CURRICULUM

OF

GEOLOGY

FOR

BS/MS

(Revised 2018)

HIGHER EDUCATION COMMISSION
ISLAMABAD

CURRICULUM DIVISION, HEC

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CONTENTS

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PREFACE

The curriculum, with varying definitions, is said to be a plan of the teaching-learning process that students of an academic program are required to undergo to achieve some specific objectives. It includes scheme of studies, objectives & learning outcomes, course contents, teaching methodologies and assessment/ evaluation. Since knowledge in all disciplines and fields is expanding at a fast pace and new disciplines are also emerging; it is imperative that curricula be developed and revised accordingly.

University Grants Commission (UGC) was designated as the competent authority to develop, review and revise curricula beyond Class-XII vide Section 3, Sub-Section 2 (ii), Act of Parliament No. X of 1976 titled “Supervision of Curricula and Textbooks and Maintenance of Standard of Education”. With the repeal of UGC Act, the same function was assigned to the Higher Education Commission (HEC) under its Ordinance of 2002, Section 10, Sub-Section 1 (v).

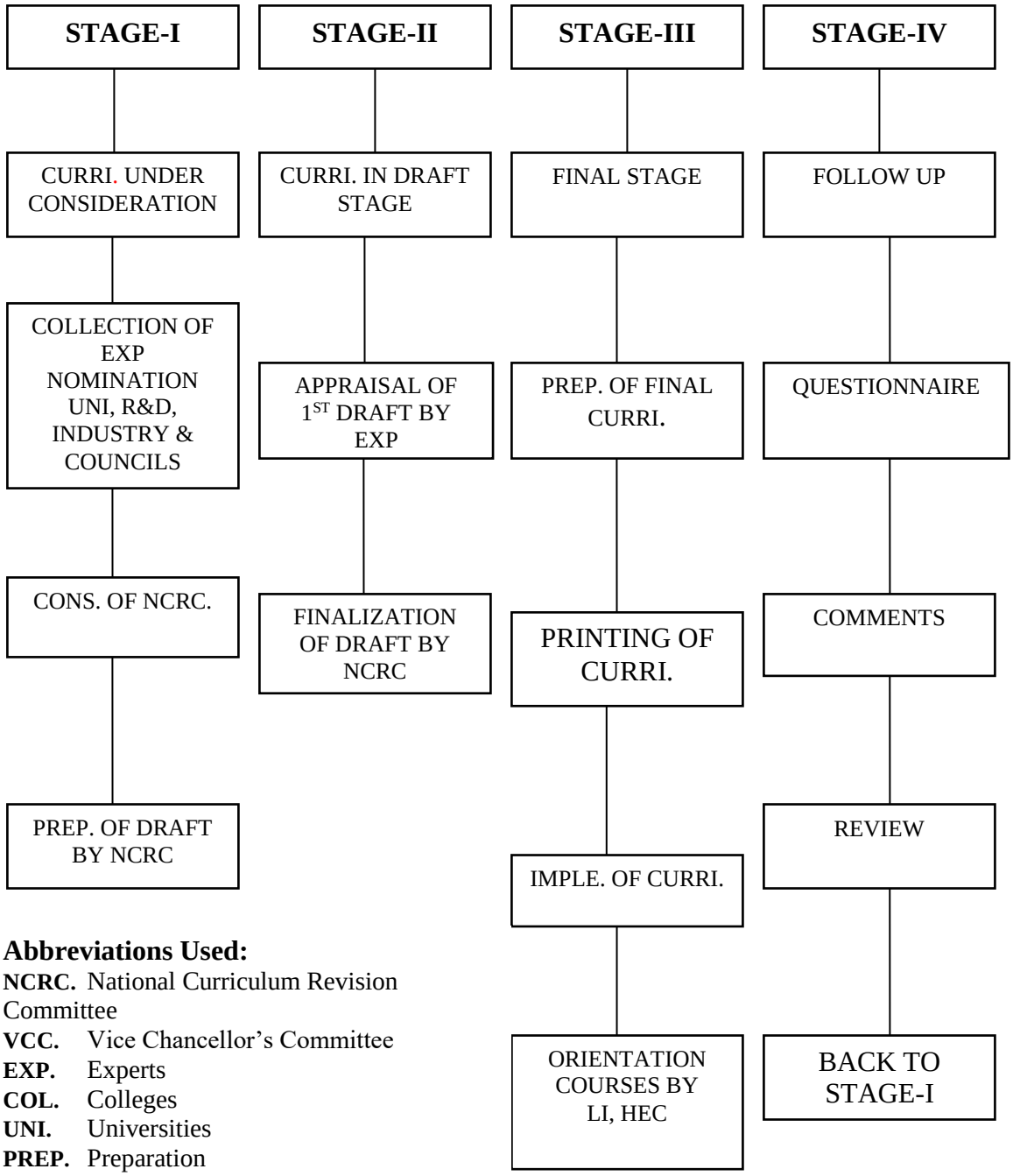
In compliance with the above provisions, the Curriculum Division of HEC undertakes the revision of curricula regularly through respective National Curriculum Revision Committees (NCRCs) which consist of eminent professors and researchers of relevant fields from public and private sector universities, R&D organizations, councils, industry and civil society by seeking nominations from their organizations.

In order to impart quality education which is at par with indigenous needs and international standards, HEC NCRCs have developed unified framework/ templates as guidelines for the development and revision of curricula in the disciplines of Basic Sciences, Applied Sciences, Social Sciences, Agriculture and Engineering.

It is hoped that this curriculum document, prepared by the respective NCRC’s, would serve the purpose of meeting our national, social and economic needs, and it would also provide the level of competency specified in Pakistan Qualification Framework to make it compatible with international educational standards. The curriculum is also placed on the website of HEC
http://hec.gov.pk/english/services/universities/RevisedCurricula/Pages/default.aspx

(Muhammad Raza Chohan)
Director General (Academics)

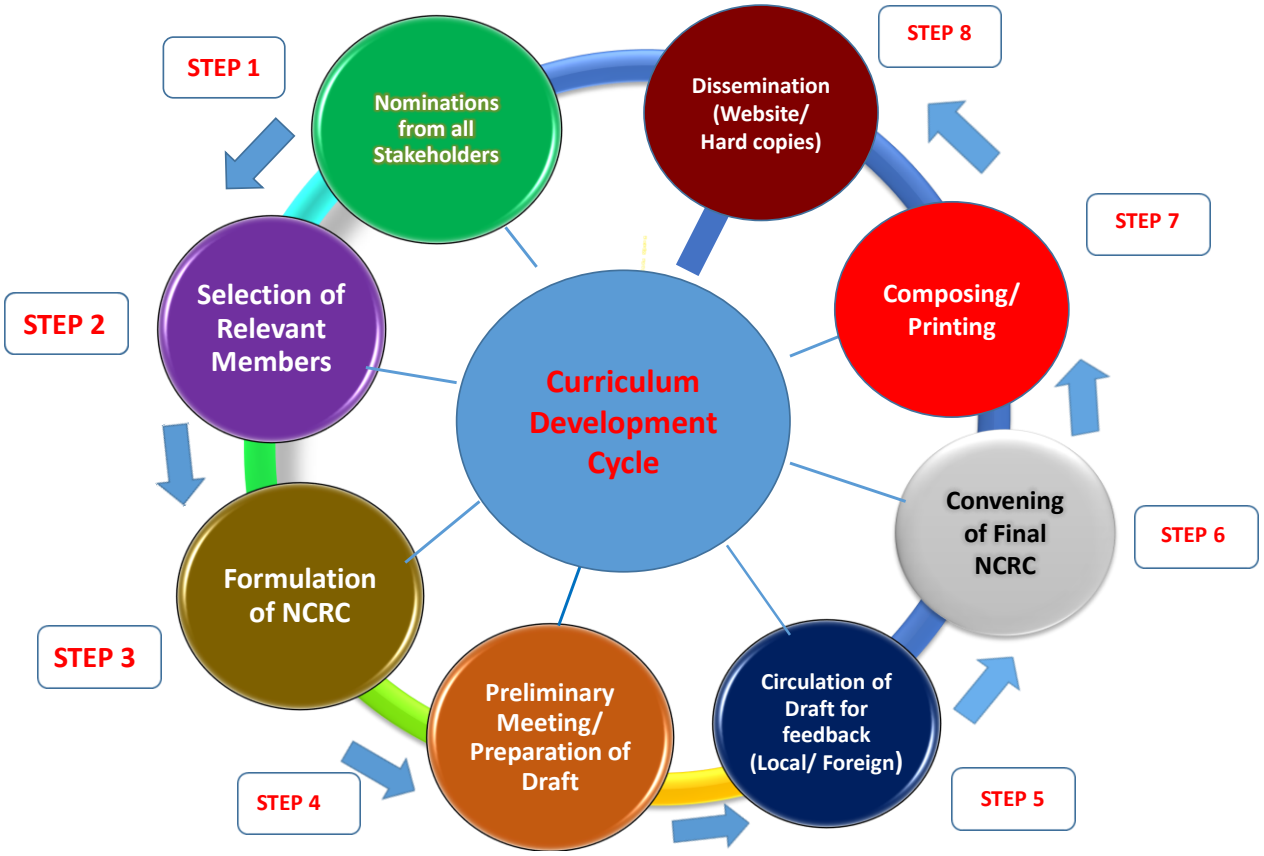
CURRICULUM DEVELOPMENT



Abbreviations Used:

NCRC. National Curriculum Revision Committee
VCC. Vice Chancellor's Committee
EXP. Experts
COL. Colleges
UNI. Universities
PREP. Preparation
REC. Recommendations
LI Learning Innovation
R&D Research & Development Organization
HEC Higher Education Commission
CONS: Constitution

CURRICULUM DEVELOPMENT CYCLE



INTRODUCTION:-

The list of the participants who attended the meeting of National Curriculum Revision Committee (NCRC) Meeting for the discipline of Geology is as below:

1.	Dr. Ishatiaq Ahmed Khan Jadoon Professor, HoD / Chairman, Department of Earth Sciences, COMSATS Institute of Information Technology, Abbottabad.	**Convener**
2.	Dr. Muhammad Basharat Associate Professor, Institute of Geology, University of Azad Jammu & Kashmir, Muzafarabad.	**Secretary**
3.	Prof. Dr. Muhammad Zafar Professor, Department of Earth & Environmental Sciences, Bahria University, E-8, Shangrilla Road, Islamabad.	Member
4.	Dr. Viqar Hussain Professor, Department of Geology, University of Karachi, Karachi.	Member
5.	Dr. Muhammad Rustam Khan Professor (Meritorious), Institute of Geology, University of Azad Jammu & Kashmir, Muzafarabad.	Member
6.	Prof. Dr. Mirza Shahid Baig Professor (Meritorious), Institute of Geology, University of Azad Jammu & Kashmir, Muzafarabad.	Member
7.	Dr. Muhammad Hassan Agheem, Professor, Institute of Geology, University of Sindh, Jamshoro.	Member
8.	Dr. Anwar Hussain Alizai Director, Geological Survey of Pakistan, Sariab Road, Quetta.	Member
9.	Dr. Rubina Firdous Director, Geological Survey of Pakistan, St-17, Block # 02, Gulistan-e-Jauhar,	Member

	Karachi.	
10.	Dr. Laeiq Ahmad Assistant Professor, Department of Geology, University of Swabi, Anbar, Swabi.	Member
11.	Dr. Javed Akhter Qureshi Assistant Professor, Department of Earth Sciences, Karakoram International University, Gilgit.	Member
12.	Dr. Mohibullah Assistant Professor, Department of Geology, University of Balochistan, Quetta.	Member
13.	Dr. Rakhshinda Sadaf Assistant Professor, Department of Geology, Federal Urdu University of Arts Science & Technology, Karachi.	Member
14.	Mr. Khalid Aziz General Manager, Pakistan Gems and Jewelry Development Company, Karachi.	Member
15.	Mr. Mudassar Zubair Khan Deputy Chief Geologist, Pakistan Petroleum Limited, Karachi.	Member
16.	Mr. Najeeb Ahmed Amir Deputy Director, Seismic Section, Pakistan Meteorological Department, Islamabad.	Member
17.	Mr. Rabeel Bhatti Assistant Director Curriculum, HEC, Islamabad.	Coordinator

The following members attended the preliminary meeting only and could not attend the final meeting due to pre-occupation:

1.	Dr. Syed Abid Hussain Professor, Dean, Faculty of Engineering, Department of Mining and Geological Engineering,	Member

	BUITEMS, Quetta.	
2.	Dr. Shahid Ghazi Professor, Institute of Geology, University of the Punjab, Quaid-i-Azam Campus, Lahore.	Member
3.	Dr. Naseem Aadil Director, Department of Engineering Geology University of Engineering & Technology, Lahore.	Member
4.	Dr. Shahid Jamil Sameeni Associate Professor, Institute of Geology, University of the Punjab, Quaid-i-Azam Campus, Lahore.	Member
5.	Dr. Muhammad Zubair Abu Bakar Associate Professor , Chairman, Department of Geological Engineering, University of Engineering & Technology, Lahore	Member
6.	Dr. Asghar Ali Ex-NCRC Experts, House No. 471, Street No. 14, Sector G-14/4, Islamabad.	Member
7.	Mr. Zahid Rafi Director, Seismic Section, Pakistan Meteorological Department, Islamabad.	Member

Aims and Objectives:

National Curriculum Revision Committee members held intensive deliberations in two (preliminary and final) meetings on multidimensional aspects of the required curriculum. The main tasks of this group were:

1. To develop international standard Geology curriculum for undergraduate and postgraduate degree programs that could uniformly be adopted by the public and private sector institutions.
2. To impart cutting edge knowledge and practical based skills among our graduates through rigorous theory, practical work and field exercises focused on key and applied aspects.
3. To develop entrepreneurial skills for launching professional career in the geological field.
4. To devise components for the smooth implementation of teaching and research program at HEIs of Pakistan.

As a starting point, BS Geology four years degree program was taken up for the discussion on its nomenclature, duration, eligibility criteria, course streams and contents to be offered. This followed deliberations to revise MS Geology program in terms of duration of the degree, core courses, elective courses and thesis. After prolonged discussions BS and MS in Geology degree programs were finalized.

Vision

Produce innovation oriented Geology graduates who can contribute to the betterment of society.

Mission

To impart the best quality Geology education through advanced teaching tools providing impetus for sustainable socio-economic development of Pakistan.

PREAMBLE

With the advent of new technologies, the world has turned into a global village. In view of tremendous research taking place world over new ideas and information pours in like a stream, making it imperative to update the curricula after regular intervals, for introducing latest development and innovation in the relevant field of knowledge.

In exercise of the powers conferred under Section 3 Sub-Section 2 (ii) of Act of Parliament No. X of 1976 titled “Supervision of Curricula and Textbooks and Maintenance of Standard of Education” the erstwhile University Grants Commission was designated as competent authority to develop review and revise curricula beyond Class-XII. With the repeal of UGC Act, the same function was assigned to the Higher Education Commission under its Ordinance of 2002 Section 10 Sub-Section 1 (v).

In compliance with the above provisions, the HEC undertakes revamping and refurbishing of curricula after regular intervals in a democratic manner involving universities/DAIs, research and development institutions and local Chamber of Commerce and Industry. The intellectual inputs by expatriate Pakistanis working in universities and R&D institutions of technically advanced countries are also invited to contribute and their views are incorporated where considered appropriate by the National Curriculum Revision Committee (NCRC).

RATIONALE

Considering the recent advancements in the science and technology and their impacts in the field of Geology, coupled with contemporary requirements of Outcome Based Education (OBE), there is a dire need to update the curriculum of Geology program.

SCOPE

The scope of the document is to provide minimum standards in the form of guidelines for the development, delivery and assessment of the Geology programs. The guideline areas include; Program Educational Objectives (PEOs), Program Learning Outcomes (PLOs) and Course Learning Outcomes (CLOs), scheme of studies, course outlines, credit hours distribution, assessment criterion, and recommendations.

Program Educational Objectives (PEOs)

Following are the sample program educational objectives that are expected to be exhibited by the Geology graduates.

1. Demonstrate sound knowledge and skills.
2. Work, manage and illustrate effective teamwork, interpersonal skills and professional growth.
3. Undertake professional practice considering ethical, societal and environmental implications.

Note: Institutions are expected to customize their own PEOs for their program requirements.

PROGRAM LEARNING OUTCOMES (PLOs)

- Geology program provides the necessary technical as well as professional skills consistent with Higher Education Commission (HEC) accreditation standards and national development needs.
- Committed to providing high quality educational experiences (coursework and research) that enable its graduates to become

responsible and competent professionals at all levels of employment as geologists

METHODS OF INSTRUCTIONS AND LEARNING ENVIRONMENT

This shall comprise the following:-

- Classroom lectures, duly supported by audio-visual aids, demonstrations and relevant handouts.
- Assignments and tutorials requiring use of latest of reference materials and internet facility.
- Homework load for the students should be rationalized considering the credit hours of the course.
- Semester projects and class presentations.
- Laboratory experiments and design exercises.
- Final year project
- Field works such as survey camp and internship
- Extension lectures and class room discussions by renowned professionals.
- Enhanced use of modern computing facilities in the institutions.
- The notebooks/field books/graphs and drawing sheets pertaining to the field work and practical should be completed within the allocated time and submitted to the teacher. In case of field visit, the students shall be required to write a field report.

ASSESSMENT

- Classroom attendance, class assignments, class tests, homework assignments, quizzes, viva voce, presentations etc., should be considered for the award of sessional marks.
- The academic pursuit and achievements of a student in a semester/academic year are to be evaluated by holding semester examinations.

The details of the assessment are mentioned below:

Sessional Exams

- Assignments & Quizzes
- Presentations/Group Discussion
- Mid Term

Final Exam

- Written (Long Questions, Short Questions, MCQs)

RECOMMENDATIONS

The following recommendations are made for implementation of these schemes in the country:

1. HEC is recommended to facilitate establishment of Pakistan Geological Council (PGC) in line with Pakistan Engineering Council (PEC) to register, monitor and regulate the geoscience professional/academic activities in the country. For this purpose an adhoc committee of geoscientists is recommended to be constituted as soon as possible under the supervision of HEC.

2. The HEC funded geoscience labs and research centers are recommended to be established in North, Center and South regions of Pakistan to promote research activities in the country.

3. A centralized geoscientific database may be established not only to integrate geologic knowledge but also to attract foreign investment in the country.

4. HEC is recommended to facilitate for the provision of at least one 4x4 vehicle for Geological field works to the departments through the respective Universities.

5. Internship/practical training for 4-year BS is recommended to promote links between academia and industry with cooperation and support of HEC/University.

6. HEC is recommended to allocate appropriate funds for scholarships to geoscience graduate students on merit to promote graduate research activities of geosciecntists keeping in view industrial requirements.

7. Geological field camps to be organized by HEC through Geological Survey of Pakistan (GSP), professional organizations (Public/Private) and/or Universities.

8. The 4 years BS degree in geology is a professional degree and must be treated at par with other professional degrees.

9. Considering severe energy crises (Oil, Gas and Coal) in the country, the HEC is recommended to facilitate in creating Energy Research Fund (ERF) through petroleum industry to address energy crises in the country. Furthermore, HEC may encourage petroleum and mineral industry/Geosceince Institutions (Public/Private) to establish “Chairs” in public and private sector universities to coordinate between industry and academia for promotion of research and resource optimization.

10. A geoscience conference is recommended to be organized annually on rotational basis in different universities with the financial support of HEC to promote research culture in the country.

11. Indigenous scholarship program offered by HEC need to be improved and strengthened with rationalized allocation of scholarships to geoscience students.

12. HEC is recommended to revise the current eligibility criteria about repairing of instruments with increase of time limit.

13. A research based National University of Petroleum and Minerals is recommended to be established in Pakistan to assist Industry for adequate assessment and exploration of these resources.

14. Training workshops on different geoscience disciplines are recommended to be offered by Industry/Geoscience Institutions to promote knowledge and awareness about applied geology.

15. There is no standard curriculum of Geophysics with HEC. It is recommended that curriculum of BS/MS/PhD in Geophysics may be prepared on urgent basis, to streamline and facilitate the geophysics discipline in universities.

ELIGIBILITY CRITERIA FOR ADMISSION IN 4-YEAR PROFESSIONAL BS DEGREE PROGRAM IN GEOLOGY

Intermediate Science or Equivalent with minimum 50% marks from the following groups:

1. Pre-Medical Group
2. Pre-Engineering Group
3. Other Groups (studied at least two subjects from Chemistry, Physics, Computer Science, and Mathematics)
4. Three years Diploma in Associate Engineering (DAE)-equivalent to F.Sc

SCHEME OF STUDY FOR 4-YEARS BS IN GEOLOGY

Semester I	Course	Credit Hour	Total
Chem. 301	Chemistry I	2+1	3
Eng. 301	English I	3+0	3
Geol. 301	Physical Geology	2+1	3
Math. 301	Mathematics I	3+0	3
Phy. 301	Physics I	2+1	3
Isl. St./Eth. 301	Islamic studies/Ethics	2+0	2
Total			**17**

Semester II	Course	Credit Hour	Total
Chem. 302	Chemistry II	2+1	3
Geol. 302	Mineralogy	2+1	3
Geol. 303	Geomorphology	2+1	3
Math. 302	Mathematics II	3+0	3
Phy. 302	Physics II	2+1	3
Geol. 304	Geological Fieldwork I	0+2	2
Total			**17**

Semester III	Course	Credit Hour	Total
Geol. 401	Structural Geology	2+1	3
Geol. 402	Paleontology	2+1	3
Geol. 403	Optical Minerology & Petrography	2+1	3
Geol. 404	Geostatistics	2+1	3
Eng. 401	Communication Skills (English II)	2+1	3
Pak. St. 401	Pakistan Studies	2+0	2
Total			**17**

Semester IV	Course	Credit Hour	Total
Eng. 402	Tech. Report Writing (English III)	3+0	3
Geol. 405	Stratigraphy	2+1	3
Geol. 406	Geological Fieldwork-II	0+2	2
Geol. 407	Hazards and Disaster Management	3+0	3
Geol. 408	Igneous and Metamorphic Petrology	2+1	3
Mgt. 401	Principles of Management	3+0	3
Total			**17**

Semester V	Course	Credit Hour	Total
Geol. 501	Geotectonics	2+1	3
Geol. 502	Sedimentology	2+1	3
Geol. 503	Geophysics	2+1	3
Geol. 504	Field Geology	3+0	3
Geol. 505	Micropaleontology and Biostratigraphy	2+1	3
Geol. 506	Introduction to GIS and RS	2+1	3
Total			**18**

Semester VI	Course	Credit Hour	Total
Geol. 507	Sequence Stratigraphy	2+1	3
Geol. 508	Geochemistry	2+1	3
Geol. 509	Petroleum Geology	2+1	3
Geol. 510	Engineering Geology	2+1	3
Geol. 511	Well Logging	2+1	3
Geol. 512	Geological Fieldwork – III	0+2	2
Total			**17**

Semester VII	Course	Credit Hour	Total
Geol. 601	Geology and Tectonics of Pakistan	3+0	3
Geol. 602	Economic Geology	2+1	3
Geol. 603	Environmental Geology	2+1	3
Geol. 604	Hydrogeology	2+1	3
Geol. 605	Computer Applications in Geology	2+1	3
Geol. 606	Elective-I	2+1	3
Total			**18**

Semester VIII	Course	Credit Hour	Total
Geol. 607	Elective-II	2+1	3
Geol. 608	Elective-III	2+0	3
Geol. 609	Project Report/Thesis	0+6	6
Total			**12**

Note: Total Credit Hours = 133

Note:

1. The recommended credit hours for the completion of BS Geology program should not be less than 130 and not more than 140 credit hours as required by HEC.
2. Internship is recommended in public/private sector organizations after sixth semester.
3. The allocation of the research project/thesis topic is recommended with the consultation of concerned supervisor.
4. Research Project/Thesis is recommended to be evaluated through open defence.
5. Elective courses shall be selected in consultation with the relevant research supervisor.
6. Elective courses shall be offered subject to availability of appropriate faculty (resource persons).
7. Minimum duration of each geological field trip is recommended as 10 days.

LIST OF ELECTIVE COURSES

Groups	Elective Course	Credit Hour
Group-I Mineralogy, Petrology and Geochemistry	Igneous Petrology	2+1
	Metamorphic Petrology	2+1
	Sedimentary Petrology	2+1
	Mineralogy II	2+1
	Geochemistry II	2+1
	Thermodynamics	2+1
	Geochemical Exploration	2+1
	Isotope Geochemistry	2+1
	Low Temperature Geochemistry	2+1
	High Temperature Geochemistry	2+1
Group-II Paleontology and Stratigraphy	Stratigraphy II	2+1
	Micropaleontology II	2+1
	Invertebrate paleontology	2+1
	Vertebrate paleontology	2+1
	Palynology and Paleoebotany	2+1
Group-III Economic Geology, Industrial Geology and Coal Geology	Mineral Prospecting and Exploration	2+1
	Coal Geology	2+1
	Mining Geology	2+1
	Metallogeny and Plate Tectonics	2+1
	Gemology	2+1
	Mineral Economics	2+1
	Industrial Mineralogy	2+1
	Instrumental Techniques	2+1
	Clay Mineralogy	2+1
	Exploration and Exploitation of Coal	2+1
	Environment and Clean Coal Technology	2+1
	Mineral Processing	2+1
Group-IV Engineering Geology and Geotechnical Engineering	Engineering Geology II	2+1
	Rock Mechanics	2+1
	Soil Mechanics	2+1
	Introduction to Geotechnical Engineering	2+1
	Excavation and Tunneling	2+1
	Foundation Engineering	2+1
	Dam Engineering	2+1
	Landslide Hazards and Risk Assessment	2+1
	Earthquake Engineering and Risk Assessment	2+1

Group-V Petroleum Geosciences	Sequence Stratigraphy II	2+1
	Petroleum Engineering	2+1
	Reservoir Geology	2+1
	Organic Geochemistry	2+1
	Petroleum Geology of Pakistan	2+1
	Petroleum Economics	3+0
	Seismic Techniques	2+1
Group-VI Applied Geophysics	Seismic Stratigraphy	2+1
	Earthquake Seismology	2+1
	Geomagnetism and Paleomagnetism	2+1
	Electrical and Radiometric Exploration Methods	2+1
	Bore-Hole Geophysics	2+1
	Seismic Prospecting	2+1
	Gravity and Magnetic Methods	2+1
	Rock Physics	2+1
Group-VII Sedimentology	Clastic Sedimentology	2+1
	Carbonate Sedimentology	2+1
	Basin Modeling	2+1
	Quaternary Geology	2+1
Group-VIII Hydrogeology	Hydrogeology	2+1
	Groundwater Investigation	2+1
	Groundwater Engineering	2+1
	Chemical Hydrogeology	2+1
Group-IX Marine Geology	Marine Geology	2+1
	Oceanography	2+1
	Marine Geochemistry	2+1
	Geology of Arabian Sea	2+1
Group-X Environmental Geosciences	Environmental Geology II	2+1
	Soil and Water Resources	2+1
	Environmental Hazards	2+1
	Water Resources and Environment	2+1
	Environmental Impact Assessments and Management	2+1
	Natural Resources Management	2+1
	Occupational Health and Safety	2+1
	Environmental Geochemistry	2+1
	Geospatial Techniques in Geology	2+1
Group-XI Structure, Tectonics and Neotectonics	Structural Geology II	2+1
	Metamorphic Structures	2+1
	Applied Structural Techniques	2+1
	Tectonics of Pakistan	3+0
	Neotectonics	3+0

DETAIL OF CORE COURSES
FOR 4 YEARS BS IN GEOLOGY

Course Title: **Physical Geology**
Course Code: **Geol. 301**
Number of Credits: **3(2+1)**
Course Type: **Core**
Prerequisite: **Nil**

Objectives and Learning Outcomes:
This course is designed to impart basic knowledge of geology. This will help the students to understand various types of rocks and minerals and to learn about sedimentary and structural features and the processes operative within and on the surface of the earth.

Course Contents:
Introduction and scope of geology; importance and relationship with other sciences; history and philosophy of geology; Earth as a member of the solar system; its origin, age, composition and internal structure; introduction to plate tectonics, Isostasy; mountain building processes; earthquakes and volcanoes; weathering and erosion; introduction, identification and classification of rocks; sedimentary, igneous and metamorphic structures; physical properties of mineral; introduction to fossils in sedimentary rocks; introduction to folds, faults, joints, cleavage, foliation, lineation; Geological Time Scale; Concept and techniques of geological dating, relative and absolute dating;; Use of Brunton Compass and GPS, etc.

Labs:
Concept of scale and maps, topographic maps, geological time scale and evolution of life, major geological events, sense of relief and physiographic features with the help of models and topographic maps, contouring. Simple geological maps and drawing of cross-sections. Use of field instruments viz, Brunton compass/clinometer, Identification of basic rock types and minerals.

Recommended Books:

1. Physical Geology (15th Edition) by Charles Plummer, Diane Carlson, Lisa Hammersley, 2015, McGraw-Hill
2. Laboratory Manual in Physical Geology (9th Edition), Richard M. Busch, 2011, American Geological Institute, Pearson Education
3. Physical Geology, By Plummer, (14th Edition), Charles (Carlos) Plummer, Diane Carlson, Lisa Hammersley, 2012 McGraw-Hill
4. Principles of Physical Geology by Holmes, A., 1978, Nelson.
5. Foundation of Structural Geology by Park, R. G., 1983, Blackie.
6. Elementary Exercises upon Geological Maps by Platt, J. I., 1961, Thomas Murby and Co.
7. An Introduction of Geological Structures and Maps by Bennison, G.M.,

1997, Edward Arnold.
8. Physical Geology by Plummer, McGeay and Carlson, 2005.
9. Lab Manual for Physical Geology by Jones, Norris. W., Johns and Charles E., 2005, McGraw-Hill.
10. How Does Earth Work: Physical Geology and Process of Science by Smith, G. and Pun, A., 2006, Prentice Hall.
11. The Mapping of Geological Structures by McClay, K.R., 1987, Open University Press.

Course Title: **Mineralogy**
Course Code: **Geol. 302**
Number of Credits: **3(2+1)**
Course Type: **Core**
Prerequisite: **-------**

Objectives and Learning Outcomes:

This course is designed to acquire the knowledge about the physical and optical properties of various rock forming minerals and related phase diagrams. The outcomes include the learning and identifying various silicate and non-silicate minerals, Identification of various rock types and the environment in which they are formed.

Course Contents:

Classification of minerals; study of internal structure; polymorphism and isomorphism; crystal systems; crystal chemistry; paragenesis, physical and optical properties of the common silicate and non-silicate mineral groups; introduction to X-Ray differactometry and universal stage and their application; phase equilibrium studies; one component; binary and ternary system; introduction to mineralogy and crystallography; elements of symmetry; crystal notation; study of normal classes of crystallographic systems.

