Department of Earth & Planetary Sciences
University of Allahabad

Pre- D. Phil. Course Work

1. Every student admitted to the Department for D. Phil./Ph.D. programme will be required to pass the 'Course Work'.

2. The candidate can submit his/her thesis only if he/she has passed the Course Work.

3. All candidates admitted to D.Phil/Ph.D. programme shall be required to complete the coursework prescribed by the DPC/Supervisor during the initial one or two semesters. Maximum of two attempts shall be allowed to the candidate for passing a course/ item. If the candidate does not pass items within the stipulated time, failing which his/ her D.Phil registration shall stand cancelled. There will be no provision of supplementary examination.

4. There will be two Core papers, and two Elective papers that a candidate has to opt from his/her research area. Each paper will be of 100 marks and 2 credits.

5. The paper on Research Methodology will cover areas such as quantitative methods, Computer applications, research ethics and review of published research work in the relevant field as envisaged in the UGC guidelines, 2016.

6. In each paper there will be 40 marks for Sessional Test and 60 marks for the End Semester examination as per CBCS guidelines of the University of Allahabad.

7. Total 8 Credits will be assigned to the D.Phil. /Ph.D. coursework.

8. All papers shall be in conformity with the credit hour instructional requirement and will specify content, instructional and assessment methods.

9. The minimum marks in each paper to pass the coursework will be 40% and the minimum 55% in aggregate in order to be eligible to continue in the D.Phil/Ph.D. programme and submit the dissertation/thesis.

10. The papers will be evaluated by the respective course instructors

11. A candidate will be eligible for appearing in the examination, if he/she fulfills the minimum attendance requirement, submits fees and the examination form within the stipulated time. Attendance requirement will be as per the D.Phil. prescribed Ordinance of the University of Allahabad.

12. The grades, as per CBCS guidelines, will be assigned as under:

Percentage of marks obtained	Letter Grade	Grade Point	Classification
Absent	Ab	0	Absent
Below 40% in each paper and 55% in aggregate	F	0	Failed
40% in each paper and 55% in aggregate	P	4	Passed
Above 55% and below 65% in aggregate	C	5	Average
Above 65% and below 70% in aggregate	B	6	Above Average
Above 70% and below 75% in aggregate	B^+	7	Good
Above 75% and below 80% in aggregate	A	8	Very Good
Above 80% and below 85% in aggregate	A^+	9	Excellent
85% and above	O	10	Outstanding

13. The papers are as follows:

A. Core papers:

	Papers	Credit	Hrs/Week
EPS-701	Research Methodology	2	2
EPS-702	Communication skills and Seminar Presentation	2	2

B. **Elective papers:** Research Theme – Specific papers

Paper code	Title	Credits	Hrs/Week
EPS-703	Geoexploration	2	2
EPS-704	Field Geology and Laboratory Techniques	2	2
EPS-705	Applied Mineral Sciences	2	2
EPS-706	Evolution of Igneous Rocks	2	2
EPS-707	Terrestrial Remote Sensing and Technology	2	2
EPS-708	Earth Landforms and their evolution	2	2
EPS-709	Advanced Sedimentology	2	2

EPS-710	Applied Palaeontology	2	2
EPS-711	Advanced Indian Stratigraphy	2	2
EPS-712	Ore Systems Study	2	2
EPS-713	Geohydrology	2	2
EPS-714	Micropaleontology and Oceanography	2	2
EPS-715	Advanced Geochemistry	2	2
EPS-716	Tectonometamorphic Evolution & Deep-earth processes	2	2
EPS-717	Seismology	2	2
EPS-718	General Geophysics	2	2
EPS-719	Earth's Climate	2	2
EPS-720	Impact Cratering Research	2	2
EPS-721	Advanced Engineering Geology	2	2
EPS-722	Rock mechanics	2	2
EPS-723	Himalayan Geology	2	2
EPS-724	Environmental Geology	2	2
EPS-725	Gemmology	2	2
EPS-726	Experimental Mineralogy & Petrology	2	2

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Core Papers

EPS 701: Research Methodology

Unit I

Research methodology: An introduction, Meaning of research, objective of research, motivation in research, types of research, research approaches, importance of knowing how research is done, research process, application of research.

Unit II

Defining the research problems: Literature Survey related to the planned doctoral work, defining the question to be studied and formulating hypothesis/hypotheses.

Unit III

Method of data collection: Collection of research data, observation method, interview method, collection of data through quesnaires, collection of data through schedules, other method of data collection, Sampling and methods of data analysis, study design based on the nature of the investigation-experimental study, theoretical study, comparison.

Unit IV

Research ethics: proper citation of earlier work done, avoid plagiarism, etc.
Laboratory Safety measures: Handling of Radiation, Bio-hazardous and other toxic experimental materials

Good laboratory practices: Recording and storage/ retention of recorded materials, Maintenance of equipments, proper storage and disposal of hazardous materials (chemical & biological), Management and user responsibilities in proper utilization of the facilities

Unit V

The computer-its role in research: Introduction, the computer and computer technology, the computer system, important characteristics, the binary number system, computer applications in earth sciences research.

Suggested Readings:

1.Panneerselvam, R. Research Methodology, PHI Learning Pvt Ltd, New Delhi, 2nd ed., ISBN : 978-81-203-4946-9.
2.Taylor, B. 2006 Research Methodology: A guide for researchers in management and social sciences. PHI Learning Pvt Ltd, New Delhi, 1st ed.
3.Creswell, J.W. 2014 Research Design: qualitative, quantitative and mixed methods, approaches. SAGE publications, 304p.
4.Turabian K. A manual for writers of research papers, theses, and dissertations. The University of Chicago Press, 488p.
5.Kothari, C.R. 2004 Research Methodology: Methods and techniques. New Age.

6. Raja Raman : Fundamentals Of Computers,4ed, PHI Learning Pvt Ltd, New Delhi 2006, ISBN-81-203-2591-8, 417 p.

EPS 702: Communication Skill & Seminar Presentation

Unit I

Basic aims of communication skills. History of communication technologies. Modern communication methods. Speed of data communication in various wired and wireless communication methods. Various communication technologies and frequencies in the present wireless communication technologies.

