbai

Syllabus for B.Sc IVth Semester Courses in Geology (November 2016 onwards)

Contents:

- Theory Syllabus for Courses:
- S.Geo.4.01 - Economic Geology
- S.Geo.4.02 - Optical mineralogy and Systematic Mineralogy
- S.Geo.4.03 - Field Geology and Hydrogeology
- Practical Course Syllabus for S.Geo.4.PR

S.Y. B.Sc. Geology
Title: Economic Geology

Course: S.Geo.4.01

Learning Objectives: To understand the fundamental processes involved in the formation and distribution of various ore deposits.

Number of lectures: 45

Unit 1

(15 lectures)

Introduction to economic mineral deposits

Introduction, definition of metalliferous and non-metalliferous deposits, ore mineral, gangue, tenor of ore, industrial minerals, overburden and country rock.

Classification of economically important metalliferous and non-metalliferous mineral deposits. Stratiform and stratiform ore deposits.

Structural and stratigraphic controls on mineralization, metallogenic epochs and provinces.

Ore genesis -I

Processes of formation of mineral deposits.

Magmatic concentration (early and late magmatic mineral deposits)

Sublimation and pegmatitic deposits

Unit 2

(15 lectures)

Ore genesis -II

Hydrothermal processes, cavity filling and metasomatism:

Hydrothermal processes: Principle, character of solution, types of openings in rocks, factors affecting deposition from hydrothermal solutions, wall rock alterations.

Cavity filling deposits: processes of formation and characteristic features of: fissure veins and its types (in brief), stock work, saddle veins, ladder veins, pitches and flats, breccia filling deposits, solution cavity fillings.

Contact Metasomatic Deposits: definition, criteria of replacement, resulting mineral deposits.

Sedimentation deposits, Metamorphic deposits

Evaporation deposits: brief account of non-metallic deposits of ocean water, lake water, ground water and hot springs.

Residual deposits: conditions favouring formation of residual deposits.

Mechanical concentration: principles and processes of formation of placer deposits (eluvial, alluvial, beach and aeolian).

Unit 3

(15 lectures)

Ore genesis - III

Oxidation and solution in the zone of oxidation, ore deposits in the zone of oxidation.

Supergene sulphide enrichment: requirements for supergene sulphide deposition, recognition of sulphide enrichment. Gossans and cappings, role of iron gossans, limonite and false gossans.

List of recommended reference books

1. Jensen M.R. and Bateman A.M. (1981), Economic mineral deposits, John Wiley & Sons.
2. Evans A.M. (1993), Ore geology and Industrial minerals, Blackwell Science.
3. Prasad U. (2000), Economic Geology - Economic Mineral Deposits, 2nd ed., CBS, India.

Practicals

Identification (with the help of physical properties), chemical composition, origin and Indian occurrences of Ore minerals and Industrial minerals of following minerals.

Barite	Ilmenite
Barytes	Kyanite
Bauxite	Limonite
Biotite	Magnesite
Calcite	Magnetite
Chalcopyrite	Malachite
Chromite	Marble
Cuprite	Muscovite
Dolomite	Psilomelane
Fluorite	Pyrite
Galena	Pyrolusite
Garnet	Serpentine
Graphite	Sphalerite
Gypsum	Stibnite
Hematite	Talc
	Tourmaline

Distribution of mineral deposits

Formation, association and Indian distribution of following ore minerals: Mica, Copper, Manganese, Lead and Zinc, Bauxite, Chromite, Gold

S.Y. B.Sc. Geology

Course: S.Geo.4.02

Title: Optical Mineralogy and Systematic Mineralogy

Learning Objectives:

To introduce the basic concept needed to understand the optical mineralogy and to learn the physical and optical properties and characteristics of common rock forming minerals.

Number of lectures: 45

Unit 1

(15 Lectures)

Optical Properties of Minerals:

Nature and behaviour of light: Non-polarised and Polarised light, Refraction and Refractive index, Double refraction, Nicol prism and Filter polaroid, Isotropic and Anisotropic substances, Polarizing Microscope: Its Construction and Working.

Optical characteristics: Relief, Becke's test, Twinkling, Pleochroism, Birefringence, Polarization colours, Newton's scale, Extinction and Extinction angle, Anomalous polarization colours, Uniaxial and Biaxial minerals, Optical indicatrix, Interference figures, Optic sign, Sign of elongation, Use of Quartz wedge, Mica plate and Gypsum plate.

Unit 2

(15 Lectures)

Systematic Mineralogy: part I

Stability relationships, Condition of formation, Crystallography, Physical and optical properties, Composition and structure, Diagnostic Features, Occurrence and Uses of:

Silica Group

Feldspar Group

Feldspathoid Group

Mica Group

Unit 3

(15 Lectures)

Systematic Mineralogy: part II

Stability relationships, Condition of formation, Crystallography, Physical and optical properties, Composition and structure, Diagnostic Features, Occurrence and Uses of:

Amphibole Group

Pyroxene Group

Olivine Group

Garnet Group

Zeolite Group

Clay minerals

List Of Recommended Reference Books

11. Read H.H. (Rev. ed. C.D. Gribble) (1988), Rutley's Elements of Mineralogy" (27TH Edition), CBS Publications.

12. Cornelius K. and Hurlbut Jr. S. (1994), Manual of Mineralogy, Twenty first Edition and Minerals and Rocks Exercises in Crystallography, J. Wiley & Sons.
13. Dana J.D. and Ford W.E. (rev. ed.) (2010), Dana's Manual of Mineralogy, J. Wiley & Sons.
14. Rogers A.F. and Kerr P.F. (1942), Optical Mineralogy (2nd Edition), McGraw- Hill Co. Inc., New York.
15. Berry L.G., Mason B.H. and Dietrich R.V. (1983), Mineralogy, concepts, descriptions, determinations, W.F. Freeman and Co.
16. Deer W.A., Howie A.H. and Zussman J. (1992), An introduction to rock forming minerals, Longman Scientific and Technical.
17. Shelly David (1985), Optical Mineralogy (2nd Edition), Elsevier.
18. Nesse W.D. and Schulze D.J. (2004), Introduction to Optical Mineralogy" (Third Edition) and An Atlas of Minerals in Thin Section, Oxford University Press.
19. Perkins Dexter (2011), Mineralogy (International Edition), Pearson Education.
20. Wenk H.R. and Bulakh A. (2004), Minerals: their constitution and origin, Cambridge University Press.

Practicals:

Mineralogy:

Study of Physical and Optical characters, mode of formation and occurrence in Rock types of the following :

Igneous rock forming minerals: Quartz, Orthoclase, Microcline, Albite, Labradorite, Leucite, Nepheline, Sodalite, Muscovite, Biotite, Hornblende, Augite, Aegirine, Hypersthene, Olivine, Tourmaline and Apatite.