Labs:

Mega-scopic and microscopic identification of common rock forming minerals; construction and interpretation of phase diagrams from giving experimental data; lab work related to XRD and Universal stage.

Recommended Books:

1. Principles of Mineralogy by William, H.B., 1990, Oxford University Press.
2. Optical Mineralogy by Kerr, P.F., 1959, McGraw-Hill.
3. Minerals and Rocks by Klein, C., 1989, John Wiley and Sons.
4. A Color Atlas of Rocks and Minerals in Thin Sections by Mackenzie, W.S. and Adams, A.E. 1996, John Wiley and Sons.
5. Atlas of Rock-Forming Minerals in Thin Section by Mackenzie, W.S., Donaldson, C.H. and Guilford, C.P., 1980, John Wiley and Sons.
6. An Introduction to Rock Forming Minerals by Deer, W. A., Howie, R. A. and Zussman, J., 1992, Longman.

7. Manual of Mineralogy by Klein,C., Hurlbut, C.S., Dana, J.D., 1993, Wiley, New York.
8. Mineral Characterization and Processing by Mohapatra, B. K., Misra, V., Reddy P.S.R., 2005 - Allied Publishers Pvt. Ltd, India
9. Principles of Mineralogy by William. H.B., 1990, Oxford University Press.
10. Mineralogy by Perkins, D., 2002, Prentice Hall.

Course Title: **Geomorphology**
Course Code: **Geol. 303**
Number of Credits: **3(2+1)**
Course Type: **Core**
Prerequisite: **Nil**

Objectives and Learning Outcomes:

This course is designed to acquire the knowledge about the formation of various landforms on the surface of the earth. This will help the students to understand the processes by which various types of structures developed on the earth surface due to erosional and depositional processes.

Course Contents:

Geomorphological processes; weathering and erosion; glaciers and their erosional and depositional landforms; geological work of wind and associated features; erosional and depositional work of surface and subsurface water; valley and base-level development and its types; drainage pattern, stream meandering and development of flood plains; erosional and depositional work of sea; development of coastal landforms; geomorphic cycles and associated landforms produced by tectonics and volcanic activity; introduction to tectonic geomorphology; introduction to topographic maps; aerial photographs and satellite imageries.

Labs:

Identification of geomorphic features by using topographic maps, relief maps and interpretation of 3D relief diagrams on computer.

Recommended Books:

1. Geomorphology: The Mechanics and Chemistry of Landscapes, Robert S. Anderson, Suzanne P. Anderson, 2010, Cambridge University Press
2. Landscapes and Geomorphology: A Very Short Introduction, Andrew Goudie, Heather Viles, 2010, Oxford University Press.
3. Process Geomorphology by Ritter, Kochel and Miller, 2002, the McGraw-Hill Company.
4. Tectonic Geomorphology, Douglas W. Burbank, Robert S. Anderson, 2000, John Wiley and Sons.
5. Principles of Geomorphology by Thornbury, W.D., 1991, John Wiley and Sons.
6. Geomorphology of Earth Surface Processes and Form by Aharma, V.K., 1986, McGraw-Hill.

7. Geomorphology by Chorley, R.J., 1984, Methuen.
8. Image Interpretation in Geology by Drury, S.A., 1986, Allen and Unwin.
9. Remote Sensing and Image Interpretation by Lillis, T.M. and Kiefer, R.W., 1987, John Wiley and Sons.
10. Fundamentals of Geomorphology (4th Edition) (2017), by Ricahrd John Hugget, Routledge (Taylor and Francis Group)

Course Title: **Geological Fieldwork-I**
Course Code: **Geol. 304**
Number of Credits: **2(0+2)**
Course Type: **Core**
Prerequisite: **Nil**

Objectives and Learning Outcomes:

This preliminary field trip is for identification of rock types and geomorphic features which will help the students to understand in identifying various types of criteria to recognize rocks and other geological and geomorphological features in the field.

Labs:

Field based exercises. During the first two years students will perform about two weeks of fieldwork. It will lead to become familiar with major rocks and basic geological mapping techniques. Each field trip will be followed by report writing and Viva Voce / Evaluation.

Recommended Books

1. Field Geology by Lahee, F. H. 1961, McGraw-Hill.
2. Geology in the Field by Compton, R.R. 1985, John Wiley and Sons.
3. Basic Geological Mapping by Barnes, J.W. and Lisle, R.J., 2004, John Wiley and Sons.

Course Title: **Structural Geology**
Course Code: **Geol. 401**
Number of Credits: **3(2+1)**
Course Type: **Core**
Prerequisite: **Nil**

Objectives and Learning Outcomes:

This course is designed to acquire the knowledge about the pre-and post-deformational structures and their development in the crust. This will help in understanding the mechanics of deformation and types of structures to deal with exploration of natural resources and geohazards assessment.

Course Contents:

Introduction to structural geology, stress and strain; Mohr circle of stress; factors controlling the mechanical behavior of rocks; folds, geometry and

classification of folds. The mechanics of folding: similar and parallel folds. First and second order folding. Faults, slip and separation, types of faults: normal, thrust, strike-slip faults, criteria for recognition of fault, joints: terminology, geometry and classification; foliation: terminology, classification and relationship with bedding; lineation: terminology and classification; contacts; unconformity: concept, classification, recognition and significance; tectonitcs; primary structures and facing based on primary structures; introduction to structural balancing technique and application of structural geology in exploration.

Labs:

Map exercises, linear and planar structures, and construction of geological cross-sections; orthographic projections (geometrical exercises); basic balance cross-sections, stereographic projections and use of structural computer software.

Recommended Books:

1. Structural Geology of Rocks and Regions, George H. Davis, Stephen J. Reynolds, Charles F. Kluth, 2011, John Willy and Sons.
2. Structural Geology, Haakon Fossen 2010, Cambridge University Press.
3. Structural Geology: An Introduction to Geometrical Techniques, Donal M. Ragan, 2009, Cambridge University Press.
4. Foundation of Structural Geology by Park, R. G., 1983, Blackie.
5. Structural Geology of Rocks and Regions by Davis, G. H. and Reynolds, S. J., 1996, John Wiley and Sons.
6. Laboratory Exercise Book in Structural Geology by Ghauri, A. A. K., 1989, National Centre of Excellence in Geology, University of Peshawar.
7. An Introduction to Geological Structures and Maps by Bennisen, G. M., 1975, Edward Arnold.
8. Structural Geology by Twiss, R. J. and Moores, E. M., 1995, W. H. Freeman and Co.
9. Selected references.

Course Title: **Palaeontology**
Course Code: **Geol. 402**
Number of Credits: **3(2+1)**
Course Type: **Core**
Prerequisite: **Nil**

Objectives and Learning Outcomes:

This course is designed to acquire the knowledge about various types of fossils and their significance. This will help the students to understand various morphological features of fossils; their classification, identification and distribution in geologic time.

Course Contents:

Introduction to fossils and their significance; modes of fossilization, study of

morphology, range and broad classification of major invertebrate phyla i.e. coelenterata, brachiopoda, mollusca, arthropoda (trilobite) and echinodermata (echinoidea); introduction to micro fossils; introduction to palaeobotany; evolution of life on earth; introduction and classification of major vertebrates i.e. mammals, amphibians, reptiles and picies;
introduction to micropalaeontology i.e. foraminifera, briozone, ostrocodes and conodonts etc. Index fossils; introduction to major invertebrate and microfossils of Pakistan.

Labs:

Megascopic identification and description of fossils up to genus level related to phyla studied.

Recommended Books:

1. Invertebrate Fossils by Moore, R. C., Lalicker, C. G. and Fischer, A. G., 1952, McGraw-Hill.
2. Principles of Paleontology by Raup, D.M. and Stanley, S.M., 1985, W.H. Freeman and Co.
3. Vertebrate Paleontology by Romer, A.S., 1966, University Chicago Press.
4. Invertebrate Paleontology and Evolution by Clakson, E.N.K., 1998, Blackwell Publishing.
5. Genetics, Paleontology and Macroevolution by Levinton, J.S., 2001, Cambridge University Press.
6. Invertebrate Palaeontology and Evolution (4^{th} Edition), by E. N. Clarkson, 2007, Published by Blackwell Publishing Company.

Course Title: **Optical Minerology and Petrography**
Course Code: **Geol. 403**
Number of Credits: **3(2+1)**
Course Type: **Core**
Prerequisite: **Nil**

Objectives and Learning Outcomes:

This course is designed to help the students to identify the minerals in sedimentary, igneous and metamorphic rocks using polarizing microscope and also classifying the rocks on the basis of rock texture and mineral composition.

Course Contents:

Introduction to polarizing microscope; optical properties of opaque and non-opaque minerals in plane polarized light and under crossed nicol including metallc under reflected light; description of optical properties of common rock forming minerals; mineralogy and common texture of igneous, sedimentary and metamorphic rocks.

Labs:

Identification and description of common minerals; study of rocks and minerals

in thin sections, texture and composition; classification of rocks using different techniques, volume estimates and other elementary petrographic techniques.

Recommended Books:

1. Optical Mineralogy by Kerr, P.F., 1959, McGraw-Hill.
2. Minerals and Rocks by Klein, C., 1989, John Wiley and Sons.
3. Igneous and Metamorphic Petrology by Best, M. G.,1982, W. H. Freeman and Co.
4. Minerals in Thin Sections by Perkins, D., 2000, Prentice Hall.
5. Petrography of Igneous and Metamorphic Rocks by Philpotts, A.R., 1989, Prentice Hall.
6. Atlas of Rock-Forming Minerals in Thin Sections by MacKenzie, W.S. Guilford, C.P., 1980, John Wiley and Sons.
7. Introduction to Optical Mineralogy by Nesse, W.D., 2003, Oxford University Press.
8. An Atlas of Minerals in Thin Sections by Schulze, D. J., 2003, CD-RM, Oxford University Press.

Course Title: **Geostatistics**
Course Code: **Geol. 404**
Number of Credits: **3(2+1)**
Course Type: **Core**
Prerequisite: **Nil**

Objectives and Learning Outcomes:

This unit is designed to provide students with an introduction to the geostatistical techniques used in estimation from spatial data. Applications will be mainly in the areas of mining, petroleum, Hazards, soil science and environmental management.

Course Contents:

Descriptive statistics and exploratory data analysis, random variable; moments; probability distributions; normal and lognormal distributions, random function model, modeling spatial continuity; experimental variograms covariance functions; correlograms and madograms; variogram and covariance function models; isotropy and anisotropy, estimation methods: simple kriging

Labs:

Calculating a range of descriptive statistics and carry out a variety of methods for exploratory data and variance analysis; use variograms and covariance functions to model spatial continuity; understand the random function model for the analysis of spatial data; carry out simple and ordinary kriging.

Books Recommended:

1. Geostatistical Estimation: S. Rouhani, in Rouhani et al. (1996).
2. Modeling Spatial Variability using Geostatistical Simulation, A. J. Des-Barats, in Rouhani et al., 1996.

3. Goovaerts, P. 1997, Geostatistics for Natural Resources Estimation, Oxford University Press.
4. Olea, R.,1999, Geostatistics for Engineers and Earth Scientists, Kluwer.
5. Armstrong, M.,1999, Basic Linear Geostatistics, Springer.
6. Clark, I., and Harper, W., 2000, Practical Geostatistics 2000. Ecosse Geostatistical Sales, Alloa, Scotland.

Course Title: **Stratigraphy**
Course Code: **Geol. 405**
Number of Credits: **3(2+1)**
Course Type: **Core**
Prerequisite: **Nil**

Objectives and Learning Outcomes:

This course is designed to acquire the knowledge about principles of stratigraphy, Stratigraphic code of Pakistan, stratigraphic successions formed during different geologic time with special focus on Pakistan and principles of biostratigraphy and biostratigraphic zones.

Course Contents:

Principles of stratigraphy; laws of superposition and faunal succession; geological time scale with divisions; Unconformities, classification and nomenclature of stratigraphic units: lithostragraphic, biostratigraphy and chronostratgraphic units; contacts; litho-and-biofacies; principle of stratigraphic correlation; Stratigraphic code of Pakistan; outline of stratigraphy of Pakistan; principles of biostratigraphy and biostratigraphy zones.

Labs:

Preparation of stratigraphic columns and their correlation, facies maps, isopach, stratigraphic map.

Recommended Books:

1. Principles of Stratigraphy by Weller, J. M., 1962, Harper Brothers.
2. Stratigraphy of Pakistan by Shah, S. M. I. (Ed), 1977, GSP Memoir 12, Geological Survey of Pakistan, Quetta.
3. Principles of Sedimentology and Stratigraphy by Boggs, S., 2001, Prentice Hall.
4. Stratigraphic Code of Pakistan, Geological Survey of Pakistan, 1962, Memoirs of GSP, V. IV, Part-I.
5. The Geology of Stratigraphic Sequences by Miall, A. D., 1997, Springer.
6. Applied Stratigraphy by EAM Koutsoukos., 2005. Springer.
7. Stratigraphy and Historical Geology of Pakistan by Kazmi, A. H and Abbasi, I.A., 2008, Graphic Publishers, Karachi, Pakistan.
8. Stratigraphy of Pakistan by Geological Survey of Pakistan, 2009, Memoir 22, Geological Survey of Pakistan, Quetta.
9. Principles of Sedimentology and Stratigraphy, Fifth edition, by Sam Boggs Jr., 2014, Pearson

Course Title: **Geological Fieldwork-II**
Course Code: **Geol. 406**
Number of Credits: **2(0+2)**
Course Type: **Core**
Prerequisite: **Nil**

Objectives and Learning Outcomes:

The second-year field work will be performed for about two weeks. This course is designed to identify various types of rocks, field stratigraphy, fossils, structural features and landforms in the field. This will help the students to understand various types of criteria to recognize rocks and other geological features in the field.

Labs:

Field based exercises; the students will become familiar with major rocks, field stratigraphy, fossils, structures, section measurement and basic geological mapping techniques. Each field trip will be followed by report writing and Viva Voce / Evaluation.

Recommended Books:

1. Field Geology by Lahee, F.H. 1961, McGraw-Hill.
2. Geology in the Field by Compton, R. R. 1985, John Wiley and Sons.
3. Basic Geological Mapping by Barnes, J. W. and Lisle, R. J., 2004, John Wiley and Sons.

Course Title: **Hazards and Disaster Management**
Course Code: **Geol. 407**
Number of Credits: **3(3+0)**
Course Type: **Core**
Prerequisite: **Nil**

Objectives and Learning Outcomes:

This module provides basic knowledge of hazards and disasters. It will help to learn about Geo-hazards risk and its management. On completion of this module, students should understand the nature and types of hazards and disasters, associated risks and impacts to these disasters.

Course Contents:

Definitions of Natural Hazards and Disasters, Classification of Natural Hazards, Geo Hazards, Disaster Risk Reduction and Disaster Risk Transfer, Plate Tectonics and Plate Boundaries, Global Distribution of Earthquakes and Volcanoes, Folding, Faulting and Fault Lines, Types of Geo-hazards o Earthquake, Volcanoes, Tsunami, Landslide/Mass wasting, Mitigation and Preventive Measures, Geo-hazards Risk Assessment, Early Warning System for Geo-hazards

Books Recommended:

1. COCH, Nicholas K. (2004) Geohazards Natural and Human. Copley Custom Textbooks, Connecticut, USA.
2. HYNDMAN, Donald and Hyndman, David (2010) Natural Hazards and Disasters. Brooks Cole, 3rd Revised Edition, Stamford, Connecticut, USA.
3. KELLER, Edward A. and DeVecchio, Duane E. (2011) Natural Hazards: Earth's Processes as Hazards, Disasters, and Catastrophes. Prentice Hall; 3 Edition, Upper Saddle River, New Jersey, USA. 21
4. KREBS, Robert E. (2003) The Basics of Earth Science. Greenwood, Westport, Connecticut, USA. 5. STRAHLER, Alan H. and Strahler, Arthur (2004) Physical Geography: Science and Systems of the Human Environment. John Wiley & Sons, 3 Edition, Hoboken, New Jersey, USA. BURTON,
5 Kates, R.W. and White, G.F. (1993) The Environment as Hazard, The Guildford Press, London, UK.
6. DAMON, P. C. (2006) Introduction to International Disaster Management. Butterworth-Heinemann, UK.
7. DILLEY, Maxx (2005) Natural Disaster Hotspots: A Global Risk Analysis. World Bank and University of Columbia, US.
8. ELLIOT, J.E. (2006) An Introduction to Sustainable Development. Third Edition. Routledge, London, UK. 5. SMITH, Keith; and Petley, David N. (2009) Environmental Hazards: Assessing Risk and Reducing Disaster.Ke ,nodnot ,eldelt oR .

Course Title: **Igneous and Metamorphic Petrology**
Course Code: **Geol. 408**
Number of Credits: **3(2+1)**
Course Type: **Core**
Prerequisite: **-------**

Objectives and Learning Outcomes:

This course is designed to acquire the knowledge about the origin of magma and the role of magmatic and metamorphic process in the formation of igneous rocks. The learning outcomes include understanding the classification of various igneous rocks and their genesis in different tectonic settings. This course is designed to expose the students to the solid-state transformation of pre-existing igneous, metamorphic and sedimentary rocks into metamorphic rocks. The learning outcomes include familiarization with metamorphic processes and the resulting textures and structures in the metamorphic rocks.

Course Contents:

Composition, origin, differentiation and evolution of magma; classification of igneous rocks; mineralogy and petrology and occurrence of the following series: tholeiitic and alkali-olivine basalt; basalt–andesite series; study of granite, granodiorite, syenite, carbonatite, mafic and ultramafic rocks and ophiolites; lamprophyres; facies analysis of volcanic rocks; mode of

occurrences and types of extrusive rocks; texture and structure of igneous rocks; economic importance of igneous rocks.

Introduction to metamorphism; types, grades, zones and facies of metamorphism; metamorphic diffusion and differentiation; study of thermal and regional metamorphism of igneous, argillaceous, calcareous and arenaceous rocks; metamorphism in relation to plate tectonics; study of textures and structures of metamorphic rocks; metamorphism and deformation; history and dating of metamorphic rocks; differentiation between metamorphism and metasomatism; paired metamorphic belts. Himalayan and pre-Himalayan metamorphism in Pakistan.

Labs:

Megascopic and microscopic identification and description of igneous rocks. Discrimination diagrams. Petrographic and hand specimen identification of metamorphic textures, structures, and metamorphic history of rocks. ACF and AKF ternary diagrams and petrogenesis.

Recommended Books:

1. Igneous and Metamorphic Petrology by Best, M. G., 2002, Black Well.
2. Petrology of Igneous and Metamorphic Rocks by Hyndmann, D.W., 1995, McGraw-Hill.
3. Igneous Petrogenesis by Wilson, M., 1989, Unwin Hyman.
4. Petrology: Igneous, Sedimentary and Metamorphic by Blatt, H.,Tracy, R. and Owens, D., 2005, W.H. Freeman and Co.
5. Introduction to Igneous and Metamorphic Petrology, Winter, J.D., 2001, Prentice Hall.
6. Igneous Rocks: A Classification and Glossary: Recommendations of the IUGS Sub-commission, Maitre, R. W., Le Bas, M. J., Streckeisen, A., Zanettin, B. and Bonin, B. (eds.), 2005.
7. Igneous and Metamorphic Petrology by Best, M. G., 2002, Black Well.
8. Petrology of Igneous and Metamorphic Rocks, by Hyndmann, D. W., 1995, McGraw-Hill.
9. Petrology: Igneous, Sedimentary and Metamorphic by Blatt, H., Tracy, R. and Owens, D., 2005, W. H. Freeman and Co.
10. Metamorphism and Plate Tectonic Regimes by Ernst, W. G, 1975, Hutchison and Ross, Inc.
11. Metamorphic Petrology by Turner, F. J., 1981, McGraw-Hill.

Course Title: **Geotectonics**
Course Code: **Geol. 501**
Number of Credits: **3(2+1)**
Course Type: **Core**
Prerequisite: **Nil**

Objectives and Learning Outcomes:

This course is designed to acquire the knowledge about plate tectonics, various types of plate boundaries, their kinematics and dynamics. This will help the students to conceive the mountain building phenomenon, understand seismicity, volcanism and metallogeny.

Course Contents:

Theory and introduction to plate tectonics. Concept of continental drift and sea floor spreading, oceanic ridges and trenches; continental rifts; intra-oceanic islands; hot spot and mantle plumes; plates and plate boundaries; relative and absolute plate motions; extensional, compressional and transpressional tectonics; subduction zones; transform and transcurrent faults; introduction to neo-tectonics and related hazards, application of geotectonics in natural resource exploration.

Labs:

Specified maps/assignments/labs related to continental drift, sea-floor spreading and extensional, compressional and transform plate margins.

Recommended Books:

1. Plate Tectonics: Continental Drift and Mountain Building, Wolfgang Frisch, Martin Meschede, Ronald C. Blakey, 2010, Springer.
2. Economic Geology and Geotectonics, Donald Harvey Tarling, 1981, Wiley
3. An Introduction to Seismology, Earthquakes, and Earth Structure. Stein, Seth; Wysession, Michael 2009. Chichester: John Wiley and Sons.
4. Plate Tectonics – Geodynamics, Turcotte, D. L.; Schubert, G. 2002, Cambridge University Press Tectonics by Moores, E. M. and Twiss, R. J., 1995, W. H. Freeman and Co.
5. Global Tectonics by Keary, P. and Vine, F. J., 1996, Blackwell.
6. Plate Tectonics: How it Works by Cox, A. and Hort, R. B., 1986, Blackwell.
7. The Evolving Continents by Windley, B. F., 1984, John Wiley and Sons.
8. Gravity field, seismicity, and tectonics of the Indian Peninsula and the Himalayas, R. K. Verma.

Course Title: **Sedimentology**
Course Code: **Geol. 502**
Number of Credits: **3(2+1)**
Course Type: **Core**
Prerequisite: **Nil**

Objectives and Learning Outcomes:

This course is designed to acquire the knowledge about various types of sedimentary rocks and their diagenesis. This will help the students to understand the classification and depositional system of the sedimentary rock.

Course Contents:

Introduction to sedimentology; origin, transportation and deposition of sediments; texture of sedimentary rocks and their statistical parameters; sedimentary structures, their classification, morphology, significance and paleocurrent analysis; classification and description of sedimentary rocks; provenance of sediments; diagenesis; concepts of sedimentary facies and facies associations; physico-chemical controls of the sedimentary environments; diagnostic features of glacial, eolian, fluvial, lagoonal, lacustrine, deltaic, tidal, turbidites and marine environments; tectonic controls of sedimentation.

Labs:

Grain size analysis of sediments and sedimentary rocks; megascopic and microscopic study of sedimentary rocks for classification; use of ternary diagrams, discrimination diagrams for tectonic setting, separation and identification of heavy minerals; study of primary sedimentary structures and their uses in facing or top bottom. Rose diagrams and paleocurrent analysis.

Recommended Books:

1. Sand and Sandstone by Pettijohn, F. J., Potter, P. E. and Siever, R., 1972, Springer-Verlag.
2. Principles of Sedimentology by Friedman, G. M. and Sanders, J. E., 1978, John Wiley and Sons.
3. Depositional Sedimentary Environments by Reineck, H. E. and Singh, I. B., 1980, Springer-Verlag.
4. Carbonate Sedimentology by Tucker, M. E. and Wright, V. P., 1990, Blackwell.
5. Sedimentary Environment and Facies by Reading, H. G., 1986, Blackwell.
6. Applied Sedimentology by Selly, R. C., 1988, Chapman and Hall.
7. Petrology of Sedimentary Rocks by Boggs Jr. S., 1992, Merril Publishing Co.
8. Principles of Sedimentology and stratigraphy by Boggs, Jr. S., 2012, 5th Edition, Pearson Publishing Co.
9. Sedimentary Rocks by Pettijohn, F. J., 1975, Harper and Row.

10. Sedimentary Geology by Prothero, D. and Schwab, F., 1996, W.H. Freeman and Co.

Course Title: **Geophysics**
Course Code: **Geol. 503**
Number of Credits: **3(2+1)**
Course Type: **Core**
Prerequisite: **-**

Objectives and Learning Outcomes:

This course is designed to acquire knowledge about the subsurface geology based on different geophysical methods, with an aim to understand the structure of the earth, exploration of natural resources, and assessment of geohazards.

Course Contents:

Introduction to geophysics and geodynamics of earth. Classification and brief description of various methods of geophysics such as seismic; gravity, magnetic; electrical. Geophysical data acquisition, processing and interpretation; applications of geophysical techniques for exploration of natural resources i.e. oil, gas, metallic minerals, ground water and engineering works.

Labs:

Analysis and interpretation of geophysical data about seismic; gravity, magnetic; electrical, and seismicity.

Recommended Books:

1. Whole Earth Geophysics: An Introductory Textbook for Geologists and Geophysicists, Robert J. Lillie, 2008, Prentice Hall.
2. Gravity and Magnetic Exploration: Principal, Practices, and Application, William J. Hinze, Ralph R. B. von Frese, Afif H. Saad, 2013.
3. Tectonics - Recent Advances, 2012, Evgenii Sharkov, InTech.
4. Introduction to Applied Geophysics by Burger R. H., Sheehan, A. and Jones, C. 2000, W. W. Norton
5. Applied Geophysics by Telford, W. M., Geldart, C. P., Sheriff, R. E. and Keys, D. A., 1976, Cambridge University Press.
6. Introduction to Geophysics by Garland, G. D., 1971, W. B. Saunders Co.
7. Seismic Exploration by Al-Sadi, H. N., 1980, Birkhauser Verlag.
8. Introduction to Geophysical Prospecting by Dobrin, M. B. and Savit, C. H., 1988, McGraw-Hill.
9. An Introduction to Geophysical Exploration by Kearey, P., and Brooks, M., 1991, Osney Mead.
10. Basic Exploration Geophysics by Robinson, E. S. and Coruh, C., 1988, John Wiley and Sons.
11. Geophysical Methods in Geology by Sharma, P. V., 1987, Elsevier.
12. Quantitative Geophysics and Geology by Lliboutry, L, 2000.

13. The Solid Earth: An Introduction to Global Geophysics by Fowler, CMR., 2005.

Course Title: **Field Geology**
Course Code: **Geol. 504**
Number of Credits: **3(3+0)**
Course Type: **Core**
Prerequisite: **Nil**

Objectives and Learning Outcomes:

This course is designed to understand the geological mapping techniques in the field. This will help the students in learning the use of field equipments and data acquisition and preparation of geological maps and cross-sections.

Course Contents:

Introduction of topographic and geological maps; methods and techniques of surface and subsurface geological mapping; introduction to instruments for geological mapping; interpretation of geological maps with reference to outcrop patterns; correlation techniques; field description of igneous, metamorphic and sedimentary rocks; modes of geological illustration including structural contour, isopach and lithofacies maps, block and fence diagrams; scan line survey; preparation of geological maps and cross sections; awareness and compliance of Health and Safety Environment (HSE) particularly during geological work.

Labs:

Uses of field instruments; field data acquisition and interpretation; section measurement and preparation of cross section; structural balancing; geological fieldwork and report writing of an assigned area.

Recommended Books:

1. Elements of Field Geology by Himus, G. W. and Sweeting, G. S., 1968., University Tutorial Press Ltd.
2. Field Geology by Lahee, F.H., 1961, McGraw-Hill.
3. Geology in the Field by Compton, R. R., 1985, John Wiley and Sons.
4. Introduction to Field Geology. Bevier, M. L., 2006. McGraw-Hill Ryerson.

Course Title: **Micropalaeontology and Biostratigraphy**
Course Code: **Geol. 505**
Number of Credits: **3(2+1)**
Course Type: **Core**
Prerequisite: **Nil**

Objectives and Learning Outcomes:

This course is designed to acquire the knowledge about various microfossils and their distribution in geological succession. Paleogene biostratigraphy with special reference to Pakistan.

Course Contents:

Introduction to foraminifera, foraminiferal cell and test morphology, ecology of larger benthic, smaller benthic and planktonic foraminifera. Introduction to Bryozoa, Ostracoda, Conodonts, Algae, pollen and spores, organic walled microplanktons and nanno fossils.

Paleogene biostratigraphy with special reference to Pakistan.

Labs:

Basic micropalaeontological and biostratigraphic techniques; morphological and taxonomic studies of selected/index microfossils.

Recommended Books:

1. Microfossils by Brasier, M. D., 1980, Allen and Unwin.
2. Invertebrate fossils by Fischer, G. A. and Moore, R. C., latest Ed., McGraw-Hill.
3. Introduction to Marine Micropaleontology by Haq and Boersman, 1980, Elsevier.
4. Paleontology by Tucker, V. C. T and Noeld, E. W., 1985, Pergaman Press.
5. Plankton Stratigraphy by Balli and Saunders, 1986, Oxford University Press.
6. Microfossils (2nd Ed.) by Howard A. Armstrong and Martin D. Brasier, 2005, Blackwell Publishing.
7. Principles of Sedimentology and Stratigraphy (Fifth edition), by Sam Boggs Jr., 2014, Publisher missing
8. Stratigraphy of Pakistan, By Shah, S. M. I., 2009. Geological Survey of Pakistan. Memoir, Vol. 22.

Course Title: **Introduction to GIS and RS**
Course Code: **Geol. 506**
Number of Credits: **3(2+1)**
Course Type: **Core**
Prerequisite: **Nil**

Objectives and Learning Outcomes:

The basic aim of the course is to understand basic knowledge regarding GIS, RS and different types of data sets and data models, to understand the concepts of RS and satellite image processing techniques and to analyze spatial data.

Course Contents:

Introduction to Geographical Information System; data types, data models and structures; data sources and capturing techniques; displaying and manipulating spatial information, vector data preparation, GPS Survey; introduction to the concept of RS, electromagnetic spectrum, atmospheric interaction; Technology of Remote Sensing (Orbits, Satellites, Sensors and Platforms); applications of Remote Sensing, satellite image processing cycle, image enhancement, data fusion and mosaicing and information extraction (classification and vectorization).

Labs:

Introduction to ArcGIS, Exploring GIS Data set in Arc Catalog, working on vector data in ArcGIS (Scanning, Digitization and Editing), Integrating GPS data in GIS Environment, Applications of GIS, ERDAS Imagine, ENVI - Environnent, Noise Corrections, Geometric Corrections, Radiometric Corrections.

