ANNEXURE - 3

REVISED CURRICULUM
OF
M. Sc. PROGRAMME IN APPLIED GEOLOGY

Department of Earth Science
Aryabhatta School of Earth Sciences
Assam University, Silchar

2015

M.Sc. (Applied Geology) Revised Course Scheme (w.e.f. 2015)

First Semester

CourseNo.	Course Title	Mark Distribution			Credit	Contact Hours
		Semester	Sessional	Total		
ES - 101	Geomorphology, GIS & Remote Sensing	70	30	100	6	
ES - 102	Palaeontology	70	30	100	6	
ES - 103	Mineralogy	70	30	100	6	
ES - 104	Igneous Petrology	70	30	100	6	
ES - 105	Practical on ES-101,102,103 and 104	70	30	100	6	
	Total	**350**	**150**	**500**	**30**	

Second Semester

Course No.	Course Title	Mark Distribution			Credit	Contact Hours
		Semester	Sessional	Total		
ES - 201	Structural Geology and Tectonics	70	30	100	6	
ES - 202	Sedimentology	70	30	100	6	
ES - 203	Open course*	70	30	100	6	
ES - 204	Open course**	70	30	100	6	
ES - 205	Practical on ES – 201, 202 and Field work	70	30	100	6	
	Total	**350**	**150**	**500**	**30**	

Third Semester

Course No.	Course Title	Mark Distribution			Credit	Contact Hours
		Semester	Sessional	Total		
ES - 301	Stratigraphy	70	30	100	6	
ES - 302	Petroleum Geology	70	30	100	6	
ES - 303	Hydrogeology	70	30	100	6	
ES - 304	Metamorphic Petrology & Geochemistry	70	30	100	6	
ES - 305	Practical on ES – 301, 302, 303 and 304	70	30	100	6	
	Total	**350**	**150**	**500**	**30**	

Fourth Semester

Course No.	Course Title	Mark Distribution			Credit	Contact Hours
		Semester	Sessional	Total		
ES - 401	Ore Geology and Mining Geology	70	30	100	6	
ES - 402	Environmental Geology and Geo-Engineering	70	30	100	6	
ES - 403	Project Oriented Dissertation	140	60	200	12	
ES - 404	Practical on ES 401, 402 and Field work	70	30	100	6	
	Total	**350**	**150**	**500**	**30**	

* Know your Planet (**For Non-Geology students**)

(i) Treasures of Earth (For Non-Geology students**); (ii) Geology, Tectonics and Mineral Resources of Northeast India (**For Geology students**)

M.Sc. (Applied Geology) Revised Course Curriculum (w.e.f. July 2015)

Candidates who have passed Three Years Degree Course (Science) examination (Honours and Pass) with Geology/having Geology as one of the pass subjects will be considered eligible for admission to the M.Sc. (Applied Geology). Students admitted to the M. Sc. (Applied Geology) Program shall be required to pursue their studies for **two** consecutive academic sessions involving four semesters; each of six months duration. They will be examined and evaluated on grade basis at the end of each semester in respective courses of theory and practical as per credits assigned. The M.Sc. (Applied Geology) shall consist of (a) Core Courses (b) Open courses (c) Geological Field Training and (d) Project Oriented Dissertation involving a total of 120 credits distributed equally over the four semesters (30 credits per semester) as detailed below:

(a) The Core courses will be compulsory for all the students admitted to M.Sc. (Applied Geology). There will be twelve core Theory courses, each of 6 credits and four core Practical courses including two field works each of 6 credits covering major branches of Geology.

(b) There shall be two open courses (Theory) each of 6 credits within 2^{nd} semester. A student is required to complete at least one open course (six credits) from other departments of AUS.

(c) Two compulsory geological field trainings each of two weeks duration are available for the students in the 2^{nd} and 4^{th} semester. The field work in second semester will be conducted under the supervision of a faculty where as the one in fourth semester will be undertaken by the student independently within the northeast India as assigned by the Department. Following each field work the student will submit a report for evaluation and shall undertake corresponding viva-voce examination at the end of respective semester.

(d) There shall be a compulsory Project Oriented Dissertation of 12 credits in the 4^{th} semester. The area of Dissertation shall be assigned to the students in the beginning of the 3^{rd} semester based on the preference & merit of the student as well as expertise available with the Department. Students are required to submit their findings in the form of a project oriented dissertation thesis followed by an open seminar presentation for the purpose of evaluation before the faculty members and the board of examiners at the end of the semester.

FIRST SEMESTER

ES - 101: Geomorphology, GIS and Remote Sensing
Total Credit: 6
Contact hours:
Full Marks: 100 (Semester 70+ Sessional 30)

UNIT I: Introduction to Geomorphology; Geomorphic processes; Fluvial, Glacial, Coastal landforms; Models of Landform evolution, Davis' Model, Penk's Model, King's Model; Tectonic Geomorphology; geomorphic markers; Geomorphic indices of active tectonics

UNIT II: Components of remote sensing, energy sources, Electromagnetic spectrum, energy interaction in the atmosphere, Atmospheric windows, Spectral reflectance, Types of satellites and sensors, Photogrammetry: introduction, types of Aerial photographs; Stereoscopic models; Stereoscopes; Pocket and Mirror.

UNIT III: Digital image processing; Introduction to digital image; Image rectification and restoration; Image enhancement; Image classification; Data margin and GIS integration, Remote sensing data interpretation: Manual and Digital; Application of Remote sensing in Geosciences: Hydrology, Mineral exploration, Natural Diasastar management.

UNIT IV: Satellite programmes: Indian remote sensing satellite (IRS) series, Landsat Series: Microwave Remote sensing: Introduction, Radar development, Radar image interpretation, Application; Hyperspectral Remotesensing: Principles Data interpretations, Applications, Thermal Infra Red Remotesensing: Principles, data interpretations, Applications.

UNIT V: Introduction to Geographic Information System: History of GIS development; GIS techniques and technology: relating information from different sources; GIS uncertainties, GIS data representations, data capture, vector to rastar transformation, Map projection, coordinate systems.