Metamorphic rock forming minerals: Garnet, Staurolite, Chlorite, Talc, Serpentine, Actinolite, Tremolite, Anthophyllite, Epidote, Andalusite, Kyanite, Sillimanite, Calcite, Dolomite, Asbestos, Chrysolite, Magnesite.

Study of Physical properties, mode of occurrence and conditions of origin of the following Secondary minerals: Quartz (Rock crystal), Amethyst, Calcite (Rhombohedral, Scalenohedral & Nail-head spar), Stilbite, Scolecite, Mesolite, Chabazite, Laumontite, Apophyllite (Prismatic & Pyramidal), Gyrolite and Okenite.

S.Y. B.Sc. Geology

Course: S.Geo.4.03

Title: Field Geology and Hydrogeology

Learning Objectives:

Understanding of construction & working of field equipment, Outcrops observations, measurements, recordings & interpretations and Hydro geological concepts, exploration, exploitation & recharge of groundwater.

Number of lectures: 45

Unit 1

(15 Lectures)

Nature of Geologic Surveying:

Uses of geologic surveying, Diversity of Surveys, Scope of geological field-work.

Study of Outcrops, Importance of Contacts and Discrimination between different types of contacts. Discrimination of Strike and Dip.

Topographical Maps (SOI) - Map Index and Map Scale, Map folding, map reading. Study of Geological Maps and understanding Map Symbols.

Field Observations: Schedule for Field Observations. General Suggestions for Field work: Beginning a field problem. Collecting and trimming samples. Taking photographs.

Data recording and mapping in various terrains

Lava flow mapping- Mapping in igneous terrains

Field observations of sedimentary rocks

Data recording for structurally complicated terrains- foliations and lineations

Methods of Geologic Mapping:

Method of reconnaissance mapping – Contact mapping on topographical map, Tape and Compass, Detailed geological mapping using Plane Table survey.

Mapping of horizontal contacts using Altimeter: Its construction and use.

Unit 2

(15 lectures)

Ground Water:

Definition, Utilisation, Hydrogeologic Cycle, Subsurface movement of water, Zones of Groundwater. Definition of Watertable. Types of Aquifers. Presentation of Water Level data on Maps and Graphs. Natural and Artificial Discharge of Groundwater. Springs.

Occurrence of Groundwater:

Origin of groundwater. Rock properties affecting groundwater. Vertical distribution of groundwater. Geological formations as aquifers.

Groundwater Movement:

Darcy's Law, Coefficient of permeability. Groundwater flow rate. Laboratory and field measurements of permeability. Tracing groundwater movements. Groundwater flow-lines and flow-nets.

Unit 3

(15 lectures)

Surface Investigations for Groundwater:

Conventional methods – surface indicators of ground water, biological indicators , Test-drilling.

Geophysical log in ground water exploration:

Resistivity logging, Potential logging, Temperature logging.

Geophysical exploration for ground water:

Resistivity method and Seismic method.

Ground water recharge:

Artificial Recharge of Groundwater: Concept. Methods. Water Spreading, rain water harvesting. Waste water reused. Recharge mounds. Induced recharge.

List of recommended reference books

12. Coe, A.L (Ed) (2010) Geological field techniques, Wiley-Blackwell
13. Compton R.R. (1985), Geology in the Field., John Wiley and Sons.
14. Gokhale N.W. (2009), A Guide to Field Geology, CBS Publ. India
15. Berkman D.A. (1987), Field Geologists' Manual., Monograph Series 9., The Australasian Institute of Mining and Metallurgy, Victoria, Australia.
16. Mathur S.M. (2001), Guide to Field Geology., PHI Learning., India.
17. Todd D.K. (1980), Groundwater Hydrology, 2nd ed. John Wiley.
18. Bouwer H. (1978), Groundwater Hydrology., McGraw-Hill
19. Chorley R.J. (ed) (1969), Introduction to Geographical Hydrology., Metheun.

Practicals:

Calculation of true and apparent dip
Calculating rake and plunge of lineation
Plotting geological map and outcrop completion
Flow Nets.
Problems on permeability, porosity and rate of flow.
Water table contour map and its application



St. Xavier's College

Mumbai

Syllabus

For B.Sc Vth Semester Courses in Geology

(June 2016 onwards)

- Contents:
- Theory Syllabus for Courses:
 - S.Geo.5.01 –Precambrian Geology of India
 - S.Geo.5.02 – Igneous Petrology
 - S.Geo.5.03 - Structural Geology
 - S.Geo.5.04 –Metamorphic Petrology
 - S.Geo.5.AC- Remote Sensing and Image Interpretation
- Practical Course Syllabus for: S.Geo.5. PR and S.Geo.5.AC.PR
- Evaluation and Assessment guidelines.

T.Y. B.Sc. Geology
Title: Precambrian Geology of India

Course: S.Geo.5.01

Learning Objectives:

1. To bring about an understanding of the principals of Stratigraphy.
2. Understand the Precambrian Stratigraphy of India.

Number of lectures: 60

Unit 1

Introduction

(15 lectures)

Earth's Crustal Structure and Tectonic framework of India- Cratons.

Tectonic Elements of Continents & Oceans.

Tectonic Divisions of India.

Indian Cratons:

DharwarCraton,

BastarCraton,

SinghbhumCraton

AravalliCraton

Unit 2

Proterozoic History

(15 lectures)

Proterozoic Sedimentary Basins:

Vindhyan

Basin,

Delhi Basin

Cuddapah& Kurnool Basins.

Kaladgi Basin.

Unit 3

Mobile Belts

(15 lectures)

Proterozoic Eastern Ghat Mobile Belt

Marginal & Transition Zone

Western Charnockite Zone

Western & Eastern Khondalite Zone.

Satpura Mobile Belt

Central Indian Tectonic Zone

Sausar, Mahakoshal&BetulSupracrustal Belts.