Recommended Books:

1. Remote Sensing by Siamak Khorram, Frank H. Koch, Cynthia F. Van der Wiele. 2012. Springer.
2. Introduction to Geographic Information Systems by Kang-Tsung Chang. 2010. McGraw-Hill Publishers.
3. GIS: Fundamentals, Applications and Implementations by Elangovan. 2006. McGraw-Hill Publishers.
4. Remote Sensing of the Environment by John R. Jensen. 2009. Amazon publishers.
5. Matt Duckham, Michael F. Goodchild, Michael F. Worboys, 2003, Foundations of Geographic Information Science, Tylor and Francis, New York, USA.
6. Michael N. Demers 2002, Fundamentals of Geographic Information System, John Wiley and Sons, Inc., Singapore.
7. Kang-Tsung Chang, 2002, Introduction to Geographic Information Systems, McGraw-Hill Company, New York, U.S.A.
8. W. G. Rees, 2001, Physical Principles of Remote Sensing Cambridge University Press, United Kingdom. ISBN: 0521669480.

9. Asanta Shrestha and Birendra Bajracharya, 2000, GIS for Beginners, By ICIMOD, Kathmandu, Nepal.
10. Thomas M. Lilles and Ralph W. Kiefer, 2000, Remote Sensing and Image Interpretation John Wiley and Sons.
11. Robert A. Schowengerdt, 1997, Remote Sensing 2nd edition, Academic Press.
12. James B. Campbell, 1996, Introduction to Remote Sensing, the Guilford Press, New York, USA.

Course Title: **Sequence Stratigraphy**
Course Code: **Geol. 507**
Number of Credits: **3(2+1)**
Course Type: **Core**
Prerequisite: **Nil**

Objectives and Learning Outcomes:

This course is designed to acquire the knowledge about various types of stratigraphic sequences and their relationship with the sea level changes. This will help the students to learn about the formation of various sedimentary rock sequences during geologic time.

Course Contents:

Introduction, history, concept and significance of sequence stratigraphy; data sources: seismic reflections, outcrops, well logs, core; seismic facies; sea level changes, their causes and effects; accommodation, eustatic and relative sea curve; hierarchy of sequence stratigraphic elements; types of sequences and systems tracts; applications to hydrocarbon exploration and basin analysis.

Labs:

Interpretation of seismic reflections; picking up/identification of sequence boundaries, system tracts and seismic facies.

Recommended Books:

1. Silici-clastic Sequence Stratigraphy in Well Logs, Cores and Outcrops by Van Wagoner, J. C., et al., 1990, AAPG Meth Expl. Ser. No.7.
2. Sea-level Changes an Integrated Approach by Wilgus, B. S., et al., 1988. SEPM.
3. Seismic Stratigraphy: Application to H-carbon Exploration by Payton, C. W., 1977, AAPG Mem. 26.
4. Sequence Stratigraphy and Facies Association by Posamentier, H. W., et al., 1993, Blackwell.
5. Sequence Stratigraphy by Emery, D. and Myers, K. J., 1996, Oxford, Blackwell.

Course Title: **Geochemistry**
Course Code: **Geol. 508**
Number of Credits: **3(2+1)**
Course Type: **Core**
Prerequisite: **Nil**

Objectives and Learning Outcomes:

This course is designed to provide the basic understanding about geochemistry and how the distribution and dispersion of elements in minerals and rocks within different prevailing environments. How the geochemical signature / signatures are created to provide the heterogeneity that lead towards useful geochemical proxies / tools. These proxies can play and important role in the mineral exploration and in the provenance domain.

Course Contents:

Development of geochemistry as a discipline; composition of meteorites; origin and cosmic abundance of elements; geochemical structure of the earth; geochemical classification of elements; polymorphism and pseudomorphism; geochemical cycle; mobility and dispersion of elements under different geochemical environments; introduction to geochemistry of igneous, metamorphic and sedimentary rocks; geochemical anomalies and their application in mineral exploration; introduction to geochemical analytical techniques; introduction to organic geochemistry, organic matter, types, and its importance in petroleum industry.

Labs:

Processing and interpretation of geochemical data. Ternary diagrams interpretation.

Recommended Books:

1. Introduction to Geochemistry by Krauskopf, K. B., 1967, McGraw-Hill.
2. Principles of Geochemistry by Mason. B., 1966, John Wiley and Sons.
3. Geochemistry in Mineral Exploration by Rose, A. W., Hawkes, H. H. and Webb, J.S., 1983, Whitstable Litho Ltd.
4. Inorganic Geochemistry by Henderson, P., 1982, Pergamon Press Ltd. Geochemistry by Brownlow, A. H., 1996, Prentice Hall.
5. Geochemistry by Beaumont, E. A., and Foster, N. H., 1988, AAPG Special Bulletin, Publication No.8.
6. Geochemistry. Pathways and Processes by McSween, H. Y., Jr, Richardson, S. M. and Uhle, M. E., 2003, Columbia University Press, New York.

Course Title: **Petroleum Geology**
Course Code: **Geol. 509**
Number of Credits: **3(2+1)**
Course Type: **Core**
Prerequisite: **Nil**

Objectives and Learning Outcomes:

This course is designed to acquire the knowledge about the processes involved in the formation, migration and accumulation of petroleum in the rocks and drilling and well logging techniques for petrophysical evaluation and production of oil and gas. This will help the students to learn about the global occurrences of oil and gas with special emphasis on Pakistan so that they can effectively use their knowledge in the exploration and development of the country's energy resources.

Course Contents:

Introduction and history of hydrocarbon exploration; the nature and classification of petroleum hydrocarbons, their origin, migration and accumulation, traps, seal and cap rocks; source rock-evaluation; kerogene and its types; reservoir rocks characterization, reservoir fluid, reservoir conditions and dynamics; tight reservoirs; exploration petroleum cycle in Pakistan; prospect and exploration in frontiers areas; introduction to drilling operations, well site geology and mud logging; well failure/success analysis; petroleum prospect risk analysis; nonconventional hydrocarbons, introduction to play fairways and petroleum system.

Labs:

Preparation of various types of subsurface maps, e.g. isopach, isochore and isoliths etc. Preparation of fence diagrams. Identification of pay zone, analysis of pyrolysis data and correlation diagrams. Visits to well/drilling sites.

Recommended Books:

1. Elements of Petroleum Geology, Richard C. Selley, 1998, Acad. Press.
2. Hydrocarbon Exploration and Production: Frank Jahn, Mark Cook and Mark Graham, 1998, Elsevier.
3. Wellsite Geological Techniques for Petroleum Exploration: Methods and Systems of Formation Evaluation, Bhagwan Sahay, Awadesh Rai, Manoj Ghosh, 1988, Oxford and IBH Pub. Co.
4. Petroleum Geology by North, F. K., 1985, Allen and Unwin.
5. Geology of Petroleum by Leverson, A. I., 1970, W. H. Freeman and Co.
6. Geology and Tectonics of Pakistan by Kazmi, A. H. and Jan, M. Q., 1997, Graphic Publishers.
7. Geology of Pakistan by Bender, F. K. and Raza, H. A., (eds.) 1995, Gebruder Borntraeger.
8. Hydrocarbons from Coal by Law, B. E., and Rice, D. D., 1993, AAPG Studies in Geology # 38.
9. Principles of Petroleum Development Geology by London, R. C., 1996,

Prentice Hall.
10. Petroleum Geology of the North Sea: Basic Concepts and Recent Advances by Glennie, K. W., 1998. Marston Book Services Ltd.
11. Sedimentary Basins and Petroleum Geology of the Middle East by Alsharhan, A. S., and Nairn, A. E. M., 1997.
12. Petroleum Geology of Libya by Hallett, D., 2002.

Course Title: **Engineering Geology**
Course Code: **Geol. 510**
Number of Credits: **3(2+1)**
Course Type: **Core**
Prerequisite: **Nil**

Objectives and Learning Outcomes:

This course is designed to acquire the knowledge about rock mechanics and their role in the construction of huge structure. This will help the students in learning various techniques of determination of physical and geotechnical parameters of soils and rocks for construction of buildings and foundations. Upon successful completion of the course, the student will be able to identify basic concept of engineering geology, applications and engineering rock mass classification, to understand the concept of strength, chemical and mechanical behavior of rock and to review building code, common engineering problem and their remedial measures.

Course Outline:

Introduction to the engineering geology and its application; weathering, physical and chemical; earthquakes, causes and intensity scale; rock mass classification; geotechnical studies of rocks and soils; geological factors and strength of rocks; chemical and mechanical behavior of rocks; geotechnical investigation; uses of sedimentary, igneous and metamorphic rocks as construction material; Building Code of Pakistan; dam and tunnel engineering; common engineering problems and their remedial measures.

Labs:

Sieve analysis, slake durability, moisture, void ratios, porosity, angle of repose, and other geotechnical properties of soils. Uniaxial and Triaxial Testing; tensile, compressive and shear tests of rocks.

Recommended Books:

1. Practical Engineering Geology by Steve Hencher – 2012. Amazon
2. Engineering Geology: Principles and Practice by David George Price, Michael de Freitas – 2008. Springer.
3. Foundations of Engineering Geology by Waltham, T, 2002.
4. Engineering Geology by Goodman, R. E., 1993, John Wiley and Sons.
5. Rock Slope Stability Analysis by Gian Paolo Giani. 1992. Amazon.
6. Engineering Geology by F G Bell – 2007. Buttersworth.

7. Measuring Engineering Properties of Soil by Wray, W. K., 1986, Prentice, Hall.
8. Fundamentals of Engineering Geology by Bell, F. A. G., 1983, Butter, Worth.
9. Engineering Geology by Beavis, F. C., 1985, Blackwell.
10. Geology for Engineers by Blyth, F. G. H. and De Freites, M. H., 1960, Butter and Tonner Ltd.
11. Geology and Engineering by Legget, R. F., 1962, McGraw-Hill.

Course Title: **Well Logging**
Course Code: **Geol. 511**
Number of Credits: **3(2+1)**
Course Type: **Core**
Prerequisite: **Nil**

Objectives and Learning Outcomes:

This course will enable the students to acquire knowledge about logging environment and techniques and interpretation of various logs for exploration of hydrocarbon.

Course Contents:

Introduction, logging environment (Pressure/ temperature), lithology interpretation from different types of log e.g. gamma ray and spectral gamma ray logs, resistively logs, sonic or acoustic logs, density and photoelectric log, the neutron log, sequences and depositional environments from logs, determination of value of shale and movable hydrocarbons.

Labs:

Quantitative uses of logs, e.g. porosity/ permeability calculation, hydrocarbons/ water saturation, shale volume calculation, graphic presentation.

Recommended Books:

1. M. H Rider, 1999, Geological Interpretation of Well Logs, 2nd Edition, Whittles publishing services.
2. Charles Gibbson, and George Asquith, 1982, Basic Well Log analysis for Geologist (Methods), American Association of Petroleum Geologists.
3. Principles and application of Well Logging, by Hongqi Liu, 2017, Springer.
4. The Imperial College Lectures in Petroleum Engineering (An Introduction to Petroleum Geosciences), Vol. 1, by Michael Ala, 2017, World Scientific.

Course Title: **Geological Fieldwork-III**
Course Code: **Geol. 512**
Number of Credits: **2(0+2)**
Course Type: **Core**
Prerequisite: **Nil**

Objectives and Learning Outcomes:

The duration of field work will be for about two weeks and is designed to identify various types of rocks, stratigraphic features, fossils, primary and secondary structures and landforms in the field. Exercises will include the construction of profiles and cross sections, out crop sketches, scan line survey and geological mapping techniques.

Labs:

Field based exercises. Observations and plotting of geological information on topographic sheet. Study of geomorphic features. Measurement of stratigraphic sections. Recognition of structural features. Study of fossils, primary and secondary structures. Field description of sedimentary, igneous and metamorphic rocks. Report writing based on geological mapping of an assigned area and fieldwork Viva Voce and Evaluation.

Recommended Books:

1. Elements of Field Geology by Himus, G. W. and Sweeting, G. S., 1968., University Tutorial Press Ltd.
2. Field Geology by Lahee, F. H. 1987, McGraw-Hill.
3. Geology in the Field by Compton, R. R. 1985, John Wiley and Sons.
4. Basic Geological Mapping by Barnes, J. W. and Lisle, R. J., 2004, John Wiley and Sons.

Course Title: **Geology and Tectonics of Pakistan**
Course Code: **Geol. 601**
Credit Hours: **3(3+0)**
Course Type: **Core**
Prerequisite: **-**

Objectives and Learning Outcomes:

This course is designed to acquire the knowledge about the geology and tectonics, tectono-stratigraphy of Pakistan. This will help the students to learn about the tectonic elements, distribution of natural resources, and to assess the geohazards in Pakistan.

Course Contents:

Introduction of general geology and tectonics of Pakistan. Physiographic and tectonic divisions; geology and stratigraphy of the accreted terrains such as Karakoram and Kohistan plate, Indian plate, stratigraphy and structure of foreland basins, Chamman fault, Makran convergence zone, and southern Indus basins, oroclines and suture zones. Himalayan and pre-Himalayan orogenic events, magmatism and metamorphism (pre-Himalayan and post-Himalayan); Economic mineral and fuel deposits of Pakistan.

Labs:

Reconstruction of continents through times, regional tectonic elements of the Pakistan, geology and tectonics of Salt Range/Kohat-Potwar Plateau, Sulaiman/Kirthar fold belt, Makran convergence zone, on-and-offshore Pakistan.

Recommended Books:

1. Geodynamics of Pakistan by Farah, A. and DeJong, K. A. (eds.), 1979, Geological Survey of Pakistan.
2. Geology of Himalaya, Karakuram, Hindukush in Pakistan by Tahirkheli, R. A. K., 1982, Geol. Bull., University of Peshawar.
3. Precambrian to early Paleozoic Orogenesis in the Himalaya, Baig, M.S., and Lawrence, R. D., 1987, Kashmir Journal of Geology, V.5, p.1-22.
4. Evidence for late Precambrian to early Cambrian orogeny in northwest Himalaya, Pakistan. Baig, M. S., Lawrence, R. D, and Snee, L. W., 1988, Geological Magazine, London, V. 125, No. 1, p. 83-86.
5. Timing of pre-Himalayan orogenic events in the northwest Himalaya: 40 Ar/ 39 Ar constraints. Kashmir Journal of Geology, Baig, M. S., Snee, L. W., La Fortune, R. J., and Lawrence, R. D., 1989, V. 6and7, p. 29-40.
6. Geochronology of pre-Himalayan and Himalayan tectonic events, northwest Himalaya, Pakistan, Baig, M. S., 1991, Kashmir. Kashmir Journal of Geology, V.8 and 9, p. 197**.**
7. Geology of Himalaya by Gansser. A., 1964, John Wiley and Sons.
8. Reconnaissance Geology of West Pakistan, 1961, Hunting Survey, Report.
9. Geology and Tectonics of Pakistan by Kazmi, A. H. and Jan, M. Q., 1997, Graphic Publishers.
10. Geology of Pakistan by Bender, F. K. and Raza, H. A. (eds.), 1995, Gebruder Borntraeger.
11. Metallogeny and Mineral Deposits of Pakistan by Kazmi, A. H., and Abbasi, S. G., 2001, Orient Petroleum Incorporation.
12. Stratigraphy and Historical Geology of Pakistan by Kazmi, A. H and Abbasi, I. A., 2008, Graphic Publishers, Karachi, Pakistan

Course Title: **Economic Geology**
Course Code: **Geol. 602**
Number of Credits: **3(2+1)**
Course Type: **Core**
Prerequisite: **Nil**

Objectives and Learning Outcomes:

This course is designed to acquire the knowledge about the formation of various types of economic mineral deposits and their significance. The outcomes are understanding the processes which are involved in the genesis of various ores deposits, hydrocarbons, gemstones and other industrial minerals.

Course Contents:

Introduction to economic minerals and rocks and their classification; grade and reserve estimation of deposits; introduction to ore microscopy; environment and processes of formation of economic mineral deposits: magmatic segregation, hydrothermal solution, metasomatism, sedimentation, evaporation, residual and mechanical concentration and metamorphism; relationship of mineral deposits plate tectonic settings; introduction of geological exploration/prospecting; brief description of economic minerals such as fuel minerals gemstones, copper, lead, zinc, iron, gold, chromite, manganese, salt, gypsum, bauxite, barite, fluorite, clays, phosphorite, building and dimension stones, industrial rocks and minerals, radioactive minerals and rocks with special reference to Pakistan.

Labs:

Identification and description of economic minerals, microscopic studies and lab exercises on grade and reserve estimation from provided data.

Recommended Books:

1. Metals and Society: An Introduction to Economic Geology by Arndt, and C. Ganino – 2012, Springer.
2. Economic Geology: Principles and Practice by Walter L. Pohl – 2011, John Wiley and Sons.
3. Introduction to mineral exploration by Charles and Micheal. 2006, Black well.
4. Hand book of mineral and coal exploration in British Colombia by Aime and MABC.2009, Springer.
5. Directory of Mineral Deposits of Pakistan by Zaki, A., 1969, Geological Survey of Pakistan.
6. Ore Deposits by Park, C.F. and Mac Diarmid, R.A.,1970, W. H. Freemanand Co.
7. Economic Mineral Deposits by Jenssen, M. L. and Bateman, A.M., 1972, John Wiley and Sons.
8. Mineral Prospecting Manual by Chausier, J.B., 1987, NorthOxford Academic Press.
9. An Introduction to Ore Geology by Evans, A.M., 1987, Blackwell.
10. Atlas: Economic Mineral Deposits by Dixan, C. J.,1979, Chapman Lordin and Hall.
11. Metallogeny and Mineral Deposits of Pakistan by Kazmi, A. H. and Abbas, S.G., 2001, Orient Petroleum Inc.
12. Handbook of Exploration Geochemistry, Govett, G.J.S. (ed.), 1995, Elsevier
13. Ore Deposit Geology by Edward, R.and Atkin sons, K.,1986, Chapman and Hall.
14. Introduction to Mineral Exploration, 2nd edition, b**y** Moon, C.J., Whateley, M.K.G. and Evans, A.M. (Editors). 2006**,** Blackwell Publishing, Oxford.

15. Magmatic Sulfide Deposits: Geology, Geochemistry and Exploration by Naldrett, AJ., 2004

Course Title: **Environmental Geology**
Course Code: **Geol. 603**
Number of Credits: **3(2+1)**
Course Type: **Core**
Prerequisite: **Nil**

Objectives and Learning Outcomes:

This course is designed to acquire the knowledge about the role of geology in the environmental degradation. This will help the students to learn how various geological processes and related human activities are involved in contaminating our ecosystem.

Course Contents:

Introduction to environmental geology; management of natural resources; global climatic changes; environmental controls for erosion, desertification and coastal degradation; introduction to environmental impact assessment and initial environmental examination; environmental impact of mining, dams, reservoirs, highways, their assessment and controls; geological hazards such as floods, landslides, earthquakes, tsunamis, volcanoes, glaciers and shoreline processes and their remedial measures; industrial pollution, solid and liquid waste disposal, groundwater contaminations, river lake and marine pollution and their impact on human health; clean sources of energy, introduction to acid mine drainage.

Labs:

Sampling and analysis of air, water, soil and rocks, geochemical analysis. Exercises can be done on published data.

Recommended Books:

1. Geology and the Environment by Bernard W. Pipkin, D. D. Trent, Richard Hazlett. 2010. Yolande Cossio. USA.
2. Environmental Geology: Handbook of field methods and case studies Klaus. Knödel, Gerhard Lange, Hans-Jürgen. Voigt. 2007, Springer, New York.
3. Environmental Geology by Montgomery, C. W., 2005, McGraw-Hill.
4. Radio Propagation and Remote Sensing of the Environment by Armanel, N.A., Polyakove, V. M., 2005, CRC Press.
5. Lab Manual for Environmental Geology by Harvey Blatt – 2012. Worth Publishers Environmental Geology by Keller, E. A., 2000, Prentice Hall, Publishing Co. New Jersey, US.
6. Applied Chemical Groundwater Hydrology by Mazore, E., 1988, McGill.
7. Earthquake Risk and Damage by Liu, B. C., 1981, Westview.

Course Title: **Hydrogeology**
Course Code: **Geol. 604**
Number of Credits: **3(2+1)**
Course Type: **Core**
Prerequisite: **Nil**

Objectives and Learning Outcomes:

This course is designed to acquire knowledge about the exploration of groundwater resources and their management. This will help the students to learn how to manage and conserve water resources, how to overcome the acute shortage of water supply and also how to maintain its purity for meeting the present demand as well as the demand of the future generation.

Course Contents:

The hydrologic cycle. Aquifer system and types; occurrence and movement of groundwater; hydrologic properties of rocks and their measurements, fluctuation of groundwater levels and causes; recharge and discharge of ground water; groundwater exploration by geological, hydro-geological and geophysical methods and remote sensing techniques; well hydraulics, tube well drilling techniques, designing, development; flow-net analysis and pumping tests; water logging and causes of water table declination; groundwater chemistry, salinity, quality analysis and deterioration of water quality. Groundwater resources of Pakistan.

Labs:

Preparation of water table and piezometric surface maps. Flow-net analysis; study and preparation of hydro-geologic maps; graphical presentation of published chemical data of groundwater.

Recommended Books:

1. Hydrogeology: objectives, methods, applications by Ric Gilli, Eric Gilli, Christian Mangan, 2012, CRC Publishers Taylor and Francis Group, USA.
2. Hydrogeological Conceptual Site Models: Data Analysis and Visulization by Neven Krešić, Alex Mikszewski. 2012. CRC Publishers Taylor and Francis group, USA.
3. Fundamentals of Hydrology by Tim Davie. 2012. Rourledge for Taylor and Francis Group, USA.
4. Elementary Hydrogeology by Singh. 2010. Prentice Hall, USA.
5. Hydrogeology Lab Manual by Lee. 2010. Prentice Hall, USA.
6. Hydrogeology, Principles and Practice by Geofluids, S. Q. L., 2005, Blackwell Synergy.
7. Introduction to Hydrogeology by Geofluids, H., 2003, Blackwell Synergy.
8. Groundwater Hydrology by Todd, D. K., 1995, John Wiley and Sons.
9. Groundwater Resource Evaluation by Walton, W. C., 1970, McGraw-Hill.
10. Introduction to Groundwater by Michael, P. 1985, George Allen and

Unwin.
11. Applied Hydrogeology by Fetter, C. W., 1994, MacMillan Pub. Co.
12. Groundwater by Ragunath, H. M., 1992, Wiley Eastern Ltd.
13. Groundwater Hydrology by Bouwer, H., 1988, McGraw-Hill.
14. Hydrology and Groundwater Resources of NWFP by Kruseman, G. P., 1988, WAPDA.
15. Field Hydrogeology by Brassington, R., 1988, John Wiley and Sons.

Course Title: **Computer Applications in Geology**
Course Code: **Geol. 605**
Number of Credits: **3(2+1)**
Course Type: **Core**
Prerequisite: **Nil**

Objectives and Learning Outcomes:

The course is designed to acquire knowledge about the use of computer to carry out various assignments: 1) To learn basics of the operating systems, some of the commonly used software and programs in geology. The statistics applied to geology and geophysics; use of internet, establishing a workplace network, to learn basic computer hardware, preliminary information about the computer encoding systems and various kinds of file formats. 2) Learn applied geology, geophysics and structural computer programs.

Course Contents:

Learn basic programs (word, excel, illustrator, power point), basic programming and numerical analysis (using MATLAB); basic geographical information systems and visualization; some of the field equipment; basic knowledge related to *Computer hardware* ***(***CPU, memory, motherboard and bus, power supply, monitor, video card, hard drive, ports (ethernet, parallel, serial, USB), CD, zips, etc. System run programs (drivers, Operating systems like Windows, Unix, Mac and Linux, other software used in industries Geographix, Petrel, Petromod, Kingdom Sweet. Computer encoding (Digital, Analogue), various kinds of scripts like MATLAB, ASCII, EBCDIC, and UNICODE; basics of networking. Use of common geological, structural and geophysical computer programs.

Labs:

Basic exercises on geological, structural and geophysical computer programs.

Recommended Books:

1. Basic Category Theory for Computer Scientists, C. Benjumin Piercce, 1991.
2. An Introduction to Computing Infrastructure: Hardware and Operating Systems, John Williams, 1996, Que E and T.
3. Introduction to Computers, Peter Norton, 2004, Technology Education.
4. Introduction to Computers, Gary B. Shelly, Steven M. Freund, Misty E. Vermaat, Edition 8, 2010, Technology Education.

5. An Introduction to Operating Systems-Concepts and Practice, Pramod Chandra P. Bhatt, 2004, PHI Learning Pvt. Ltd.
6. Introduction to Computers, Rajmohan Joshi, 2009.
7. Computer Networks, Andrew S. Tanenbaum, 5th Edition, Andrew S. Tanenbaum, 2010.
8. Use common geological, geophysical and structural programs.

Geol. 606: Elective (3 credit hours)
Geol. 607: Elective (3 credit hours)
Geol. 608: Elective (3 credit hours)
Geol. 609: Project Report/Thesis (6 Credit hours)

Semester VII and VIII (List of Elective Courses)

GROUP-I: MINERALOGY, PETROLOGY AND GEOCHEMISTRY

Objectives:

The courses for this group of specialization have been designed to offer advance level courses covering various aspects of mineralogy and petrology of igneous, sedimentary and metamorphic rocks. These courses will enable the students to fully understand (1) the mineralogical and chemical characteristics of various types of rocks, (2) the magmatic processes for the formation of igneous rocks and (3) the concept of metamorphic facies and zones. After completing these courses, the students will be able to carry out their independent research on the mineralogical and petrological aspects of all rock types.

This group comprises of following courses:

1. Igneous Petrogenesis
2. Metamorphic Petrology II
3. Sedimentary Petrology II
4. Mineralogy II

Course Title: **Igneous Petrology**
Number of Credits: **3(2+1)**
Course Type: **Elective**
Prerequisite: _____

Objective and Learning Outcomes:

This course aims at the process involved in the formation of igneous rocks. At the end of the course students will be able to define Mantle-magma systems and source of magma. This will help the students to evaluate petrogenic provinces. Define the ophiolite.

Course Contents:

Mantle-magma systems and source of magma; physio-chemical factors in magmatic evolution; petrogenesis of igneous rocks; petrogenic provinces:

basaltic provinces, granite-granodiorite provinces and mafic-ultramafic complexes; tectonism-magmatism relationship; magmatism at convergent and divergent plate boundaries; intracontinental hotspots; intraplate magmatism; magmatism related to collisional environments and island arcs; ophiolites; volcanic chains and island arcs. Igneous rock associations.

Labs:

Petrographic study of rock units. Modal analysis and discriminate diagrams.

Recommended Books:

1. Igneous Petrology by Hill, A., 1987. Longman Scientific and Technical.
2. Petrology: Igneous, Sedimentary and Metamorphic by Ehlers, E. G. and Blatt, H. W. H., 1982, W. H. Freeman and Co.
3. Petrology: Igneous and Metamorphic Rocks by Hyndman, D. W.,1972, McGraw-Hill.
4. Igneous and Metamorphic Petrology by Best, M. G.,1982, W. H., 1982, W. H. Freeman and Co.
5. Igneous and Metamorphic Petrology by Turner, F. J. and Verhoogen, J. 1960, McGraw-Hill.
6. Igneous Petrogenesis by Wilson, M., 1989, Unwing Hyman.
7. Igneous Petrogenesis by Carmichael, I. S. E., Turner, F. J. and Verhoogen, J., 1974, McGraw-Hill.
8. Igneous Petrology by McBirney, A. R., 1984, Freeman Cooper and Co.
9. Introduction to Igneous and Metamorphic Petrology by Winter, J. D., 2001, Prentice Hall.

Course Title: **Metamorphic Petrology**
Number of Credits: **3(2+1)**
Course Type: **Elective**
Prerequisite: _____

Objective and Learning Outcome:

This course is about the detailed study of metamorphic rocks. The pressure and temperature at which these rocks are formed are evaluated. At the end of the course students will be able to define characteristics of metamorphic reactions and role off liquids and differentiate different types of metamorphic facies series. This will help the students to evaluate tectonics of regional metamorphic belts; paired metamorphic belts; define different types of metamorphic structures of continental crust.

Course Contents:

Basic characteristics of metamorphic reactions and role of fluids; concept of iso-grades and iso-reaction grades; very low grade and ocean floor metamorphism; contact and regional metamorphism; metamorphic facies series; P-T gradients, mineralogical characteristics of individual facies; progressive and retrogressive metamorphism of pelites, basic rocks and carbonates; high grade metamorphism, anatexis and migmatites; tectonics of regional metamorphic

belts; paired metamorphic belts; metamorphic structures of continental crust; metasomatic processes.

Labs:

Construction and interpretation of ACF and AKF diagrams; petrographic study of various rock suites; mineral and mineral phase equilibria and P-T conditions.

Recommended Books:

1. Petrology: Igneous, Sedimentary and Metamorphic by Ehlers, E. G. and Blatt, H. W. H., 1982, W. H. Freeman and Co.
2. Igneous and Metamorphic Petrology by Hyndman, D. W., 1972, McGraw-Hill.
3. Igneous and Metamorphic Petrology by Best M. G.,1982, W. H. Freeman and Co.
4. Metamorphic petrology by Turner, F. J., 1981, McGraw-Hill.
5. Metamorphism and Plate Tectonics Regimes by Ernst, W. G. 1975, Dowden, Hutchisnson and Ross, Inc.
6. Petrology of the Metamorphic Rocks by Mason, R., 1981, George Allen and Unwin/Thomas Murby.
7. Introduction to Igneous and Metamorphic Petrology by Winter, J. D., 2001, Prentice Hall.

Course Title: **Sedimentary Petrology**
Number of Credits: **3(2+1)**
Course Type: **Elective**
Prerequisite: **-------**

Objective and Learning Outcome:

The main objective of this course is to introduce students to one of the three major rocks types. The students will be able to classify sedimentary rocks, define sedimentary environment. This will help the students to evaluate texture of different sedimentary rocks.

Course Contents:

Classification of sedimentary rocks, sedimentary environments; diagenesis of clastic, non-clastic and other sedimentary rocks; fabric, framework, geometry, texture and composition; study of heavy minerals; provenance of sedimentary rocks.

Labs:

Study of texture, mineral composition and diagenesis of various types of sedimentary rocks in hand specimens and thin sections; heavy mineral separation and analysis.

Recommended Books:

1. Principles of Sedimentology and Stratigraphy by Boggs, S., 2001, Prentice Hall.

2. Sedimentary Geology by Prothero, D., Schwab, F., 1996, W. H. Freeman and Co.
3. Sequence Stratigraphy by Emery, D. and Myers, K. J., 1996, Blackwell.
4. Sedimentary Petrology, An Introduction by. Tucker, M. E., 1981, Blackwell.
5. Sedimentary Rocks by Pettijohn, F. J., 1975, Harper and Row.
6. Sedimentary Petrology by Tucker, M. E., 1990, Blackwell.