Books Recommended:

Miller, V.C. 1961: Photogeology. McGraw Hill.
Sabbins, F.F. 1985: Remote Sensing Principles and Applications. Freeman.
Ray, R.G. 1969: Aerial Photographs in Geologic Interpretations. USGS Prof. Paper, 373.
Drury, S.A. 1987: Image Interpretation in Geology. Allen & Unwin.
Moffitt, F.H. and Mikhail, E.M. 1980: Photogrammetry. Harper and Row.
Lillesand, T.M. and Kieffer, R.W. 1987: Remote Sensing and Image Interpretation. John Wiley
Paine, D.P. 1981: Aerial Photography and Image Interpretation for Resource Management. John Wiley
Pandey, S.N. 1987: Principles and Applications of Photogeology. Wiley Eastern, New Delhi.
Gupta, R.P. 1990: Remote Sensing Geology. Springer Verlag
Moffitt, F.H. and Mikhail, E.M., 1980: Photogrammetry, Harper and Row
Thornbury, 2nd Edition: Principles of Geomorphology, CBS
Sharma: Indian Geomorphology, Concept
Singh, S., 2001: Geomorphology, Pustakalaya Bhawan, Allahabad.

ES - 102: Palaeontology
Total Credit: 6
Contact hours:
Full Marks: 100 (Semester 70 + Sessional 30)

UNIT- I: Principles of paleontology vis-à-vis paleobiology; Species concept and speciation. Origin and diversity of life; Adaptation and functional morphology; Mechanism of evolution; Palaeobiogeography, Major Mass Extinction Events of Earth's history.

UNIT-II: Functional morphology and evolutionary history of Brachiopoda, Mollusks and echinoids. Trace fossils: kinds, classification and their significance in palaeoenvironmental analysis.Variations in pedicle opening in brachiopods, variation in occulogenital system and ambulacralplates in echinoids.Evolution and ecology of corals.

UNIT- III: Foraminifera: Brief morphology, classification, Morphology and classification of Ostracoda,Radiolaria, Conodonts and their significance; Introduction to calcareous algae, dinoflaggellates andtheir significance.

UNIT- IV: Morphology of plant fossil, use of plant fossil, major subdivisions of plant fossil, Evolution of land floras, Palynology including spore/pollen morphology and their application.

UNIT- V: Major subdivisions of vertebrates, Morphology of different diagonostic element of vertebrates: skull, jaw, vertebral column, ribs, teeth, General Evolution of vertebrates, Evolution, Evolution of Horses; elephants; primates and man.

Books Recommended:

Alfred R. Loeblich, Jr. and Helen Tappan(1998):Foraminiferal Genera and their classification: Van Nostrand Reinhold Company, New York
Arnold (2002): Quaternary Environmental Micropaleontology (Ed. Simon K. Haslett), Oxford niversity Press, New York.
B.K.Sengupta: Modern Foraminifera
Benton, M.J. (1990): Vertebrate Paleontology. Unwin Hyman, Lindon.
Bignot, G., Grahm and Trottman (1985): Elements of Micropaleontology, London.
Boardman, R.S., Cheethan, A.M. and Rowell, A.J. (1988): Fossil Invertebrates, Blackwell.
Clarksons, E.N.K. (1998): Invertebrate Paleontology and Evolution, Allen and Unwin, London.
Colbert, E.H. (1984): Evolution of Vertebrates. Willey Eeastern Ltd.
Glaessner. N.(1944) :Principles of Micropaleontology,Melbourne
Haynes,J.R; 1981: Foraminifera, John Wiley
Jones, D..J. Introduction to Microfossils:,Cambrigde University press
Jones, Robert Wynn. (1996): Micropaleontology in Petroleum Exploration,Clarendon Press
M. Brasier: Micropaleontology, Blackwell
Prothero, D.R. (2004): Bringing Fossil to Life An Introduction to Paleontology (2nd Ed.), McGraw Hill.
Raup, D.M. and Stanley, S.M (2008): Earth System History, Blackwell Publ.
Raup, D.M. and Stanley, S.M. (1985): Principles of Paleontology ,CBS Publ..
Romer, A.S. (1966): Vertebrate Paleontology (3rd Edn.) Chicago University Press.
Strean, C.W. and Carroll, R.L. (1989): Paleontology the record of life, John Wiley.
Swnnerton, H.H. (1950): An outline of paleontology, Edward Arnold and Co.
Vladimir Pokorny(1963):Principles of Zoological Micropaleontology,Vol.1,Pergasmon press, Oxford, London, New York,pp.91

ES - 103: Mineralogy
Total Credit: 6
Contact hours:
Full Marks: 100 (Semester 75 + Sessional 30)

UNIT I: Introduction to crystal chemistry: bonding in minerals, solid solution, exsolution, polymorphism, isomorphism, pseudomorphism, polytipism, polysomatism; Atomic and Ionic radii, Pauling's rules governing the ionic structures; Spheres in closest packing: Cubic closest packing, Hexagonal closest packing, Body centered cubic packing. Voids in closest packing.

UNIT II: Structure & Classification of Silicate minerals. Detailed study of following mineral groups with reference to their general formulae, classification, atomic structure, chemistry, diagnostic physical and optical properties, P-T stability, alteration and occurrences: a. Nesosilicates: Olivine Group, Garnet Group, Aluminosilicate Group (Kyanite, Andalusite, and Sillimanite) b. Cyclosicates: Beryl.

UNIT III: Detailed study of following mineral groups with reference to their general formulae, classification, atomic structure, chemistry, diagnostic physical and optical properties, P-T stability, alteration and occurrences: a. Inosilicates: Pyroxene Group; Amphibole Group, b. Phyllosilicates: Kaolinite Group; Serpentine Group; Mica Group; Chlorite Group, c. Tectosilicates: Feldspar Group; Cordierite.

UNIT IV: Twinning and twin laws; common types of twins and their examples in minerals. Concept of Crystal Field Theory and mineralogical spectroscopy; Liquid crystals and their applications

UNIT V: Light – mineral interactions, Refractive index determinations; Pleochroism; Isotropism vs Anisotropism, Interference color; Birefringence; Extinction - types and determination. Optical Indicatrix- Uniaxial and Biaxial Interference Figures and Optic sign determination, 2V and 2E.