Unit II

Printing technologies and unit of font size specification in printed and typed matters. Word and pdf structures for write-ups. Heuristics for communication our ideas to others. Aristotle's definion 5 canons for development of Rhetoric. Invention, Arragement, style, Memory and Delivery.

Unit III

Various methods of expressing views to individuals and groups of peoples. Communication to a group in form of Presentation and slideshows. Power point presentation. Slide design, Transition and Animation.

Unit IV

Preparation of subject matter and graphical representation of data in dissertation. Linear and log scales for plotting data Callibration reqirement of measuring instruments. Primary and secondary Voltage reference. Methodologies behind ISI and ISO standards.

Unit V

Practical skill development for delivering seminars and group discussions. Elementary ideas of various search engines. LaTex Search, Google search etc. Write of manuscripts for Journals. Concept of Peer review. Reasons for rejection. Writing abstract and Key words.

RESEARCH THEME SPECIFIC PAPERS

EPS-703: Geoexploration

Unit I

Basic principles of geophysical exploration.

Gravity Method: Gravity force and potential, Stable and unstable gravimeters, Worden, Lacoste and Romberg, Hartley, Askania and Gulf gravimeters, field procedure and reduction of gravity data. Various types of corrections applied to gravity data, preparation of gravity anomaly maps and their interpretation in terms of shape and size using simple models.

Unit II

Magnetic Method: Basic Theory, inverse square law, concept of potential, magnetism on atomic scale, Dia- para- ferro magnetic materials, susceptibilities and densities of various rocks and minerals, magnetic properties of rocks, working principle of the Fluxgate, Proton Precession and Rubidium vapour magnetometers. Magnetic anomalies over single pole, and dipole.

Unit III

Electrical methods: Electrical resistively, current distribution in homogeneous ground due to single electrode and dipoles. Resistively method: Basic principles, various types of electrode configurations, Wenner and Schlumberger configurations. Theory of images, Tagg's method of interpretation. Elements of SP and IP method.

Unit IV

Seismic Method: Elementary principle of reflection and refraction methods. Ray parameter. Geometry for seismic wave paths: Reection from single-horizontal interface, normal-move-out. Different methods for velocity estimation. Dipping reflector, Dip-move-out. Geometry of refraction paths. Head waves, single-horizontal refractor, method of estimation of velocity of layers and depth of the interface. Double and multiple horizontal refractors. Estimation of velocity and thickness of layers. Intercept time, delay time. Geophones, Electromagnetic geophones. Hydrophones.

Unit V

Basic Principle of EM method.

Suggested Readings:

1. Telford, Geldart, Sheriff and Keys; 1990 Applied Geophysics, Cambridge University Press, pp 769.
2. Milton B. Dobrin, Introduction to Geophysical Prospecting, 3rd Ed., McGraw Hill, pp.867
3. William Lowrie,2007 Fundamentals of Geophysics, Cambridge University Press, The eunburgh building , Cambridge ,ISBN: 13- 978-0-521-85902-8,381p.
4. Edwin S. Robinson, 1988 Basic Exploration Geophysics, John Wiley & Sons, 562 p.
5. Gadallah, M.R., Fisher, R., 2009 Exploration Geophysics, ISBN 978-3-540-85159-2,Springer XXII, 262 p. 110 illus.

EPS-704: Field Geology and Laboratory Techniques

Unit I

Introduction to Field Geology and Mapping Techniques, Essential Equipments and Supplies, Compass, Clinometer and GPS, Topographic Maps, Aerial Photographs and Satellite images,

Unit II

Mapping Methodology and basic field procedures, Recording Observations, Geological Mapping, Procedures to collect samples and specimens,

Unit III

Identification and description of various minerals, rock types, primary and secondary structures and fossils and biogenic structures, Stratigraphy of the area based on field observations, A Short Field Visit and preparation of a Field Report.

Unit IV

Various sample preparation techniques in mineralogy; X-ray crystallography and Bragg's equation, powder method in X-Ray crystallography; Electron probe micro analysis and scanning electron microscopy – principle, application and their utility in mineral sciences; Introduction to LA-ICP-MS, SHRIMP analysis and infra red spectroscopy.

Unit V

Calculation of mineral formulae using microchemical data of important rock-forming minerals.

Suggested Readings:

1. Mathur, S.M., 2001, Guide to Field Geology, Prentice-Hall of India Pvt. Ltd., New Delhi, 2001, ISBN- 81-203-1915-X, 220p.
2. Bhattacharyya, A. and Chakraborty, C. (2005) Analysis of Sedimentary Successions: A Field Manual, Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi-Kolkata, 445p.
3. McClay, K.R. 2005 The Mapping of Geological Structures, John Wiley & Sons, Chichester, 161p.
4. Compton, R.R. 1962 Manual of Field Geology, John Wiley & Sons Inc., 378 p.
5. Barnes, J.W. and Lisle, R.J. 2004 Basic Geological Mapping (Geological Field Guide), John Wiley & Sons Inc., ISBN- 978-0-470-84986-6, 378 p.

EPS-705: Applied Mineral Sciences

Unit I

Geological and geochemical aspects of raw materials for refractory, cement, glass and ceramic, fertilizer and other chemical industries.

Unit II

Basic concepts of crystallography and optical mineralogy.

Unit III

Introduction to X- ray powder diffraction, DTA, DSC, TG, SEM, TEM, EPMA and UV-VIS- NIR and vibrational spectroscopic methods (IR and Raman) and their mineralogical applications.

Unit IV

Electrical and magnetic properties of minerals.

Unit V

Study of common rock-forming mineral groups (silicates and non-silicates).

Suggested Readings:

1. Jones, M.P., 1987, Applied mineralogy: a quantitative approach, Springer, ISBN-0-86010-510-5, 259 p.
2. Petruk, W., 2000, Applied Mineralogy in the Mining Industry: Ottawa, Ontario, Canada, Elsevier, ISBN-0-444-50077-4, 268 p.
3. Deer, W.A., Howie, R.A., and Zussman, J. 1979 An Introduction to the Rock-forming Minerals, ELBS and Longman, 696p.
4. Zussman, J. 1967 Physical Methods in Determinative Mineralogy, Academic Press, London and New York, 513p.

EPS-706: Evolution of Igneous Rocks

Unit I

Forms, textures and structures of igneous rocks. Classification of magmatic rocks.