Unit 4

Precambrians of Extra – Peninsula

(15 lectures)

Precambrian of Himalaya (Lesser & Higher Himalayas)

Precambrian of the Tethyan Basement

Salkhala Group

Vaikrita Group

Jutogh Group

Daling Group

Precambrians of the Lesser Himalaya

Western Sector

Central Sector
Eastern Himalaya

List Of Recommended Reference Books

1. Dasgupta, A. (2010) Phanerozoic Stratigraphy of India; World Press, Kolkata.
 2. Ramakrishnan, M. and Vaidhyanadhan, R. (2010) Geology of India - Vol. 1, Geological Society of India, Bangalore.
 3. Vaidhyanadhan, R. and Ramakrishnan, M. (2008) Geology of India - Vol. 2, Geological Society of India, Bangalore.
 4. Prasad, C.V.R.K. (2005) Elementary Exercises in Geology; Universities Press (India) Pvt. Ltd, Hyderabad.
 5. Directorate of Geology and Mining, Nagpur. (2000) Geology and Mineral Resources of Maharashtra.
 6. Deshpande, G.G. (1998) Geology of Maharashtra; Geological Society of India, Bangalore.
 7. Kumar, R. (1996) Fundamentals of Historical Geology and Stratigraphy of India, 4th ed., New Age International (P) Limited, Publishers.
 8. Lemon, R.R. (1990) Principles of Stratigraphy; Merrill Publishing Company, Ohio.
 9. Wadia, D.N. (1984) Geology of India, 4th ed., Tata McGraw-Hill Publishing, New York.
 10. Krishnan, M.S. (1982) Geology of India and Burma; 6th Ed. CBS Publishers & Distributors (India).
-

Practical:

Stratigraphy and Geology of India

- I) Study of common sedimentary, igneous and metamorphic rocks in Hand specimen from different stratigraphic horizons.
- II) Diagrammatic examples of Lithostratigraphic boundaries and classification.
- III) Study of Geological maps with geological history of the area in chronological order.
- IV) Problems:
 - a) Stratigraphic sequence from geological section.
 - b) Characteristics of a Fold & Fault from a geological map.
 - c) Stratigraphic Boundary Problem.
 - d) Understanding Precambrian Geological Time Scale.

T.Y. B.Sc. Geology
Title: Igneous Petrology

Course: S.Geo.5.02

Learning objective:

To provide students a systematic approach in understanding the origin of igneous rocks, nomenclature, classification and their association with particular tectonic settings.

Number of lectures: 60

Unit-1

(15 lectures)

The Interior of the Earth:

Evidence of the Earth's Composition and Mineralogy: Seismic data, The Geothermal Gradient, Meteorites, Xenoliths.

Mantle Petrology; Low Velocity Zone, Pressure and Temperature variations with Depth and high pressure experimentation.

Classification and Description of Igneous Rocks:

The IUGS Classification System, Other aspects of classification; Chemical Classification;

Textures of Igneous rocks,

Crystallinity, Granularity, Shape of Crystals and Mutual Relations.

Equigranular, Inequigranular, Directive and Intergrowth Textures.

Terms related to some specific Textures and Microstructures :Perlitic Cracks, Spherulites, Orbicular Structure, Rapakivi Structure, Zoned Crystals, Xenocrysts, Quench Texture, Crystal Pseudomorph, and Cumulus Crystals.

Characters of the Common Igneous Rocks: Plutonic and Volcanic types; Examples of Common Igneous Rock Types and their Indian Occurrences.

Unit 2

(15 lectures)

The Phase Rule and crystallization and melting relations in one, two and three component Systems:

Melting Behavior of Natural Magmas, Phase Equilibrium and The Phase Rule, One Component Systems, Two Component (Binary Systems) and Its Petrogenetic Significance.

Binary Systems with Complete Solid Solution, Binary Eutectic Systems, Binary Peritectic Systems, the Alkali Feldspar System,

Ternary Systems:- Ternary Eutectic Systems, Ternary Systems with Solid Solution

Reaction Series, The Effect of Pressure and Fluid on Melting Behavior. The effects of Pressure on the Melting and Crystallization of Magma; Time and Crystallization; Rock Types and Mode of Occurrence.

Unit 3

(15 lectures)

The Evolution of Magmas:

Differentiation: Fractional Crystallization; Other Differentiation Mechanisms.

Magmatic Mixing and Assimilation.

Melting of the Mantle, Partial Melting, Magma Generation and Differentiation.
Generation of Basaltic magma from a Chemically Uniform Mantle.

Unit 4

(15 lectures)

Brief study of Plate tectonic settings and associated igneous rocks.

Subduction –Related Activity: Island Arc Volcanism, Rocks and Magma Series, The Ophiolite Suite; Calcalkaline and Tholeiite Groups; Petrogenesis of Island Arc Magmas, Plutonic Rocks – Batholiths related to subduction zones.

Gabbroic Layered Intrusions; Anorthosites; Alkali Basalts and Nephelinites; Carbonatites, Kimberlites and related Rocks.

List Of Recommended Reference Books

1. Bose M.K. (1997), Igneous Petrology. The World Press Pvt. Ltd. 568 p.
2. Bowen N.L. (1928), The evolution of Igneous Rocks. Princeton Univ. Press. N.J 332 p.
3. Hall A. (1987), Igneous Petrology. Longman. 573p.
4. Hatch F.H., Wells A.K and Wells M.K. (1984), Petrology of the igneous rocks. CBS Publishers, 551 p.
5. Philpotts A.R. (1994), Principles of igneous and metamorphic Petrology, Prentice Hall of India. 498p.
6. Turner F.J &Verhoogen J. (1951), Igneous and Metamorphic Rocks, McGraw Hill.
7. Williams H, Turner F.J & Gilbert C.M. (1955), Petrography. San Francisco: W.H. Freeman and company. 406p
8. Winter J. D. (2001), an Introduction to Igneous and Metamorphic Petrology, Prentice Hall, 697p.
9. Ehlers, E.G. and H. Blatt (1982), Petrology, Igneous, Sedimentary and Metamorphic, W.H Freeman, San Francisco.
10. Philpotts A. R. (2009), Petrography of Igneous and Metamorphic Rocks, Cambridge University Press, 686p.

Practical Course:

Megascopic identification and Petrography of Igneous Rocks

Igneous Textures.