Books Recommended:

Azaraoff: Elements of X-ray Crystallography.
Berry, L.G., Mason, B. and Dietrich, R.V.: Mineralogy, CBS Publishers
Buerger: Elementary Crystallogaphy
Dana, E.S. and Ford, W.E.: A textbook of Mineralogy. Wiley Eastern Limited.
Dana: Elements of Mineralogy
Deer, Howie and Zusmann: Rock forming minerals
Deer, W.A., Howie, R.A. & Zussman, J. : An Introduction to the rock forming minerals, Longman
Guillman: Art and Science of Crystal Growth
Kerr,P.F. Optical Mineralogy. McGraw Hill Book Company
Klein, C. and Huburt, Jr., C.S., 1993: Manual of Mineralogy. John Wiley.
Moorhouse, W.W.: Optical Mineralogy.
Nesse, D.W.: Optical Mineralogy, McGraw Hill.
Philips, Wm, R. and Griffen, D.T. 1986: Optical Mineralogy, CBS Edition
Philips,F.C. Introduction to crystallography.
Putnis, Andrew. 1992: Introduction to Mineral Sciences. Cambridge Univ. Press.
Spear, F. S. (1993) : Mineralogical phase equilibria and Pressure- Temperature- Time paths
Winchell: Elements of Optical Mineralogy part I and II

ES - 104: Igneous Petrology
Total Credit: 6
Contact hours:
Full Marks: 100 (Semester 70 + Sessional 30)

UNIT I: Composition, physical properties, origin, differentiation and evolution of magma; Classification of Ultramafic, mafic and Acid igneous rocks. Textures of igneous rocks and their significance. Rock associations in time and space. Igneous rocks of continental and oceanic regions, plate margin magmatic rocks.

UNIT II: Phase rule and phase diagrams. Phase relations in Binary and Ternary systems, Application of phase rule in the study of silicate systems Binary: Diopside-Anorthite; Albite-Anorthite; Leucite-Quartz and Ternary: Diopside-Albite-Anorthite; Diopside-Forsterite-Anorthite; Forsterite-Anorthite-Silica.

UNIT III: Petrology, mode of occurrences, tectonic setup and distribution of the following groups of magmatic rocks:

a. Basalt clan
b. Granite and Granitic rocks
c. Andesites and related rocks
d. Ultramafic rocks
e. Alkaline rocks and Carbonatites

UNIT IV: Upper mantle mineral assemblages and its chemical composition. Partial melting processes in the upper mantle and magma genesis. Basaltic magma spectrum in relation to partial melting processes. MORB and evolution of depleted mantle, OIB and enriched mantle; Concept of hot spots and mantle Plumes.

UNIT V: Magmatism in relation to global tectonic processes. Characteristic magma series associated with specific tectonic settings. Magmatism at constructive plate margins: Mid-oceanic ridges. Magmatism at destructive plate margins: island arcs, active continental margins. Within plate magmatism: Oceanic islands and continental flood basalts.

Books Recommended:

Best, Myron G., 2002:. Igneous and Metamorphic Petrology, Blackwell Science.
Bose, M.K., 1997: Igneous Petrology, World Press, Kolkata.
Carmichel, Turner and Verhoogen: Igneous Petrology, Mc.Graw Hill.
Cox, K.G., Bell, J.D. and Pankhurst, R.J., 1993: The Interpretation of Igneous Rocks.
Faure, G.: Origin of Igneous Rocks, Springer.
Mc Berney, 1993: Igneous Petrology
Middlemost. E.A.K.: Igneous Petrology
Philpotts, A.R. 1994: Principles of Igneous and Metamorphic Petrology, Prentice Hall.
Sood, M.K., 1982: Modern Igneous Petrology. Wiley-Interscience Publ., New York.
Wilson, M., 1993: Igneous Petrogenesis. Chapman & Hall, London.
Winter John D., 2009: Principles of Igneous and Metamorphic Petrology (2nd Edition)

ES - 105: Practical on ES – 101, 102, 103 and 104
Total Credit: 6
Contact hours:
Full Marks: 100 (Semester 70 + Sessional 30)

Section A: Study of nature of aerial photographs: resolution, mosaics, symbols, gully pattern, drainage analysis, and image parallax. Determination of scale, height, dip, slope, vertical exaggeration, and image distortion. Interpretation from imageries. Making false color composites and study of multispectral scans and spectral patterns. Exercises on digital image processing. Study of environmental hazard maps. Morphometric analysis in different river basins.

Section B: Study of vertebrate fossils, pollens, foraminifers, ostracods and Trace fossils of India. Coiling geometry in Gastropoda, cephalopoda. Application and interpretation in sedimentary depositional environment. Techniques of separation of microfossils from matrix; SEM applications in micropaleontology; Study of surface ultrastructures of foraminifera; Study of larger benthic foraminifera useful in Indian stratigraphy with special reference to Cenozoic petrolliferous basins of India; Important palynomorphs of Cretaceous and Paleogene age.

Section C: Handspecimen study of minerals. Thin section study of minerals.

Section D: Megascopic and microscopic study of igneous rocks. Exercises on calculation of modal mineralogy and assigning name to rocks; Calculation of CIPW Norms; Exercises on Binary and Ternary Phase diagrams.

SECOND SEMESTER

ES - 201: Structural Geology and Tectonics
Total Credit: 6
Contact hours:
Full Marks: 100 (Semester 70 + Sessional 30)

UNIT I: Mechanical principles and properties of rocks and their controlling factors, Concept of stress; Theories of rock failure; Two-dimensional stress analyses; Concept of strain, two dimensional strain analysis; Types of strain ellipses and ellipsoids, their properties and geological significance;

UNIT II: Mechanics of folding and buckling. Fold development and distribution of strain in folds. Morphological & Geometrical classification of folds. Causes and dynamics of faulting with special reference to stress and strain, strike-slip faults, normal faults, over thrust and nappe and their characteristics.

UNIT III: Brittle and ductile shear zones, geometry and products of shear zones; Mylonites and cataclasites; Planar and linear fabrics in deformed rocks, their origin and significance. Concept of petrofabrics, Planar and linear fabrics in deformed rocks, graphic treatment, Types of fabrics, fabric elements and interpretation of fabric data on microscopic and mesoscopic scale.