Course Title: **Mineralogy II**
Number of Credits: **3(2+1)**
Course Type: **Elective**
Prerequisite: **-------**

Objective and Learning Outcome:

The minerals are formed under various conditions of depth and chemical composition. This course will enable the students to differentiate between physical and chemical properties of different minerals. Define different group of minerals. Students will be able to measure the triple junction of angles. Students can evaluate the assessment and performance of industrial rocks and minerals.

Course Contents:

Physical and chemical properties of minerals; relationship between the structure, chemistry and properties of silicates, carbonates, oxides, sulfides, and phosphates; mechanisms of mineral nucleation and crystal growth; importance of kinetics in mineral formation; interpretation of mineral analysis.
Measurement of mineral triple junction angles; description of grain boundaries and their implication for the development of rock textures; triangular and X-Y plots; mineralogical evaluation for the assessment and performance of industrial rocks and minerals.

Labs:

Microscopic identification of the common rock forming minerals in thin sections, using transmitted and reflected light microscopy.

Recommended Books:

1. Mineralogy for Students by Battey, M. H., 1981, Longman.
2. Mineralogy by Berry and Masson, 1983, W. H. Freemen and Co.
3. Mineralogy by Perkins, D., 2002, Prentice Hall.
4. Minerals in Thin Sections by Perkins, D., 2000, Prentice Hall.
5. Petrology of Igneous and Metamorphic Rocks by Philpotts, A. R., 1989, Prentice Hall.
6. Atlas of Rock Forming Minerals in Thin section by Mackenzie, W. S., Guilford, C. P., 1980, John Wiley and Sons.
7. Introduction to Rock Forming Minerals by Deer, W. A., Howie, R. A., and Zussman, J., 1992, Longman.

GEOCHEMISTRY

Objectives and Learning Outcome:

Advance level courses have been designed in this group of specialization. These courses will enable the students to fully understand (1) the basic concepts of thermodynamics, (2) the geochemical techniques applied in mineral exploration, (3) the isotopes and their role in source rock characterization and dating, (4) the elemental distribution in sedimentary rocks, (5) geochemical characteristics of igneous and metamorphic rocks and their petrogenesis. After completing these courses, the students will be able to carry out their independent research related to the petrogenetic and paleotectonic history of various types of rocks and geochemical exploration of mineral deposits.

This group comprises the following courses:

1. Geochemistry II
2. Thermodynamics
3. Geochemical Exploration
4. Isotope Geochemistry
5. Low Temperature Geochemistry
6. High Temperature Geochemistry

Course Title: **Geochemistry II**
Number of Credits: **3(2+1)**
Course Type: **Elective**
Prerequisite: **-------**

Objective and Learning Outcomes:

This course imparts basic understanding about the geochemistry. This will help the students to understand the geochemistry of different rocks. Define the causes of geochemical diversity.

Course Contents:

Geochemistry of igneous, sedimentary and metamorphic rocks; modal analysis for classification, chemical characterization and identification of minerals; classification and distribution of elements in the earth crust; introduction to analytical geochemistry; causes for geochemical diversity in the igneous rocks; geochemical characteristics of igneous rocks as petrogenetic indicators; processes which modify the composition of primary magmas; geochemical characteristics of different magma series; geothermometry and geobarometry; metasomatic processes and environment.

Labs:

Characterization of igneous rocks on the basis of their (a) modal and (b) chemical composition; calculation of normative composition from the major element chemistry of igneous rocks; the use of major and trace element composition of igneous rocks as a means to determine their paleotectonic

setting; graphical representation of metamorphic mineral paragenesis (ACF and AKF diagrams); protolith of a variety of metamorphic rocks on the basis of their major and trace element geochemistry; the use of mineral chemical data for estimating pressure-temperature conditions of metamorphism.

Recommended Books:

1. Igneous and Metamorphic Petrology by Best, M. G., 1982, W. H. Freeman and Co.
2. Petrogenesis of Metamorphic Rocks by Butcher, K. and Frey, M., 1994. Springer-Verlag.
3. The Interpretation of Igneous Rocks by Cox, K. G., Bell, J. D. and Pankhurst, R. J., 1979. George Allen and Unwin.
4. Petrology of the Igneous Rocks by Hatch, F. H., Wells, A. K. and Wells, M. K., 1975, Murby.
5. Introduction to Geochemistry by Krauskopf, K. B., 1982, McGraw-Hill.
6. Petrology by Nockolds, S. R., Knox, R. W. O'B. and Chinner, G. A., 1978, Cox and Wyman.
7. Using Geochemical Data: Evaluation, Presentation and Interpretation by Robinson, 1993, Longman.
8. Geochemistry by Wedepohl, K.H., 1967, Holt, Rinenhart and Winston.
9. Igneous Petrogenesis by Wilson, M., 1989, Academic Press.
10. Geochemistry, by Brownlow, A. H., 1996, Prentice Hall.
11. Magmatic Sulfide Deposits: Geology, Geochemistry and Exploration by Naldrett, AJ., 2004
12. Geochemistry. Pathways and Processes by Mcsween, H. Y., jr, Richardson, S. M. and Uhle, M. E., 2003, Columbia University Press, New York.
13. Quantitative Geochemistry by Zou, H., 2007

Course Title: **Thermodynamics**
Number of Credits: **3(2+1)**
Course Type: **Elective**
Prerequisite: **-------**

Objectives and Learning Outcomes:

Objective of this course is to familiarize the students to the basic fundamentals and concepts of thermodynamics.

Course Contents:

Introduction and definitions of thermodynamic properties such as system, components, entropy, enthalpy and chemical potential; laws of thermodynamics; Gibbs's energy and equilibrium; Henry's law; osmosis and osmotic pressure; ideal and real solutions; solid solutions; the phase rule with examples of different mineral associations; the ionization of weak electrolytes; chemical equilibrium of gas and general solution reactions; calculation of entropy changes in reversible and irreversible process and determination of P-T conditions.

Labs:

Exercises on the entropy, enthalpy, chemical potential and laws of thermodynamics. Specified assignments /projects.

Recommended Books:

1. Basic Chemical Thermodynamics by Waser, J., latest Ed., the Benjamin Cummings Publishing Company.
2. Equilibrium Thermodynamics in Petrology by Powell. R., 1978, Harper and Raw Publishers.
3. Thermodynamics in Geology by Fraser, D. G.,1979, D.Riedel Publishing Company.
4. Elementary Applied Thermodynamics by Granet. I., 1965, John Wiley and Sons, Inco.
5. Elements of Chemical Thermodynamics by Yeremin, E. H., 1986, Mir Publishers.
6. Geochemistry by Brownlow, A. H., 1996, Prentice Hall.

Course Title: **Geochemical Exploration**
Number of Credits: **3(2+1)**
Course Type: **Elective**
Prerequisite: **-------**

Objectives and Learning Outcomes:

To acquaint students to the basic principles of exploration geochemistry. This course will help students to learn about the various exploration methods of minerals and metals.

Course Contents:

Basic principles for geochemical exploration; geochemical dispersion, geochemical mobility and association of elements; classification of mineral deposits; types of geochemical anomalies in bed-rock, residual and over burden, drainage sediments and natural waters; orientation surveys; role of path finder elements in mineral exploration; geochemical data acquisition methods; decay pattern in stream sediments; statistical interpretation of geochemical data; geochemical methods and selection of sediments in mineral exploration with emphasis on litho stream sediments and soil survey; geochemical evaluation and appraisal of ore deposits, surface geochemical surveys for petroleum exploration.

Labs:

Preparation of histogram, frequency diagrams and geochemical maps.

Recommended Books:

1. Geochemistry in Mineral Exploration by Rose, A. W. Hawkes, H. E.and Webb, J. S., 1981, Academic Press.
2. Exploration Geochemistry by Bradshaw, P. M. D., Clew, D. R. and Walker, J. L., latest Ed., Barringer Research, Rexadale.

3. Geochemical exploration by Joyee, A. S.,1984, Australian Mineral Foundation. Incorporated.
4. Geochemical Exploration by Elliott, I. L. and Fletcher, W. K., latest Ed., Elsevier Scientific Publishing Company.
5. Petroleum Geochemistry and Basin Evaluation by Gerard Demaison and Relof J. Murris, 1984, AAPG Memoir 35.
6. Geochemistry Pathways and Processes by McSween, H. Y., jr, Richardson, S. M. and Uhle, M. E., 2003, Columbia University Press, New York.

Course Title: **Isotope Geochemistry**
Number of Credits: **3(2+1)**
Course Type: **Elective**
Prerequisite: **-------**

Objectives and Learning Outcomes:

To impart the basic understanding of the stable and radiogenic isotope geochemistry to the students. Radiogenic isotopes have very useful contribution in dating techniques.

Course Contents:

Principles of stable isotopes geochemistry; stable isotopes in the atmosphere and hydrosphere; stable isotope variations in various types of rocks and weathering and diagenetic processes; carbon and sulphur-isotope studies of organic matter; fossil fuels and related materials, applications in burial and tectonic evolution. On the other hand radioactive decay introduction, decay mechanisms (beta, positron, electron capture, alpha), fission, rates of radioactive decay, half-life, decay series and secular equilibrium, applications of natural radioactivity and units of radioactivity; an introduction to isotopic dating methods and radiogenic isotope as tracers of geological processes**:** introduction, K-Ar, Ar^{40}-Ar^{39}, Rb-Sr, Sm-Nd, U-Th-Pb (concordia, discordia, zircons, isochrons), extinct radio nuclides, fission tracks, cosmogenic nuclides and C^{14} dating, heterogeneity of the earth's mantle, Nd and Sr isotope compositions of the ocean. Laser probe isotope geochemistry and dating techniques.

Labs:

Data oriented exercises; Discrimination diagrams and interpretation; mass spectrometry of stable isotopes and radioactive nuclides.

Recommended Books:

1. Attendorn H. G. and Bowen R. N. C. (1987) Radioactive and Stable Isotope Geology. Chapman and Hall, London. QE501.4. N9 B69.
2. Barrie A. and Prosser S. J., (1996) Automated analysis of light-element stable isotopes by isotope ratio mass spectrometry. In: Mass Spectrometry of Soils (eds: T. W. Boutton and S. Yamasaki). Marcel Dekker Inc. New York, p 1-46. S593.M4415.

3. Boutton T. W. and Yamasaki S. editors (1996) Mass Spectrometry of Soils. Marcel Dekker Inc, New York. S593.M4415.
4. Coleman D. C. and Fry B. editors (1991) Carbon Isotope Techniques. Academic Press Inc. San Diego. QH 324.3.C37.
5. Faure G., (1986) Principles of Isotope Geology. John Wiley and Sons, New York.
6. Hoefs J., (1997) Stable Isotope Geochemistry. Springer, Berlin. QE515.H67
7. Knowles R. and Blackburn T. H. editors (1993) Nitrogen Isotope Techniques. Academic Press, Inc. San Diego. QH324.35.N1 N57.
8. Lajtha K. and Michener R. H. editors (1994) Stable Isotopes in Ecology and Environmental Science. Blackwell Scientific Publishing. QH541.15.S68 L35.
9. Longstaffe F. J., (1987) Stable isotope studies of diagenetic processes. In: Stable Isotope Geochemistry of Low Temperature Fluids (ed. T. K. Kyser) Mineralogical Association of Canada, Saskatoon, May 1987. Volume 13, p 187-257. QE501.4.N9 S725.
10. Longstaffe F. J. (1989), Stable isotopes as tracers in clastic diagenesis. In: Short Course in Burial Diagenesis (ed. I. E. Hutcheon) Mineralogical Association of Canada, Montreal, May 1989. volume 15, p 201-277.
11. Sharp Z. (2007) Principles of Stable Isotope Geochemistry. Pearson Prentice Hall, New York. Valley J. W. and Cole D. R. editors (2001) Stable Isotope Geochemistry. Mineralogical Society of America, Reviews in Mineralogy and Geochemistry, volume 43. QE501.4.N9 S724.
12. Attendorn H. G. and Bowen R. N. C, 1987, Radioactive and Stable Isotope Geology. Chapman and Hall, London. QE501.4.N9 B69 Boutton T.W. and Yamasaki S. editors, 1996, Mass Spectrometry of Soils. Marcel Dekker Inc, New York. S593.M4415.
13. Dicken A.P., 1995, Radiogenic Isotope Geology. Cambridge University Press. QE501.4.N9 D53 Coleman D. C. and Fry B. editors, 1991, Carbon Isotope Techniques. Academic Press Inc. San Diego. QH 324.3.C37 .
14. Faure G., 1986, Principles of Isotope Geology. John Wiley and Sons, New York. Knowles R. and Blackburn T. H. editors (1993) Nitrogen Isotope Techniques. Academic Press, Inc. San Diego. QH324.35.N1 N57.
15. Lewis C. L. E. and Knell S. J. editors, 2001, The Age of the Earth: From 4004 BC to AD 2002. The Geological Society of London. QE508.A33.
16. Longstaffe F. J., 1987, Stable isotope studies of diagenetic processes. In: Stable Isotope Geochemistry of Low Temperature Fluids (ed. T. K. Kyser) Mineralogical Association of Canada, Saskatoon, 1987. Volume 13, p 187-257. QE501.4.N9 S725.
17. Longstaffe F. J., 1989, Stable isotopes as tracers in clastic diagenesis. In: Short Course in Burial Diagenesis (ed. I. E. Hutcheon) Mineralogical Association of Canada, Montreal, 1989, volume 15, p 201-277.

Course Title: **Low Temperature Geochemistry**
Number of Credits: **3(2+1)**
Course Type: **Elective**
Prerequisite: **-------**

Objectives and Learning Outcomes:

To acquaint the students to the basic principles of Low Temperature Geochemistry and its applications in the contemporary disciplines of geosciences.

Course Contents:

Factors affecting element distribution in sedimentary rocks; chemical weathering and rock decomposition; sequence of mineral alteration; variousstage so weathering; differential loss of elements during weathering environments/agents of chemical weathering; general nature of weathering reactions such as solution and hydration, weathering of carbonates; oxidation, hydrolysis of silicates; the system $CaCo3$-$CaMgCo_3$(sediments and diagenesis; evaporates and their formation; oxidation and reduction in sedimentation of iron, manganese and sulphur; other oxidation and reduction processes; organic material in sediments such as carbon and its compounds, organic matter in black shales; carbon compounds as reducing agents.

Labs:

Calculation of gains and losses during weathering. Characterization of sedimentary rocks on the basis of their chemistry; the use of geochemical data on sedimentary rocks as a guide to source rock composition, weathering condition and environment of deposition.

Recommended Books:

1. Chemical Fundamental of Geology by Gill, R. C., 1985, Harper Collins.
2. Petrology of Sedimentary Rocks by Greensmith J. T., latest Ed., Gerge Allen and Unwin.
3. Introduction to Geochemistry by Kranskopf, 1982 McGraw-Hill.
4. Sedimentary Carbonate Minerals by Lippman, F.,latest Ed., Springer-Verlag.
5. Aqueous Environmental Geochemistry, Langmuir, D., 1997 Prentice Hall
6. Low-Temperature Geochemistry by TuGuangzhi (Ed.), 1996, Brill Academic Publishers.
7. Geochemistry of hydrothermal ore deposits by Barnes, H. L., 1979, John Wiley and Sons.
8. Principles of Geochemistry by Manson, B. ND Moore, C. B., 1982, John Wiley and Sons.
9. Treatise on geochemistry Vol. 5, Surface and ground water, weathering, and soils by Holland, H. D. and Turekian, K. K. (Ex. Eds.); J. I. Drever, J.I (Vol. Ed.), 2004, Elsevier.

10. Treatise on geochemistry Vol. 6, The oceans and marine geochemistry by Holland, H. D. and Turekian, K. K. (Ex. Eds.), Elderfield, H. (Vol. Ed.), 2004, Elsevier.
11. Treatise on geochemistry Vol. 7, Sediments, digenesis, and sedimentary rocks soils by Holland, H. D. and Turekian, K. K. (Ex.Eds.), Mackenzie, F. T. (Vol. Ed.), 2004, Elsevier.
12. Treatise on geochemistry Vol. 8, Biogeochemistry by Holland, H. D. and Turekian, K. K., (Ex. Eds.), Schlesinger, W. H., (Vol. Ed.), 2004-2005, Elsevier.
13. Treatise on geochemistry Vol. 9, Environmental geochemistry (Ex. Eds.), Lollar, B. S., (Vol. Ed.), 2004, Elsevier.

Course Title: **High Temperature Geochemistry**
Number of Credits: **3(2+1)**
Course Type: **Elective**
Prerequisite: **-------**

Objectives and Learning Outcomes:

To provide a basic understanding about the High Temperature Geochemistry and its applications in the fields of geosciences.

Course Contents:

Geochemical characteristics of igneous rocks as petrogenetic indicator; binary variation diagrams and fraction at ion indices. triangular variation diagrams; geochemical characteristics of primary magmas; processes which modify the composition of primary magmas; convection and mixing in magma chambers, fractional crystallization, crystal contamination, zone refining, liquid immiscibility, gaseous transfer processes; geochemical characteristics of different magma series.

Distribution of elements in metamorphic rocks; behavior of trace elements during the metamorphism of pelitic rocks; geochemistry of granulite facies rocks and problems of their origin; graphical presentation of metamorphic mineral paragenesis (ACF and AKF diagrams). metasomatism, its types and transfer of material.

Labs:

Characterization of igneous rocks on the basis of their modal and chemical composition. Calculation of normative composition from the major element chemistry of igneous rocks. The use of major and trace element composition of igneous rocks as a means to determine their paleotectonic setting. The use of mineral chemical data for estimating pressure temperature conditions of metamorphism (data oriented exercises).

Recommended Books:

1. Principles of Isotope Geology by Faure, G., 1986, John Wiley and Sons.
2. Geochemistry in mineral exploration by Rose, A. W., Hawkes, H. E. and Webb, J.S., 1981, Academic Press.
3. Igneous petrogenesis by Wilson M., 1989, Unwin Hyman.

4. The interpretation of igneous rocks by Cox K. G., Bell J. D. and Pankhurst, R. J.,1987, George Allen and Unwing.
5. Chemical Fundamentals of Geology by Gill R. C., 1985, Hper Collins.
6. Archean Geochemistry by Kroner, A., Hanson, G. N. and Goodwib., 1984, Springer-Verlog.
7. Archean Geochemistry by Kroner, A., Hanson, G. N. Goodwib.,1984, Springer-Verlog.
8. Treatise on geochemistry. Vol. 1, Meteorites, comets, and planets by Holland, H. D. and Turekian, K. K. (Eds.), Davis, A. M. (Vol. Ed.), 2004, Elsevier.
9. Treatise on geochemistry Vol. 2 The mantle and core by Holland, H. D. and Turekian, K. K. (Ex. Eds.), volume editor. Carlson, R. W. (Vol. Ed.), 2004, Elsevier.
10. Treatise on geochemistry Vol. 3 The crust by Holland, H. D. and Turekian, K. K. (Ex.Eds.), Rudnick, R. L. (Vol. Ed.), 2004, Elsevier.

GROUP-II: PALEONTOLOGY AND STRATIGRAPHY

Objectives:

Advance level courses have been designed in this group of specialization. These courses will enable the students to fully understand (1) the morphology of various types of vertebrate and invertebrate fossils, (2) the microfossils and micro-organisms and their role in sedimentary depositional system, (3) the deposition of various sedimentary sequences during geologic time and (4) the role of palynology and paleobotany in petroleum industry. After completing these courses the students will be able to carry out their independent research on establishing the stratigraphy of an area.

This group comprises the following courses:

1. Stratigraphy II
2. Micropaleontology II
3. Invertebrate Paleontolgoy
4. Vertebrate Paleontology
5. Palynology and Paleobotany

Course Title: **Stratigraphy II**
Number of Credits: **3(2+1)**
Course Type: **Elective**
Prerequisite: **-------**

Course Contents:

Lithostratigraphy, facies analysis; evolutionary concepts in biostratigraphy: diachronism evolution and biochronology; Tectonostratigraphy: interpretation of complex deformed terrains; principles and practices in event stratigraphy, cyclostratigraphy, seismic and sequence stratigraphy; stratigraphic applications of isotope geochemistry; global standard stratigraphy: chronostratigraphy; Interpretation of stratigraphic record: facies analysis, sea

level changes, paleoenvironment and paleoclimates, Use of satellite imageries for stratigraphic interpretation.

Labs:
Specified Assignments/Projects.

Recommended Books:

1. International Stratigraphic, Guide: A Guide to Stratigraphic Classification. Terminology and Procedures by Salvador A., 1994, the International Union of Geological Sciences, Trondheim and Geological Society of America, Inc.
2. Remote Sensing Digital Image Analysis, An Introduction by Richards J. A., 1983, Springer-Verlag.
3. Principles of Stratigraphical Analysis by Blatt, H., Berry, W. B. N. and Brande, S., 1991, Blackwell.
4. The Geological Interpretation of Well Logs by Rider, M. H., 1986, Blackie.
5. Seismic Stratigraphy Hand Book of Geophysical Exploration Seismic Exploration by Hardage, B. A., 1987, Vol. 9, Geophysical Press Ltd.
6. Sequence Stratigraphy, Sea Level-change, and Significance for Deep Sea by Haq, B. U., 1991, In Macdonald, D. I. M. (eds.) Sedimentation Tectonics and Ecstasy, Sea Level Changes at Active Margins. Special Publication of International Association of Sedimentologists.
7. Facies Models: Response to Sea Level Change by Walker, R. G. and James, N.P., (eds.) 1992, Geological Association of Canada.

Course Title: **Micropaleontology II**
Number of Credits: **3(2+1)**
Course Type: **Elective**
Prerequisite: **-------**

Course Contents:

General techniques of collection and preparation of samples; Morphological, taxonomic, stratigraphical and paleoecological studies of Foraminifera, Ostracoda, Chitinozoa, Micropalankton, Pollen, Spores and Miscellaneous group. Study of Nano fossils. Importance and applications of micropaleontology

Labs:
Sampling and laboratory techniques; microscopic examination and identification of microfossils from Pakistan; preparation of thin sections of larger foraminifera and their identification.

Recommended Books:

1. Aspects of Micropaleontology by Banner, F. T. and Jord, A. R., 1982, Allen and Unwin.
2. Elements of Micropaleontology by Bignot, G., 1985, Graham and Trotman.

3. Stratigraphy of Fossils Foraminifera by J enkins, D. G. and Murray J. W., 1981, Ellis Horwood.
4. Introduction to Microfossils by Jones, D. J., 1980, Hafner Pub. Co.
5. Introduction to Marine Paleontology by Haq and Boersma, 1980, Elsevier.
6. Plankton Stratigraphy by Bolli, H. M. and Saunders, 1986, Cambridge Press.

Course Title: **Invertebrate Paleontology**
Number of Credits: **3(2+1)**
Course Type: **Elective**
Prerequisite: **-------**

Course Contents:

Organic evolution and fossil record through ages; detail classification, evolution and geographical distribution of important invertebrates; Phyla like Brachiopoda, Molluska, coelenterata, Orthropoda and Echinodermeta etc.

Labs:

Description and identification of invertebrate fossils up to species level.

Recommended Books:

1. Invertebrate and Evaluation by Clarkson, E. N. K., 1986, Allen and Unwin.
2. Invertebrate Fossils by Moore, R. C., Lalicker, C. G. and Fischer, A. G., 1952, McGraw-Hill.
3. Principles of Paleontology by Raup, D. M. and Stanely, S. M., 1985, W. H. Freeman and Co.
4. Palaeontology by Tucker, V. C. T. and Noeld, E. W., 1985, Pergamon Press.
5. Paleobiology of Invertebrate by Tasch, P., 1980, John Wiley and Sons.
6. A Trip Through Time: Principles of Historical Geology by Cooper J. D., 1990, Merril. Columbus.

Course Title: **Vertebrate Palaeontology**
Number of Credits: **3(2+1)**
Course Type: **Elective**
Prerequisite: **-------**

Course Contents:

Vertebrate life through ages; study of major groups of vertebrate fossils. Evolution of some well-known selected Fishes, Amphibians, Reptiles, Dinosaurs and Mammals. Study of vertebrate fauna of Pakistan.

Labs:

Description and identification of vertebrate fossils.

Recommended Books:

1. Vertebrate Paleozoology by Olson, C. V., latest Ed., Wiley and Interscience.
2. Vertebrate Paleontology by Romer, A. S., 1974, University of Chichago Press.
3. Geology of India by Wadia, D. N., latest Ed., Tata McGraw-Hill.
4. Dinosaur Encyclopedia by Don Lessem and Donald F. Glut, 1993, Random House.
5. A Geologic Time Scale by Felix, M., James, G. and Smith A., 2004, Cambridge University Press.

Course Title: **Palynology and Paleobotany**
Number of Credits: **3(2+1)**
Course Type: **Elective**
Prerequisite: **-------**

Course Contents:

Introduction, methods of study, techniques of collection and preparation of palynomorphs; types and functions of spores; Pollen and spores morphology, development of homospores; Suprageneric classification of triletspores; distribution of palynomorphs during various geological periods with special reference to Pakistan; scope and application of palynology in petroleum industry; study of nano fossils. Introduction, aims and objectives of paleobotany. Taxonomy of fossils and study of various groups of fossil plants. Paleobotany as fossil fuels.

Labs:

Identification of Gondwanic and other flora from Pakistan.

Recommended Books:

1. Microfossils by Braiser, M. D., 1980, Allen and Unwin.
2. Introduction to Marine Paleontology by Haque and Boersman, 1980, Elsevier.
3. Paleobotany by Stewart, W. N., 1983, Cambridge Press.
4. Principles of Paleobotany by William, C. D., Latest Ed, Ronall Press.

GROUP-III: ECONOMIC GEOLOGY

Objectives:

Advance level courses have been designed in this group of specialization. These courses will enable the students to fully understand (1) the processes of formation of various types of magmatic, hydrothermal, sedimentary, metamorphic and metasomatic ore deposits, (2) the ore reserves calculation and their economic evaluation and extraction, (3) the coalification processes and coal utilization and evaluation, (4) the techniques of mineral exploration, (5) the plate tectonics and its role in the formation of metallic mineral deposits and (6) the identification and evaluation of gems and gemstones. After completing these courses the students will be able to carry out their independent research on the characterization and genesis of various types of mineral deposits and their economic evaluation.

This group comprises the following courses:

1. Mineral Prospecting and Exploration
2. Coal Geology
3. Mining Geology
4. Metalogeny and Plate Tectonics
5. Gemology
6. Mineral Economics
7. Industrial Mineralogy
8. Instrumental Techniques
9. Clay Mineralogy
10. Exploration and Exploitation of Coal
11. Environment and Clean Coal Technology
12. Mineral Processing

Course Title: **Mineral Prospecting and Exploration**
Number of Credits: **3(2+1)**
Course Type: **Elective**
Prerequisite: **-------**

Objective and Learning Outcome:

To introduce the students to reserves and grades calculation to evaluate the ore deposits. At the end the students should be able to understand different prospecting techniques. Differentiate between prospecting and exploration. Define different exploration techniques.

Course Contents:

Mineral Prospecting, Mineral prospecting techniques, Importance of prospecting claims to mineral discovery and exploration: Field exploration techniques; mineral potential of Pakistan; reserve identification and estimation; grade analysis; risk assessment and economic evaluation; geochemical exploration: principles of geochemical dispersion, choice of media for sampling, field methods and sampling theory, analytical methods and quality

control, and data interpretation, geochemical and metallogenic provinces; geochemical survey of rock, soil, water and stream sediments for mineral exploration.

Geophysical exploration: principal geophysical techniques, including magnetic, electromagnetic, electrical, radiometric, gravity and seismic methods as applied to mineral exploration.

Labs:

Case studies and exercises on geochemical and geophysical data interpretation.

Recommended Books

1. Economic Evaluation in Exploration, by Friedrich, W. W., 1986, Springer- Verlag.
2. Statistics and Data Analysis in Geology, by Davis, J. C., 1986, John Willey and Sons.
3. Geological Problem Solving with Lotus 123 for Exploration and Mining.
4. Geology, by George, S. Koch, G. S. Jr., 1990, Pergamon Press.
5. Geochemistry in Mineral Exploration by Rose, A. W., Hawkes, H. E. and Webb, J. S., 1983, Whitstable Litho Ltd.
6. Geochemical Exploration by Joyce, A. S., 1984, Australian Mineral Foundation.
7. Mineral Prospecting Manual by Chaussier, J. B. and Morer, J., 1987, North Oxford Academic.
8. Exploration and Mining Geology byPeters, W. C., 1978, John Wiley and Sons.
9. Techniques in Mineral Exploration by Reedman, J. H., 1979, Applied Science Publishers.
10. Exploration Methods: Course Notes by Claverino, J., Dawney, R. and Stephenson, P., 1994, Australian International Assistance Bureau.
11. Evaluation of Mineral Reserves by Journal, A. G., 2004, Oxford University Press.
12. Introduction to Mineral Exploration, 2nd edition, by Moon, C. J., Whateley, M. K. G. and Evans, A. M. (Editors). 2006, Blackwell Publishing, Oxford.

Course Title: **Coal Geology**
Number of Credits: **3(2+1)**
Course Type: **Elective**
Prerequisite: **-------**

Objectives and Learning Outcomes:

Currently Pakistan is facing severe energy crises, so the aim of this subject is to know about the indigenous coal reserves and geology of coal including the formation, composition exploration, exploitation and utilization in various industries

Course Contents:

Definition, composition; classification and origin of coal; litho types and coal minerals; chemical and petrographical analysis; application of coal petrography; depositional environments of coal and coal bearing strata, coalification process, types of coal basins and their tectonic setting, concepts of cyclicde position in coal basin, origin of splits and partings in coalseams; comparison between modern and ancient coal forming environments; structural problems relevant to exploration and mining; coal utilization and resource evaluation; methods of coal exploration: geological, geophysical and drilling; coal bearing sequences of Pakistan; coal mining and its environmental impacts.

Labs:

Petrography of coal and associated rocks; preparation of coal pellets, petrographic methods of coal analysis; specified assignments/projects. Reserve estimation and quality assessment exercises based on published data.

Recommended Books:

1. Significance of Coal Resources of Pakistan by Kazmi, A. H. and Raza, H. A., 1990, Geological Survey of Pakistan.
2. Sedimentology of Coal and Coal Bearing Sequences by Rehmani, R. A. and Flores, R. M.,1984, International Association of Sedimentologists, Blackwell.
3. Coal Geology and Coal Technology by Ward, C. R., 1984, Blackwell.
4. Terrigenous Clastic Depositional Systems, Application to Petroleum, Coaland Uranium Exploration by Galloway, W. E. and Hobday, D. K., 1983, Springer-Verlag.
5. Principles and Applications of Coal Petrology SEPM Short Course No.8 by Crelling, J. C. and Dutcher, R. R., 1980, Society of Economic Paleontologists and Mineralogists Indian University at Bloomington.
6. Stach's Textbook of Coal Petrology by Stach, E., et al., 1982, Gebruder Borntraeger.
7. International Handbook of Coal Petrology by International Committee for Coal Petrology, 1985, University of Newcastle upon Tyne.
8. Coal: Typology, Chemistry, Physics and Constitution by Van Krevelen, D. W., 1981, Elsevier.
9. Coal Combustion and Gasification by Smoot, L. D. and Smith P. J.,1985, Plenum Press.