Unit II

Silicate melt equilibria, binary and ternary phase diagrams.

Unit III

Petrology and geotectonic evolution of granites, basalts, andesites and alkaline rocks. Petrology of gabbros, kimberlites, komatiites, anorthosites and carbonatites.

Unit Iv

Origin of primary basic and ultra-basic magmas.

Unit V

Plate tectonics and evolution of igneous rocks.

Suggested Readings

1. Winter, J.D. 2009 Principles of Igneous and Metamorphic Petrology, 2nd Edition, Prentice Hall, 720 p.
2. Gill, R. (2010) Igneous Rocks and Processes: A Practical Guide, Wiley-Blackwell, Chichester, ISBN-978-1-4443-3065-6, ISBN-978-0-632-06377-2, 428 p.
3. Wilson, M. Igneous Petrogenesis. Boston, MA: Unwin Hyman, 1989. ISBN: ISBN-10-.0-412-53310-3, 466 p.
4. Frost, B.R. and Frost, C.D., 2013. Essentials of Igneous and Metamorphic Petrology, Cambridge University Press, 314 p.
5. Philpotts, A.R., 2003, Petrography of Igneous and Metamorphic Rocks, Waveland Pr Inc., 192 p.
6. Faure, G., 2001. Origin of Igneous Rocks: The Isotopic Evidence, Springer-Verlag, Berlin, ISBN: 3-540-67772-0, 512 p.

EPS-707 Terrestrial Remote Sensing and Technology

Unit I

Basic principles of remote sensing - energy sources and radiation principles, atmospheric absorption, interaction of energy with earth's surface, air-photo interpretation.

Unit II

Multispectral remote sensing in visible, infrared, thermal IR, and microwave regions, digital processing of satellite images.

Unit III

Remote sensing in landform and land use mapping, structural mapping, hydrogeological studies and mineral exploration.

Unit IV

Global and Indian Space Missions.

Unit V

GIS - basic concepts, raster and vector mode operation.

Suggested Readings

1. Rees, W.G. (2001) Physical Principles of Remote Sensing, 2nd Edition, Cambridge University Press, London, Paperback (ISBN-0-521-66034-3), 343 p.
2. Gupta, R.P. (2003) Remote Sensing Geology, 2nd Edition, Springer-Verlag, Berlin, ISBN- 3-540-43185-3, 627p.
3. Lillesand, T.M. and Kiefer, R.W. and Chipman, J.W. (2007) Remote Sensing and Image Interpretation, 6th Edition, John Wiley & Sons, ISBN- 10- 81-265-1335-7, ISBN- 13-978-81-265-1335-2, 756 p.
4. Sabins, F.F. (1978) Remote Sensing: Principles and Interpretations, W.H. Freeman, San Francisco, ISBN: 0716724421, 432 p.
5. Borengasser, M., Hungate, W.S. and Watkins, R. (2007) Hyperspectral Remote Sensing: Principles and Applications, CRC Press (1566706548, 9781566706544), Paris, 121p.

EPS-708: Earth Landforms and their evolution

Unit I

Basic concepts and significance of geomorphology; Cycle of erosion, fluvial landforms and drainage patterns; Evolution of landforms in aeolian, marine, glacial and karst landscapes.

Unit II

An elementary idea about morphogenesis and morphography; Morphometric analysis, morphochronology.

Unit III

Neotectonics - geomorphological indicators, active faults, drainage changes, recurrent seismicity.

Unit IV

Geomorphology of India - Peninsular, Extra-peninsular and Indo-Gangetic plains;

Unit V

Application of geomorphology in mineral prospecting, civil engineering, military purposes, hydrogeology and environmental studies.

Suggested Readings:

1. Holmes,A.(1992): Holmes Principles of Physical Geology, Edited by P. McL. D. Duff. Chapman and Hall. ISBN – 0 442 30780 2, 791 p.
2. Sharma, H.S. (1990): Indian Geomorphology, Concept Publishing Co., New Delhi. ISBN : 81-7022-344-X, 358 p.
3. Thornbury, W.D. (1980): Principles of Geomorphology, Wiley Easton Ltd., New York. 594 p.

EPS-709: Advanced Sedimentology

Unit I

Texture - shape, size, fabric and surface textures, methods of textural analysis, textural parameters and their significance.
Unit II
Petrogenesis of sandstones, graywacke and graywacke problem; plate - tectonics and sandstones composition; Argillaceous rocks, their classification and genesis.
Unit III
Various chemical sedimentary rocks and their petrogenesis.
Unit III
Facies and facies analysis; Facies models of key continental sedimentary environments such as eolian, glacial, delta and fluvial. Facies models of coastal such as deltaic, esturerine, tidal flat, barrier and lagoon environments; Facies models of marine environments.
Unit IV
Fluid flow mechanics and formation of sedimentary bedforms.
Unit V
Sequence stratigraphy.

Suggested Readings:

1. Lindholm, R.C. (1987) A Practical Approach to Sedimentology, Allen and Unwin, London, 276 p.
2. Miall, A.D. (2000): Principles of Basin Analysis, Springer-Verlag.
3. Prothero, D.R. and Schwab, F. (2004) Sedimentary Geology: An introduction to sedimentary rocks and Stratigraphy,W.H. Freeman and company, New York., 557 p,2004
4. Selley, R. C. (2000) Applied Sedimentology, Academic Press. 2nd ed. 523p. ISBN:0126363757.
5. Tucker, M.E. (1990): Carbonate Sedimentology, Blackwell Scientific Publication. Scientific Publications. ISBN 0-632-01472-5, 482 p.

EPS-710: Applied Paleontology
Unit I
Application of paleontology in organic evolution & palaeoenvironmental interpretations. Modern systematics, Species concept in paleontology, nomenclature and identification of fossil species.
Unit II
Ichnofossils, their modes of preservations and ichnofacies.
Unit III
Recent developments on organic evolution; Coevolution of the Earth and its biota; Evolution of Primary Producers in the Sea; Macroevolution and mass extinction.
Unit IV
Faunal Provinces; Distribution, migration and dispersal of organisms Approaches to palaeoecology; Taphonomy: principles and practices.
Unit V
Functional Morphology, growth and form.