UNIT IV: Plate Tectonics: recent advances, pros and cons. Dynamic evolution of continental and oceanic crust. Tectonic features of extensional-, compressional-, and strike-slip-terrains and relevance to plate boundaries. mantle plumes.

UNIT V: Study of large scale tectonic features of the Earth. Tectonics of Precambrian Orogenic Belts of India. Formation of mountain roots. Anatomy of orogenic belt. Structure and origin of the Alpine-Himalayan belt, the Appalachian-Caledonian belt and the Andes. Plate tectonic evolution of India.

Books Recommended:

Condie, Kent. C. (1982): Plate Tectonics and Crustal Evolution, Pergamon Press Inc.
Gass I.G. (1982): Understanding the Earth. Artemis Press (Pvt) Ltd. U.K.
Ghosh, S.K. (1993): Structural Geology: Fundamental and Modern Developments. Pergamon Press.
Hobbs, B.E., Means, W.D. and Williams, P.F. (1976): An outline of Structural Geology, John Wiley and Sons, New York.
Ramsay, J.G. (1967): Folding and fracturing of rocks, McGraw Hill.
Ramsay, J.G. and Huber, M.I. (1983): Techniques of Modern Structural Geology, Vol. I, Strain Analysis,
Academic Press.
Ramsay, J.G. and Huber, M.I. (1987): Techniques of Modern Structural Geology, Vol. II, Folds and Fractures, Academic Press.
Ramsay, J.G. and Huber, M.I. (2000): Techniques of Modern Structural Geology, Vol. III (Application of continuum mechanics), Academic Press.
Turner, F.J. and Weiss, L.E. (1963): Structural analysis of Metamorphic Tectonites, McGraw Hill.
Windley B. (1973): The Evolving continents, John Wiley and Sons, New York.

ES - 202: Sedimentology
Total Credit: 6
Contact hours:
Full Marks: 100 (Semester 70 + Sessional 30)

UNIT I: Earth Surface System: liberation of flux of sediments. Sedimentary structures: classification, significance and field recording. Fluid flow mechanics and formation of sedimentary bedforms, Concept of Flow Regime.

UNIT II: Sedimentary Environments and Facies; Walther's law of facies succession, Processes and characteristics of fluvial, estuarine, deltaic, lagoonal, barrier beach, tidal flats and deep-sea environments.

UNIT III: Marine and continental evaporate. Shallow water carbonates. Volcanoclastic: on-land and marine. Palaeocurrent properties and indicators, Palaeocurrent analysis. Significance of ichnofossils in sedimentological studies, Cyclic sedimentation.

UNIT IV; Petro genesis of sandstones, Graywacke and graywacke problem; plate - tectonics and sandstones composition, Sedimentary basins in relation to Plate tectonics, Clastic petrofacies, Palaeoclimate indicators.

UNIT V: Diagenesis and fluid flow. Diagenesis of mudstones, sandstones and carbonate rocks: changes in mineralogy, fabric and chemistry. Heavy minerals and their uses in provenance studies.

Books Recommended:

Allen, J.R.L. 1985: Principles of Physical Sedimentation. George Allen & Unwin.
Allen, P. 1997: Earth Surface Processes. Blackwell.
Nichols, G. 1999: Sedimentology and Stratigraphy. Blackwell.
Reading, H.G. 1996: Sedimentary Environments. Blackwell.
Davis, R.A. Jr. 1992: Depositional Systems. Prentice Hall.
Einsele, G. 1992: Sedimentary Basins. Springer Verlag.
Prothero, D.R. and Schwab, F. 1996: Sedimentary Geology. Freeman.
Miall, A.D. 2000: Principles of Sedimentary Basin Analysis. Springer Verlag.
Pettijohn, F.J., Potter, P.E., and Siever, R. 1990: Sand and Sandstone. Springer Verlag.
Blatt, H., Murray, G.V., and Middleton, R.C. 1980: Origin of Sedimentary Rocks.
Bhattacharya, A. and Chakraborti, C. 2000: Analyses of Sedimentary Successions. Oxford -IBH.
Boggs, Sam Jr. 1995: Principles of Sedimentology and Stratigraphy. Prentice Hall.
Sengupta, S. 1997: Introduction to Sedimentology. Oxford - IBH.
Reineck, H.E. and Singh, I.B. 1980: Depositional Sedimentary Environments. Springer Verlag.
Collins, J.D., and Thompson, D.B. (1982): Sedimentary Structures, George Allen and Unwin, London.
Lindholm, R.C. (1987) A Practical Approach to Sedimentology, Allen and Unwin, London.
Selley, R. C. (2000) Applied Sedimentology, Academic Press.
Tucker, M.E. (1981): Sedimentary Petrology: An Introduction, Wiley and Sons, New York.
Tucker, M.E. (1990): Carbonate Sedimentolgy, Blackwell Scientific Publication.

ES - 203: Know your Planet
Total Credit: 6
Contact hours:
Full Marks: 100 (Semester 70 + Sessional 30)

UNIT- I: Solar system, origin of earth, Bing bang theory, Distribution of crust, mantle and core, Interior of the earth: density, heat budget, magnetism, gravity, isostasy. Geological time scale.
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UNIT- II: Basic idea of plate tectonic: different types of plates and plate boundaries, evidences and results. Positions of different continents in geological time. Journey of India and origin of Himalya.

UNIT- III: Seismicity. Different types of seismic wave, Earth quake and Tsunami: theory evidences and results. Major Earth quakes and Tsunami of India: causes and results

UNIT- IV: Origin of life, Evolution of life: mechanism and major trend, Fossil: basic and application, Major Mass extinction Events of Earth s history.