Course Title: **Mining Geology**
Number of Credits: **3(2+1)**
Course Type: **Elective**
Prerequisite: **-------**

Objectives and Learning Outcomes:

This subject is important for geologists to get familiar with various methods of mining. Moreover, keeping in view the mining waste and its impacts on

environment should be evaluated. Another objective and outcome will be the awareness of safety measures because normally the conventional and out dated methods are being used and as a result not only the mineral wealth is being destroyed but many casualties and mine hazards also occur throughout the world.

Course Contents:

Terminology related to mining; mining survey techniques; surface and subsurface mining methods; opening of mines; structural controls in mining; correlation of surface and subsurface data; spatial relationship of seams; surface and underground mapping methods; calculation of ore grade and tonnage; gases in mines and spontaneous combustion; rock pressure and support; collapses in mines and their safety/remedial measures; mine-refuse disposal management; ore grade control in mining; impact of mining on environment and their remedies and rehabilitation; introduction to mining explosives; coring, core logging and data interpretation; the effects of gasses and radioactive isotopes on miners health. Miner's diseases, their monitoring and remedial measures.

Labs:

Bore-hole data interpretation. Ore grade and tonnage/reserve estimation.

Recommended Books:

1. Mining Geology by Mckinstry, H. B., 1948, Prentice-Hall.
2. Exploration and Mining Geology by Peters, W. E., 1978, John Wiley and Sons.
3. Techniques in Mineral Exploration by Reedman, J. H., 1979, ASP.

Course Title: **Metallogeny and Plate Tectonics**
Number of Credits: **3(2+1)**
Course Type: **Elective**
Prerequisite: **-------**

Objectives and Learning Outcomes:

For an economic geologist, it is important to know about the relationship of economic minerals and plate tectonics. It is now a known fact that the ore minerals are specific to certain tectonic environments. So far, it is essential that someone should know that rich kind of ore minerals or economic minerals could be present in a geological entity where he/she is working. Moreover, the students will have precise information about the occurrence of various economic minerals.

Course Contents:

Introduction to ore deposits; ore forming processes, plate tectonics, geology and ore deposits; ore deposits models; metal deposits of oceanic–type crust. Intercontinental, intracontinental hotspots and an organic magmatic metallic deposit; deposits of the early and advanced stage rifting; deposits of fore arc,

back arc, passive and active margin and other deposits; metal deposits in relation to collisional events; ophiolite deposits; tectonic related mineralization in Pakistan. Metallogenic deposits of Pakistan.

Labs:

Specified assignments/projects related to Metalogenic provinces of Pakistan

Recommended Books:

1. Metal Deposits in Relation to Plate Tectonics by Sawkins, F. J., 1990, Springer-Verlag.
2. Mineral Deposits and Global Tectonic Setting by Mitchell, A. H. G. and Garson, M. S., 1981, Academic Press.
3. Metallogenic Evolution of a Collisional Mountain Belt in Pakistan: A Preliminary Analysis by Sillitoe, R. H., 1978, Jour. Geol. Soc. London, vol.135, pp. 377-387.
4. Metallogeny and Plate Tectonic by Strong, D. F. (ed.), 1976, Geol. Soc. Canada Special Publication 14.
5. An Introduction to Ore Geology by Anthony Evans, M., 1987, Blackwell.
6. Ore Deposit Geology, by Edward, R. and Atkinsons, K., 1986, Chapman and Hall.
7. The Earth: A Very Short Introduction by Martin Redfern, 2003, Oxford University Press.
8. Continents and Supercontinents by Rogers, J. J. W., 2004, Oxford University Press.
9. Tectonic Boundary Conditions for Climate Reconstructions by Crowly, T. J., 1998, Oxford University Press.
10. Plate Tectonics and Hydrocarbon Accumulation by Dickinson, W. R. and Yarborough, H., 1982, AAPG Education Course Note Series.

Course Title: **Gemology**
Number of Credits: **3(2+1)**
Course Type: **Elective**
Prerequisite: **-------**

Objectives and Learning Outcomes:

The Curriculum of gemology is designed to provide students all required knowledge about gemstones, their occurrences, their physical and chemical properties and the internationally employed scientific methods for the identification and grading of Gemstones. After completion of the course of Gemology one can work anywhere in the world in the gem and jewellery sector or can start his or her own gem business.

Course Contents:

Physical and optical properties related to gemstones, color and causes of colors in gemstones, special optical properties, chatoyancy, asterism, luminescence, play of colors, labradorescence etc. construction and working of gemological instruments, polar scope, refractrometer, dichroscope,

spectroscope, study of emission and absorption spectroscope. Classification of gemstones, detailed study of all gemstone families; Diamond, Corundum, Beryl, Topaz, Tourmaline, Spinel, Quartz and other gem varities.
Synthetic gemstones, history of synthetics, methods of manufacturing, methods of differentiation between natural and synthetic gemstones, imitation gemstones like glass, plastic etc. Synthetic diamonds and their methods of manufacturing and methods of identification.

Construction and working of gemological microscope, study of different various microscopic natural and synthetic inclusions, their classification and identification of natural versus synthetic on the basis of microscopic inclusion.
Gemstone treatment and their identification, methods of gemstone enhancements, dyeing and irradiation, heat treatment principals and practices, various types of diffusion and other types of enhancement.

Processes of gem cutting, styles of gem cutting, grading and evaluation of gemstones, world gem deposits and gem deposits of Pakistan, introduction to gemstone mining methods.

Lab:

Use of various instruments for gemstone identification, identification of rough and cut gemstones by physical and optical properties, identification of natural, synthetic, artificial and treated gemstones.

Recommended Books:

1. Decorative Stones: The complete source book by Price, M. T., 2007, Thames and Hudson.
2. Gem Identification Made Easy by Matlins, A. L., 1989, Gemstone Press.
3. Gemology 3rd edition by Read, P. G., 2005, Elsevier.
4. Gems 6th edition by O'Donoghue, M., 2006, Butterworth Heinemann.
5. Gems and Precious stones by Lyman, K., 2005, A Fireside Book.
6. Gems: Their source, Description and Identification 4th edition. by Webster, Are, 1983, Butterworth Heinemann.
7. Gemstones, Herbent, G. F., 1977, Chapman and Hall.
8. Gemstones of the World by Schumann, W., 1997, Sterling Publishing Co.
9. Handbook of Gem Materials 5th edition. by Kraus, E. H., 1947, McGraw-Hill.
10. Identification of Gemstones by O'Donoghue, M., 2003, Butterworth Heinemann.
11. Philips Guide to Gems by Oldershaw, C., 2006, Octopus Publishing.
12. Speaking of Healing Through Gems by Saha, N. N., 1995, Sterling Publishers.
13. Synthetic, limitation and Treated Gemstones by O'Donoghue, M.,1997, Butterworth Heinemann.
14. The Spectroscope and Gemology by Andarson, B., 1998, Gemstone Press.

Course Title: **Mineral Economics**
Number of Credits: **3(2+1)**
Course Type: **Elective**
Prerequisite: **-------**

Objectives and Learning Outcomes:

The main objectives of this course are to explore and exploit mineral resources on economic basis. The outcome of this course includes making of feasibility reports, evaluating mineral/metal resources through calculating resource grades, exploitation cost and market value etc.

Course Contents:

Financial evaluation of ore reserves/ore resources; mineral prospecting and exploration cost; calculation/verification of ore grade and tonnage; capital cost, mine development cost and operative cost; basis of revenue calculation; taxation system; risk analysis and management; development decisions based on economic evaluation, financial requirements, cash flow and internal rate of return (IRR), payback period; mineral policy; mining rules and regulations; project financing. Minerals world trade/marketing; mineral exchange working; introduction to PC-I AND PC-II (Planning Commission, Govt. of Pakistan).

Labs:

Exercises to develop economic models for mineral deposit mining and assignments/projects on published data.

Recommended Books:

1. International Mineral Economics by Goecht, W., Zant, II and Eggert, R. C., 1988, A Guide to Mineral Resources Development by Woaks, M. and Carman, J. S.
2. Deposit Evaluation: a Practical Approach by Annels, A. E., 1991, Chapman and Hall.
3. R. K. Senha, Industrial Minerals, Aa Balkema, 1983

Course Title: **Industrial Mineralogy**
Number of Credits: **3(2+1)**
Course Type: **Elective**
Prerequisite: **-------**

Objectives and Learning Outcomes:

The use of industrial rocks/minerals has increased manifold in recent years. This course is designed to introduce students to common rocks/minerals being utilized in the industries. The outcomes of this course are to understand physical and chemical properties of industrial rocks and minerals, kinematics of the mineral formation, beneficiation processes of various industrial minerals and rocks.

Course Contents:

Physical and chemical properties of minerals; relationship between the structure, chemistry and properties of various rocks and minerals. Mechanisms of mineral nucleation and crystal growth; importance of kinetics in mineral formation. Exploration and Exploitation techniques; sands and gravels, hard rock aggregates, dimension stone, slate, limestone and dolomite, magnesite, clays (common clay/shale, kaolin, bentonite, and fuller's earth), silica sand, dunite and serpentinite, feldspars, nepheline syenite; natural abrasive raw materials, gypsum, anhydrite, chromite, barite and gemstones including diamond and their industrial uses. Mineralogy and chemistry of raw materials for cement, glass, agriculture, chemical and refractories; industrial minerals and their environmental impacts; risk assessment and economic evaluation. Economic potential of industrial rocks and minerals in Pakistan.

Labs:

Interpretation of geological maps in terms of their industrial rock and mineral potential; use of resource map of various types to suggest potential areas of worth, reserve estimation; risk analysis (exercises based on supplied data).

Recommended Books:

1. Applied Mineralogy by Jones, M. P., 1987, Graham and Trotman.
2. X-ray diffraction and the identification and analysis of clay mineral by MOORE, D. M. and Reynolds, Jr., R. C., 1989, Oxford University Press.
3. Minerals and rocks for industry by Ahmad, Z. and Siddiqi, R. A., 1992, Geological survey of Pakistan, Quetta.
4. Geology of the Industrial Rocks and Minerals by BATES, R. L., 1960. Dover
5. Mineral Resources and Their Management by Lunden, J. B.,1985,
6. Refractories for Iron and Steel making by Chesters, J. H., 1974, the Metals Society.
7. Industrial Geology by Knill, J. L., 1978, Oxford University Press.
8. Mineral Processing Technology by Wills, B. A., 1988, Pergamon Press.

Course Title: **Instrumental Techniques**
Number of Credits: **3(2+1)**
Course Type: **Elective**
Prerequisite: **-------**

Objectives and Learning Outcomes:

This course provides introduction to advanced analytical techniques for the analysis of rocks and minerals. At the end of course, students will be able to analyze various rocks and minerals after learning the operating principles of these instruments.

Course Contents:

Theory of x-ray diffraction (XRD) for mineral identification; X-ray fluorescence (XRF), atomic absorption spectrophotometry for elemental

analysis; DTA for differential thermal analysis and TG (thermogravimetric) analyzer. Methods of sample preparation; software programs.

Labs:
Analysis of rocks and minerals by using the above mentioned instruments.

Recommended Books:

1. Atomic Absorption Spectroscopy by Welz, B., 1976, Verlag, Chemie. Weinheim.
2. Differential Thermal Analysis by McKenzie, R. C., 1972, Academic Press.
3. Introduction to Mass Spectrometry and its Applications by Kiser, R. W., 1965, Prentice-Hall.
4. Elemental Analysis in Geochemistry by Volborth, A., latest edition., Elsevier Publishing Company.
5. Introduction to X-ray spectrometry by Williams, K. L.,1987, George Allen and Unwinn.
6. Laboratory Handbook of Petrographic Techniques by Hutchison, C. S., 1974, John Willey and Sons.

Course Title: **Clay Mineralogy**
Number of Credits: **3(2+1)**
Course Type: **Elective**
Prerequisite: **-------**

Objectives and Learning Outcomes:
Clay minerals make an important resource in making medicines, pottery, drilling fluids etc. The main objective of this course is to get the students know the importance of clay minerals and their uses in various industries. The students would learn about different clays minerals and their parent rocks, mineralogical and chemical composition and distribution in Pakistan.

Course Contents:
Introduction, structure and classification of clay minerals; introduction to analytical methods for clay separation and their identification; origin and diagenesis; clay minerals during diagenesis and low grade metamorphism; paleothermometery ; geological significance in petroleum industry; depositional environments; clay minerals and sedimentation; significance of clay minerals in soils, drilling fluids and reservoirs; industrial applications. Economic clay deposits of Pakistan

Labs:
Identification of clay minerals by XRD and XRF techniques; data oriented exercises.

Recommended Books:

1. Clay minerals by Grim R. E., 1986, McGraw-Hill, New York.

2. X-RayIdentification and crystal structure of clay minerals by Brown G., latest edition, Min. Soc. London.
3. Crystal Structure of Clay Minerals and their X-Ray Identification by Brindley and Brown, 1980, Min Soc. London.
4. X-Ray Diffraction and the Identification and Analysis of Clay Minerals by Moore and Renolds, 1989.

Course Title: **Exploration and Exploitation of Coal**
Number of Credits: **3(2+1)**
Course Type: **Elective**
Prerequisite: **-------**

Objectives and Learning Outcomes:

One of the biggest coal reserves are located in Thar dessert of Pakistan. The objective of this course to produce graduates with sufficient knowledge of coal, its types and its exploration and extractions methodologies. The students would be able to map coal deposits and determine the grades in the field and laboratory, to calculate reserves and learn about possible mining techniques.

Course Contents:

Field techniques; outcrop mapping, remote sensing; open pit and underground mining methods; open hole drilling, core drilling, portable drilling, core and open whole logging; in situ and non in situ coal sampling methods and analysis; coal exploitation and data collection; geotechnical properties, coal resources and coal reserves; hydrological characteristics of coal and coal bearing sequences; collection and handling of hydrogeological data; surface and subsurface waters; dewatering of open pit mines; dewatering of underground mines, water quality and groundwater rebound; physical properties of coal bearing sequences, surface geophysical methods: density, seismic velocity, seismic reflection coefficients; electrical methods, seismic survey, gravity, electrical and radiometric methods; types of geophysical borehole logging.

Labs:

Outcrop mapping, field sampling, observation of drilling techniques; application of geophysical techniques in coalfield; study of geophysical logs.

Recommended Books:

1. Drilling Practices Manual by P. L., 1986. Pen Well.
2. Introduction to Geophysical Exploration by Kearey, P. Brooks, M. and Hill, I., 2002 3rd Ed. Blackwell Scientific Publications, London.
3. Geophysics in Mineral Exploration: Fundamentals and Case Histories in Geology. by Lowe, C.,
4. Thomas, M. D. and Morris, W. A (Eds), 1999. Association of Canadian Geophysics, short course Vol. 14, Sundbury.

Course Title: **Environment and Clean Coal Technology**
Number of Credits: **3(2+1)**
Course Type: **Elective**
Prerequisite: **-------**

Objectives and Learning Outcomes:

Although coal is a cheap energy resource as compared to oil and gas, however, its exploitation has long lasting effects on the environment. This subject would introduce the students to clean coal technologies. They would learn about different necessary measures to be taken in coal exploitation.

Course Contents:

Coal mining and contamination of water; spoil dumping; dust suspension and subsidence; coal miner's diseases; international and national environmental regulations; clean coal technology: coal as alternate source of energy; gas in coal, coal bed methane; underground coal gasification technology; coal liquefaction technology; coal as an oil-prone source rock.

Labs:

Identification of cleats and pores in coal with Scanning Electronic Microscope (SEM), Identification of minerals with XRD.

Recommended Books:

1. Underground Coal gasification by Green, M. B. 1993. John Wiley and Sons, Inc
2. Coal bed Methane and World Geology by Gayer and I. Harris (eds) Geological Society Special Publication No. 109. Illinois State Geological Survey.
3. Coal liquefication pioneer and plant study. ETSU/DTI Report No. COAL RO 4o.
4. Treatment of mine drainage, World Coal 7 AAPG Studies in Geology Series. Chapman and Hall.

Course Title: **Mineral Processing**
Number of Credits: **3(2+1)**
Course Type: **Elective**
Prerequisite: **-------**

Objectives and Learning Outcomes:

To acquaint the students with the principles and practical knowledge of ores, and the physical concentration processes in order to obtain value-added mineral products.

Course Outlines:

Introduction: Economic justification and scope of mineral processing for upgrading ores and minerals, types of flow sheets, liberation and concentration. Comminution: Definition and objectives of crushing and

grinding. Conventional and non-conventional methods of crushing and grinding. Laboratory and industrial crushers and grinding mills, grinding circuits. Use of micro waves in crushing.

Laboratory Sizing and Industrial Screening:

Laboratory sizing, wet and dry sieve analysis, size distribution, sub-sieve techniques, movement of solids in fluids, Stokes and Rittinger laws, industrial screening, performance of screens, types of screens, screening surfaces.

Classification:

Principles of classification, free and hindered settling ratios, hydraulic and mechanical classifiers. Principles of cyclones and hydrocyclones. **Gravity**

Concentration:

Principles of gravity concentration, gravity separators, jigging, Humphrey's spirals, flowing film concentration, tabling, concentration ratio, grade recovery relationship; heavy fluid and heavy media separation (H.M.S). **Flotation:** Flotation, chemical and physical aspects, process, uses with examples. Flotation reagents, absorption mechanism, types and applications of reagents, and differential flotation of complex ores. **Flocculation and dispersion:** Introduction to electrical double layer theory, flocculation, coagulation and dispersion phenomena, mechanism and application

Magnetic and Electrostatic Separation:

Magnetic, electrostatic and electro-dynamic separation: principles, machines and applications

Labs:

1. Sampling on a given lot of ore using Coning and Quartering and mechanical samplers.
2. Use of jaw crushers for crushing limestone and gypsum.
3. Use of Rolls for closed-sized crushing for iron ore and chromite.
4. Use of ball-mill and rod-mill for grinding of a given ore sample 78.
5. Synthesis of xanthate collectors.
6. Flotation of a given ore sample.
7. Flotation of a coal sample from Pakistan.
8. Flocculation of a sample using synthetic/polymer flocculants.

Recommended Text Books:

1. B. A. Wills, Mineral Processing Technology, 7th Ed., 2006.
2. S. K. Jain, A. A. Balkema, Ore Processing, 1987.

Recommended Reference Books:

1. Spotis woods and Kelly, Mineral Processing
2. SME Mineral Processing Handbook, Society of Mining Engr. of amimmpe Inc. New York, 1986

4. Crozier, Flotation Pergamon, 1992
5. Flotation: A. M. Gaudin memorial volume, Volume 1, American Institute of Mining, Metallurgical, and Petroleum Engineers, 1976, Digitized in 2007.

GROUP-IV: ENGINEERING GEOLOGY AND GEOTECHNICAL ENGINEERING

Objectives:

Advanced level courses have been designed in this group of specialization. These courses will enable the students to fully understand (1) the rock and soil mechanics and their role in construction industry, (2) the earthquake related seismicity and intensity, (3) the geological and geophysical surveys, (4) the infrastructure development and (5) the techniques for evaluation of building materials. After completing these courses the students will be able to carry out their independent study on the site development for construction.

This group comprises the following courses:

1. Engineering Geology II
2. Rock Mechanics
3. Soil Mechanics
4. Introduction to Geotechnical Engineering
5. Excavation and Tunneling
6. Foundation Engineering
7. Dam Engineering
8. Landslide Hazards and Risk assessment
9. Earthquake Engineering and Risk assessment

Course Title: **Engineering Geology II**
Number of Credits: **3(2+1)**
Course Type: **Elective**
Prerequisite: **-------**

Course Contents:

Rock and soil mechanics and its application in civil engineering; study of geological factors in relation to the construction of buildings and foundations, roads, highways, excavation and tunneling, mine openings, dams and bridges; construction materials; slope stability analysis, hazard assessment, mass movement, their causes and prevention; application of geophysical methods for site investigation; construction in earthquake zone; dams and their kinds, geological investigations for selecting a site for a dam; landslides, classification, geometry, causes and preventive methods; ground water and character of ground water; case histories of important (small and mega) engineering projects in Pakistan.

Labs:

Specified assignments/projects.

Recommended Books:

1. Principles of Engineering Geology by Attewell, P. B. and Farmer, I. W., latest Ed., John Willey and Sons.
2. Engineering Geology by Beavis, F. C., 1985, Blackwell Scientific Publications.
3. Principles of Engineering Geology by Johnson, R. B. and Degraff, J. V., latest edition, John Willey and Sons.
4. Fundamentals of Engineering Geology by Bell, F. A. G., 1983, Butter Worth.
5. Engineering Geology by Goodman, R. E., 1993, John Wiley and Sons.
6. Foundations of Engineering Geology by Waltham, T, 2002.
7. A Geology for Engineers (7th edition) By F. G. H Blyth PhD 1984.

Course Title: **Rock Mechanics**
Credit Hours: **3(2+1)**
Course Type: **Elective**
Prerequisite: **Nil**

Objectives and Learning Outcomes:

Upon successful completion of the course, the student will be able to explain the concepts of stress, strain in 2D and 3D and theory of elasticity, to illustrate mechanical properties of rocks including index and engineering properties, to explain in situ stress measurement techniques and to use rock failure theories

Course Contents:

Fabric and mechanical nature of rocks; determination of rock quality for engineering purposes; stress strain behaviors of different rocks; rock mass strength. theories of failure; types of fracture; rock deformation in compression; factors controlling mechanical behaviors of rocks; excavation methods in rocks; distribution of stresses around underground excavations; use of photo elasticity in rock mechanics. Measurement of stresses in situ; wave propagation in rocks; dynamic models.

Labs:

Specified assignments/projects on uniaxial and triaxial strength.

Recommended Books:

1. Rock Mechanics for Underground Mining by Brady, B. H. G. and Brown, E.T., 1985, Allen and Unwin.
2. Engineering Geology by Beavis, F. C., 1985, Blackwell.
3. Structural and Geotechnical Mechanics by Newwark, N. M., latest Edition., Prentice Hall.
4. Engineering Geology and Rock Mechanics by Duncan, N., 1969, Leonar Hill.
5. Rock Engineering by Franklin, J. A. and Dusseault, M. B., 1989, McGraw-Hill.

Course Title: **Soil Mechanics**
Credit Hours: **3(2+1)**
Course Type: **Elective**
Prerequisite: **Nil**

Objectives and Learning Outcomes:

The main objective of the course is to explain different soil classification systems and their applications in solving different soil mechanics problems and to calculate different engineering properties of soil.

Course Contents:

Introduction and concept of soil mechanics; soil formation and its classification, survey and sampling with its important engineering properties like soil grading, moisture contents, void ratios, density, permeability, shearing strength, bearing capacity, consolidation and settlements.

Labs:

Index properties of soil; determination of soil density, permeability, unconfined shearing and compressive strength of soil and Atterberg's limits.

Recommended Books:

1. Problems in Engineering Soils by Capper, P. L., Cassie W. E. and Geddes, J. D., latest Ed., John Wiley and Sons.
2. Engineering Geology by Beavis, F. C., 1985, Black well Scientific Publications.
3. Structural and Geotechnical Mechanics by Newwark, N. M., latest Edition., Prentice Hall.
4. Engineering Geology and Rock Mechanics by Duncan, N., latest Edition., Leonar Hill.

Course Title: **Introduction to Geotechnical Engineering**
Credit Hours: **3(2+1)**
Course Type: **Elective**
Prerequisite: **Nil**

Objectives and Learning Outcomes:

The basic aim of the course is to identify the significance of geotechnical engineering to understand the construction material and engineering properties of soil and to evaluate the soil classification and slope stabilization techniques.

Course Contents:

Scope of geotechnical engineering; Engineering significance of geotechnical investigation; Geotechnical investigation at selected sites; Geotechnical mapping procedure; Construction material and uses; Types of concrete; Asphalt; Introduction to slope stabilization methods; Basic mechanics of slope

failure; Slope classification. Slope stability; rock and soil mechanics and its application in civil engineering; study of geological factors in relation to the construction of buildings and foundations, roads, highways, excavation and tunneling.

Labs:
Specified assignments/projects.

Recommended Books:

1. Principles of Engineering Geology by Attewell, P. B. and Farmer, I. W., latest Edition., John Willey and Sons.
2. Engineering Geology by Beavis, F. C., 1985, Blackwell Scientific Publications.
3. Principles of Engineering Geology by Johnson, R. B. and Degraff, J. V., latest Edition., John Willey and Sons.
4. Fundamentals of Engineering Geology by Bell, F. A. G., 1983, Butter Worth.
5. Engineering Geology by Goodman, R. E., 1993, John Wiley and Sons.
6. Foundations of Engineering Geology by Waltham, T, 2002.
7. A Geology for Engineers (7th edition) by F. G. H Blyth PhD 1984.

Course Title: **Excavation and Tunneling**
Credit Hours: **3(2+1)**
Course Type: **Elective**
Prerequisite: **Nil**

Objectives and Learning Outcomes:
The aim of the course is to design shape and sizes of underground opening and different geological structures, to propose different site investigation techniques, to select both mechanical and conventional excavations techniques and to able to choose different ground control systems.

Course Contents:
Introduction to excavation and tunneling; major tasks of engineering geologists; ground behavior; geotechnical site investigation; exploration during tunnel construction; prediction of rock mass conditions and behavior; theory of rock drilling and rock blasting; mechanical rock excavation methods; sealing/grouting, operation and maintenance of underground constructions; environmental issues of rock engineering; excavations and tunneling under difficult conditions; tunnels and excavation designs; tunneling through TBM, geological problems and remedial measures. Important case studies of Pakistan and Kashmir.

Field Visits:
Visits to excavation and tunneling sites in Pakistan and Kashmir.

Recommended Books:

1. Civil excavations and tunneling: a practical guide, R. Tatiya, Thomas Telford. 2005.
2. Tunnel Engineering Handbook, by J. O. Bickel, and T. R. Kuesel, Van Nostrand Reinhold Co., 1982.
3. Rock Mechanics Design in Mining and Tunneling by Z. T. Bieniawski, A. A. Balkema, 1984.
4. Engineering Geology: Principles and Practice, David George Price, M. H. De Freitas – 2009.

Course Title: **Foundation Engineering**
Credit Hours: **3(2+1)**
Course Type: **Elective**
Prerequisite: **Nil**

Objectives and Learning Outcomes:

To explain stress distribution in soils and other concepts of foundation engineering, to calculate the bearing capacity of foundation both in soil and rock and to design different earth retaining structures.

Course Contents:

Stress distribution in soils, site investigation, planning of boring, boring methods, sampling, in-situ (field) tests, settlement of structures, initial (elastic) settlement, consolidation settlement, allowable settlement, settlements of footings on granular and cohesive soils, bearing capacity of soils, design of shallow foundations, types of shallow foundations, rigid design of shallow foundations on cohesionless and cohesive soils, use of in-situ tests in foundation design, retaining structures, excavations, review of earth pressure theory, earth retaining systems, cantilever and gravity retaining walls, anchored walls, reinforced earth walls, design of retaining structures, pile foundations,, classification of piles, types of piles, bearing capacity of a single pile in cohesionless and cohesive soils, design of pile groups and settlement of pile groups.

Recommended Books:

1. Foundation Design and Construction, M. J. Tomlinson Hall, Harlow, England: Longman Scientific and Technical; New York: Wiley, 1995
2. Principles of Foundation Engineering, B. M. Das, Thomson Learning, 2007 Matching item Foundation design and construction/M. J. Tomlinson; with contributions by R. Boorman - 6th ed. Harlow, England: Longman Scientific and Technical; New York: Wiley, 1995
3. Foundation Design, Principle and Practice, D. P. Coduto, Prentice.

Course Title: **Dam Engineering**
Credit Hours: **3(2+1)**
Course Type: **Elective**
Prerequisite: **Nil**

Objectives and Learning Outcomes:

The objective of the study is to understand different types of dams and their construction material, to explain site investigation, location and environmental impact of dams and to review different dam design and case histories.

Course Contents:

History of dam; types of dams by structure, size and use, construction material; construction elements; power generation plant; spillways; dam creation; common purposes; site investigation, location; impact assessment; environmental impact; human and social impact; economics; dam failure. Dam design after geological, structural and geotechnical investigations. Common problems and remedial measures in dam engineering. Case studies of known earth fill and concrete dams of Pakistan.

Field Visits:

Field visits to Dams of Pakistan.

Recommended Books:

1. Advanced Dam Engineering for Design, Construction, and Rehabilitation, Editor R. B. Jansen, Springer, 1998.
2. Engineering Soundbite: Ethical Issues from the St. Francis Dam Failure, Paul Guyer, Guyer Partners, 2011.
3. Geotechnical Engineering Investigation Handbook, Second Edition, Roy E. Hunt, A. A Balkema Publishers London, 2005
4. Engineering Geology and Construction, Fred G. Bell, London [u.a.]: Spon, 2004.

Course Title: **Landslide Hazards and Risk Assessment**
Credit Hours: **3(2+1)**
Course Type: **Elective**
Prerequisite: **Nil**

Objectives and Learning Outcomes:

Students will develop the ability to perform basic hazard mapping and risk assessments. The course will provide the students with multidisciplinary knowledge and understanding of the various landslide types. The course will give students an overview and an understanding of landslide processes from geologic conditioning, triggering and landslide hazards. It will give the students an overview of landslide mapping products that are used in society for planning and mitigation.

Course Contents:

Definition and concept of slope; Types and classification of slopes; Causes and factors affecting slope failures; Geological conditions associated with slopes; Description and type of landslide susceptibility; Input data for landslide risk assessment; Method for landslide susceptibility assessment; Method for landslide hazards assessment; Landslide hazards zoning maps.

Course Title: **Earthquake Engineering and Risk Assessment**
Credit Hours: **3(2+1)**
Course Type: **Elective**
Prerequisite: **Nil**

Course Learning Outcomes:

The main aim is to understand seismic motion sources, earthquake, hazards and mitigation, seismicity and wave propagation, to understand the use of active faults in earthquake risk assessment and to illustrate earthquakes and their determination; earthquakes and their relationship to the tectonics of the area.

Course Contents:

Earthquake and its causes with reference to world and Pakistan; distribution and relationship with plate tectonics; mathematical analysis of seismological processes on the basis of elastic wave theory; seismic waves and their analysis in earthquake seismology; frequency, magnitude, energy of an earthquake and their relationship; source parameters and their determination; composite fault plane solutions of earthquakes and their determination; earthquakes and their relationship to the tectonics of the area; application of seismic zones for building code in earthquake prone area; risk analysis, hazards and remedial measures.