Suggested Readings:

1. Boardman, R.S. Cheethan, A.M. & Rowell, A.J. (1988) Fossil Invertebrates Blackwell Scientific Publications, ISBN- 0-674-01972-5, 208 p.

2. Clarkson, E.N.K. (1998) Invertebrate Palaeontology and Evolution, (Allen & Unwin), ISBN-978-0-632-05238-7, 468p.
3. Prothero, D.R. (2004) Bringing Fossil to Life – An Introduction to Palaeontology (McGraw Hill), 503p.
4. Raup, D.M. and Stanley, S.M. (1971) Principles of Palaeontology (CBS Publications) san fransisco : Free man, 886p.
5. Strean, C.W. and Carroll, R.L. (1989) Palaeontology – the record of life (John Wiley), 459 p.

EPS-711: Advanced Indian Stratigraphy

Unit I

Introduction to Sequence-, magneto-, seismic-, chemo- stratigraphy.

Unit II

Sequence stratigraphy

Unit III

Stratigraphic correlation; Facies concept in stratigraphy; Precambrian geochronology; Chronostratigraphy of the Precambrian of Singhbhum-Chotanagpur-Orissa Belt, Eastern and Central India.

Unit IV

Introduction to important fossiliferous Paleozoic, Mesozoic and Cenozoic sedimentary basins of India. Introduction to Quaternary Geology

Unit V

Precambrian/ Cambrian boundary, Permian/ Triassic boundary and Cretaceous/ Tertiary boundary in India.

Suggested Readings:

1. Naqvi, S.M. and Rogers, J.J.W. (1987): Precambrian Geology of India. Oxford University Press, USA, 1987. ISBN: 0195036530 / 0-19-503653-0, 453 p.
2. Schoch, Robert, M. (1989): Stratigraphy: Principles and Methods, Van Nostrand Reinhold, New York, 375pp.
3. Doyle, P. & Bennett. M.R. (1996): Unlocking the Stratigraphic Record (John Villey) 532 p.
4. Ramakrishnan, M and Vaidyanadhan, R. 2008, Geology of India (in two volumes). Geological Soc. of India, Bangalore, ISBN: 978-81-85867-77-9.

EPS-712: Ore Systems Studies

Unit I

Concept of ore bearing fluids, their origin and migration; Wall rock alteration; Geological controls of ore localization

Unit II

Role of plate tectonics in ore deposits; Organic matters and its implication in ores; Fluid inclusions in ores - principles, assumptions, limitations and applications.

Unit III

Studies of ore deposits associated with ultramafic-mafic rocks; felsic-silicic igneous rocks;

Unit IV

Ores of sedimentary affiliation - biochemical, chemical and clastic sedimentation, placers and residual concentration deposits; Ores of metamorphic affiliations.

Unit V
Ore microscopy: techniques, textures and microstructures of ores, interpretation of ore texture and optical properties of ore minerals; Application of ore microscopy.

Suggested Readings:

1. Cuilbert, J.M. and Park, Jr. C.F.(1986): The Geology of Ore Deposits, Freidman, 985 p.
2. Evans, A.M. (1993): Ore Geology and Industrial Minerals, Blackwell. 400 p, Publisher: Wiley, ISBN: 9780632029532, 390 p.
3. James R. Craig and David J.Vaughan (1994): Ore Microscopy and Petrography, ISBN4-06-257003-3, 434 p.
4. Mookherjee, A. (1999): Ore Genesis-A Holistic Approach, Allied Publisher, New Delhi, 657 p.
5. Wolf, K.H. (1976-1981): Hand Book of Strata bound and Stratiform Ore Deposits, Elsevier Publ. ISBN:19761981, 506 p.

EPS-713: Geohydrology

Unit I
Hydrological cycle with special reference to groundwater; Geological factors controlling groundwater occurrence and distribution; Aquifers and aquifer systems, geological formations as aquifers; Groundwater in different geological terrains of India; Bernoulli's equation and hydraulic head; Darcy's law and Reynolds number;
Unit II
Hydraulic conductivity, transmissivity, storage coefficient and specific capacity; Water table contour maps and flow net analysis.
Unit III
Evaluation of hydrologic properties through pump tests and various methods for steadying and unsteady flow; Chemical characteristics of groundwater for various uses viz. domestic, industrial and irrigation; Prevention of saline water intrusion in coastal and other aquifers.
Unit IV
Application of radioisotopes in hydro-geological studies; Groundwater contamination with special reference to arsenic, fluoride and nitrates.
Unit V
Groundwater level fluctuations and environmental influences; Artificial recharging to groundwater and rainwater harvesting; Management of groundwater resources; Conjunctive use of groundwater and surface water; Groundwater problems. Effects of water in landslides; Environmental effects of over-exploitation of groundwater; Water logging problems; Groundwater legislation.

Suggested Readings:

1. F.G. Driscoll (1988): Groundwater and Wells, UOP, Johnson Div.St.Paul. Min. USA. 1089 p.
2. H.M. Raghunath (1990): Groundwater, Wiley Eastern Ltd., 520 p.
3. H.S. Nagabhushaniah (2001): Groundwater in Hydrosphere (Groundwater hydrology), CBS Publ.. ISBN-8123907516, 387 P.
4. K. R. Karanth (1989): Hydrogeology, Tata McGraw Hill Publ.. 1989, ISBN-13: 978-0- 07- 451712-3, 458 p.

EPS-714: Micropaleontology and Oceanography

Unit I
Scope of subject; Modern field and laboratory techniques in the study of microfossils (collection, sampling and processing techniques, scanning electron microscopy and mass spectrometry).
Unit II
Types of microfossils, Environmental significance of microfossils in general; Application of calcareous microfossils in reconstruction of history of past, environmental changes and biostratigraphic correlation;
Unit III
Micropaleontology in petroleum exploration; Geochemical study of microfossil tests (stable isotopes, radiocarbon isotopes and elemental composition) and its application in paleoceanography and paleoclimatology and tracing history of marine pollution.
Unit IV
Interpretation of sea floor tectonism from micropaleontological evidence.
Unit V
Ocean circulation; Concept of mixed layer, thermocline and pychnocline, Coriolis force and Ekman spiral, upwelling, Elnino, deep ocean circulation, concept of thermohaline circulation, formation of bottom waters, water masses of the world oceans, oceanic sediments.