Equigranular:

- a. Coarse –grained, Holocrystalline, Panidomorphic.
- b. Coarse –grained, Holocrystalline, Hypidiomorphic
- c. Medium –grained, Holocrystalline, Hypidiomorphic
- d. Fine –grained, Holocrystalline, Panidomorphic. (Orthophyric)
- e. Fine –grained, Holo/ Hemicrystalline, Hypidiomorphic
- f. Fine-grained, Holocrystalline, Allotriomorphic (Aplitic)
- g. Fine- grained, Hemicrystalline, Aphanitic, (Felsitic)
- h. Fine –grained, Holohyaline, Aphanitic

Inequigranular:

- a. Coarse/Medium/Fine, Holo/Hemicrystalline, Porphyritic
- b. Coarse/Medium/Fine, Holo/Hemicrystalline, Glomeroporphyritic
- c. Coarse/Medium, Holo/Hemicrystalline, Ophitic/ Subophitic
- d. Medium/ Fine, Holo/Hemicrystalline, Poikilitic
- e. Medium/Fine, Holocrystalline, Intergranular
- f. Medium/Fine, Hemicrystalline, Intersertal
- g. Medium/Fine, Intergranular-cum-ophitic (Ophimottling)

Directive:

- a. Fine, Hemicrystalline/Holohyaline, Banded (Fluidal)
- b. Fine, Hemicrystalline, Trachytic

Intergrowth:

- a. Graphic/Micrographic
- b. Perthitic
- c. Granophyric

Igneous Mega-Structures

1. Vesicular/ Amygdaloidal Lava
2. Blockery/ Clinkery Lava
3. Ropy Lava Surface
4. Columnar Joint Block
5. Flow Banding
6. Glomeroporphyritic Clusters
7. Intrusive Contacts and Xenoliths

Igneous Micro-Structures

1. Reaction: (a. Corona , b. Myrmekite)
2. Xenolithic
3. Spherulitic/ Variolitic
4. Perlitic Fracture

Study of the Texture, Mineral composition, Mode of occurrence, and Association of the following Rock Types.

1. Granite
2. Rhyolite
3. Pegmatite
4. Aplite
5. Quartz porphyry
6. Pitchstone
7. Obsidian
8. Syenite (Hornblende / Biotite)
9. Trachyte
10. Feldspar porphyry
11. Nepheline Syenite

12. Diorite
13. Gabbro
14. Norite
15. Dolerite
16. Basalt (Vesicular/ Non- Vesicular/ Porphyritic, Amygdaloidal)
17. Picrite
18. Peridotite
19. Dunite
20. Anorthosite
21. Carbonatite

T.Y.B.Sc Geology

Course: S.Geo.5.03

Title: Structural Geology

Learning Objectives:

To understand the concept of stress and strain and how rock behaves under different stress regimes.
A detailed study of various geological structures i.e. Joints, Folds and Faults

Number of lectures: 60

Unit 1

(15 lectures)

Introduction, Types of Structures, Stress, Strain, Measurements of Stress and Strain, Mechanical Behaviour of Rocks

Introduction and Review

Structures and Structural Geology

Fundamental Concepts

Stress

Definitions

Stress on a Plane

Stress at a Point

Mohr Construction

Mohr's Hypothesis

Stress Ellipsoid

Strain

Definitions

Kinds of Strain

Strain Ellipsoid

Mohr Circles for Strain

Simple and Pure Shear

Measurement of Strain in Rocks

Kinds of Strain

Strain Markers

Flinn Diagram

Mechanical Behavior of Rock Materials

Elastic (Hooken) Behavior

Permanent Deformation – Ductility

Controlling Factors

Unit 2

(15 lectures)

Study of Structures I: Joints and Faults

Joints and Shear Fractures

Griffith and Coulomb theory of fractures

Joints and Fracture Mechanics

Classification of joints

Fault Classification and Terminology

Anatomy of Faults
Criteria for Faulting

Fault Mechanics

Anderson's Fault Types
Brittle versus Ductile Faults
Shear Zones
Shear – Sense Indicators

Thrust Faults

Nature of Thrust Faults
Detachment within a Sedimentary Sequence
Small – Scale Features of Thrust Sheets

Strike – Slip Faults

Properties and Geometry
Environments of Strike – Slip Faulting
Fault Geometry and Other Fault Types
Termination of Strike – Slip Faults
Transforms

Normal Faults

Properties and Geometry

Unit 3

(15 lectures)

Study of Structures II: Folds-I

Fold Geometry and Classifications

Descriptive Anatomy of Simple Folds
Map – Scale Parallel Folds and Similar Folds
Recognition of Folds

Fold Classifications

Based on interlimb angle
Ramsay standard classification

Noncylindrical and Sheath Folds

Fundamentals of Parallel Folds and Similar Folds

Complex Folds

Identification of overturned folds

Occurrence and Recognition
Fold Interference Patterns
Recognition of Multiple Fold Phases

Unit 4.

(15 lectures)

Study of Structures II: Folds-II

Fold Mechanics

Fold Mechanisms and Accompanying Phenomena
Deformation Mechanisms and Strain
Theory of progressive evolution of fold shapes in single competent layers.
Layer parallel shortening
Dependence of fold shape on viscosity contrast in a single layer buckles
High competence contrast, Low Competence contrast

Zone of contact strain and its interrelationship with buckle folds
Change of fold shape with packing distance of competent layers
Fold styles in multilayers

List Of Recommended Reference Books

1. Fossen, H. (2010), Structural Geology, Cambridge University Press
2. Hobbs D.W., Means W.D. And Williams P.F. (1976), An Outline of Structural Geology, John Wiley.
3. Benninson, G and Moseley, K. (2003), An introduction to geological structures and maps, 7th edition, Arnold Publications
4. Lisley, R (2003) Geological structures and maps: a practical guide, Butterworth-Heinemann Ltd.
5. Billings M.P. (1972), Structural Geology, 3rd ed., Prentice- Hall, Inc., Englewood cliffs, New Jersey.
6. Ragan D.M. (1968), Structural Geology- An Introduction to Geometrical Techniques, 2nd ed., John Wiley and Sons.
7. Ramsay J.G. and Huber M.I. (2002), The Techniques of modern structural geology, 2nd ed., Vol. 2, Elsevier Science Ltd.

Practical Course:

- Profiles and cross sections of geological maps with showing various structural features: folds, faults, dykes, two series of dipping beds. (8 maps atleast)
- Patterns of dipping strata; Three-Point problems.
- Trigonometric solution of fault problems
- Equal-area net part I
 - a. Plotting a line that lies in a plane
 - b. Determining the angle between two lines
 - c. True strike and Dip from apparent dips
 - d. Attitude of intersection of two planes
- Equal-area net part II
 - a. Determining the angle between two planes
 - b. Determining the orthographic projection of a line on a plane
 - c. Determining the angle between a line and a plane
 - d. Bisecting the angle between two lines
 - e. Bisecting the angle between two planes

T.Y. B.Sc. Geology
Title: Metamorphic Petrology.

Course: S.Geo.5.04

Learning Objectives:

As a branch of petrology, metamorphic petrology deals with the change in rock structure, composition and texture based on the varying pressure and temperature conditions. This course aims at preparing the learner for appreciating the processes that lead to such changes. The learner will be able to identify in hand specimen as well as through petrographic examination, the various rocks.

Number of lectures: 60

Unit 1:

(15 lectures)

Introduction to Metamorphic Petrology

Definition of metamorphism.