UNIT- V: Basic idea of geochronology, Parent-daughter isotopes; Radioactivity, Half life, Decay Equation; Isotope dating: basics and application, Dating of Rocks

Books Recommended:

Bott, M.H.P., 1982: The interior of the earth its structure, constitution and evaluation.
Condie, K. C. : Plate tectonics and crustal evolution
Kearey, P. & Brooks, M., 1991: Introduction to Geophysical Prospecting, Osney Mead, Oxford.
Nagata, T.: Rock Magnetism, Maruzen Co., Ltd., Tokyo
Parkinson, W.D., 1983: Introduction to Geomagnetism, Scottish Acad., Press, Edinburgh
Pick, M., Picha, J. & Vyskocil, V. 1973: Theory of the Earth s Gravity Field, Elsevier.
Tarling, D.H. 1983: Palaeomagnatism, Chapman and Hall, London
Telford, W. M., Geldart, C.P., Sheriff, R.E. & Keys, D.A., 1976: Applied Geophysics, Cambridge University Press, London.
Walther, JV , 2009: Essentials of Geochemistry.

ES – 204 (i): Treasures of Earth
Total Credit: 6
Contact hours:
Full Marks: 100 (Semester 70 + Sessional 30)

UNIT- I: Definition of energy: primary and secondary energy; difference between energy, power and electricity; renewable and non-renewable sources of energy; potential of hydroelectric power, solar energy, wind, wave and biomass based power and energy.

UNIT- II: Scope of water resources: past, present and future; distribution of water resources in the Earth; introduction to surface and groundwater resources; major rivers of India and their potential for generation of energy; groundwater prospect zones of India and its future requirement.

UNIT- III: Mineralogy, genesis, classification, uses and distribution of metallic ores: Fe, Cu, and Zn; Mineralogy, origin, classification, uses and distribution of radioactive minerals and precious and semi-precious ores minerals.

UNIT- IV: Petroleum: its different states of natural occurrence, chemical composition and physical properties of crudes in nature; origin and migration of oil.

UNIT- V: Coal and its properties: different varieties and ranks of coal and origin of coal; mineral and organic matter in coal; geology and petrography of coalfields of India.

Books Recommended:

Evans, A.M. 1993. Ore Geology and Industrial Minerals. Blackwell ScLPubL
Gokhale, K.Y.GK. and Rao, T.C. 1978. Ore deposits ofIndia their distribution and processing, Tata-McGraw Hill, New Delhi.
Deb, S. 1980. Industrial minerals and rocks ofIndia. Allied Publishers.
Todd, D.K. 2006. Groundwater hydrology, 2nd Ed., John Wiley & Sons, N.Y.
Davis, S.N. and De Weist, R.J.M. 1966. Hydrogeology, John Wiley & Sons Inc., N.Y.
Karanth K.R., 1987, Groundwater: Assessment, Development and management, Tata McGraw-Hill Pub. Co. Ltd.
Fetter, C.W. 2001. Applied Hydrogeology, Prentice Hall Inc., N.J., U.S.A.
Coal Geology: Larry Thomas, 2002, Wiley and Sons.
Coal: it's composition, analysis, utilisation and valuation.: E.E.Somermier 2008, Mc GrawHiIl
Petroleum Geology: F.K.North, I986,Allen and.l)nwin
Petroleum Formation and Occurrence: B.P.Tissot and D.H.Welte 1978, Publisher: Springer-Verlag
Elements of petroleum Geology: R.C.Shelley 1998, Academic press
Petroleum Development Geology: P.A.Dickie, 1986, Publisher: Pennwell Publishing, Tulsa, Oklahoma
Petroliferous basins ofIndia: Publisher: KDMIPE, ONGC, 1986.
Energy and the Environment by Fowler, J.M 1984. McGraw-Hill
Global Energy Prospectives by Nebojsa Nakicenovic 1998, Cambridge University Press.
Energy Resources and Systems: Fundamentals and Non-Renewable Resources by Tushar K. Ghosh and M. A. Prelas. 2009, Springer
Introduction to Wind Energy Systems: Hermann-Josef Wagner and Jyotirmay Mathur. 2009, Springer.
Renewable Energy Conversion, Transmission and Storage. Bent Sorensen, 2007, Springer.
World Energy resources: C.E. Brown. 2001, Springer.

ES – 204 (ii): Geology, Tectonics and Mineral Resources of N. E. India
Total Credit: 6
Contact hours:
Full Marks: 100 (Semester 70 + Sessional 30)

UNIT – I: Detailed Stratigraphic succession, Lithology, Structure and Tectonics, Fossil content and Mineral Resources of Nagaland

UNIT – II: Detailed Stratigraphic succession, Lithology, Structure and Tectonics and Mineral Resources of Meghalaya

UNIT – III: Detailed Stratigraphic succession, Lithology, Structure and Tectonics, Fossil content and Mineral Resources of Assam

UNIT – IV: Detailed Stratigraphic succession, Lithology, Structure and Tectonics, Fossil content and Mineral Resources of Folded belt of Nagaland-manipur including Ophiolites.

UNIT – V: Detailed Stratigraphic succession, Lithology, Structure and Tectonics, Fossil content and Mineral Resources of folded belts of Cachar-Mizoram-Tripura

Books Recommanded:

Karunakaran, C.1972: Geology and Mineral Resources of the states of India, Misc. Publ., Geol. Surv. India
Dasgupta, A.B. and Biswas, A.K. 2000: Geology of Assam. Geol Soc. India, Bangalore.
D. N. Wadia, 1957: Geology of India (3rd ed) . Mc Millan, London, 536p.
E. H. Pascoe, 1968. A manual of the Geology of India & Burma (Vols. 1 – 1v) Govt. of India Press, Delhi.
M.S. Krishnan, 1982. Geology of India and Burma (6th ed) CBS Publishers & Distributors, Delhi, 536p.
S.M. Naqvi, 2005. Geology and Evolution of the Indian plate (from Hadean to Holocene-4 Ga to 4ka) Capital publishing co., 450p.
S.M. Naqvi, and J.J.W. Roger, 1987. Precambrian Geology of India (Oxford Monograph on Geology and Geophysics) Oxford Univ. Press 223p

ES - 205: Practical on ES – 201, 202 and Field Work
Total Credit: 6
Contact hours:
Full Marks: 100 (Semester 70 + Sessional 30)

Section A: Preparation and interpretation of geological maps and sections; Structural problems concerning economic deposit based on orthographic and stereographic projections; Recording and plotting of the field data; Study of deformed structures in hand specimens; Strain estimation from the data already collected from the field; Study of dip-isogons from the fold profiles; Preparation of geotectonic maps.