Suggested Readings:

1. Arnold (2002): Quaternary Environmental Micropaleontology (Ed. Simon K. Haslett), Oxford University Press, New York, ISBN: 0340761970 9780340761977 0340761989 9780340761984, 340 P.
2. Bignot, G., Grahm and Trottman (1985): Elements of Micropaleontoogy, London,.ISBN: 0-86010-485-0, 0-86010-490-7, 217p.
3. David Tolmazin (1985): Elements of Dyanamic Oceanography, Allen and Unwin , 181 P.
4. Haq, B. U. and Boersma, A., (1998) Introduction to Marine Micropaleontology, Elsevier.ISBN; 9780444826725., 376 p.
5. Rui Xin Huang (2010) Ocean Circulation, Cambridge University Press. J. Phys. Oceanogr., 28,791 p. .

EPS-715: Advanced Geochemistry

Unit I
Introduction and principles of geochemistry; Introduction, chemical composition and properties of atmosphere, hydrosphere and lithosphere; Geochemial cycles; Concepts of biogeochemical cycle;
Unit II
Geochemical classification of elements; Periodic table with special reference to transition and trace (including rare-earth) element geochemistry.
Unit III
Stable isotope geochemistry of carbon and oxygen and its applications to geology; Radiogenic isotopes; Decay scheme of K-Ar, U-Pb and Rb–Sr and Sm-Nd; Petrogenetic implications of Sm-Nd, Rb-Sr; Radiometric dating of single minerals and whole rocks.

Unit IV
Element partitioning in mineral/rock formation and concept of distribution coefficient; Mineral stability in Eh-Ph diagrams; Sampling procedures and introduction to analytical techniques used in geochemistry; A brief introduction to geochemistry of natural waters and

sedimentary rocks; Geochemical processes involved in rock weathering and soil formation; Principles of ionic substitution in minerals.

Unit V

Crystal structure of some simple compounds – AX structures (NaCl, CsCl, ZnS, NiAs), AX_2 structure (fluorite, rutile); A brief idea about some other commpounds such as A_2X_3 (corundum), ABX_3 (calcite, ilmenite) and AB_2X_4 (Spinel).

Suggested Readings:

1. Klein, C. and Hurlbut, C.S. (1993): Manual of Mineralogy, John Viley and Sons, New York. , 681 p.
2. Mason, B. and Moore, C.B. (1991): Introduction to Geochemistry, Wiley Eastern.
3. Rollinson, H.R. (1993): Using geochemical data: Evaluation, Presentation, Interpretation. Longman U.K. ISBN: 0-582-06701-4 John willy & sons. 352 p.
4. Shikazono, N. (2003): Geochemical and Tectonic Evolution of Arc-Backarc Hydrothermal Systems - Implication for the Origin of Kuroko and Epithermal Vein-Type Mineralizations and the Global Geochemical Cycle, Eslevier Science. ISBN: 0-444-511504, 463 p.
5. Mishra, K.C. (2012): Introduction to Geochemistry: Principles and Applications, Wiley-Blackwell, Chichester, U.K., 438p.

EPS-716: Tectonometamorphic Evolution & Deep-Earth Processes

Unit I

Mineralogical phase rule for closed and open systems; Nature of metamorphic reactions; Metamorphic facies and facies series, UHT and UHP metamorphisms and their relationship with tectonic settings.

Unit II

Detailed characteristic of different grades and facies of metamorphism.

Isograds and reaction isograds and their delineation in field; Schreinemakers rule and construction of petrogenetic grids with special reference to petrological problems.

Unit III

Metamorphic differentiation; Anatexis and origin of migmatites; Experimental work on anatexis; Regional metamorphism and paired metamorphic belts.

Unit IV

Plate tectonics as a unifying theory of metamorphism and tectonics; P-T-t and P-T-t-d paths, their implications on tectonometamorphic evolution.

Unit V

Thermodynamics of metamorphic rocks; Geothermobarometry.

Suggested Readings:

1. Blatt, H. and Tracy, R.J. (1996): Petrology (Igneous, Sedimentary, Metamorphic), W.H. Freeman and Co., NewYork. ISBN 0-7167- 1335-7, 530 p.
2. Bucher, K. and Martin, F. (2002): Petrogenesis of Metamorphic Rocks (7^{th} Rev. Ed.), Springer–Verlag ,. 978-3-540-43130-5, 341 p.
3. Philpotts, A.R. (1994): Principles of Igneous and Metamorphic Petrology, Prentice Hall., 667 p.
4. Rastogy, R.P. and Mishra, R.R. (1993): An Introduction to Chemical Thermodynamics, Vikash Publishing House. 626 p.

5. Spear, F. S. (1993): Mineralogical Phase Equilibria and pressure – temperature – time Paths, Mineralogical Society of America. I S B N 0-939950-34-0, 799 p.
6. Winter, J.D. (2001): An introduction to Igneous and Metamorphic Petrology, Prentice Hall. ISBN-10: 0132403420, Publisher: Prentice Hall, 02/09/2001., 272 p.

EPS-717: Seismology

Unit I

Introduction to earthquake phenomena, concept of focus, focal depth, epicentre, great Indian earthquakes, intensity and magnitude scales and energy of earthquakes, foreshocks and aftershocks, elastic rebound theory.

Unit II

Seismicity of India, Himalayas and global seismicity, seismic zonation, seismic micro-zonation, seismic zoning of India.

Unit III

Induced seismicity, concept of inhomogeneity and anisotropy, types and causes of earthquakes. Seismic ray theory for spherically stratifieded earth and velocity structure from travel time data, propagation and characteristics of body waves, surface waves, group and phase velocities, different phases of body waves and their applications.

Unit IV

preparation of preliminary reports and identification of phases, determination of epicentre, focal depth and magnitudes, theory of elasticity, reection of body waves, focal mechanism solutions and tectonic implications, earthquake generation models, hazard analysis, reflection of seismic waves from the free surface.

Unit V

Principle of electromagnetic seismograph, displacement meters, velocity meter, accelerometer and strain meter seismographs, WWSSN stations, seismic arrays for detection of nuclear explosions, wideband seismometry, strong motion seismograph.