Agents of metamorphism

Types of Metamorphism

Introduction to metamorphic fluids

Metasomatism and examples of metasomatism

Classification of Metamorphic rocks

Textures and structures of metamorphic rocks

Unit 2:

(15 lectures)

Thermodynamics and metamorphism

Phase rule and phase diagrams

Introduction to chemographic projections

Types of metamorphic reactions

Concept of metamorphic facies

Unit 3:

(15 lectures)

Metamorphism- types and products-I

Metamorphism of basic rocks and their facies

UHP and UHT metamorphism of basic rocks

Introduction to P-T-t paths

Metamorphism of pelitic rocks- Barrovian zones

Partial melting and migmatites

Unit 4:

(15 lectures)

Metamorphism- types and products-II

Metamorphism of carbonate rocks- Contact and regional

Zones of metamorphism of calc-silicate rocks

Charnockites and Khondalites-Granulites with reference to Indian examples

Porphyroblasts and Tectonism: pre-, syn- and post- tectonic porphyroblasts

Introduction to paired metamorphic belts

List Of Recommended Books:

1. Winter J.D (2013) Principles of Igneous and Metamorphic Petrology (Second Edition), PHI Learning Private Limited, Delhi.
2. Williams H, Turner F.J & Gilbert C.M. (1955), Petrography, W.H. Freeman and company. San Francisco, 406p.
3. Greensmith J. (1989), Petrology of the Sedimentary rocks (7th Edition), C.B.C. Publishers, New Delhi.
4. Blatt H., Tracy R.J. and Owens B.E. (2006), Petrology – Igneous, sedimentary and Metamorphic (3rd Edition), W.H. Freeman and Company, New York.

5. Yardley Bruce W.D. (1989), An Introduction to Metamorphic Petrology, Longman Singapore Publishers (Pvt.) Ltd.
6. Harker Alfred (1974), Metamorphism, Chapman and Hall, London.
7. Turner F.J and Verhoogen J. (1960), Igneous and Metamorphic Petrology, McGraw-Hill.
8. Bayley B. (1996), Introduction to Petrology, Prentice Hall, New York.
9. Miyashiro A. (1998), Metamorphism and Metamorphic Belts, George Allen &Unwin, New York.
10. Mason Roger (1984), Petrology of the Metamorphic Rocks, CBS Publishers and Distributors, New Delhi.
11. Winkler Helmut G.F. (1987), Petrogenesis of Metamorphic Rocks (Fifth Edition), Narosa Publishing House, New Delhi.
12. Philpotts A and Ague J. (2009) Principles of Igneous and Metamorphic Petrology (Second Edition), Cambridge University Press, UK.

Practical Course:

Calculations of stable mineral composition at equilibrium

Megascopic and Microscopic Identification of Metamorphic Rocks.

Metamorphic Textures

1. Idioblastic
2. Porphyroblastic
3. Granuloblastic
4. Xenoblastic

Metamorphic Structures

1. Cataclastic
2. Slaty cleavage
3. Maculose
4. Granulose
5. Schistose
6. Gneissose

Metamorphic Rocks

1. Quartzite
2. Marble
3. Slate
4. Phyllite
5. Mica Schist (with Staurolite/ Garnet)
6. Actinolite/ Chlorite Schist
7. Mica- Gneiss
8. Hornblende Gneiss.
9. Granulite
10. Eclogite
11. Serpentinite
12. Khondolite
13. Charnockite

T.Y. B.Sc. Geology

Course: S.Geo.5.AC

Title: Remote Sensing and Image Interpretation

PRE-REQUISITES: Courses S.Geo.3.0 and S.Geo.4.0

Additional Requirements (Recommended): Laptop Computer.

Learning Objectives:

Gathering data about various earth surface features through space and air borne sensors has been effectively used for understanding and analyzing various phenomenon ranging from vegetation , agriculture, natural resources mapping and exploitation to environment monitoring. Remote sensing is today an integral part of any study that needs inputs in the form of spatial and spectral reflectance of earth's surface characteristics. This course, aimed at all learners with a background in the earth sciences, will develop skills in understanding how the satellite image data is acquired and interpreted. The use of printed satellite imageries as well as data in digital form will result in the learner also developing the necessary competence in automated classification of satellite image data.

Number of lectures: 60

Unit 1

(15 lectures)

Concepts of Remote Sensing

Concepts and Foundations of Remote Sensing

Definition of Remote Sensing.

Energy Sources and Radiation Principles.

Energy interactions in the Atmosphere: Scattering, Absorption.

Energy interactions with earth surface features: Spectral Reflectance of Vegetation, Soil and Water,

Spectral response patterns, Atmospheric Influences on Spectral Response Patterns.

Brief history of Remote Sensing from the advent of photography till today's aerial and space-based remote sensing systems.

The concept of resolution: Spatial, Spectral, Temporal and Radiometric.

Unit 2

(15 lectures)

Satellite Sensors and Data

Space Borne Imaging Systems- The Landsat, IRS, SPOT and High resolution Land Satellites
(the characteristics of these satellites- their orbits, their sensors, and their resolutions)

Multispectral, Thermal and Hyper spectral Sensing

Across track scanning.

Along track scanning.

Operating principles of Across track Multispectral Scanners.

Across track Thermal scanning.

Thermal Radiation principles.

Unit 3

(15 lectures)

Introduction to Digital Image Processing

Introduction.

Image Rectification and Restoration.

Image Enhancement.

Contrast Manipulation.
Spatial Feature Manipulation.
Multi-Image Manipulation.

Unit 4

(15 lectures)

Digital Imaging classification

Image Classification: Supervised Classification.

The Classification Stage: Minimum-Distance to Means Classifier, Parallelepiped Classifier, Gaussian Maximum Likelihood Classifier.

The Training Stage.

Unsupervised Classification.

Classification Accuracy Assessment.