Section B: Megascopic study of clastic and non-clastic rocks. Study of primary, secondary, and biogenic sedimentary structures in hand specimens, in photographic atlases, field photographs, and wherever possible on outcrops. Exercises related to palaeocurrent analysis and interpretation of depositional sedimentary environments. Microscopic examination of important rock-types. Heavy mineral separation and microscopic examination. Grain-size analysis by sieving method; Plotting of size-distribution data as frequency and cumulative curves, computation of statistical parameters and interpretation.

Section C **(Field work):** Students are compu lsorily required to undergo field work of two weeks duration on various components of Field Geology. Each student is required to submit a report duly certified by the Teachers in-Charge of the Field tour and the Head of Department and has to take a viva- voce examination at the end of semester.

THIRD SEMESTER

ES - 301: Stratigraphy
Total Credit: 6
Total Lectures:
Full Marks: 100 (Semester 70 + Sessional 30)

UNIT I: Controls on the development of stratigraphic records. Completeness/ incompleteness of stratigraphic records. Lithostratigraphy: correlation and stratigraphic code. Biostratigraphy: controlling factors, zonation, time significance, quantitative stratigraphy.Geochronology and chronostratigraphy, Sequence stratigraphy. Brief ideas of magneto- seismic- chemo- and event stratigraphy; Stratigraphic correlations.

UNIT II: Classification and correlation of Precambrian crystalline rocks of India with particular reference to Dharwar, Singbhum, Bundelkhand, Aravalli; Mobile belts: eastern Ghats and Satpura. Stratigraphic classification and correlation of the Proterozoic rocks of India; Precambrian – Cambrian boundary problem.

UNIT III: Classification, lithology, correlation and fossils of Palaeozoic rocks of India with particular reference to Tethyan basins, Jammu and Kashmir, Himachal Pradesh, Uttaranchal and Peninsular India.

UNIT IV: Classification, lithology, correlation and fossils of Gondwana Super Group; Classification and correlation of Mesozoic rocks of India with particular reference to Jammu and Kashmir, Himachal Pradesh; Kutch, Rajsthan, Tamilnadu, Narmada and Assam- Meghalaya.

UNIT V: Classification, lithology, correlation and fossils of Tertiary rocks of India with particular reference to Rajasthan, Jammu and Kashmir, Kerala, Maharashtra, Kutch, Uttaranchal, Assam-Meghalaya and Tamilnadu; Quaternary stratigraphy of India; Neogene-Quaternary boundary problem.

Books Recommended:

Pomerol, C. 1982: The Cenozoic Era: Tertiary and Quaternary. Ellis Harwood Ltd.
Goodwin, A.M. 1991: Precambrian Geology: The Dynamic Evolution of Continental Crust. Academic Press.
Doyle, P. and Bennet, M.R. 1996: Unlocking the Stratigraphic Record. John Wiley.
Brenner, R.E. and McHargue, T.R. 1988: Integrative Stratigraphy: Concepts and Applications. Prentice Hall.
Naqvi, S.M. and Rogers, J.J.W. 1987: Precambrian Geology of India. Oxford University Press.

ES - 302: Petroleum Geology
Total Credit: 6
Total Lectures:
Full Marks: 100 (Semester 70 + Sessional 30)

UNIT I: Petroleum its composition and origin. Migration of petroleum and natural gas. Reservoir properties: porosity and permeability, fluid saturation, relative permeability and fluid flow. Characteristics of reservoir rocks and traps (structural, stratigraphic and combination). Pressure condition in the reservoir. Identification and characterisation of Source rock.

UNIT II: Geophysical exploration for hydrocarbon: Gravimetric and Seismic surveys-principles and interpretation. Oil well drilling and drilling fluids. Estimation of oil and gas reserves.

UNIT III: Wireline logging: principles and interpretations of Spontaneous Potential log, Natural gamma ray log, Porosity logs-sonic, density, neutron logs, Resistivity log, Conventional electric log, Induction logging, Resistivity and water saturation.

UNIT IV: Development of oil fields-aims, methods and stages, Primary and enhanced oil recovery-stimulation of initial recovery, water flooding, thermal recovery method, miscible flood method, polymer flooding, MEOR.

UNIT V: Onshore and offshore petroliferous basins of India; Geology of productive oil and gasfields of India with special reference to NE India; Elements of unconventional petroleum systems; Basin-centered gas, fractured-shale gas system, shallow biogenic gas and natural gas hydrates.

Books Recommended:
North F. K., 1985: Petroleum Geology.
Tissot, B.P. and Welte, D. H., 1984: Petroleum Formation and occurrences.
Shelly, R.C., 1998: Elements of Petroleum Geology
Leverson: Geology of Petroleum

ES - 303: Hydrogeology
Total Credit: 6
Total Lectures:
Full Marks: 100 (Semester 70 + Sessional 30)

Unit-I
Scope of hydrogeology; Groundwater in hydrogeological cycle; types of aquifers; properties of aquifers: water table, porosity, permeability, hydraulic conductivity, transmissivity, storativity.

Unit-II
Principles of groundwater flow: Darcy's law, hydraulic head, flow nets, flow in relation to groundwater contours, flow across a water table, regional flow pattern; determination of hydraulic conductivity: formulas, laboratory methods, field methods: tracer tests, pumping tests of wells.

Unit-III
Groundwater exploration: remote sensing & GIS, electrical resistivity method; subsurface investigation of groundwater: test drilling, water level measurement; groundwater occurrence in different rock types: sedimentary, igneous and metamorphic.

Unit-IV
Groundwater chemistry: units of measurement, major and minor ion chemistry; hydrochemical data presentations: Trilinear, Stiff, Durov, SAR; concept of hydrochemical facies and their evaluation.

Unit-V
Surface and groundwater interaction: stable and non-stable isotope analysis, environmental tracers analysis, water table fluctuation method; types of wells, major drilling methods; Groundwater management and development.