Suggested Readings:

1. K. E. Bullen, Edited by Bruce A. Bolt An Introduction to the Theory of Seismology (4th Edition) Paperback (ISBN-0-521-23980 x: ISBN-0-521-28389 2) Cambridge University Press., 499 p.
2. Seth Stein and Michael Wysession, An Introduction to seismology, Earthquakes and Earth Structure, Blackwell Publishing. ISBN: 978-0-86542-078-6 ,Paperback 512 p.

3. Charles F. Richter, 1958. Elementary Seismology San Francisco: W. H. Freeman and Company. 768 p.

4. Bath, M. 1973. Introduction to seismology. 395 pp. New York: John Wiley and Sons.
5. Fowler, The Solid Earth: An introduction to global Geophysics, Cambridge University Press, New York ,ISBN-0-521-58409, 685 p.

EPS-718: General Geophysics

Unit I

History of development and scope of geophysics, monistic and dualistic hypotheses for the origin of solar system, Kepler's law of planetary motion, planet and satellites of the system and their characteristics, shape and size of the earth, international gravity formula and rotation of the earth.

Unit II
Concept of isostasy, Airy, Heiskanan and Pratt-Hayford hypotheses.
Unit III
Internal constitution of the earth, continental drift, ocean oor spreading, plate tectonics and its geological implications, new global tectonics and plate margin process, oceanic ridges, trenches and island arcs, geodynamics of Indian subcontinents and formation of Himalayas.
Unit IV
Origin of geomagnetic field, polar wandering, secular variations, geomagnetic storms, Sun spot, solar flares, lunar and solar variations.
Unit V
Fundamentals of palaeo-magnetic studies and palaeo-magnetism of rocks.

Suggested Readings:

1. Howell, Benjamin, 1978 Introduction to Geophysics, R E Krieger Publishing,. ISBN 10: 0882755404 - ISBN 13: 9780882755403, 399 p.
2. Telford, Geldart,1991, Sheriff and Keys; Applied Geophysics, Cambridge University Press, ISBN 0 521. 32693 1, 531 p.
3. Kent C. Condie, Plate Tectonics & Crustal Evolution 2nd Ed., Pergamon Press, Elmsford, N.Y., ISBN-0-7506-3386-7, 310 p.
4. David Gubbins, Seismology and Plate Tectonics Paperback, Cambridge University Press (ISBN-0-521-37141-4| ISBN-0-521-37995-4, 339 p.
5. Jacobs, J.A., 1967. The Earth's Core and Geomagnetism, Pergamon Press, Oxford, 137 p.

EPS-719: Earth's Climate

Unit I

Introduction -Climate in the Spotlight, -The Spectrum of Scientific Opinion. The Earth's Natural Greenhouse Effect -General Overview ,-Why the Earth is a Nice Place to Live. The Radiative Balance, The Importance of Water.

Unit II

Greenhouse Gases: An Overview, -The Role of Carbon Dioxide, -The Role of Methane, -Major Uncertainties. CO_2 Emissions -Human Emissions of CO_2, -How Much Carbon in the Ground?, -Different Concerns of Rich and Poor Countries. The Earth's Carbon Reservoirs –
Unit III

What is Biogeochemistry?, -Why is the Atmospheric Carbon Reservoir so Small?, -Breathing of Gaia, -The Missing CO_2 Sink. Carbon Cycling: The Biological Carbon Pump, -The Marine Carbon Cycle, -The Terrestrial Carbon Cycle. Climate and Weather -Climate and Weather: The Earth's Climate Machine. Global Wind Systems -Trade Windsand the Hadley Cell,-The Highs and Lows of the Westerlies, -The Vital Importance of Monsoon Rains, -Why are there Seasons?.

Unit IV

Clouds, Storms and Climate -Cloud Formation and Climate,-Hurricanes and Global Warming. Global Ocean Circulation -Introduction and Overview, Origin of the Gulf Stream,-

The Deep Atlantic Conveyor. El Niño and the Southern Oscillation -El Niño and its Effects,- Unit V

Upwelling and Climate. Outlook for the Future -Introduction to Climate Change,-Advances in Computer Modeling,-Physics versus Fudge Factors.

Suggested Readings:

1. Rapid Climate Change: Past Evidence & Future Prospects, 2011. by U. S. Climate Change Science Program & Subcommittee On Global Change Research, Nova Science Publishers Inc. ISBN-10: 1607414228, ISBN-13: 978-1607414223, 325 p.

2. Ruddiman, W.F., 2002. Earth's Climate:Past and Future. W.H. Freman & Co., New York. ISBN-10: 0716784904,465p.

3. Jim Pipe, Suzy Gazlay., 2008. Earth's Weather and Climate. Gareth Stevens Publishing. ISBN: 0836889274, 32 p.

4. Dennis Klocek, 2010. Climate: Soul of the Earth. Lindisfarne Books ,ISBN 978-1-58420-094-9, 304 p.

EPS-720: Impact Cratering Research

Unit I

Impact craters, Types of impact craters/structures, Stages of impact crater development (contact, compression, excavation and modification).

Unit II

Geomorphology and remote sensing studies of impact craters/structures.

Unit III

Shock metamorphic features, Nature and composition of projectiles.

Unit IV

Impactites, Angle of impact, Scaling of crater dimension, Impact cratering process and Mass extinctions and Large Igneous Provinces.

Unit V

Planetary evolution and role of impact cratering.

Suggested Readings:

1. Melosh, H.J. (1989) Impact Cratering: A Geologic Process. Oxford University Press, New York, 245p.
2. French, B.M. (1998) Traces of Catastrophe: A Handbook of Shock-Metamorphic Effects in Terrestrial Meteorite Impact Structures. Lunar Planetary Institute Contribution No. 954, Lunar Planetary Institute, Houston, 120p.

3. Reimold, U.W. and Gibson, R.L. (2009) Meteorite Impact! Springer Verlag, Berln,. ISBN: 978-3-642-10463-3, 337p.
4. Osinski, G.R., and Pierazzo, E. (2013). Impact Cratering: Processes and Products. Wiley-Blackwell, Chichester, ISBN: 978-1-4051-9829-5, 330p.
5. Katsuragi, H. (2016). Physics of Soft Impact and Cratering, Lecture Notes in Physics. Springer, Japan, ISBN: 978-4-431-55647-3, ISBN: 978-4-431-55648-0, v.910, 317p.
6. Glass, B.P. and Simonson, B.M. (2013). Distal Impact Ejecta Layers: A Record of Large Impacts in Sedimentary Deposits. Springer-Verlag, Berlin, ISBN: 978-3-540-88261-9, ISBN: 978-3-540-88262-6, 731p.