Labs:

Calculation of g-value, PGA analysis; Specified problems on data processing, analysis, fault solutions and interpretation.

Recommended Books:

1. The Interior of the Earth its Structure, Constitution and Evaluation by Bott, M. H. P., 1982, Edward Arnold.
2. Introduction to Seismology by Bath, M., 1979, Birkhauser Verlag, Basal.
3. An Introduction to the Theory of Seismology by Bullen, K. E. and Bolt, B. A., 1985, Cambridge University Press.
4. Quantitative Seismology by Aki, K. and Richards, P. G., 1980, W. H. Freeman and Company.
5. Seismic Waves and Sources by Ben-Menaham, A. and Singh, S. S., 1981, Springer-Verlag.

GROUP-V: PETROLEUM GEOSCIENCES

Objectives and Learning Outcome:

Advance level courses have been designed in this group of specialization. These courses will enable the students to fully understand (1) the formation, migration and accumulation of hydrocarbons, (2) the sequence stratigraphy and importance of trace fossils, (3) techniques of geological, geophysical and geochemical prospecting for hydrocarbons, (4) the hydrocarbon reserves estimation and risk analysis (5) petroleum economics, (6) the clay minerals and their role in petroleum industry, (7) the geochemical assessment of source rock for hydrocarbons and (8) the hydrocarbon resources of Pakistan. After completing these courses, the students will be able to carry out their independent research on the hydrocarbon characterization, exploration and economic evaluation.

This group comprises the following courses:

1. Sequence Stratigraphy II
2. Petroleum Engineering
3. Reservoir Geology.
4. Organic Geochemistry
5. Petroleum Geology of Pakistan
6. Petroleum Economics
7. Seismic Techniques

Course Title: **Sequence Stratigraphy II**
Credit Hours: **3(2+1)**
Course Type: **Elective**
Prerequisite: **Sequence Stratigraphy**

Objectives and Learning Outcome:

This course will enable the students to acquire knowledge about the sequence stratigraphy and its hierarchy along with composite sequences with the used wireline log and core data sets. This will help in interpretation and evaluation for reservoirs, source rocks and seals for structural and stratigraphic traps to understand the petroleum system of sedimentary basins.

Course Contents:

Concepts of sequence stratigraphy; sequence hierarchy and composite sequences; various approaches of sequence stratigraphy, clastic and carbonate sequence stratigraphy; time stratigraphy, genetic sequence stratigraphy, fluvial sequence stratigraphy, sequence stratigraphy in wireline log and core data sets; application of sequence stratigraphy in tectonically active basins; importance of trace fossils in sequence stratigraphy. Fundamentals of seismic stratigraphy; concepts and models of various depositional systems; seismic reflections in response to strata surfaces and unconformities; seismic sequence analysis; integration of seismic data with geology; seismic facies analysis; reflection character analysis; geologic

interpretation and evaluation for reservoirs, source rocks and seals for structural and stratigraphic traps.

Labs:

Interpretation and seismic reflection patterns. Surface and seismic facies and identification of sequences. Core analysis and wire line logs, key surfaces, their recognition and significance.

Recommended Books:

1. Silici-clastic Sequence Stratigraphy in Well Logs, Cores and Outcrops by Van Wagoner, J. C., and others, 1990, AAPG Meth Expl. Ser. No.7, 55p.
2. Sea-level Changes an Integrated Approach by Wilgus, B. S. and others, SEPM.
3. Seismic Stratigraphy: Application to H-carbon Exploration by Payton, C. W., 1977, AAPG Mem. 26p.
4. Sequence Stratigraphy and Facies Association by Posamentier H. W. and Others, 1993, Blackwell Scientific Publications.
5. Sequence Stratigraphy by Emery, D. and Myers, K. J., 1996, Oxford, Blackwell Science.
6. Seismic Stratigraphy II, An integrated Approach by Orville Roger Berg and Donald G. Woolverton, AAPG Memoir 39 Tulsa, Oklahoma, USA.
7. Reflection Seismology, A tool for Energy Resource Exploration by Kenneth H. Waters,1981, John Wiley and Sons.
8. Principles of Sequence Stratigraphy by Catuneanu, O., 2006.
9. Applied Stratigraphy by EAM Koutsoukos., 2005. Springer.
10. The Geology of Stratigraphic Sequences by Miall, A. D., 1997

Course Title: **Petroleum Engineering**
Credit Hours: **3(2+1)**
Course Type: **Elective**
Prerequisite: **Nil**

Objectives and Learning Outcome:

This course will enable the students to acquire knowledge of drilling and production techniques such as drilling rigs, cementation and testing jobs. This will also help to understand about EOR and HSE.

Course Contents:

Introduction to rig components, drilling methods and operations; types of bits; drilling fluids, composition and function; cementation and casing operations; coring operations; mud and wireline logging; well testing and completion; well production operations; evaluation and analysis of well data i.e. well cutting, cores, logs and production data; secondary and enhanced oil recovery, common drilling problems and preventive measures, HSE at well site, PVT analysis.

Labs:

Study of mass properties of rocks, wire line logs, cores, well cuttings, DST and MDT pressure data. Production Histogram Plots.

Recommended Books:

1. Introduction to Geophysical Prospecting by Dobrin, M. D. and Savil, C. H., 1988, McGraw-Hill.
2. Geophysical Methods by Robbert, E. S., 1989, Prentice Hall.
3. Petroleum Engineering, Drilling and Well Completions by Gatlin, C., Latest Edition., Prentice – Hall.
4. Drilling of Oil and Gas by Sereda, N. G. and Solvyon, E. M., latest Ed., Wells Mir Publications.
5. Well Log Formation Evaluation by Merkel, R. H., 1986, AAPG course notes #14.
6. Introduction to Petroleum Engineering, by John R. Fanchi and Richard L. Christiansen, 2017, Wiley

Course Title: **Reservoir Geology**
Credit Hours: **3(2+1)**
Course Type: **Elective**
Prerequisite: **Nil**

Objectives and Learning Outcome:

This course will enable the students to acquire knowledge about Reservoir rock types and their distribution with special reference to Pakistan. Fluid contacts; reservoir zonation and mapping techniques of reservoirs, Reserve estimates and Appraisal and development techniques.

Course Contents:

Petrophysical evaluation; reservoir rock types: elastic, carbonates and non-marine reservoirs. Reservoir properties, depositional and diagenetic controls; fluid properties and their saturation; hydrocarbon distributing and fluid contacts; reservoir zonation and thickness mapping, reservoir pore spaces configuration; mapping reservoir heterogeneity; reservoir estimation and calculation of reservoir volumetric, material balance and production, decline curve methods; appraisal and development of reservoir basic concepts.

Labs:

Porosity and permeability distribution maps, reservoir facies distribution map, isopach maps, isochore maps, log correlation map.

Recommended Books:

1. Introduction to Petroleum Reservoir Analysis by Koederitz I. F. Heaveey., A. H. and Honarpour 1989, Contribution in Petroleum/Geology and Engineering-6 Gulf Publishing Co.
2. Development and Exploration of Oil and Gas Field by Muravyor, R. et al., latest Edition., Peace publishers.

3. Petroleum Geology by North F. K. 1985. Allen and Unwin London.
4. Applied Subsurface mapping by Tearpock. D. J. and Bischke. R. E., 1991. Prentice Hall.
5. Basics of Reservoir Engineering by Coss, R., 1993, Editions Technip.
6. Reservoir Characterization by Lake, L. W. and Carrol Jr, H. B., 1986. Academic Press.
7. Modern Well.Test Analysis (A Computer Aided Approach) by Roland, H. N., 1995, Petrowy.
8. Geostatistical Reservoir Modeling by Clayton, V. Deutsch, 2002, Oxford, University Press.
9. Well Log Formation Evaluation by Richard H. Merkel,1986, AAPG course notes #14

Course Title: **Organic Geochemistry**
Credit Hours: **3(2+1)**
Course Type: **Elective**
Prerequisite: **Nil**

Objectives and Learning Outcome:

This course will enable the students to acquire knowledge about organic matters, its types and composition; conversion of organic matter to hydrocarbon. Generation of hydrocarbons into source rocks and accumulation of hydrocarbon into reservoir rocks and Geochemical prospecting and exploration methods

Course Contents:

Introduction to organic geochemistry; organic matters, its types and composition; conversion of organic matter to hydrocarbon; composition of biogenic matters; geochemical conditions for the accumulation and formation of hydrocarbons; generation and composition of petroleum hydrocarbons and coal; geochemical assessment of source rocks; geochemical assessment of primary and secondary migration; application of different geochemical prospecting and exploration methods; geochemistry of formation fluids; Fingerprinting / biomarker study /Oil-source / oil-oil correlation.

Labs:

Determination of TOC, maturity indicators, pyrolysis, van krevelen diagram, GS, GS-MS. Hydrocarbon Window Plots.

Recommended Books:

1. Geochemistry, by Beaumont, E. A. and Foster, N. H., 1988, AAPG special publication, No.8.
2. Geochemical Model for Characterization of Hydrocarbon Gas Sources in Marine Sediments by Bernad B et al., latest Ed., Proceeding 9th Offshore Technical Conference, John Wiley and Sons.
3. Marine Geochemistry by Chester, R. 1990, Unwin Hyman, London.

4. Predictive Source Bed Stratigraphy by Demaison, G. J., 1984, Proceedings Eleven World Petroleum Congress, John Wiley and Sons.
5. Petroleum Geochemistry and Source rock Potential of Carbonate Rocks by Demaison, G. J. and Moonne. G. T., 1984, AAPG Special Publication No.
6. Geochemistry and Basin Evolution by Kantsler, A. J. et al., 1983, AAPG Memorial No.35.
7. Introduction to Exploration Geochemistry (organic) by Levinson, A. A., latest Ed., Applied Publishing Ltd.
8. Recent Advances in Coal Geochemistry by Lynnchi, L. and Chou, C. L., 1980, The Geological Society of America, Inc., Special Paper, 248.
9. Advances in Organic Geochemistry by BJOROY et al., 1981, John Wiley and Sons.
10. Advances in Petroleum Geochemistry vol. 2 by Jim Brooks and Dietrich Welte, Academic Press.
11. Fossil Fuel Biomarkers, Applications and Spectra by Philip, R. P., 1985, Elsevier Science Publishers.
12. Illustrated Glossary of Petroleum Geochemistry by Miles, J., 1991, Oxford Science London.
13. Geochemistry in Petroleum Exploration by Waples, D. W., 1985, International Human Resource Development Corporation, Boston, USA.
14. An Introduction to Petroleum Geoscience, by Michael Ala, 2017, World Scientific.
15. Introduction to Organic Geochemistry (2nd Edition), Stephen Killops and Vanessa Killops, 2015, Blackwell Publishing.
16. The Imperial College Lectures in PETROLEUM ENGINEERING (An introduction to Petroleum Geosciences), Vol. 1, by Michael Ala, 2017, World Scientific.

Course Title: **Petroleum Geology of Pakistan**
Credit Hours: **3(2+1)**
Course Type: **Elective**
Prerequisite: **Nil**

Objectives and Learning Outcome:

This course will enable the students to acquire knowledge about exploration trends and techniques, Tectonics and depositional settings, Lithostratigraphic divisions of various geological periods. Shale gas and oil and Environmental impacts.

Course Contents:

History of petroleum exploration; new trends for petroleum exploration; tectonic framework; sedimentary basins and their evolution and distribution; tectonics, depositional settings and lithostratigraphic divisions of the rocks of various geological periods; facies development and their association in depositional basins such as Indus, Baluchistan and offshore regions; evaluation of petroleum potentials of different basins; structural styles and

petroleum play in the basins of Pakistan; geothermal gradients and their maturity; productive and potential oil and gas reservoirs and source and seal rocks and their distribution in the basins. Play Fairways and Petroleum System in basins; case studies. Scope of shale gas and oil. Hazards and Environmental impacts of shale gas/oil exploration.

Labs:

Case histories of oil and gas fields of Pakistan.

Recommended Books:

1. Geodynamic of Pakistan by Farah, A., and Dejong K. A., 1979, Geological Survey of Pakistan.
2. Marine Geology and Oceanography of Arabian Sea and Coastal Pakistan by Haq, B. U. and Milliman, G. D., 1984, Jan Nostrand Reinhold Co.
3. Petroleum Geology of Pakistan by Kadri, I. B., 1995, Pakistan Petroleum Limited.
4. Petroleum Source Rocks of Pakistan by Raza H. A., 1991, Int. Petroleum Seminar, Sp. Publ.
5. Petroleum for Future by Raza, H. A. and Sheikh, A. M., 1988, (HDIP),
6. Geology and Tectonics of Pakistan by Kazmi, A. H. and Jan, Q., 1997, Graphic Publishers.
7. Geology of Pakistan by Bender and Raza, 1995, Gebruder Borntraeger.
8. Selected technical proceedings of PAPG and SPE meetings
9. Stratigraphy and historical geology of Pakistan by Kazmi, A. H and Abbasi, I. A., 2008, Graphic Publishers, Karachi, Pakistan

Course Title: **Petroleum Economics**
Credit Hours: **3(3+0)**
Course Type: **Elective**
Prerequisite: **Nil**

Objectives and Learning Outcome:

This course will enable the students to acquire knowledge about petroleum economics in the upstream oil and gas business. It will provide the knowledge, language and tools to improve commercial business awareness with focus on value creation. The course will enable students to calculate the profitability of a project, calculate, and understand the role of taxation in upstream Petroleum Industry.

Course Contents:

Introduction: Principal economic characteristics; how to evaluate the economic viability of a project; cash flow techniques applicable in economic evaluations; how to use economic criteria to choose investments models to weigh risk and uncertainty; forecasting oil production; defining reserves, operating expenses, capital expenditures, inflation, factors effecting oil and gas prices, cash flow techniques; economic criteria: interest, hurdle rate, time value of money, selection, ranking criteria; risk, uncertainty: types of risk, mathematical

techniques, probabilistic models, uncertainty in economic analysis; economic factors in computer spreadsheet analysis.

Recommended Books:

1. Mian, M. A., (2011). Project Economics and Decision Analysis, Volume 1: Deterministic Models. 2nd Edition.
2. Mian, M. A., (2011). Project Economics and Decision Analysis, Volume 2: Probabilistic Models. 2nd Edition.
3. Wood, David, (2016). Upstream Petroleum Fiscal and Valuation Modeling in Excel: A Worked Examples Approach
4. Chris Hinkin, (2017). Introduction to Petroleum Economics.

Course Title: **Seismic Techniques**
Credit Hours: **3(2+1)**
Course Type: **Elective**
Prerequisite: **Nil**

Objectives and Learning Outcome:

This course will enable the students to acquire knowledge about principles and seismic methods for data acquisition. Seismic interpretation of 2D and 3D seismic reflection data and Vertical seismic profiling.

Course Contents:

Basic Principles of the seismic method and seismic interpretation 2D and 3D seismic reflection data: Introduction, structural and stratigraphic, interpretation, reservoir, identification and evaluation, horizon and formation attributes visualization, exercises in structural and stratigraphic interpretation of 2D and 3D seismic data. Vertical seismic profiling, interactive, interpretation of 2D and 3D seismic on work station.

Labs:

Interpretation of various seismic sections, use of software to solve these problems, Graphic Plotting Data.

Recommended Books:

1. C. L Liner, 2004, Element of 3D Seismology, Pennwell Corporation, USA.
2. RE Sheriff, and L. P., 1995, Geldart, Exploration, Seismology, Cambridge University Press.
3. W. M. Telford, L. P Geldart and R. E, Sheriff, 1990, Applied Geophysics, Cambridge University Press.
4. M. B Dobrin, and C. H Savit, 1988, Introduction to Geophysical Prospecting, McGraw-Hill.
5. E. S. Robinson and C. Coruh, 1988, Basic Exploration Geophysics, John Wiley and Sons New York.
6. G. Nichols, 1999, Sedimentalogy and Stratigraphy, Blackwell Science Publisher.

GROUP-VI: APPLIED GEOPHYSICS

Objectives:

Advance level courses have been designed in this group of specialization. These courses will enable the students to fully understand (1) the concepts and models of various depositional systems, (2) the seismic facies analysis, (3) the seismic zonation of Pakistan, (4) the palaeomagnitism and its application, (5) the radiometric dating techniques, (6) the electrical, gravity and magnetic techniques in geophysics. After completing these courses, the students will be able to carry out their independent research on the application of geophysical techniques in hydrocarbon exploration.

This group comprises the following courses:

1. Seismic Stratigraphy
2. Earthquake Seismology
3. Geomagnetism and Paleomagnetism
4. Electrical and Radiometric Exploration Methods
5. Bore-Hole Geophysics
6. Seismic Prospecting
7. Gravity and Magnetic Methods
8. Rock Physics

Course Title: **Seismic Stratigraphy**
Credit Hours: **3(2+1)**
Course Type: **Elective**
Prerequisite: **----------**

Objectives and Learning Outcomes:

To enable the students, learn about basic principle of seismic methods and seismic stratigraphy, methods of acquisition, processing and interpretation of seismic data. Students are expected to understand the fundamental of seismic stratigraphy and its application for basin modeling, depositional systems, and petroleum exploration.

Course Contents:

Physical principles and basic theory; seismic waves; types of seismic methods; velocities of seismic waves in rocks and factors influencing these velocities; surveying techniques; seismic energy sources; instruments; data acquisition and processing techniques; interpretation; applications and case histories.

Fundamentals of seismic stratigraphy; concepts and models of various depositional systems; seismic reflections in response to strata surfaces and unconformities; seismic sequence analysis; integration of seismic data with geology; seismic facies analysis; reflection character analysis; geologic interpretation and evaluation for reservoirs, source rocks and seals for structural and stratigraphic traps.

Labs:
Specified assignments on data processing, analysis and interpretation.

Recommended Books:
1. Seismic Exploration by Al-Sadi, H. N., 1980, Birkhauser Verlag. Basel.
2. Dobrin, M. B. and SAVIT, C. H., 1988, McGraw-Hill.
3. Introduction to Geophysical Prospecting by Kearey, P. and Brooks, M., 1991, Osney Mead.
4. Basic Exploration Geophysics by Robinson, E. S. and Coruh, C., 1988, John Wiley and Sons.
5. Geophysical Methods in Geology by Sharma, P. V., 1987, Elsevier Scientific Publishing Company.
6. Applied Geophysics by Telford, W. M., Geldart, C. P., Sheriff, R. E. and Keys, D. A., 1976, Cambridge University Press.
7. Seismic Stratigraphy Interpretation and Petroleum Exploration by Brown, Jr., L. F and Fisher, W. B, 1985, AAPG.
8. Field Geophysics by Milson, J., 1989, Open University Press.

Course Title: **Earthquake Seismology**
Credit Hours: **3(2+1)**
Course Type: **Elective**
Prerequisite: **----------**

Objectives and Learning Outcomes:
To enable the students, understand the basic principles of seismological processes and their analysis in earthquake seismology. Students are expected to interpret seismic waves for types of faults for seismic hazard assessments.

Course Contents:
Mathematical analysis of seismological processes on the basis of elastic wave theory; seismic waves and their analysis in earthquake seismology; frequency, magnitude, energy of an earthquake and their relationship; source parameters and their determination; composite fault plane solutions of earthquakes and their determination; geographical distribution of important earthquakes; earthquakes and their relationship to the tectonics of the area.

Labs*:*
Specified problems on data processing, analysis, fault solutions and interpretation.

Recommended Books:
1. The Interior of the Earth, its Structure, Constitution and Evaluation by Bott, M. H. P., 1982, Edward Arnold.
2. Introduction to Seismology by Bath, M., 1979, Birkhauser Verlag, Basal.
3. An Introduction to the Theory of Seismology by Bullen, K. E. and Bolt, B. A., 1985, Cambridge University Press.

4. Quantitative Seismology by Aki, K. and Richards, P. G., 1980, W. H. Freeman and Company.
5. Seismic Waves and Sources by Ben-Menaham, A. and Singh, S. S., 1981, Springer-Verlag.

Course Title: **Geomagnetism and Paleomagnetism**
Credit Hours: **3(2+1)**
Course Type: **Elective**
Prerequisite: **----------**

Objectives and Learning Outcomes:

To enable the students, learn about basic principles of geomagnetism andpaleomagnetism for its application to sedimentation and tectonism.

Course Contents:

Fundamentals of geomagnetism; magnetic properties of rocks; description of magnetic field of the earth; paleomagnetic sampling; measurement of NRM; magnetic cleaning techniques and field tests of paleomagnetic stability; paleointensity analysis; paleomagnetism and its applications.

Labs:

Specified assignments/projects.

Recommended Books:

1. Paleomagnetism by Tarling, D. H., 1983, Chapman and Hall.
2. Rock Magnetism by Nagata, T., latest Ed., Maruzen Co., Ltd.
3. Introduction to Geomagnetism by Parkinson, W. D., 1983, Scottish Acad., Press.

Course Title: **Electrical and Radiometric Exploration Methods**
Credit Hours: **3(2+1)**
Course Type: **Elective**
Prerequisite: **----------**

Objectives and Learning Outcomes:

To enable the students, understand methods of acquisition, processing and interpretation of electrical resistivity, induced polarization, electromagnetic, and radiometric data self for subsurface exploration for hydrocarbons, water, and depositional systems.

Course Contents:

Fundamentals of current flow in the earth; electrode arrangements and field procedures; instruments; processing and interpretation of resistivity data; field procedure, data acquisition and interpretation of self-potential, induced polarization and electromagnetic methods; study of case histories. Physical principles and basic theory; radioactivity of rocks; radioactive dating methods;

field surveys and instruments; data processing and interpretation; application of radiometric methods in exploration of minerals and energy resources.

Labs:
Specified problems on data acquisition, processing and interpretation.

Recommended Books:

1. Introduction to Geophysical Prospecting by Dobrin, M. B. and Savit, C. H., 1988, McGraw-Hill.
2. An Introduction to Geophysical Exploration by Kearey, P. and Brooks, M., 1991, Osney Mead.
3. Basic Exploration Geophysics by Robinson, E. S. and Coruh, C., 1988, John Wiley and Sons.
4. Geophysical Methods in Geology by Sharma, P. V., 1987, Elsevier Scientific Publishing Company.
5. Field Geophysics by Milson, J., 1989, Open University Press.
6. Radon Mapping in the Search for Uranium by Telford, W. M., 1982, In; Fitch, A. A. (ed.) Developments in Geophysical Exploration Methods. Applied Science.
7. Introduction to Geophysical Prospecting by Dobrin, M. B. and Savit, C. H., 1988, McGraw-Hill, New York.
8. Applied Geophysics by Telford, W. M., Geldart, C. P., Sheriff, R. E. and Keys, D. A., latest Ed., Cambridge University Press, London.
9. Field Geophysics by Milson, J. 1989, Open University Press, Milton Keynes.
10. Interpretation Theory in applied Geophysics by Grant, F. S. and West, G. F., latest Ed., McGraw-Hill, New York.
11. Kearey, P., Brooks, M., and Hill, I., 2002. An Introduction to Geophysical Exploration, 3rd Ed., Blackwell Scientific Publications, London.

Course Title: **Borehole Geophysics**
Credit Hours: **3(2+1)**
Course Type: **Elective**
Prerequisite: **----------**

Objectives and Learning Outcomes:
To make the students understand the fundamental and advanced of borehole geophysics, methods of acquisition, processing and its interpretation for hydrocarbon exploration.

Course Contents:
Introduction; basic theory of geophysical methods; petrophysics and formation evaluation; different types of logging techniques, instrumentation and their field application; log analysis and interpretation; application of borehole geophysics for lithological, environmental, water resources, geotechnical, mineral and hydrocarbon studies. Borehole logging; VSP, Case histories.

Labs:
Specified assignments on data acquisition/processing and interpretation.

Recommended Books:

1. An Introduction to Geophysical Exploration by Kearey, P., Brooks, M., and Hill, I., 2002, 3rd Edition., Blackwell Scientific Publications, London.
2. Geophysics in Mineral Exploration: Fundamentals and Case Histories Geology by Lowe, C., Thomas, M. D., and Morris, W. A., (Eds) 1999, Association of Canada, Short Course Notes Volume 14, Sudbury.
3. An Introduction to Applied and Environmental Geophysics by Reynolds, J. M., 1997, Wiley, New York.
4. Sharma, P. V., 1997, Environmental and Engineering Geophysics, Cambridge University Press.
5. Applied Geophysics, 2nd Ed. by Telford, W. M. Geldart, L. P. and Sherriff, R. E., 1990, Cambridge University Press, Cambridge.
6. Geotechnical and Environmental Geophysics, Vol. I-III by Ward, S. H. (ed), 1990, Society of Exploration Geophysicists, Tulsa, Okla.
7. Drilling Practices Manual by Moone, P. L., 1986, Pen Well.

Course Title: **Seismic Prospecting**
Credit Hours: **3(2+1)**
Course Type: **Elective**
Prerequisite: **----------**

Objectives and Learning Outcomes:
To make the students understand the fundamental and advanced seismic methods: acquisition, processing and interpretation for subsurface structural analysis and hydrocarbon exploration.

Course Contents:
Planning for 2D and 3D seismic surveys and concepts of recording parameters; types of seismic surveys; onshore and offshore seismic surveys; Methodology of seismic data acquisition, seismic equipment, types of seismic energy sources and recording equipment, acquisition methods, quality control of data during acquisition and processing, field processing, Work flow for various basic and advanced processing techniques, seismic mapping and interpretation of 2D and 3D seismic data; well seismic (VSP), Forward seismic Modeling, Ray tracing, synthetic seismograms generation, AVO for lithology and DHI, Applications in Exploration and Production.

Labs:
Specified assignments/projects.

Recommended Books:

1. Statistics for Geoscientists: Techniques and applications by Pal, S. K., 1998. Concept Publishing Company.

2. Statistics and Data Analysis in Geology by Davis, J. C., 1986, John Wiley.
3. Geomathematics by Agterberg, F. P., 1974, Elsevier Scientific.
4. Spectral Analysis in Geophysics by Bath, M., latest Ed., Elsevier.
5. Fundamental of Geophysical Data Processing by Claerbout, J. F., latest Edition., McGraw-Hill.
6. Introduction to Digital Filtering in Geophysics by Kulhanek, O., 1976, Elsevier.

Course Title: **Gravity and Magnetic Methods**
Credit Hours: **3(2+1)**
Course Type: **Elective**
Prerequisite: **----------**

Objectives and Learning Outcomes:

To enable the students, learn about basic principles of gravity and magnetic methods; acquisition, processing and interpretation of gravity and magnetic data for its application to crustal deformation and mineral exploration.

Course Contents:

Physical principles and basic theory; instrumentation; planning of the survey and evaluation of errors; different survey methodologies; rock densities/rock susceptibilities and their measurements Isostasy; data acquisition, processing; interpretation and mapping to identify gravity/magnetic anomalies; regional fields and residual anomalies, derivatives, continuation of the field, two and three- dimensional modeling; applications in petroleum industry and case histories.

Labs:

Specified problems on data acquisition; processing and interpretation.

Recommended Books:

1. Introduction to Geophysical Prospecting by Dobrin, M. B. and Savit, C. H., 1988, McGraw-Hill.
2. An Introduction to geophysical Exploration by Kearey, P. and Brooks, M., 1991, Osney Mead.
3. Basic Exploration Geophysics by Robinson, E. S. and Coruh, C., 1988, John Wiley and Sons.
4. Geophysical Methods in Geology by Sharma, P. V., 1987, Elsevier Scientific Publishing Company.
5. Applied Geophysics by Telford, W. M., Geldart, C. P., Sheriff, R. E., and Keys, D. A., 1990, Cambridge University Press.
6. Interpretation Theory in applied Geophysics by Grant, F. S. and West, G. F., 1965, McGraw-Hill.
7. Theory of the Earth's Gravity Field by Pick, M., Picha, J. and Vyskocil, V. 1973, Elsevier Sci. Publ. Company.
8. Field Geophysics by Milson, J. 1989, Open University Press

Course Title: **Rock Physics**
Credit Hours: **3(2+1)**
Course Type: **Elective**
Prerequisite: **----------**

Objectives and Learning Outcomes:

To introduce concepts of rock physics to students for assessment of deformation and properties of rocks for stress analysis and hydrocarbon exploration.

Course Contents:

Fundamentals and principles of rock physics, their scope and utility, concepts of elasticity, plasticity and viscosity, rock permeability, porosity, elastic properties of the fluids, seismic wave propagation, porous media, fluid substitution model and rock properties model. In-situ stress measurement, pore pressure, effective pressure, fluid migration, seismic signature, isotropy and anisotropy, velocity dispersion and attenuation, causes of velocity dispersion and attenuation, fluid distribution patterns into the pores, rock physics as interpretation tool and Empirical relations between different rock physics parameters.

Labs:

Velocity–density cross–plotting exercise, fluid substitution Modeling, Rock Physics parameter extraction from seismic data, seismic wave propagation modeling, Ray tracing exercise in MATLAB, Synthetic seismogram generation exercises in MATLAB.

Recommended Books:

1. M. Gary, T. Mukherjee, and J. Dvorkin, the Rock Physics, Handbook, Cambridge University Press, 2000.
2. P. Avseth, T. Mukherjee, and G. Mavko, 2005, Quantitative Seismic Interpretation: Applying Rock Physics tools to reduce interpretation Risk. Cambridge University Press.
3. N. Barton, 2007, Rock Quality, Seismic velocity, attenuation and anisotropy, Taylor and Francis, Balkema.
4. Y. Gu'eguen, and M. Bout' eca, 2004, Mechanics, of Fluid-Saturated Rocks, Elsevier.

GROUP-VII: SEDIMENTOLOGY

Objectives and Learning Outcome:

Advance level courses have been designed in this group of specialization. These courses will enable the students to fully understand (1) the sedimentary processes, structures and textures, classifications, compositions of carbonates, arenaceous, argillaceous and rudaceous rocks, (2) Diagenetic processes and their effects on physio-chemical properties of rocks. (3) the sedimentary basin development in relation to plate tectonics (geosynclines to tectonic basins), (4) the sedimentary basins and Quaternary deposits of Pakistan and (5) the Quaternary geology and related nano-tectonics and after completing these courses the students will be able to carry out their independent research related to the texture, composition and diagenesis of various types of sedimentary rocks.