Books Recommended:
Chow, V.T. 1988: Advances of Hydroscience. McGraw Hill.
Walton, W.C. 1988: Ground Water Resource Evaluation. McGraw Hill.
Black, W. et al (Eds), 1989: Hydrogeology. Geol. Soc. Am. Publications.
Mahajan, G. 1990: Evaluation and Development of Ground Water. D.K. Publishers.
Raghunath, N.M. 1982: Groundwater. Wiley Eastern.
Karanth, K.R. 1987: Groundwater Assessment - Development and Management. Tata McGraw Hill.
Todd, D.K. 1980: Groundwater Hydrology. John Wiley.
Davies, S.N. and Dewiest, R.J.M. 1966: Hydrogeology. John Wiley.
Freeze, R.A. and Cherry, J.A. 1979: Groundwater. Prentice Hall.
Fetter, C.W. 1990: Applied Hydrogeology. Merrill Publishing.
Alley, W.M. 1993: Regional Groundwater Quality. VNR, New York.
Subramaniam. V. 2000: Water. Kingston Publications, London.
James L. Drever, 2nd Edition: The Geochemistry of Natural Water.

ES - 304: Metamorphic Petrology and Geochemistry
Total Credit: 6
Contact hours:
Full Marks: 100 (Semester 75 + Sessional 30)

UNIT I: Kinetics of metamorphism. Metamorphic textures and structures. Types of metamorphic equilibrium reactions. Graphical representation of mineral assemblages in composition diagrams (ACF AKF and AFM diagrams). Progressive metamorphism of pelites, basic rocks and carbonates. Metamorphism in relation to plate tectonics.

UNIT II: Concept of Barrovian and Buckan type of metamorphism. Metamorphic facies; Classification of metamorphic facies. Description of each facies of regional and contact metamorphism with special emphasis on characteristic minerals, mineral assemblages and P-T conditions of metamorphism.

UNIT III: Meteorites: classification, mineralogy, origin, significance; Primary Chemical Differentiation of the earth. Geochemical composition of the crust and mantle. Principles of ionic substitution in minerals; Element partitioning in mineral/ rock and concept of distribution coefficients. Geochemical characteristics of trace elements and rare earth elements (REE) in minerals and selected rock types

UNIT IV: General characteristics of isotopes. Stable isotopes: fundamentals and principles; nature, abundance and fractionation of stable isotopes. Isotopes of Oxygen, Hydrogen, Carbon and Sulphur, Application of stable isotopes in geological studies.

UNIT V: Radiogenic isotopes: Criteria for useful radioactive nuclides, Radioactive decay mechanisms. Srontium, Lead and Neodymium isotopes. Radio active decay schemes, growth of daughter isotopes and radiometric dating. Geochronology: Rb-Sr, U-Pb and Sm-Nd isotope systematization

Books Recommended:

Mason, B. & Moore, C.B. 1991: Introduction to Geochemistry
Krauskopf, K.B. 1967: Introduction to Geochemistry.
Faura, G. 1986: Principles of Isotope Geology.
Hoets, J. 1980: Stable Isotope Geochemistry. Springer Verlag.
Marshal, C.P. & Faibridge, R.W. 1999: Encyclopedia of Geochemistry.
Nordstorm, D.K. and Munoz, J.L. 1986: Geochemical Thermodynamics.
Henderson,P.1987: Inorganic Geochemistry
Rollinson, H. 1993: Using geochemical data: evaluation, presentation and interpretation. Longman.
Winkler: Metamorphic Petrology
Yoder, H.S.: Modern Igneous Petrology
Turner, F. J., 1980: Metamorphic Petrology, Mc Graw Hill.
Bucher, K. and Martin, F. 2002: Petrogenesis of Metamorphic Rocks, Springer-Verlag
Walther, 2009: Essentials of Geochemistry

ES - 305: Practicals on ES – 301, 302, 303 and 304

Total Credit: 6
Total contact hours:
Full Marks: 100 (Semester 70 + Sessional 30)

Section A: Study of rocks in hand specimens from known Indian stratigraphic horizons and type localities; Exercises on stratigraphic classification and correlation, sequence-, magneto- and seismic stratigraphic interpretations; Study and understanding of plate-movements through important periods during Phanerozoic eon; Study of palaeogeographic maps of various geological periods.

Section B: Preparation of lithostratigraphic sections from geophysical well logs and well data, study of wireline logs (SP, IEL, Porosity, Neutron, Gamma ray, CBL), Determination of Porosity and water saturation (for clean sand) from well log data, structure contour, isopay and isopach maps, estimation of Oil and gas reserves, preparation of geotechnical order for exploratory and development wells.

Section C: Delineation of hydrological boundaries on water table contour maps and estimation of permeability; Hydrogeomorphic mapping. Analysis of hydrochemical facies and its evolution on Trilinear and Durov diagrams. Pumping test: time-drawdown and time recovery tests and evaluation of aquifer parameters. Vertical electrical resistivity.

Section D: Megascopic and microscopic study of metamorphic rocks of different facies. Graphic construction of ACF, AKF and AFM diagrams. Plotting and interpretation of major elemental characteristics of igneous rocks. The uses and applications of major and trace element composition of igneous rocks as a means to understand the petrogenesis of the rocks. Exercies on isotopes: Stable; Radiogenic; Dating of earth samples using $^{235}U/^{207}Pb$ and $^{87}Sr/^{86}Sr$ ratio.

FOURTH SEMESTER

ES - 401: Ore Geology and Mining Geology
Total Credit: 6
Contact hours:
Full Marks: 100 (Semester 70 + Sessional 30)

UNIT I: Concept of ore genesis; Spatial and temporal distribution of ore deposits; Metallogenic epochs and Metallogenic Provinces. Nature and morphology of principles types of ore deposits; Classification of ore deposits. Textures, paragenesis and zoning of ores and their significance

UNIT II: Concept of ore bearing fluids, their origin and migration. Wall rock alteration; Structural, physicochemical and stratigraphic controls of ore localization; Ore deposits in relation to Plate tectonics; Fluid inclusions in ore – principles and applications.

UNIT III: Mineralogy, classification and genesis of ore deposits associated with orthomagmatic ores of ultramafic-mafic rocks; Ores of felsic-silicic igneous rocks; Ores of sedimentary affiliation - biochemical, chemical and clastic sedimentation, placers and residual concentration deposits; Ores of metamorphic affiliations.