List Of Recommended Reference Books

1. Drury S.A., (1993), Image Interpretation in Geology, 2nd ed., Chapman and Hall, London.
 2. Jensen John R. (2000), Remote Sensing of the Environment – An Earth Resource perspective, Pearson Education Series, Low Price Edition.
 3. Lillesand T. M., Ralph W. Kiefer and Jonathan W. Chapman (2004), Remote Sensing and Image Interpretation, 5thed, Wiley.
 4. Mather Paul M., (2004), Computer Processing of Remotely Sensed Images- An Introduction, 3rd ed., John Wiley.
 5. Narayan L.R.A. (1999), Remote Sensing and its Applications., Universities Press.
 6. Ramasamy S.M., (2005), Remote Sensing in Geomorphology, New India Publishing Agency.
 7. Schowengerdt Robert A., (2006), Remote Sensing – Models and Methods for Image Processing, 2nd ed., Elsevier (Academic Press).
 8. Wanless Harold R. (1969), Aerial Stereo Photographs, Hubbard Press, USA.
-

Practical Course:

Remote Sensing and Image Processing

- Interpretation of Satellite Imagery for – landforms, geological structures, rock and soil types, man made structures.
 - Data Products and Meta data
 - Digital Image Processing (using number matrix): enhancement, manipulation and classification.
 - Digital image processing on Computer
 - Display of various types of image formats
 - Pallets and Display elements
 - Georeferencing
 - Image enhancement
 - Image classification
-



St. Xavier's College Mumbai

Syllabus for B.Sc VIth Semester Courses in Geology (November 2016 onwards)

Contents:

- Theory Syllabus for Courses:
 - S.Geo.6.01 – Phanerozoic Geology of India
 - S.Geo.6.02 - Sedimentary Petrology
 - S.Geo.6.03 - Engineering Geology
 - S.Geo.6.04 - Photogrammetry, Photo Interpretation & Fundamentals of GIS
 - S.Geo.6.AC-Gemmology
- Practical Course Syllabus for S.Geo.6.PR
- Practical Course Syllabus for S.Geo.6.AC.PR
- Evaluation and Assessment guidelines.

T.Y. B.Sc. Geology
Title: Phanerozoic Geology of India

Course: S.Geo.6.01

Learning Objectives: To bring about an understanding of the principals of stratigraphy and Understand thePhanerozoic stratigraphyof India.

Unit 1:

(15 lectures)

Palaeozoic History

Tectonic History
Precambrian Cambrian Boundary
Marine Palaeozoic Formations of India
 Kashmir Basin
 Spiti Basin
Krol Basin

Unit 2:

(15 lectures)

Mesozoic History

Tectonic History
Permian Triassic Boundary
Marine Mesozoic Formations of India - Kashmir Basin
Marine Transgressive Sequences of Kachchh and Tiruchirapalli.

Unit 3:

(15 lectures)

Gondwana Sequence of India

Sedimentation and Palaeoclimates
Lower Gondwana Sequence of different basins.
Upper Gondwana Sequence of different basins.

Unit 4:

(15 lectures)

Cenozoic History

Tectonic History
Boundary Problems
Indian Palaeogene - Neogene Formations:
 Siwalik Supergroup
 Assam –Arakan Region
 Andaman-Nicobar Islands
Sirmur Group
Geology and Stratigraphy of Maharashtra
Deccan Flood Basalts.

Reference Books:

1. Dasgupta, A. (2010) Phanerozoic Stratigraphy of India; World Press, Kolkata.
2. Deshpande, G.G. (1998) Geology of Maharashtra; Geological Society of India, Bangalore.
3. Directorate of Geology and Mining, Nagpur. (2000) Geology and Mineral Resources of Maharashtra.
4. Krishnan, M.S. (1982) Geology of India and Burma; 6th Ed. CBS Publishers & Distributors (India).
5. Kumar, R. (1996) Fundamentals of Historical Geology and Stratigraphy of India, 4th ed., New Age International (P) Limited, Publishers.
6. Lemon, R.R. (1990) Principles of Stratigraphy; Merrill Publishing Company, Ohio.
7. Prasad, C.V.R.K. (2005) Elementary Exercises in Geology; Universities Press (India) Pvt. Ltd, Hyderabad.
8. Ramakrishnan, M. and Vaidhyanadhan, R. (2010) Geology of India - Vol. 1, Geological Society of India, Bangalore.
9. Vaidhyanadhan, R. and Ramakrishnan, M. (2008) Geology of India - Vol. 2, Geological Society of India, Bangalore.
10. Wadia, D.N. (1984) Geology of India, 4th ed., Tata McGraw-Hill Publishing, New York.

Practical Course:

Stratigraphy and Geology of India, Maharashtra and Mumbai

- V) Study of characteristic index fossils of a particular stratigraphic horizon.
- VI) Diagrammatic examples of Lithostratigraphic boundaries and classification.
- VII) Study of Geological maps with geological history of the area in chronological order.
- VIII) Problems:
 - e) Stratigraphic sequence from geological section.
 - f) Interpretation of depositional environments for stratigraphic sequences.
 - g) Stratigraphic Boundary Problem.
 - h) Understanding Phanerozoic Time Scale.

T.Y B.Sc. Geology

Course: S.Geo.6.02

Title: Sedimentary Petrology

Learning Objectives:

To understand the various provenances, processes of formation and environments of deposition of sedimentary rocks.

Number of Lectures - 60

Unit 1:

(15 lectures)

Introduction

Origin, transportation and deposition of sediments.

Classification of Sedimentary rocks

Basin, environment and facies concept.

Field techniques:

Sedimentary structures- Basic measurements and data records

Sketches and lithologs

Sediment interpretation in cores

Sedimentary Texture analysis:

Grain Size scales and laboratory methods of analysis

Shape analysis

Concept of maturity

Unit 2:

(15 lectures)

Siliciclastic sedimentary rocks

Sandstones

Field observations

Petrography and classification

Heavy minerals and other provenance indicators

Concept of diagenesis and authigenesis

Conglomerates and breccia

Classification and field observations

Depositional environments for sandstones and conglomerates

Mudrocks:

Field Observations: Textures, Structures, Colour, Nomenclature

Laboratory Studies: Mineral composition and provenance.

Unit 3:

(15 lectures)

Limestones and dolomites

Field Observations

Components and mineralogy of limestones

Classification of limestones and petrography

Carbonate diagenesis

Dolomitization and dedolomitization

Silicification of limestone

Carbonate depositional environments

Unit 4:

(15 lectures)

Other Types of Sedimentary Rocks:

Evaporites-

Origin of Giant Evaporite Deposits

Palaeoclimatic interpretation from evaporites

Bedded Cherts and Phosphate Rocks- Origin, mineralogy and types

Coal and petroleum

Organic deposits- Modern and ancient

Coal petrology

Oil shales

Formation of Kerogen and Petroleum

Volcaniclastic sediments- Types and field characters.

List Of Recommended Books:

1. Collinson J.D and Thompson D.B (2006), Sedimentary Structures (2nd Edition),
2. Lindholm R.C. (1987), A practical approach to Sedimentology, Allen and Unwin, London.
3. Nichols, G. (2009), Sedimentology and stratigraphy (2nd Edition), Wiley India.
4. Pettijohn F.J. (1984), Sedimentary Rocks (3rd Edition), CBS Publishers and Distributors, New Delhi.
5. Staw, A.V.D (2005), Sedimentary rocks in the field: A colour guide, Manson Publishing, London.
6. Tucker, M. E (2001), Sedimentary Petrology (3rd Edition), Blackwell Science Ltd. Unwin Hyman Ltd, Sydney.