This group comprises the following courses:

1. Clastic Sedimentology
2. Carbonate Sedimentology
3. Basin Modeling
4. Quaternary Geology
5. Clay Mineralogy

Course Title: **Clastic Sedimentology**
Number of Credits: **3(2+1)**
Course Type: **Elective**
Prerequisite: **Nil**

Objectives and Learning Outcome:

This course will enable the students to acquire knowledge about texture and classification of sedimentary rocks, Sedimentary environments and facies analysis, Paleocurrent analysis and Diagenesis and provenance analysis of clastic rocks

Course Contents:

Texture of clastic sedimentary rocks, Sedimentary structures, their classification and hydrodynamic conditions, Paleocurrent analysis and provenance of clastic rocks, Sedimentary environments and facies Continental environments: Deserts, rivers lakes, glaciers and wind. Transitional environments: Delta, estuary and interdeltaic complexes, Marine environments: Shelf, slope and deep marine. Diagenesis of clastic rocks.

Labs:

Petrographic study of clastic rocks and heavy mineral analysis; recording, plotting and interpretation of data for paleocurrent analysis, Rose Diagram; field techniques for study of clastic sedimentary rocks.

Recommended Books:

1. Sedimentary Environments and Facies by Reading, H. G., 1986, Blackwell Scientific Publications.
2. Ancient Sedimentary Environments by Selley, R. C., 1978, Chapman and Hall.
3. Origin of Sedimentary Rocks by Blatt. H., Middleton, G and Murrey, R., latest Ed., Prentice Hall.
4. Depositional Sedimentary Environments by Renieck, H. E. and Singh, I. B., 1980, Springer-Verlag.
5. Sand and Sandstones by Pettijohn by F.J., Potter, P. E. and Sever, R., latest Edition., Springer Verlag.
6. Principles of Sedimentology by Friedman, G. M. and Sanders, J. E., 1978, John Wiley and Sons.
7. Petrology of Sedimentary Rocks by Boggs Jr. S., 1992, Merril Publishing Co.
8. Sedimentary Rocks by Pettijohn, F. J., latest Ed., Harper and Row.
9. Depositional Systems, A Genetic Approach to Sedimentary Geology by Davis, R. A. Jr., 1983. Prentice-Hall.
10. Sedimentary Petrology, An Introduction by Tucker, M. E., 1981, Black Well Scientific Publications Osney Mead.
11. Terrigenous Clastic Depositional Systems, Application to Petroleum, Coal and Uranium Exploration by Galloway, W. E. and Hobday, D. K., 1983, Springer-Verlag, New York, Inc.
12. A Practical Guide to the Study of Glacial Sediments by David J. Evans, 2004, Oxford University Press.
13. Microfacies of carbonate rocks. Analysis, interpretation and application by Flugel, E., 2004, Springer

Course Title: **Carbonate Sedimentology**
Number of Credits: **3(2+1)**
Course Type: **Elective**
Prerequisite: **Nil**

Objectives and Learning Outcome:

This course will enable the students to acquire knowledge about carbonate mineralogy and chemistry, classification, and depositional models, microfacies, cyclicity in carbonates, carbonate depositional systems.

Course Contents:

Carbonate mineralogy and chemistry: structure of aragonite, calcite and dolomite, trace elements and isotopes, dolomite and dolomitization models: modern and ancient examples. dolomitization reactions, trace element geochemistry of dolomites, dolomite petrography; depositional textures and structures: carbonate constituents, algal stromatolites; classification of carbonates by Folk and Dunham; porosity types; concept of microfacies and microfacies types of Wilson; major controls on carbonate sedimentation; depositional processes and facies in carbonate rocks; carbonte depositional

models, platforms, rimmed shelves, ramps, epieric platforms and isolated platforms; cyclicity in carbonates; modern carbonate environments of Bahamas, Florida and Persion Gulf; carbonate depositional systems; lacustrine, shoreline, peritidal reefs, shallow and deep water; diagnetic processes and sequences and models.

Labs:

Identification of carbonate sediments in hand specimen and thin sections; staining; microfacies interpretations and XRD techniques.

Recommended Books:

1. Carbonate Sediments and their Diagenesis by Bathurst, R. G., latest Edition., Elsevier.
2. Marine Carbonate by Milliman, J. D., 1974, Springer-Verlag.
3. Carbonate Depositional Environment by Scholle, P. A. Bebout, D. G. and Moore, C. H., AAPG Mem.
4. Carbonate Sedimentology by Tucker, M. E. and Wright, V. P., 1990, Blackwell Scientific Publications.
5. Carbonate Depositional Environments by Scholle, P. A.,, Bebout, D. G. and Moore, C. H., 1993, Mem. Am. Assoc. Petrol. Geol.

Course Title: **Basin Modeling**
Number of Credits: **3(2+1)**
Course Type: **Elective**
Prerequisite: **Nil**

Objectives and Learning Outcome:

This course will enable the students to acquire knowledge about sedimentary basins, its types and classification, mechanism for formation of sedimentary basins, eustatic and relative sea level changes.

Course Contents:

Sedimentary Basins and its classification, mechanism for formation of sedimentary basins, types of basins i.e. divergent and convergent plate margin basins; foreland, forearc and back arc basins; transform margins; rift and pull apart basins; basins associated with sutures; cratonic basins and others; sedimentation and plate tectonics, clastic and non-clastic petrofacies; factors controlling basin stratigraphy and tectonic mechanism. Eustatic and relative sea level changes; causes and response; tectonic vs. eustatic controls; sedimentary basins of Pakistan. Concept of 1D, 2D, 3D and 4D basin modeling for petroleum exploration; burial history curve, geothermal gradient, heat flow, maturity levels of source rocks; expansion and migration into traps.

Labs:

Stratigraphy columns and their correlation; textural data interpretation; paleocurrent data interpretation; basin mapping methods; clastic petrofacies analysis; interpretation of depositional basins and source area.

Recommended Books:

1. Basin analysis: Principles and Applications by Allen, P. A. and Allen, J. R., 1990 Blackwell Scientific Publications Foreland Basins by Allen, P. A. and Homewood. P and William G. D., 1986, Blackwell Scientific Publications.
2. Sedimentary Basin Evolution, Facies and Sediment Budget by Einsle, G., 1992.
3. Sedimentary Environment and Facies by Reading, H. G., 1986, Blackwell Scientific Publications.
4. Geology and Tectonics of Pakistan by Kazmi, A. H. and Jan, Q., 1997, Graphic Publishers.
5. Geology of Pakistan by Bender and Raza, (ed.) 1995, Gebruder Borntraeger.
6. Sedimentary Petrology by Tucker, M. E., 1991, Blackwell Publications.
7. Principles of sedimentary Basin Analysis by Andrew D. Mial, 1990, Springer-Verlag, New York Inc.
8. Stratigraphy and Historical Geology of Pakistan by Kazmi, A. H and Abbasi, I. A., 2008, Graphic Publishers, Karachi, Pakistan.

Course Title: **Quaternary Geology**
Number of Credits: **3(2+1)**
Course Type: **Elective**
Prerequisite: **Nil**

Objectives and Learning Outcome:

This course will enable the students to acquire knowledge about Quaternary environments, stratigraphy and deposits of Pakistan, soil characteristics and stratigraphy, Dating methods and Quaternary deposits of Pakistan and its importance.

Course Contents:

The Quaternary period: Character, duration, development and climatic changes; soil characteristics; soil stratigraphy; morphological evidence and landforms; Quaternary environments; Pleistocene glaciation and sea level changes; lithological evidence of environments; types of sediments; isotopes in deep-sea sediments; biological evidence; plant fossils and animal remains; dating methods; Quaternary stratigraphy and correlation; Quaternary geology, geochronolgy and neotectonics; Quaternary deposits of Pakistan and its importance (alluvial, fluvial, colluvial, lacustrine, glacial and eoline deposits)

Labs:

Sampling techniques; assignments on specified topics/field visits to study Quaternary geology.

Recommended Books:

1. Principles of Geomorphology by Thornbury, W. D., 1991, Wiley Eastern Ltd.

2. Quaternary Geology and Environment by Jean, A. M., 2002, Publisher Springer.
3. Glacial and Quaternary Geology by Richard Fester Flint, 1971, Amazon Books.
4. Quaternary Geology for Scientists and Engineers by John, A. Catt., 1988, Amazon Books.
5. Quaternary Environments by John J. Lowe, Mick J. C. Walker, 1997, Amazon Books
6. Quaternary Geology: a stratigraphy framework for multidisciplinary work by Brown, D. O., 1978, Publisher Pergamon Press.
7. Quaternary Geochronology: Methods and Applications by Noller, J. S., Lethis, L. R., and Soweri, J. M., 2000, American Geophysical Union.
8. Geology and Tectonics of Pakistan by Kazmi, A. H. and Jan, Q., 1997, Graphic Publishers.
9. Geology of Pakistan by Bender and Raza, (ed.) 1995, Gebruder Borntraeger.
10. Late Quaternary Geology of India and See level changes by Noraxema, A. C., 2002, Geological Society of India.

GROUP-VIII: HYDROGEOLOGY

Objectives:

Advanced level courses have been designed in this group of specialization. These courses will enable the students to fully understand (1) the ground water modeling techniques and management, (2) the techniques for ground water exploration, (3) the ground water engineering and (4) the ground water chemistry and contamination. After completing these courses, the students will be able to carry out their independent research related to ground water modeling, aquifer identification and contamination of ground water.

This group comprises the following courses:

1. Hydrogeology
2. Groundwater Investigations
3. Groundwater Engineering
4. Chemical Hydrogeology

Course Title: **Hydrogeology**
Credit Hours: **3(2+1)**
Course Type: **Elective**
Prerequisite: **Nil**

Course Objectives and Learning Outcomes:

The objective of the course is to understand hydrogeological cycle, its parameters and relationship with surface and sub surface water resources, to understand the laws for ground water flow modeling and its impact on geology and to analyse different ground water problems and to evaluate hydraulic properties of geological materials.

Course Contents:

Hydrological cycle; surface and groundwater occurrences; recharge and discharge, catchment area and its distribution, surface water flow, Darcy law, hydraulic conductivity, groundwater flow, effect of geology in groundwater flow, water storage types of aquifer, methods of estimating recharge and discharge; physical and mathematical description of groundwater problems; flow nets, tube wells, drains and ditches; consideration of time-variant flow and steady-state flow; field and laboratory measurements of hydraulic properties of different geological materials; groundwater modeling techniques and resource management; soil water balance and water budget estimate of aquifers.

Labs:

Measurement of hydrogeologic properties of water-bearing formations; practical applications of mathematical ground water model.

Recommended Books:

1. Groundwater and Wells by Driscoll, F. G., 1989. Johnson Filtration System Inc. St. Paul.
2. Groundwater Hydrology by Todd, D. K., 1980, John Wiley and Sons.
3. Groundwater by Freeze, R. A. and Cherry, J. A., 1979, A. Simo and Schuster Company.
4. Principles of Hydrology by Ward, R. C. and Robinson, M., 1990, McGraw-Hill Book Company.
5. Physical and Chemical Hydrogeology by Domenico and Schwartz, 1996, John Willey and Sons.
6. Applied Hydrogeology, Fetter, C. W., 2000, 4th Ed. Englewood Cliffs, NJ: Prentice-Hall.
7. Introducing Grounds Water by Price, M., 1995, Allen and Unwin.
8. Hydrogeology, Principles and Practice by Geofluids, S. Q. L., 2005, Blackwell Synergy
9. Introduction to Hydrogeology by Geofluids, H., 2003, Blackwell Synergy.

Course Title: **Groundwater Investigation**
Credit Hours: **3(2+1)**
Course Type: **Elective**
Prerequisite: **Nil**

Course Objectives and Learning Outcomes:

The aim is to understand and explain ground water problems in site selection and construction of different structures, to analyze the principle and techniques of dewatering and its effects, to appraise the ground water flow analysis and ground subsidence related to ground water abstruction and to choose the remedial measures for ground water engineering hazards.

Course Contents:

Groundwater exploration techniques, geological and hydrogeological maps, aerial photographs and satellite imageries; use of various geophysical methods in groundwater exploration; the application of surface geophysical surveying to groundwater problems including identification of aquifer geometry, aquifer properties and water quality; principles and application in hydrogeology of well logging techniques.

Labs:

Field survey and interpretation of available data.

Recommended Books:

1. Field Hydrogeology by Braissington, R., 1998, John Wiley and Sons.
2. Groundwater Resource Evaluation by Walton, W. C., latest Ed., McGraw-Hill Kogakusho, Ltd.
3. Groundwater and Wells by Driscall, F. G., 1989, Johnson Filtration System Inc. St. Paul.

Course Title: **Groundwater Engineering**
Credit Hours: **3(2+1)**
Course Type: **Elective**
Prerequisite: **Nil**

Course Contents:

Groundwater problems in site selection and construction of dams and other huge structures; geotechnical logging and grouting techniques; groundwater table and its flow into excavations; the principles and applications of dewatering; the effect of groundwater on soil and rock strength; deep aquifers testing and groundwater flow analysis into underground workings; hydrogeology of mining areas; the analysis of ground subsidence related to groundwater abstruction. Groundwater engineering hazards and its remedial measures.

Labs:

Case studies related to dam sites and tunnels.

Recommended Books:

1. Engineering Hydrology by Wilson, E. M., 1991, MacMillan Education Ltd.
2. Field Hydrogeology by Brassington R. 1988, John Wiley and Sons.
3. Groundwater by Freeze, R. A., and Cherry, J. A., 1979, A Simon and Sechuster Company.

Course Title: **Chemical Hydrogeology**
Credit Hours: **3(2+1)**
Course Type: **Elective**
Prerequisite: **Nil**

Course Contents:

Properties and constituents of water; laws of chemistry related to water and its reaction with the aquifer matrix; principles and processes controlling composition of natural water; water-quality standards (EPA), methods of water sampling and analysis; presentation, evaluation and interpretation of water analysis data (piper and trilinear diagram, stiff pattern); sources, nature and effects of groundwater contamination; mass transport of solutes and chemical processes occurring in aquifers; septic tanks and cesspools, landfills, chemical spills and leaking underground tanks, nuclear waste, groundwater contamination prevention and remedies; monitoring wells, water treatment and techniques for the removal of physical, biological and chemical contaminants; saline intrusions in coastal and estuarine sediments.

Labs:

Groundwater sampling for chemical analysis; graphic presentation of chemical analysis data; preparation of subsurface hydrochemical maps; identification of the source and extent of contamination.

Recommended Books:

1. Domestic Water Treatment by Lehr, J. H., Grass, T. E. Pettyjohn. W. A. and Marie, J. De., 1988, National Water Well Association Ohio.
2. Ground Water and Wells by Driscall, F. G., 1989, Johnson Filteration System Inc. St. Paul.
3. Study and Interpretation of the Chemical Characteristics of Natural Water by Hem, J. D., 1992, US Geological Survey Water.
4. The Global Water Cycle by Berner, F. K., and Bernes, R. A., 1987, Prentice Hall.
5. *Contaminant Hydrogeology*, Fetter, C. W., 1999. 2nd ed, Upper Saddle River, NJ: Prentice Hall.

GROUP-IX: MARINE GEOLOGY (3 credit hours)

Objectives:

Advance level courses have been designed in this group of specialization. These courses will enable the students to fully understand (1) the classification of marine environment, (2) what dynamic processes shape the surface of the earth under the ocean surface. (2) the sea level changes through time and sedimentation processes, (3) the coastal landforms and delta development, (4) physiographic features and management of offshore environment of Arabian Sea, (5) the role of geology in evolution of coastal zones and morphodynamics. After completing these courses, the students will be able to carry out their independent research in the field of oceanography.

This group comprises the following courses:

1 . Marine Geology
2. Oceanography
3. Marine Geochemistry
4. Geology of Arabian Sea

Course Title: **Marine Geology**
Credit Hours: **3(2+1)**
Course Type: **Elective**
Prerequisite: **Nil**

Course Contents:

Development of marine geology, contribution of deep sea drilling project (DSDP) and ocean drilling program (ODP); hypsometry, topographic features of the ocean; plate tectonics and sea floor spreading, major ocean basins, gulfs and seas; geology of continental margins, estuaries, deltas, barrier islands and coral reefs; sediment types and distributions, shelf sedimentation, oxygen and strontium isotope, deep sea sedimentation; methods and instrumentation in marine geology; world wide sea level changes through time. Introduction to marine geology of Pakistan.

Labs:

Exercises of marine charts, navigation and bathymetry, acoustic seismic profiling, geography of the marine environments, sea floor spreading and plate tectonics and marine sediments.

Recommended Books:

1. Marine Geology: A planet Earth Perspective by Anderson, R. N.,1986, New York: John Wiley.
2. A Work book in Oceanography by Dudley, W. C and Min Lee, 1982 Alpha Editions, A division of Burgess Publishing Co. Minnesota.
3. Marine Geology by James P. Kennett, 1982, Prentice-Hall, INC, Englewood Cliffs, N.J.
4. Initial Reports of the Deep Sea Drilling Project, 1975, Vol. 29/ 32/ Washington, D. C.; U. S. Government Printing Office.
5. The submerged continental margin by McGregor, B. A.,1984, American Scientist 72 (3): 275-81.
6. The Ocean Basins and Margins by Nairn, A. E. M and Stehli, F. G., 1973, the South Atlantic. Plenum, New York.
7. Oceanography, an introduction to the planet oceanus by Pinet Paul R. 1992, West publishing company, New York.
8. Laboratory Exercises in Oceanography, 2nd Edition by Popkin, B. W, Grosline, D. S and Hammond, D. E., 1987, W. H. Freeman and Company. New York.
9. The Sea Floor: An In Introduction to Marine Geology by Seibold, E. and Berger, W. H., 1993, Heidelberg, Germany: Springer-Verlag. 2nd edition.
10. Oceanography by Gross, M. G., 1986, Prentice Hall.

11. Submarine Geology by Shepard, P. P., 1983, Harper and Row.
12. Essentials of Oceanography by Thurman, H. V., 1983, Mecill.

Course Title: **Oceanography**
Credit Hours: **3(2+1)**
Course Type: **Elective**
Prerequisite: **Nil**

Course Contents:

Chemical and physical nature of seawater; temperature, salinity and density of sea water; oceanic heat budget; mixing processes in the oceans; light and sound in the ocean; gases in seawater; oceanic circulation: surface circulation and thermohaline circulation, ENSO and Indian monsoon; coastal and ocean upwelling, upwelling zones and ocean sedimentary record; ocean waves and tides; sea level changes, coastal oceanography: shorelines and estuaries, continental shelf and its water; sources of marine energy: waves, tides, current and OTEC. Oceanographic tools and technology; the law of the sea.

Labs:

Solar radiation and heat balance, seawater temperature and salinity, water masses and temperature–salinity diagrams, surface currents, tides, waves, shallow water waves and coastal processes.

Recommended Books:

1. Coastal Environnements by Carter, R. W. G, 1988, Academic Press. London.
2. A Work book in Oceanography, Dudley, W. C and Min Lee, 1982, Alpha Editions, A division of Burgess Publishing Co. Minnesota.
3. The Sea by Emiliani. C. 1981, John Wiley. New York.
4. Sea water: Its Composition, Properties and Behavior by Gerry, B., 1989. Pergamon Press plc Oxford and Open University Walton Hall, Milton, England.
5. Oceanography, An Introduction to the planet Oceanus by Pinet, Paul R. 1992, West Publishing Company, New York.
6. Laboratory Exercises in Oceanography by Popkin, B. W, Grosline, D. S and Hammond, D. E., 1987, 2nd Edition. W. H. Freeman and Company. New York.

Course Title: **Marine Geochemistry**
Credit Hours: **3(2+1)**
Course Type: **Elective**
Prerequisite: **Nil**

Course Contents:

The geochemical cycle and the composition of ocean water; the transport of material to ocean, nutrients, organic carbon and carbon cycle in seawater; trace elements in the ocean, residence time and reactivity of elements; the

composition of oceanic suspended matter; the geochemistry of marine sediments, sediment interstitial waters and diagenesis; organic matter production, accumulation and preservation; marine carbonates; isotopes in marine geochemistry; chemical characteristics of hydrothermal vent fluids; geochemistry of ferromanganese deposits in the ocean; geochemical proxies and global environmental history; pollution in the sea; geochemical models.

Labs:

Exercises dealing with determination of salinity, residence time and reactivity of major elements, calculation of chemical fluxes, paleoproductivity, interpretation of geochemical proxies; geochemical analysis of marine sediments.

Recommended Books:

1. Tracers in the sea by Broecker, W. S., Peng, T. H., 1982, Eldigio, Palisades.
2. Marine Geochemistry by Chester, R; 1990, Chapman and Hall, London.
3. Particle Flux in the Ocean by Ittekkot and et al (eds) 1996, Wiley and Sons. New York.
4. Sea water: Its Composition, Properties and Behavior by Gerry, B., ed, 1989, Pergamon Press plc Oxford and Open University Walton Hall, Milton, England.
5. Methods of Seawater Analysis, Grasshoff, K., Kremling, K. and Ehrhardt, M., 1999, Wiley-VCH, New York.
6. Ocean Biogeochemical Dynamics by Sarmiento, J. L. and N. Gruber, 2006, Princeton University Press
7. Marine Geochemistry by Schulz, H. D., and Zabel, M. (eds), 2002, Springer.
8. Coastal Upwelling: Its sedimentary record, Part B: Sedimentary records of ancient coastal upwelling by Thiede, J and Suess, E (eds), 1983, Plenum Press. New York.
9. Modern and ancient continental shelf anoxia by Tyson, R. V and Pearson, T. H. (eds); 1991, Geol. Soc. Spec. Publ; 58, Blackwell, Oxford.
10. Organic matter: Productivity, Accumulation and Preservation in Recent and Ancient Sediments by Whelan, J. K and Farrington, J. W. (eds), 1992, Columbia University Press. New York.

Course Title: **Geology of Arabian Sea**
Credit Hours: **3(2+1)**
Course Type: **Elective**
Prerequisite: **Nil**

Course Contents:

Geological evolution of Arabian Sea; geology of the coastal regions of Arabian Sea; physiographic and structural features of Arabian Sea; geodynamics and sedimentation of Makran and Indus continental margins; geology of the Indus

delta and Indus fan systems; geology of DSDP and ODP-well sites from Arabian Sea; seismic stratigraphy of the northern Arabian Sea; mineralogy and geochemistry of Arabian Sea sediments; Sea level changes, oxygen minimum zone variations and its influence on Arabian Sea sediments; sedimentary record of climatic variations and Himalayan orogeny; offshore hydrocarbon and mineral resource prospects. Case study of drilled wells.

Labs:

Selected exercises based on National and International Geological Research Cruises data of Arabian Sea**.**

Recommended Books:

1. Marine Geology and Oceanography of Arabian Sea and Coastal Pakistan by Haq, B. U. and Milliman, J. D. (eds) 1984, Van Nostrand Reinhold, New York.
2. Initial Reports of the Deep Sea Drilling Project, 1975. Vol. 23 by Whitmarsh, R. D; et al., (eds) 1975, Washington, D. C; U. S. Government Printing Office.
3. Trench and Fore-arc Geology: Sedimentation and Tectonics on modern and Ancient active Plate margin by Legget, J. K. (ed) 1982, Blackwell Scientific. Oxford.
4. The Indian Ocean by Nair, A. E. M. and Stehli, F. G (eds) Plenum, New York.
5. The Tectonic and Climatic Evolution of the Arabian Sea Region by P. D. Clift, D. Kroon, C. Gaedicke and J. Craig; 2005, Geological Special Publication No.195.
6. Seismic Facies and Sedimentary Processes of Submarine Fans and Turbidite Systems by Weimer, P and Link, M. H., (eds) 1991, Springer, New York.

GROUP-X: ENVIRONMENTAL GEOSCIENCES

Objectives:

Advanced level courses have been designed in this group of specialization. These courses will enable the students to fully understand (1) the geological hazards and their management, (2) global warming, (3) soil and water chemistry, (4) anthropogenic and geologic sources of contamination, (5) environmental impact assessment and management. After completing these courses, the students will be able to carry out their independent research related to degradation of ecosystem through natural and industrial pollution.

This group comprises the following courses:

1. Environmental Geology II
2. Soil and Water Resources
3. Environmental Hazards
4. Water Resources and Environments
5. Environmental Impact Assessment and Management

6. Natural Resources Management
7. Occupational Health and Safety
8. Environmental Geochemistry
9. Geospatial Techniques in Geology

Course Title: **Environmental Geology II**
Credit Hours: **3(2+1)**
Course Type: **Elective**
Prerequisite: **Nil**

Objectives and Learning Outcomes:

The main objective is to understand different principals to environmental management, to identify different natural hazards, their causes and their mitigation, to recommend different environmental controls for erosion, desertification and its impacts on mining, dams, reservoirs and highways.

Course Contents:

Environmental management (effective management for exploitation of geology resources with the impact that this may cause on environment; appropriate waste disposal strategies to minimize the problems of contamination and pollution); recognition of natural hazards and identifying their causes and providing their mitigation; environmental controls for erosion, desertification coastal degradation; environmental impact of mining, dams, reservoir, highways their assessment and control; understanding the geological environments in major construction and engineering projects; national environmental quality standards (NEQS); initial environmental examination (IEE) and environmental impact assessment (EIA); international convention and protocols for environmental protection; Environmental Protection Agency (EPA); Case Studies.

Labs:

Case studies based on EIA reports.

Recommended Books:

1. Manual of Environmental Laws in Pakistan with guideline for development of green belts and International Conventions Protocols by Badar-ul-Amir, edition 2006, Khyber law Publishers, Lahore.
2. Pakistan's Environmental laws and their compliance, by Qadar, S. and Dogar, A. R., 2002, Lahore Law Times Publications.
3. Environmental Law by Malik, S., 2008 Eastern Book company Publishing (P) Ltd, Lucknow, India.
4. LAL'S commentary on Water and Air Pollution with environment, Revised by Mc Mehta, 4th edition, Vol 1 and 2, 2007 Delhi Law house Delhi , India
5. Environmental geology by Keller, E: A., 2000, Charles E. Merrill Publishing Co.
6. Environmental geology by Montgomery, C. W., 2005, McGraw-Hill.

7. The Encyclopedic Dictionary of Environmental change by John A. Mathews, 2003, Oxford University Press.

Course Title: **Soil and Water Resources**
Credit Hours: **3(2+1)**
Course Type: **Elective**
Prerequisite: **Nil**

Objectives and Learning Outcomes:

The main objective is to explain different types of soil and its relation to erosion, landforms and land use, to understand global warming and its effect on ecological system and to analyze ground water movement, water logging and its associated problems.

Course Contents:

Soil and its classification; types; soil erosion, landform and land use; predicting and controlling soil erosion; soluble salts in soils; aerosol particulate matter; hydrological system and agriculture; source of water resource and its types; natural water resources and policy making; hydrological cycle; frozen water reserves; global warming and surface water resources; surface water storage and ecological system; ground water movement; water logging and salinity.

Labs:

Case studies based on Soil and water analysis.

Recommended Books:

1. Global Environmental Charges by Moore, P. D., 1996. McGraw-Hill.
2. Air Pollution and Engineering Management by Davis, W. T., 2000. John Wiley and Sons.
3. Environmental Chemistry of Soil by Murray B. M.,1994, Oxford, University Press.

Course Title: **Environmental Hazards**
Credit Hours: **3(2+1)**
Course Type: **Elective**
Prerequisite: **Nil**

Objectives and Learning Outcomes:

The objectives of the course are to understand flooding and its effects, to evaluate the causes of landslides and its remedial measures, to evaluate the effects of natural hazards on socio-economic conditions of the country and worldwide and to appraise health standards and legislations on global environment.

Course Contents:

Information on river flooding and flood control; effects on agro-economy,

slope stability in hilly areas; types of landslides; their causes and remedial measures; methods of analysis of slopes; landslide inventory mapping, information on landslides and their effects on socio-economic conditions; study of case histories in Pakistan and abroad; snow avalanches; subsidence mechanism and related problems; earthquake and tsunami hazards; hazardous minerals in mining; solid and liquid waste management; safety and health standards; legislations; regulations and controls; effect on global environment; Hazards of nuclear waste assessment and its remedies.

Labs:
Case studies based on slope stability and mining activities.

Recommended Books:
1. Environmental Geology by Montgomery, C. W., 1986, Wm.C. Brown Publishers.
2. Geology and Hazardous Waste by Hussain, S. E., 1996, Prentice Hall.
3. Earthquake Risk and Damage by Liu, B. C., 1981, Westview.

Course Title: **Water Resources and Environment**
Credit Hours: **3(2+1)**
Course Type: **Elective**
Prerequisite: **Nil**

Course Contents:
Surface and groundwater resources, precipitation, evaporation, erosion and silting in catchment areas and reservoirs (dams); surface and groundwater contamination and their sources; effect of mineralogy, mining activities, industrial effluents; heavy metal concentration; contamination due to chemicals and sewage systems; decomposable organic matter and pollutant agents (industrial and agricultural fertilizers etc.); dissolved gases, minerals and suspended impurities in surface and groundwater; biological contamination (viral, bacterial, protozoa and helminthes).

Labs:
Case studies based on EIA reports and visits to the industrial sites.

Recommended Books:
1. Groundwater Contamination by Badient, P., 1999, Prentice Hall.
2. Municipal Sewage sludge by Cecil, D., 1992, Technomic Publishing Co.
3. Sources and Fates of Aquatic Pollutants by Ronald A. Hites, 1987, Oxford University Press.

Course Title: **Environmental Impact Assessment and Management**
Credit Hours: **3(2+1)**
Course Type: **Elective**
Prerequisite: **Nil**

Course Contents:

Reclaimation of agricultural land, landfill and land use, socio-economic uplift, underground drainage system, installation of tube wells and canal lining, vegetation, rock bolting, grouting; identification of environmental hazards and evaluation of risks, slope and flood control instrumentation gauges, extensometers and tilt meters etc. disposal of industrial and radioactive wastes; environmental impact assessment with special reference to Pakistan; effect of earthquakes on environment and its assessment and management.

Labs:

Case studies based on Environmental Impact Assessment with special reference to Pakistan.

Recommended Books:

1. Solid Waste Management by Grever, V., 2000, Oxford and IBH (Ltd.).
2. Environmental Management by Mukharjee, B., 2000, Vikas Publishing Hon.
3. Environmental Assessment by Singleton, R., Castle, P., and Short, D., 1999, PB Kenedy (Donlin Ltd.).
4. Global Change in the Holocene by Anson Mackay, 2005, Oxford University Press.
5. Tectonic Boundary Conditions for Climate Reconstruction by Thomas J. Crowly, 1998, Oxford University Press.

Course Title: **Natural Resouces Management**
Credit Hours: **3(2+1)**
Course Type: **Elective**
Prerequisite: **Nil**

Course Contents:

Introduction to natural resources and their sustainable management; requirements of a management plan; forest types and methodologies of watershed management; existing status of rangeland management; existing situation of wildlife at national level; wildlife census; threats faced by wildlife; available water resources and threats; effective management plan; fisheries management, existing situation of agricultural sector; agricultural products and their share in GDP; problems faced by agricultural sector; agricultural policy and management options.