UNIT IV: Study of ore minerals related to the following metals with special reference to their mineralogy, genesis, specification (if any), uses and distribution in India: Fe, Mn, Cr, Cu, Pb, Zn. Al, Sn, and W.

UNIT V: Classification and description of mining methods. Planning, exploration and exploratory mining of surface and underground mineral deposits. Exploration for placer deposits; Ocean bottom mining; Mining hazards: mine inundation, fire and rock burst.

Books Recommended:

Arrogyaswami, R.N.P. 1996: Courses in Mining Geology (IV ed). Oxford IBH.
Barnes, H.L. 1979: Geochemistry of Hydrothermal Ore Deposits. John Wiley.
Boyle, R.W. 1982: Geochemical Prospecting for Thorium and Uranium Deposits. Elsevier.
Clark, G.B. 1967: Elements of Mining (3rd ed). John Wiley.
Craig, J.M. and Vaughan, D.J. 1981: Ore Petrography and Mineralogy. John Wiley.
Dahlkamp, F.J. 1993: Uranium Ore Deposits. Springer Verlag.
Evans, A.M. 1993: Ore Geology and Industrial Minerals. Blackwell.
Guilbert, J.M. and Park, C.F. Jr. 1986: The Geology of Ore Deposits. Freeman.
Klemm, D.D. and Schneider, H.J. 1977: Time and Strata Bound Ore Deposits. Springer Verlag.
McKinstry, H.E. 1962: Mining Geology (2nd ed). Asia Publishing House.
Mookherjee, A. 2000: Ore Genesis A Holistic Approach. Allied Publishers.
Peters, W.C. 1978: Exploration and Mining Geology. John Willey and Sons.
Sawkins, F.J. 1984: Metal deposits in Relation to Plate Tectonics. Springer Verlag.
Stanton, R.L. 1972: Ore Petrology. McGraw Hill.
Torling, D.H. 1981: Economic Geology and Geotectonics. Blackwell.

ES - 402: Environmental Geology and Geo-Engineering
Total Credit: 6
Contact hours:
Full Marks: 100 (Semester 70 + Sessional 30)

UNIT I: Principles of environmental geology, orientation to environmental studies, global environmental issues in Environmental Geology. Time scales of global changes in the ecosystems and climate. Earth resources – Conservation, management, concept of sustainable development.

UNIT II Natural hazards: Seismic hazards, earthquake prediction; Landslides: Identification of landslide prone areas; Flood hazard: Management. Zoning and risk assessment: Hazard Zonation maps.

Unit III Environmental geologic mapping. Environmental change- natural and man-made; Prediction of environmental changes and areas of human concern and impact indicators. Environment impact analysis of dams, building, highways and tunnels. EIA methods. Scales of interest in EIA and EIA models. – Steady state and time dependant.

UNIT IV: Role of engineering geology in civil construction and mining industry. Various stages of engineering geological investigation for civil engineering projects. Engineering properties of rocks. Physical characters of building stones. Metal and concrete aggregates.

UNIT V: Geological considerations for evaluation of dams and reservoir sites. Geotechnical evaluation of tunnel alignments, transportation routes and bridges. Mass movements with special emphasis on landslides and causes of hill slope instability. Influence of geological conditions on foundation and design of buildings. Aseismic designs of building.

Books Recommended

Valdiya, K.S. 1987: Environmental Geology Indian Context. Tata McGraw Hill.
Keller, E.A. 1978: Environmental Geology. Bell and Howell.
Bryant, E. 1985: Natural Hazards. Cambridge University Press.
Subramaniam, V. 2001: Textbook in Environmental Science. Narosa International.
Bell, F.G. 199: Geological Hazards. Routledge.
Smith, K. 1992: Environmental Hazards. Routledge.
Peters, W.C. 1978: Exploration and Mining Geology. John Willey and Sons.
McKinstry, H.E. 1962: Mining Geology (2nd ed). Asia Publishing House.
Clark, G.B. 1967: Elements of Mining (3rd ed). John Wiley.
Arrogyaswami, R.N.P. 1996: Courses in Mining Geology (IV ed). Oxford IBH.

ES - 403: Project Oriented Dissertation
Total Credit: 12
Contact hours:
Total Marks: 200

Candidates admitted to the M.Sc. Programme in Applied Geology will be required to undergo a project oriented dissertation on the problems assigned by the Department. The dissertation will be field/laboratory/data based and will be carried out under the guidance of a faculty member. Candidates may avail the laboratory facilities at the Department/University as well as outside within the country.

The dissertation findings shall be compiled and submitted in the form of a thesis for evaluation. In addition, candidates are also required to present their dissertation findings in the form of seminar followed by viva-voce before a duly constituted committee.

A certificate duly signed by the candidate and the supervisor has to be enclosed stating the genuineness of the work and it has NOT been submitted elsewhere for any degree.

Examiners and scheme of evaluation shall be as follows:

1. Board of Examiners:
    i. Chairman: Head of Department
    ii. Expert: External Examiner
    iii. Member: Supervisor/ Internal Examiner

2. Evaluation Scheme:
    i. Evaluation jointly by External and Internal Examiners: 150 Marks
    ii. Seminar/Viva-Voce : 50 Marks

ES - 404: Practical on ES – 401, 402 and Field work
Total Credit: 6
Contact hours:
Full Marks: 100 (Semester 70 + Sessional 30)

Section A: Megascopic study of metallic ores and industrial minerals in hand specimens; Study of ore structures in hand specimens; Study of optical properties and identification of important ore minerals under ore microscope; Preparation of maps showing distribution of metallic and industrial minerals in India and also classical world mineral deposits. Exercises on calculation of Clarke Concentration. Diagrammatic representation of open cast and underground mining. Exercises on mine sampling and determination of tenor, cutoff grades, and ore reserves.

Section B: Laboratory exercises on properties of common rocks with reference to their utility in engineering projects. Laboratory exercises on maps and models of important engineering structures e.g. dam sites and tunnels. Landslide hazard zonation.

Section C (Field work): Students are compulsorily required to undergo independent field work of two weeks duration within the Northeast India as assigned by the Department. Each student is required to submit a report duly certified by the Head of Department and has to take a viva- voce examination at the end of semester.