Practical Course

Megascopic and Microscopic Identification of Sedimentary Rocks.

Sedimentary Textures. (Clastic)

Rudaceous (Conglomeratic/ Brecciated), Arenaceous (Gritty/ Sandy), Argillaceous

Sedimentary Structures

1. Parallel bedding
2. Current Bedding
3. Graded Bedding
4. Ripple Marks
5. Rain Imprints
6. Concretions/Secretions

Grain size and shape analysis

Preparation of lithologs and sections

Paleocurrent analysis

Identification and description of heavy minerals

T.Y.B.Sc. Geology
Title: Engineering Geology

Course: S.Geo.6.03

Learning Objectives: To understand the engineering properties of rocks and their use as construction material. Detailed study of various geological and geotechnical investigations for various civil engineering projects. To understand the impact of Geological activities on the environment.

Number of lectures: 60

Unit 1:

(15 lectures)

Engineering Properties of Rocks:

Specific Gravity
Porosity
Sorpton
Compressive Strength
Tensile Strength
Elasticity of Rocks
Residual Stress and Shear Stress in Rocks.

Engineering properties of soil

Soil classification
Soil gradation
Compressive and shear strength
Atterberg limits
Consolidation and swelling of clays

Unit 2:

(15 lectures)

Rocks as Construction Materials:

Types of Rocks used in construction: How are they obtained in nature? Use of Rocks as facing stone. Factors influencing Engineering usefulness of Rocks.

Use of Rocks as aggregates: Use of rock as an aggregate in different types of constructions, sources of different grades of aggregates. Properties of aggregates (Shape, Size, Surface Texture, Roundness, Coating), Cement aggregate reaction, Thermal effects on aggregate. Highway aggregate, Rail – road ballast, Runway aggregate.

Source of Rock aggregate:

Types of quarries, Exploration for quarries, processing of aggregates.

Source of sand and gravel

Unit 3:

(15 lectures)

Geological and Geotechnical investigations for Civil Engineering Projects:

Tunnels: Terminology, Geological conditions for tunnel sites, Tunnels in folded rocks and bedded rocks. Influence of divisional planes, Effects of faults, Crushed zones, Tunnels near slopes, Role of Groundwater in tunneling.

Landslides: Causes, types and prevention of landslides. Influence of divisional planes, effects of faults, Crushed zones.

Bridges: Classification, abutments, foundations, investigations for site selection.

Unit 4

Geological and Geotechnical investigations for Civil Engineering Projects:

Dams and Reservoirs: Geological conditions for the selection of dam and reservoir sites. Terminology associated with dams. Types of dams: Masonary Dams (Gravity Buttress and Arch types), Earthen dams. Types of spillways. Locations of all the important dams and Hydro – electric projects in India.

Dam failures-causes and case studies.

List Of Recommended Reference Books

Engineering Geology

8. Narayanswami S.B.S. (2000), Engineering Geology, DhanpatRai& Co, India.
9. Legget F. R and Hatheway A.W. (1988), Geology and Engineering., 3rd ed. McGraw-Hill.
10. Gupte R.B.(1992), A Textbook of Engineering Geology.2nd ed. Pune VidyarthiGrihaPrakashan.
11. Krynine D.P. And Judd W.R (2003), Principles of Engineering Geology and Geotechniques, CBS Publishers.
12. Wahlstrom E.E. (1974), Dams, Dam Foundations and Reservoir Sites. Elsevier Scientific.
13. Dunn I.S., Anderson L.R and Kiefer F.W. (1980), Fundamentals of Geotechnical Analysis, John Wiley.
14. Maslov N.N. (1987), Basic Engineering Geology and Soil Mechanics. Mir Publishers.
15. Gokhale K.V.G.K and Rao D.M. (1981), Experiments in Engineering Geology. Tata McGraw-Hill.

Practical Course:

Engineering Geology

- Geological maps to demarcate and evaluate the suitability of sites for engineering projects such as Tunnels, Dams and Reservoir construction.
- Correlation of borehole data.
- Determining uniaxial compressive strength of rocks.
- Equal-area net
 - a) Locus of rotating line
 - b) Determining core-pole angle and orientation of plane in recovered core
 - c) Determining slope stability
 - d) Determining orientation of bed in rotational fault

T.Y. B.Sc. Geology

Course: S.Geo.6.04

Title: Photogrammetry, Aerial Photo Interpretation and Fundamentals of Geographical Information Systems

Learning Objectives:

- 1.To bring about an understanding of the principles of Photogrammetry and about the various analytical techniques used. To understand the construction and working of various instruments used in the process of aerial photo interpretation
- 2.Understand the principles of GIS and study its application in Earth Sciences.

Number of lectures: 60

Unit 1

(15 lectures)

Principles of Aerial Photography

Early history of aerial photography;

Aerial cameras, Film resolution.

Electronic Imaging, Aerial Videography.

Basic Geometric Characteristics of Aerial Photographs: Geometric types of Aerial Photographs,

Taking Vertical Aerial Photographs, Geometric Elements of Vertical Photograph.

Photographic Scale.

Ground Coverage of Aerial Photographs.

Area Measurement on aerial photographs.

Unit 2

(15 lectures)

Principles of Photogrammetry:

Relief Displacement of Vertical Features in aerial photographs.

Characteristics of Relief Displacement,

Object height determination from Relief Displacement Measurement.

Correction for Relief Displacement.

Image Parallax: Characteristics of Image Parallax, Parallax Measurement.

Ground Control for Aerial Photography.

Mapping with Aerial Photographs: Stereoscopic Plotting Instruments, Orthophotos,

Photogrammetric Work Stations.

Flight Planning.

Unit 3

(15 lectures)

Aerial Photo Interpretation:

Fundamentals of Visual Image Interpretation.

Basic Visual Image Interpretation Equipment- Construction and Working.

Land-use/Land cover mapping.

Geologic and Soil mapping.

Water Resource Applications.

Archaeological Applications.

Environmental Assessment

Principles of Landform Identification.

Unit 4

(15 lectures)

Basics of Geographical Information Systems

Definitions of GIS

The components of a geographical information system.

Basic requirements for a GIS.

Data Models: Conceptual models of real world geographical phenomena.

Conceptual models of space.

Geographical Data models: Vector models of Entities – Simple points, lines and polygons.

Raster Data Structures-The grid CellData Types: Boolean, Nominal, Ordinal, Integer, Real, Topological.Data Input: Sources of Geographical Data, Geographical data Collectors and providers. Geo-referencing.