EPS-721: Advanced Engineering Geology

Unit I

Introduction to engineering geology, Rock and rock mass, Rock as construction material, geological structures, weathering and geological hazards, basic engineering properties of rock and soil and their measurement, groundwater and their influence on geological structures, Permeability

Unit II

Rock mass classification, Q index, Rock Mass Rating, Geological Strength Index, and other classification

Laboratory analysis- Uniaxial tests, triaxial tests, acoustic emissions; Determining UCS, elastic moduli, failure criteria, Mohr-Coulomb, Hoek-Brown, Griffiths

Unit III

Rock slope stability analysis (Kinematics and limit equilibrium methods), Types of failure, Stabilization of rock slopes

Unit IV

Applied Rock Engineering and Rock Mechanics – Practical applications of slopes, Tunnelling and Underground Excavations

Unit V

Excavation Methods: Conventional methods (Mechanically supported; Drill & Blast) and Mechanized Tunnelling (TBMs); selection of Excavation Methods; site investigation (Rockmass Classification) in Tunnelling; geological conditions, geomechanical behaviour, Practical examples

Support Methods in cut slopes, Tunnelling and Selection of Support Systems

Suggested readings:

1. Zhang L- Engineering Propertiesof Rocks – 2nd edition, Elsevier

2. Singh Bhawani & Goel RK - Engineering rock mass classification: tunnelling, foundations, and landslides, 365p
3. Hudson JA & Harrison JP - Engineering Rock Mechanics: An Introduction to the Principles, Elsevier Science, pp.456, 1997 (ISBN 0080438644)
4. Das B M - Principles of Geotechnical Engineering, 7th Edition Cengage Learning publisher
5. WyllieD C, MahC W - Rock slope engineering: civil and mining —4th ed.Taylor & Francis
6. Hoek E, Kaiser PK, Bawden WF - Support of underground excavations in hard rock. A.A. Balkema Publishers
7. Brady BHG and BrownET - Rock Mechanics for underground mining – 3rd edition 2004 Kluwer academic publishers
8. Hencher S – Practical engineering geology, Spon Press, Taylor & Francis Group

EPS-722: Rock Mechanics

Unit I

Introduction to Rock mechanics, Classification and index properties of rocks, Rock and rockmass strength, failure criteria and fracture mechanics.

Unit II

Plane of weakness in rocks, rock joint stiffness, measurement of shear strength along joints, stresses along joints, effect of water pressure, kinematic analysis of jointed rocks

Unit III

Stress analysis in two dimensions: tractions, internal state of stress, principal stresses; Mohr's circle. Strain analysis in two dimensions: Mohr circle

Unit IV

Behaviour of materials; deformation under stress, stress-strain relationship in rock; elasticity theory and elastic constants; anisotropy; non-elastic behaviour, Rheology of material, Creep, Brittle and Ductile behaviour of rocks, deformability of rocks.

Unit V

Application of rock mechanics in underground opening, The state of stress in a rockmass; stress fields around underground openings; Kirsch equations for circular openings; lining pressures, rock anisotropy, in situ stress measurement; support and pillars.

Blasting in underground excavation, Instrumentation

Suggested readings:

1. GoodmanRE-Introduction to Rock Mechanics 1989
2. Hudson J.A. & Harrison J.P - Engineering Rock Mechanics: An Introduction to the Principles, Elsevier Science, 456p, 1997 (ISBN 0080438644)

3. JaegerJC, CookNGW and ZimmermanRW-Fundamentals of rock mechanics – 4th ed.2007 Blackwell Publishing, 475p
4. Brady BHG and BrownET -RockMechanicsfor underground mining, – 3rd edition 2004 Kluwer Academic Publishers
5. Hoek E & Brown ET- Underground Excavations in Rock – 1st edition E & FN Spon
6. Mogi K-Experimental Rock Mechanics2007 Taylor & Francis Group, 361p
7. Hencher S - PracticalRockMechanics, CRC Press, Taylor & Francis group, 346p
8. Atkinson B K -Fracture mechanics of rock, Academic press

EPS-723: Himalayan Geology

Unit I:

Plate tectonics overview, anatomy of the orogenic belts, paleaotectonics, palaeogeography and formation of Tethyes Geosyncline.Structure and origin of the Alpine-Himalayan belt. Active tectonics and alluvial rivers, geomorphic markers of tectonic deformation.

Unit II:

Physiographic and geological sub-divisions of Himalayas, the stratigraphical and lithological units of Sub Himalaya, Lesser Himalaya, Higher Himalaya, Tethys succession and the Indus Suture Zone and their correlation with Indian Peninsular shield elements. The stratigraphic and faunal studies of the Siwalik Group.

Unit III:

Large scale mountain ranges and phases of upheaval of Himalayas.Tectonic deformation and seismicity in the newly folded mountain ranges, rate of deformation in the Himalaya-Quaternary, Holocene and GPS based rates.

Unit IV:

Active faults: concepts, methods and case studies of longitudinal, transverse and out of sequence Himalayan fault systems.Seismotectonics and neotectonics-reactivation of faults in Himalayas.

Unit V:

Environmental aspects and recent natural hazards of Himalayan region. Themetallogeny and mineral deposits of Himalayas, dating of Himalayan rocks.

Suggested Readings:

1. Gansser, A. (1964): Geology of the Himalayas, Wiley Interscience (ISBN: 978470290552/ 0470290552) 289p.
2. Wadia, D.N. (1975): Geology of India 4th edition, McGraw Hill Education India Pvt. Ltd. (ISBN: 0070966346/978-0070966345) 560p.

3. Valdiya KS (1998): Dynamic Himalaya. Universities Press (India) Limited, Hyderabad, 178p.
4. Saklani, P.S. (2006) Tectonic Geology, Satish Serial Publishing House (ISBN: 8189304224 / 9788189304225), 161p.
5. Krishnan, M.S. (2012): Geology of India and Burma, 6th Edition, CBS Publishers (ISBN 8123900120/9788123900124), 196p.
6. Gupta A. and Sarkar S.C. (2012) Crustal Evolution and Metallogeny in India. Cambridge University Press (ISBN: 1107007151/9781107007154).
7. Valdiya KS (2013): Environmental Geology: Ecology, Resources & Hazard Management, Tata McGraw-Hill, India.

EPS-724: Environmental Geology

Unit I:

Environmental dilemmas, fundamental concepts and definition of environmental geology. Concepts of natural ecosystems on the Earth and their mutual inter-relations and interactions (atmosphere, hydrosphere, lithosphere and biosphere).Concept of biodiversity.

Unit II:

Mobility of elements. Pollutant retardation, acid deposition, trace elements in hydrosphere, pollutant migration modeling. Soil degradation and changing land use pattern. Deforestation and land degradation.

Unit III:

Environmental impact assessment of degradation and contamination of surface water and groundwater quality due to industrialization and urbanization; water chemistry, residence time concept, equilibrium thermodynamics and kinetics, pollutants in aquatic systems, organic and inorganic contamination of groundwater and its remedial measures; water logging problems.

Unit IV:

Concepts of disaster,issues and concern for various causes of disasters, like Cyclone, flood, landslide, land-subsidence, forest fire and earthquake.Distribution, magnitude and intensity of earthquakes. Neotectonics and seismic hazard assessment. Preparation of seismic hazard maps. Impact of seismic hazards on long and short term environmental conditions. Mechanism of landslides, causes of major floods, cyclones and storms.

Unit V:

Disaster management, mitigation, and preparedness, techniques of monitoring and design against the disasters. Management issues related to disaster. Environmental monitoring and mapping in the areas of human-dominated environment over nature-dominated system using remote sensing and GIS tools. Mitigation through capacity building, legislative

responsibilities of disaster management. Basic tenets of environmental laws. Legislative measures of environmental protection in India.

Suggested Readings:

1. Holland H.D. (1984): The Chemical Evolution of the Atmosphere and Oceans, Wiley-Interscience Publ. (ISBN: 9780691023816), 598p.
2. Drever, J. I. (1997): The Geochemistry of Natural Waters, 3rd Edition, Prentice-Hall Publisher, 436 p.
3. Keller E.A. (2007): Introduction to environmental geology, 4th edition, Prentice-Hall Publishing (ISBN: 0132251507)
4. Aswathanarayana U. (2016): Geoenvironment, AA Balkema Pub. (ISBN: 9054106085/ 9789054106081)
5. Charles H. E. (2011): Environmental Impact Assessment: A Guide to Best Professional Practices, CRC Press (ISBN: 9781138074156), 285p.
6. Morgan R. K. (2002): Environmental Impact Assessment: A Methodological Approach, Kluwer Academic Publisher (ISBN: 0412730006/0412729903), 308p.
7. Bell, F.G. (1999): Geological Hazards: their assessment, avoidance, and mitigation, Routedge, London (ISBN: 9780203014660), 648p.

EPS-725: Gemmology

Unit I:

Gemstones, Naming and classification scheme of gemstones, Colour and chemistry of gemstones.

Unit II:

Gem identification, Origin and formation of gems, Gem production and exploration.

Unit III:

Synthetic gems, Gem cutting, Gemmological Instruments, Laboratory treated gemstones.

Unit IV:

Rules for the collection of gemstones, Geochemistry of gems and its relevance.

Unit V:

Distribution of gemstones in India and World, Scope in future perspective.

Suggested Readings:

1. Groat, L.A. (2007). The Geology of Gem Deposits. Mineralogical Association of Canada, ISBN: 0-9212-9437-9, 270p.

2. Karanth, R.V. (2000). Gems and Gem Industry in India. Memoir 45, Geological Society of India, Banglore, ISBN: 81-85867-41-0, 415p.

3. Nassau, K. (1994). Gemstone Enhancement: History, Science and State of the art, 2nd edition. Elsevier Butterworth-Heinemann, ISBN-10: 0-7506-1797-7, 252p.

4. O'Donoghue, M. (2006). Gems: Their Sources, Descriptions and Identification, 6th edition. Elsevier Butterworth-Heinemann, New York, ISBN: 978-0-75-065856-0, ISBN: 0-75-065856-8, 937p.

5. Schumann, W. (2009). Gemstones of the World Newly revised and expanded 4th edition. Sterling, New York, ISBN-10: 1-4027-6829-X, 272p.

EPS-726: Experimental Mineralogy and Petrology

Unit I:

Scope and Definition, Types of experimental petrology, Fundamental principles of thermodynamics, Phase Rules and phase diagrams, Equilibrium and Kinetics, Starting materials and its type.

Unit II:

Experimental techniques and instrumentation: High temperature furnaces, Tuttle-type hydrothermal apparatus, Kennedy-type piston cylinder apparatus, Walker type multi anvil high pressure apparatus.

Unit III:

Electrical conductivity, Preparation of cell assembly for high T_P runs, Experiments under controlled atmosphere and oxygen fugacity, Pressure and Temperature measurements with calibration, Buffers mixtures and its implications.

Unit IV:

Analytical instruments: Analysis of run products using Petrological microscope, X-ray diffractometer (XRD), Electron probe micro analyzer (EPMA) and Fourier transformed infrared (FTIR) spectroscopy etc.

Unit IV:

Applications and limitations of the experiments, Common problems in experiments, Correlation of experimental results with natural data.

Suggested Readings:

1. Edger, A.D. (1973). Experimental Petrology: Basic principles and techniques. Clarendon Press, Oxford, London, 215p.

2. Ulmer, G.C. and Barnes, H.L. (1987). Hydrothermal Experimental Techniques. John Wiley and Sons, New York, ISBN: 0-471-82145-4, 524p.

3. Johannes, W. and Holtz, F. (1996). Petrogenesis and Experimental Petrology of Granitic Rocks. Springer-Verlag, ISBN: 3-540-60416-2, 335p.

4. Dunn, T. (1993). The Piston-cylinder apparatus. In: Luth R.W. (Ed.) experiments at high pressure and applications to the Earth's mantle. Mineralogical Association of Canada, v.21, 39-94pp.

5. Liebermann, R.C. (2011). Multi-anvil High Pressure Appratus: A half century of development and progress. High pressure research, v.31 (4), 493-532pp.

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