Reference Books:

1. Lillisand Thomas M., Ralph W. Kiefer and Jonathan W. Chapman, (2004), Remote Sensing and Image Interpretation, 5th ed., Wiley.
2. Jensen John R., (2007), Remote Sensing of the Environment – An Earth Resource perspective, 2nd ed. Pearson Education Series.
3. Linder Wilfried (2003), Digital Photogrammetry- Theory and Applications, Springer.
4. Ramasamy S.M. (2005), Remote Sensing in Geomorphology, New India Publishing Agency.
5. Misra R.P. and Ramesh A. (1999), Fundamentals of Cartography, 2nd ed., Concept Publishing Company. New Delhi.
6. Longley Paul A, Michael F. Goodchild, David J. Maguire and David W. Rhind (2005), Geographic Information Systems and Science, 2nd ed., Wiley
7. Nag P. and SenguptaSmita(2008), Introduction to Geographical Information System., Concept Publishing Company, New Delhi.
8. Burrough Peter A. and Rachael A. McDonnell (1998), Principles of Geographical Information Systems, Oxford University Press.
9. Chang K. (2002), Introduction to Geographical Information Systems, Tata McGraw-Hill Edition.
10. Morain Stan and Shirley Lopez Baros (ed.) (1996), Raster Imagery in Geographical Information Systems., Onward Press.
11. Davis Bruce E (1996), GIS – A Visual Approach., Onward Press.

Practical Course:

- Test and Exercise for Stereoscopic vision
- Determination of Photo Scale and numerical problems on photo scale.
- Orientation of Stereographic pair of aerial photographs under a mirror stereoscope and point transfer. Plotting of principal point, flight line and match line.
- Construction of stereogram
- Handling of a parallax bar and height calculation
- Numerical problems on height calculation using measured relief displacement on a single aerial photograph.
- Flight Planning: Calculations necessary to develop a flight plan and draw a flight map.
- Interpretation of aerial photographs: various landforms, erosion types , horizontally bedded sandstones, shale and limestone. Intrusive igneous rocks, extrusive (lava flows). Aeolian

Landforms: transverse sand dunes, longitudinal sand dunes, loess. Glacial landforms: end moraine, basal moraine, drumlins, eskers. Fluvial Landforms: alluvial fans, deltas. Coastal landforms: beach ridges, beach cusps, dunes, surface expressions of anthropogenic activities.

T.Y. B.Sc. Geology
Title: Gemmology

Course S.Geo 6.0 AC

Learning Objectives:

To study and understand the evolution of gemstones and gem materials

PREREQUISITE : Courses S.Geo.3.0 and S.Geo.4.0

Number of lectures: 60

Unit 1

(15 lectures)

The Geological Sources of Gems

Rocks and processes that formed them.

Gem regions. Gem recovery methods

Cryptocrystalline, massive and metamict states

Hardness: definition, Mohs' scale, Cleavage: definition, description, importance in gemmology and lapidary work

Specific Gravity: Definition, Heavy liquids (bromoform, methylene iodide, sodium polytungstate and Clerici solution)

Luminescence: Fluorescence and phosphorescence, photoluminescence and Stoke's law,

Thermal conductivity and thermal conductivity meter, 10 X lens, Chelsea colour filter

Unit 2

(15 lectures)

Optical Properties

Nature of colour: absorption of light, allochromatism, idiochromatism

Lustre, sheen, chatoyancy and asterism in gemstones, play of colour, dispersion, metamerism, use of, cross filter test.

Polarization and absorption of light

Nature and production of polarized light, design and construction of polariscope and its use in gemmology.

Differential absorption of light, pleochroism, dichroscope, construction and use; Spectroscope – construction and use, absorption spectra,

Reflection: laws of reflection, importance in gemmology.

Refraction: laws of refraction, refractive index, total internal reflection, use and design of refractometer, measurement of R.I. and birefringence by refractometer and other methods. Isotropism and Anistropism in gemstones, anomalous double refraction, optic axes

Unit 3

(15 lectures)

Fashioning of gemstones

Cutting styles, critical angle, composite stones, gemstone polishing, lapidary techniques and gemstone carving.

Diamonds: Diamond cutting and polishing methods, diamond grading including cut, colour, clarity and carat weight.

Diamond synthesis, thin diamond films, chemical vapour deposition (CVD)

Gemstone simulants: Glass, plastics, diamond simulants, assembled or composite stones

Metric carat, pearl grain, kilogram, gram, milligram, meter, millimeter, micrometer, nanometer, Angstrom, litre, milliliter

Unit 4

(15 lectures)

Gemstone synthesis and treatments

Methods of staining, heat treatment, diffusion treatment, fracture filling, cavity filling, coatings, dyeing, laser drilling, atomic irradiation and their detection

Synthesis of gemstones:

Methods of manufacture: flame-fusion (Vernueil), flux-melt, hydrothermal, crystal-pulling (Czochralski), skull-crucible method, zone melting.

Reference Books:

1. Gemmology (3rd edition) 2005 by P.G. Read.
 2. Practical Gemmology (6th edition) 1976 by R. Webster.
 3. Gem Testing (10th edition) 1990 by B. W. Anderson.
 4. Gemstones of the world (4th edition) 2010 by Walter. Schumann.
 5. Gems(5th edition) 1995 by Robert Webster (revised by B.W. Anderson)
 6. Identification of gemstones (2003) by Michael O'Donoghue and Louise Joyner
 7. Gems (6th edition) 2006 edited by Michael O'Donoghue.
 8. A Handbook of gem identification (12th edition) by Richard T. Liddicoat
 9. Gem Identification Made Easy by Antoinette L. Matlins and A.C. Bonanno.
 10. Fluorescence Gems and Minerals under Ultraviolet Light 1994 by Manuel Robbins
 11. Color Encyclopedia of Gemstones. (2nd edition) 1987 by Joel E. Arem.
 12. Fluorescence Gems and Minerals Under Ultraviolet Light (1994) by Manuel Robbins
 13. Gemstone Buying Guide How to evaluate, identify, select and care for colored gems by Renee Newman.
 14. The complete encyclopedia of minerals (2001) by PetrKorbel and Milan Novak.
 15. Collecting Fluorescent minerals (2004) by Stuart Schneider.
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Practical Course:

Gem Properties and Characteristics

1. Specific gravity problems.
a) Hydrostatic method, b) comparison of specific gravity of gemstones.
2. Refractive Indices problems
a) Isotropic stones, b) Uniaxial stones, c) Biaxial stones.
3. Weight Estimation Problems
4. Problems on design, gemstone cuts.
a) Light ray path through a profile of cut; b) facet patterns and facet tally of various types of cuts; c) cabochon cuts.
5. Procedures of distinguishing, different gemstones using a dichroscope, polariscope and a loupe, on the basis of their various physical and optical characters