Labs:

Case histories and case studies of natural parks of Pakistan; visit to natural parks, identification of park problems, managing and sustaining natural parks,

establishing, designing, and managing natural reserves, ecological restoration.

Recommended Books:

1. Principle of Environmental Science (Inquiry and Applications) by William P., 2006, Cunningham and Mary Ann Cunningham.
2. Living in the Environment by Miller Jr. G. T., (12th Edition, 2002).
3. Natural Resource Conservation by Trivedi, P. R., (1st Edition, 2004)
4. Crop Production by Nazir, S. (1st Edition, 1999)

Course Title: **Occupational Health and Safety**
Credit Hours: **3(2+1)**
Course Type: **Elective**
Prerequisite: **Nil**

Course Contents:

Introduction, concepts, importance and principles of occupational health and safety; cost of accidents; hazards and risk at work place; plants and mines safety and safe work practices; fire fighting techniques; emergency response protocols; spill response protocols; risk assessment approaches; occupational health and safety management system 18001; occupational health and safety in Pakistan; labor code of Pakistan.

Labs:

Visits to various industries for hazard identification, evaluation, assessment and mitigation in order to reduce the damage; internship in various industries for learning practical approach of occupational health and safety.

Recommended Books:

1. Basics of industrial hygiene, by Nims, D. K., 1999, John Wiley and Sons,
2. Fundamentals of Industrial Hygiene by. Plog, B. A. and Quinlan, P. J., 2002, National Safety Council Press.
3. Practical Guide to Occupational Health and Safety by Erickson, P. A., 1996, Elsevier Science (USA).

Course Title: **Environmental Geochemistry**
Credit Hours: **3(2+1)**
Course Type: **Elective**
Prerequisite: **Nil**

Objectives and Learning Outcomes:

The objectives of the study are to understand abundance of elements in the surficial environment, to understand mechanism of flow of geochemical substances in the surface and subsurface environment and its hazardous effect on human health and to apply different sampling methods for collecting water and soil samples.

Course Contents:

Introduction to Environmental Geochemistry, Elements Abundance (Environment, Lithosphere, Hydrosphere, Atmosphere, Biosphere), Absolute and relative abundance of elements in the Four Geosphere, Partial abundance of elements, Hydrologic Cycle, Elements migration, Geochemical landscape classification, Geochemical flows in landscape, geochemical gradients, ecological gradients, chemical equilibrium, organic chemistry, water, waste water treatment, water and soil chemistry, Atmospheric chemistry, common pollutants, chemical equilibrium, field methods in regional geochemical surveys, Contaminated Groundwater Sampling, Drainage Samples for Environmental Analyses.

Lab:

Basic problems associated with daily life.

Recommended Books:

1. Eby, G. N. (2016). Principles of environmental geochemistry: Waveland Press
2. Fortescue, J. A., (2012). Environmental geochemistry: A holistic approach (Vol. 35): Springer Science & Business Media.
3. Alpers, C. N. and Blowes, D. W., (1993). Environmental geochemistry of sulfide oxidation: ACS Publications.
4. Andrews, J. E., Brimblecombe, P., Jickells, T. D., Liss, P. S., and Reid, B. (2013). An introduction to Environmental Chemistry: John Wiley & Sons.
5. Manahan, S. E., (1993). Fundamentals of environmental chemistry.

Course Title: **Geospatial Techniques in Geology**
Credit Hours: **3(2+1)**
Course Type: **Elective**
Prerequisite: **Basic Understanding of Remote Sensing and GIS**

Objectives and Learning Outcomes:

This course gives an introduction to geological, regolith and soil remote sensing in the application of earth resources mapping.

Course Contents:

Map projections, coordinate systems, GIS data acquisition and integration, Geospatial analysis, Terrain Modeling and Analysis, Modeling of Geospatial Processes, modeling of landscape processes, GIS for petroleum and natural resources. Aerial Photography, color science, Multispectral remote sensing, Earth Resource Satellites, Ultraviolet and thermal infrared remote sensing, Calibration, Registration and Topographic Correction, Hyper spectral remote sensing, Digital Image processing: Classification and change detection, Applications of Remote Sensing in Hydrogeology, structural geology, petrology, mineral exploration, water resource management, petroleum geology, envoimental monitoring etc .

Lab:

Mapping techniques, Building geo database, Projection systems, Data integration, Surface hydrology project, Groundwater project, ENVI intro, Intro to spectroscopy, Image analysis and interpretation techniques of multispectral and Hyper spectral imagery, Image classification and change detection Lab.

Recommended Books:

1. GIS Fundamentals, 4E, 2012, by Paul Bolstad, http://www.paulbolstad.net/gisbook.html.
2. Geographic Information Systems and Science 4E, 2015 by Paul A. Longley, Mike Goodchild, David J. Maguire, David W. Rhind, Wiley.
3. Introductory Geographic Information Systems 1E, 2012 by John R Jensen and Ryan R. Jensen, Prentice Hall.
4. Fundamentals of GIS by M. Demers, John Willey & Sons Inc., (4th edition, 2009).
5. Remote Sensing of the Environment: An Earth Resource Perspective by J. Jensen, Prentice -Hall, 2007.
6. Introductory Digital Image Processing: A Remote Sensing Perspective, 4th edition J. Jensen, Prentice-Hall, Inc. 2014.
7. Fundamentals of Satellite Remote Sensing by Chuvieco & Huete, 2010
8. Remote Sensing Geology by Gupta, Ravi P, 2003, ISBN 978-3-662-05283-9
9. Fundamentals of Geological and Environmental Remote Sensing 1st Edition by Robert K., Jr. Vincent, ISBN-13: 978-0133487800
10. Remote Sensing for Environmental Monitoring, GIS Applications, and Geology, ISBN 0819442704, 9780819442703, Publisher, SPIE, 2001.

GROUP- XI: STRUCTURE, TECTONICS AND NEOTECTONICS

Objectives:

Advanced level courses have been designed in this group of specialization. These courses will enable the students to fully understand (1) the deformational structures and their kinematics in the crust, (2) fabric development in metamorphic rocks, (3) projections and structural analysis, (4) the cross-sectional balancing, (5) the Himalayan orogeny, (6) tectonic zonation of Pakistan and (7) neotectonics behavior of various structural features. After completing these courses, the students will be able to carry out their independent research in the field of structural geology and tectonics.

This group comprises the following courses:

1. Structural Geology II
2. Metamorphic Structures
3. Applied Structural Techniques
4. Tectonics of Pakistan
5. Neotectonics

Course Title: **Structural Geology II**
Credit Hours: **3(2+1)**
Course Type: **Elective**
Prerequisite: **----------**

Objectives and Learning Outcomes:

To enable the students, revise the basic concepts and learn about advance methods of structural geology with their application to stress, deformation, mineral exploration and geohazard assessment.

Course Contents:

Stress and strain; planar and linear fabrics: analyses of fabrics, axial plane foliations/cleavages and their types and origin, transposed foliations, lineation types and origin; fabrics as kinematics indicators; structures in folded rocks: fold morphology and classifications, mechanisms of folding, strain and small scale structures in folds, superposed folding; fault geometry and morphology: classification of fault systems, geometry of 1) extensional, 2) strike slip and 3) thrust fault systems; fractures and joints**:** mechanical analyses of fractures; ductile and brittle shear zones; sense of shear indicators, strain markers, strain measurement methods, geometric and genetic classification of joints, analyses of joints in uniformly dipping strata and in folded rocks; tectonites; structural techniques and retrodeform sections.

Labs:

Structural map exercises; balanced cross-sections; fault plane solutions; stereographic exercises; structural software exercises.

Recommended Books:

1. Structural Geology by Hatcher, R. D., 1995, Prentice Hall.
2. Structural Geology of Rocks and Regions by Davis, G. H. and Reynolds, S. J., 1996, Wiley
3. Structural Geology by Twiss, R. J. and Moores, E. M., 1992, Freeman.
4. An Outline of Structural Geology by Hobbs, B. E., Means, W. D. and Williams, P. F., 1976, John Willey and Sons.
5. Principals of Structural Geology by Suppe, J., 1985, Prentice Hall.
6. The Techniques of Modern Structural Geology. V. I Stress and Strain by Ramsay J. G. and Huber, M. I., 1983, Academic Press.
7. The Techniques of Modern Structural Geology. V.II Folds and Fractures by Ramsay J. G. and Huber, M. I., 1987, Academic Press.
8. Appropriate Structural Computer Software.

Course Title: **Metamorphic Structures**
Credit Hours: **3(2+1)**
Course Type: **Elective**
Prerequisite: **----------**

Objectives and Learning Outcomes:

To enable the students, learn about microstructures for an understanding of stress and deformation through historical times.

Course Contents:

Microstructures in deformed and metamorphosed rocks; crystal defects, crystal plasticity, dislocations; annealing recrystallization, recovery, primary and secondary recrystallization, dynamic recrystallization, stress induced recrystallization, strain induced recrystallization and associated microstructures; driving forces for dynamic recrystallization; dynamic recrystallization by subgrain rotation and grain boundary migration; controls on migration rates. Ductile shear zones; mylonites, terminology; microstructures, planar and linear ductile fabric and kinematic indicators; petrofabrics: factors controlling fabric development, fabric representation-pole and inverse pole figures, orientation distribution functions; measuring techniques, pressure solution and metamorphic differentiation; cataclastic deformation; sense of shear indicators; strain markers; strain analysis.

Labs:

Microscopic studies of metamorphic textures and structures.

Recommended Books:

1. Structural Analyses of Metamorphic Tectonites by Turner, F. J and Weiss, L. E., latest Ed., 1963, McGraw-Hill.
2. The Study of Fabrics of Geological Bodies by Sander, B., latest Ed., 1966, Pergamon Press.
3. Metamorphic Textures by Spry, A. H., latest Edition., 1969, Pergamon Press.
4. Techniques of Modern Structural Geology. V. I Stress and Strain by Ramsay J. G. and Huber, M. I., 1983, Academic Press.
5. The Techniques of Modern Structural Geology. V.II Folds and Fractures by Ramsay J.G. and Huber, M.I., 1987, Academic Press.

Course Title: **Applied Structural Techniques**
Credit Hours: **3(2+1)**
Course Type: **Elective**
Prerequisite: **----------**

Objectives and Learning Outcomes:

To enable the students, learn about techniques of structural analysis for statistical analysis of structural features with application to mining, mineral, petroleum exploration, and geohazard assessments.

Course Contents:

Structural techniques: measurement of attitude and location, contour maps, attitude and dimension calculations, stereographic projections, stereographic poles and rotations; calculation of layer attitudes in drill holes. Equal area projections and structural analyses; practical strain measurements of 1) initially circular and elliptical markers, 2) lines and 3) angles, methods and representation of strain state; progressive displacement and progressive deformation. interpretation of geological maps; analyses of fracture array geometry; constructing profiles and block diagrams; balanced cross section techniques; Kinematic analysis and indicators.

Labs:

Exercises based on course contents.

Recommended Books:

1. Applied Subsurface Geological Mapping by Tearpook, D. J. and Bischke, R. E., 1991, Prentice Hall.
2. Basic Methods of Structural Geology by Marshak, S. and Mitra, S., 1988, Prentice Hall.
3. The Techniques of Modern Structural Geology by Ramsay, J. G. and Huber, M. I., 1983, Volume 1: Strain Analyses. Academic Press.
4. The Techniques of Modern Structural Geology by Ramsay, J. G. and Huber, M. I., 1987, Volume II: Folds and Fractures. Academic Press.
5. Structural Geology, an Introduction to Geometric Techniques by Ragan, D. M., 1985, John Willey and Sons).
6. Principals of Structural Geology by Suppe, J. 1985, Prentice Hall.

Course Title: **Tectonics of Pakistan**
Credit Hours: **3(2+1)**
Course Type: **Elective**
Prerequisite: **----------**

Objectives and Learning Outcomes:

This course is designed to acquire the knowledge about the tectonics of Pakistan. This will help the students to learn about structural framework and seismicity across Pakistan to understand regional deformation, earthquake hazards, mineral and petroleum exploration.

Course Contents:

Concept of Rodania, Pangea and Gondwana supercontinents; Permian separation of Afghan, Pamirs, Karakoram, Lahasa microcontinents, closure of Palaeotethys and accretion tectonics at Eurasia's southern margin; early Cretaceous split and northward flight of India, closure of northern Neotethys and collision tectonics of the Shyok Suture; Himalayan orogeny; constraints on the timing of India-Eurasia collision; resultant physiography, structures, metamorphism, climatic changes; tectonic zonation of Pakistan:

each zone to be studied in terms of its geomorphology, tectonics, stratigraphy, metamorphism, magmatism and mineral deposits. Karakoram plate; Kohistan-Ladakh Island Arc Terrane; the Himalayas: internal and external zones; Swat, Besham, Hazara, Kaghan (Nanaga Parbat) blocks; the Hill ranges (Samana, Kalachitta, Margala, Galiats). Kohat-Potwar plateaus and the Salt Ranges; the boundary faults and related tectonics: MMT, MCT, PANJAL THRUST, MBT, MFT. Afghan-India collision zone: Indus, Kurram-Waziristan- Muslim Bagh-Bela Ophiolite/Melange belt. Sulaiman-Kirthar thrust-fold belt; Katawaz basin; Makran accretionary prism; Raskoh-Chagai Arc Terrane. Indus platform and foredeep; offshore Pakistan: the Indus delta. Syntaxes and orocline of Pakistan; Precambrian to Recent tectonics of Pakistan; Tertiary Himalayan orogeny and Late Proterozoic to early Cambrian Hazaran orogeny. Makran Subduction, Arabian Sea tectonics, tectonics of passive margin of Indian plate.

Field Visits:

The field work in tectonic zones of Pakistan

Recommended Books:

1. Geology and Tectonics of Pakistan by Kazmi, A. H. and Jan, M. Q., 1997, Graphic Publishers.
2. Precambrian to Early Paleozoic Orogenesis in the Himalaya, Baig, M.S., and Lawrence, R. D., 1987, Kashmir Journal of Geology, V.5, p.1-22.
3. Evidence for late Precambrian to early Cambrian orogeny in northwest Himalaya, Pakistan.
4. Baig, M. S., Lawrence, R. D., and Snee, L. W., 1988, Geological Magazine, London, V. 125, No. 1, p. 83-86.
5. Timing of pre Himalayan orogenic events in the northwest Himalaya: 40 Ar/ 39 Ar constraints. Kashmir Journal of Geology, Baig, M. S., Snee, L. W., La Fortune, R. J., and Lawrence, R. D., 1989, V. 6 and7, p. 29-40.
6. Geochronology of pre-Himalayan and Himalayan tectonic events, northwest Himalaya, Pakistan, Baig, M. S., 1991, Kashmir. Kashmir Journal of Geology, V.8 and 9, p. 197**.**
7. Geology of Pakistan by Bender and Raza, (ed.) 1995, Gebruder Borntraeger.
8. Geodynamics of Pakistan Farrah, A., and DeJong, K., 1979, Geological Survey of Pakistan.
9. Himalayan Tectonics by Treloar P. J. and Searle, M. P., 1998, Geological Society London, Special Publication. Tectonics of Nanga Parbat and the Western Himalayas by Khan, M. A., Trelaor, P. J., Searle, M. P., and Jan, M. Q. 2000. Geological Society, London, Special Publications.
10. Geology and evolution of the Indian plate by Naqvi, S. M., 2005, Capital Publishing Company. New Delhi, India
11. Stratigraphy and Historical Geology of Pakistan by Kazmi, A. H. and Abbasi, I. A., 2008, Graphic Publishers, Karachi, Pakistan.

Course Title: **Neotectonics**
Credit Hours: **3(2+1)**
Course Type: **Elective**
Prerequisite: **----------**

Objectives and Learning Outcomes:

This course is designed to acquire the knowledge about active tectonics of Pakistan. This will help the students to learn about recognition and distribution of active faults, faults and seismicity across Pakistan to understand regional deformation, earthquake hazards assessment and mitigation.

Course Contents:

Active tectonics and neotectonics: definitions, active faults and criteria for identifying active faulting; direct measurements of tectonic movements; direct measurement with geodetic networks; triangulation of sites with reference to satellites; global positioning systems; geology and earthquakes; earthquake seismology; paleoseismology; trenching and seismic trenching; Quaternary dating methods; tectonic geomorphology; offset geological-geomorphological features (paleoseismic indicators, changes in elevations of coast lines, stream offsets, slope retreat, terraces, incised meander); fault scarp morphology; neotectonics behavior of faults and folds; hazards of active tectonics: earthquakes and mass movements; remote sensing and satellite imageries applications in neotectonics and related hazards; active tectonics and nuclear waste disposal; neotectonics of Pakistan and Himalayas.

Recommended Books:

1. Active Tectonics. National Academy Press Washington, 1986.
2. Earthquakes a Primer by Boit, B. A., 1978, W. H. Freeman and Company.
3. Geodynamics of Pakistan by Farah, A., and DeJong, K. A., 1979, Geological Survey of Pakistan.
4. Geology of Earthquakes by Roberts S. Yeats, 1997, Oxford University Press.
5. Elementary Seismology by Richter, C. F., 1958, W. H. Freeman and Company.
6. Neotectonics of North America by Slemmons, D. B., Engdahl, E. R., Zoback, D. and Blackwell, D. D., Geological Society of America.
7. Gravity Field Seismicity and Tectonics of the Indian Peninsula and the Himalayas by Verma, R. K., 1985, Allied Publishers.
8. Geodynamics of the Indian Peninsula and the Indian Plate margin by Verma, R. K., 1991, Oxford and IBH Publication Company.
9. Geology and Tectonics of Pakistan by Kazmi, A. H. and Jan, M. Q., 1997, Graphic Publishers.
10. Tectonics by Moores, E. M. and Twiss, R. J., 1995, Freeman and Company.
11. Tectonic Geomorphology by Burbank, D. and Anderson, R. 2001, Blackwell Science.
12. Quaternary Geochronology: Methods and Applications by Noller, J. S., 2000, American Geophysical Union.

ELIGIBILITY FOR ADMISSION IN 2-YEAR MS PROGRAMME

Four years BS or equivalent education in Geology/Earth Sciences/Relevant Subjects with minimum 55% marks/ or 2.5 CGPA is recommended for admission in 2-year MS programme.

SCHEME OF STUDIES FOR 2-YEAR MS IN GEOLOGY

Duration:	2-Years (4-Semesters)
Course work:	24 Credit Hours
Thesis:	6 Credit Hours

1st Semester: 12 Credit Hours course work

2nd Semester: 12 Credit Hours course work

3rd Semester: Submission of synopsis, field and lab work

4th Semester: Thesis writing and open public defense.

LIST OF COURSES

The following courses are suggested for the MS Geology programme:

Geol. 701 Advanced Geochemistry
Geol. 702 Igneous Petrogenesis
Geol. 703 Metamorphic Petrogenesis
Geol. 704 Advanced Mineralogy
Geol. 705 Geothermometry and Geobarometry
Geol. 706 Regional Stratigraphy
Geol. 707 Micropalaeontology
Geol. 708 Invertebrate Paleontology
Geol. 709 Vertebrate Paleontology
Geol. 710 Palynology and Paleobotany
Geol. 711 Mineral Prospecting and Exploration
Geol. 712 Coal Geology
Geol. 713 Metallogeny and Plate Tectonics
Geol. 715 Mineral Processing and Mineral Industries
Geol. 716 Mineral Deposits and Mineral Economics
Geol. 717 Rock Mechanics
Geol. 718 Soil Mechanics
Geol. 719 Seismotectonics
Geol. 720 Advanced Engineering Geology
Geol.721 Advanced Petroleum Geology
Geol. 722 Advanced Sequence Stratigraphy
Geol. 723 Petroleum Engineering

Geol. 724 Applications of Geophysical Methods
Geol. 725 Advanced Reservoir Geology
Geol. 726 Applied Organic Geochemistry
Geol. 727 Regional Petroleum Geology
Geol. 728 Seismic Methods and Seismic Stratigraphy
Geol. 729 Earthquake Seismology
Geol. 730 Geomagnetism
Geol. 731 Paleomagnetism
Geol. 732 Radiometric Methods
Geol. 733 Electrical Methods
Geol. 734 Bore-hole Geophysics
Geol. 735 Geophysical Data Processing
Geol. 736 Gravity and Magnetic Methods
Geol. 737 Engineering Seismology
Geol. 738 Advacned Thermodynamics
Geol. 739 Geochemical Exploration
Geol. 740 Radiogenic Isotope Geochemistry
Geol. 741 Stable Isotope Geochemistry
Geol.742 Applied High Temperature Geochemistry
Geol. 743 Applied Low Temperature Geochemistry
Geol. 744 Clastic Sedimentology
Geol. 745 Carbonate Sedimentology
Geol. 746 Advacned Sedimentary Petrology
Geol. 747 Advanced Basin Analysis
Geol. 748 Quaternary Geology
Geol. 749 Clay Mineralogy
Geol. 750 Applied Sedimentology
Geol. 751 Techniques in Sedimentology
Geol. 752 Advanced Hydrology
Geol. 753 Groundwater Investigations
Geol. 754 Groundwater Engineering
Geol. 755 Groundwater Planning and Management
Geol. 756 Hydrochemistry and Groundwater Pollution
Geol. 757 Groundwater Modeling
Geol. 758 Applied Industrial Mineralogy
Geol. 759 Mining Geology and Mineral Economics
Geol. 760 Physical and Chemical Oceanography
Geol. 761 Advanced Marine Geology
Geol. 762 Coastal Geomorphology
Geol. 763 Geology of Arabian Sea
Geol. 764 Advanced Environmental Geology
Geol. 765 Soil and Water Resources
Geol. 766 Environmental Hazards
Geol. 767 Applied Hydrogeology
Geol. 768 Environmental Impact Assessment
Geol. 769 Global Tectonics
Geol. 770 Applied Structural Geology

Geol. 771 Metamorphic Structures
Geol. 772 Applied Structural Techniques
Geol. 773 Tectonics of Pakistan
Geol. 774 Neotectonics
Geol. 775 Advanced Gemology
Geol. 776 Advanced Geomorphology
Geol. 777 Glacial Geology
Geol. 778 Advanced Remote Sensing
Geol. 779 Advanced Geographic Information System
Geol. 780 Mining Geophysics
Geol. 781 Geochronology
Geol. 782 Research Methodology
Geol. 783 Instrumental Techniques in Geology
Geol. 784 Volcanology
Geol. 785 Tectonic Geomorphology
Geol. 786 Active Tectonics of Pakistan
Geol. 787 Paleoseismology
Geol. 788 Seismic Trenching
Geol. 789 Geobotany
Geol. 790 Geoarcheology
Geol. 791 Geodesy
Geol. 792 Pegmatites
Geol. 793 Medical Geology
Geol. 794 Military Geology
Geol. 795 Stratigraphy and Petroleum Prospects of Pakistan
Geol. 796 Regional and Global stratigraphy
Geol. 797 Physical and contaminant transport Hydrogeology
Geol. 798 Landslide Hazards and Risk Assessment Modelling
Geol. 799 Slope Stabilization Techniques
Geol. 800 Petroleum Economics
Geol. 801 Aggerates of Pakistan
Geol.802 Mineral Prospecting in Pakistan
Geol. 803 Geomodeling
Geol. 804 Palaeoclimates
Geol. 805 Hazards Assesment and Mitigation
Geol. 806 Unconventional Petroleum System
Geol. 807 Waste Disposal Management
Geol. 808 Natural Disaster Management

Note: Minimum two courses from the provided list are recommended to be identified as core courses by respective departments . The details of course content and assigned credit hours will be decided by the concerned universities/institutes through their concerned forums. The design courses should be advance, literature and research oriented to meet the International Standards.

Annexure - A

COMPULSORY COURSES

COMPULSORY COURSES IN ENGLISH FOR BS (4 YEAR) IN BASIC, SOCIAL & NATURAL SCIENCES

Course Title: **English I (Functional English) (Eng. 301)**
Course Code: **----------**
Credit Hours: **3**
Course Type: **Core**
Prerequisite: **----------**

Objectives:

Enhance language skills and develop critical thinking.

Course Contents:

The course contents are **Basics of Grammar** (Parts of speech and use of articles, Sentence structure, active and passive voice, Practice in unified sentence, Analysis of phrase, clause and sentence structure, Transitive and intransitive verbs and Punctuation and spelling. **Comprehension** (Answers to questions on a given text) **Discussion** (General topics and every-day conversation) (topics for discussion to be at the discretion of the teacher keeping in view the level of students). **Listening** (To be improved by showing documentaries/films carefully selected by subject teachers). **Translation Skills. Urdu to English. Paragraph Writing.** Topics to be chosen at the discretion of the teacher. **Presentation Skills** (Introduction)

Note: Extensive reading is required for vocabulary building.

Recommended Books:

1. **Functional English**

a) Grammar

1. Practical English Grammar by A. J. Thomson and A. V. Martinet. Exercises 1. Third edition. Oxford University Press. 1997. ISBN 0194313492
2. Practical English Grammar by A. J. Thomson and A. V. Martinet. Exercises 2. Third edition. Oxford University Press. 1997. ISBN 0194313506

b) Writing

1. Writing. Intermediate by Marie-Christine Boutin, Suzanne Brinand and Francoise Grellet. Oxford Supplementary Skills. Fourth Impression 1993. ISBN 0 19 435405 7 Pages 20-27 and 35-41.

c) Reading/Comprehension

1. Reading. Upper Intermediate. Brain Tomlinson and Rod Ellis. Oxford Supplementary Skills. Third Impression 1992. ISBN 0 19 453402 2.

d) Speaking

Course Title: **Communication Skills (English II)** **(Eng. 302)**
Course Code: **---------**
Credit Hours: **3**
Course Type: **Core**
Prerequisite: **----------**

Objectives:

Enable the students to meet their real-life communication needs.

Course Contents:

The main objectives are **Paragraph Writing (**Practice in writing a good, unified and coherent paragraph). **Essay Writing (**Introduction). **CV and Job Application (**Translation skills and Urdu to English). **Study Skills (**Skimming and scanning, intensive and extensive, and speed reading, summary and précis writing and comprehension). **Academic Skills (**Letter/memo writing, minutes of meetings, use of library and internet). **Presentation Skills (**Personality development, emphasis on content, style and pronunciation).
Analytical Skills and Professional Ethics.

Note: Documentaries to be shown for discussion and review.

Recommended Books

1. Communication Skills

a) Grammar

1. Practical English Grammar by A. J. Thomson and A. V. Martinet. Exercises
2. Third edition. Oxford University Press 1986. ISBN 0 19 431350 6.

b) Writing

1. Writing. Intermediate by Marie-Chrisitine Boutin, Suzanne Brinand and Francoise Grellet. Oxford Supplementary Skills. Fourth Impression 1993. ISBN 019 435405 7 Pages 45-53 (note taking).
2. Writing. Upper-Intermediate by Rob Nolasco. Oxford Supplementary Skills. Fourth Impression 1992. ISBN 0 19 435406 5 (particularly good for writing memos, introduction to presentations, descriptive and argumentative writing).

c) Reading

1. Reading. Advanced. Brian Tomlinson and Rod Ellis. Oxford Supplementary Skills. Third Impression 1991. ISBN 0 19 453403 0.
2. Reading and Study Skills by John Langan
3. Study Skills by Riachard Yorky.

Course Title: **English III (Technical Report Writing) (Eng. 401)**
Course Code: **----------**
Credit Hours: **3**
Course Type: **Core**
Prerequisite: **----------**

Objectives:

Enhance language skills and develop critical thinking, follow the USGS guidelines for professional writing skills.

Course Contents:

The main objectives of the course are **Essay Writing (**Descriptive, narrative, discursive, argumentative). **Academic Writing** (How to write a proposal for research paper/term paper, how to write a research geological research report/professional paper/term paper (emphasis on style, content, language, form, clarity, consistency, geological contents). **Technical Report Writing. Progress Report Writing.**

Note:

Extensive reading is required for vocabulary building. **Presentation Skills**

Recommended Books:

Technical Writing and Presentation Skills (USGS guidelines for professional geo-writing)

a) Essay Writing and Academic Writing

1. Writing. Advanced by Ron White. Oxford Supplementary Skills. Third Impression 1992. ISBN 0 19 435407 3 (particularly suitable for discursive, descriptive, argumentative and report writing).

2. College Writing Skills by John Langan. McGraw-Hill Higher Education. 2004.
3. Patterns of College Writing (4th edition) by Laurie G. Kirszner and Stephen R. Mandell. St. Martin's Press.ssss

b) Presentation Skills

c) Reading

The Mercury Reader. A Custom Publication. Compiled by norther Illinois University. General Editiors: Janice Neulib; Kathleen Shine Cain; Stephen Ruffus and Maurice Scharton. (A reader which will give students exposure to the best of twentieth century literature, without taxing the taste of engineering students).

Annexure – B

Course Title: **Pakistan Studies (Compulsory)** **(Pak. St. 301)**
Course Code: **----------**
Credit Hours: **2**
Course Type: **Core**
Prerequisite: **----------**

Objectives:

The main objectives are to develop vision of historical perspective, government, politics, contemporary Pakistan, ideological background of Pakistan and to study the process of governance, national development, issues arising in the modern age and posing challenges to Pakistan.

Course Outline:

The course contents involve **Historical Perspective (i.** Ideological rationale with special reference to Sir Syed Ahmed Khan, Allama Muhammad Iqbal and Quaid-i-Azam Muhammad Ali Jinnah. **ii.** Factors leading to Muslim separatism**. c.** People and Land, Indus Civilization**,** Muslim advent**,** Location and geo-physical features.) **Government and Politics in Pakistan (**Political and constitutional phases **i.e.,** 1947-58, 1958-71**,** 1971-77**,** 1977-88**,** 1988-99, 1999 onward). **Contemporary Pakistan (a.** Economic institutions and issues**, b.** Society and social structure, **c.** Ethnicity, **d.** Foreign policy of Pakistan and challenges**, e.** Futuristic outlook of Pakistan)

Recommended Books:

1. Burki, Shahid Javed. *State and Society in Pakistan,* The Macmillan Press Ltd 1980.
2. Akbar, S. Zaidi. *Issue in Pakistan's Economy.* Karachi: Oxford University Press, 2000.
3. S.M. Burke and Lawrence Ziring. Pakistan's Foreign policy: An Historical analysis. Karachi: Oxford University Press, 1993.
4. Mehmood, Safdar. *Pakistan Political Roots and Development.* Lahore, 1994.
5. Wilcox, Wayne.*The Emergence of Banglades.,* Washington: American Enterprise, Institute of Public Policy Research, 1972.
6. Mehmood, Safdar. *Pakistan Kayyun Toota,* Lahore: Idara-e-Saqafat-e-Islamia, Club Road, nd.
7. Amin, Tahir. *Ethno - National Movement in Pakistan,* Islamabad: Institute of Policy Studies, Islamabad.
8. Ziring, Lawrence. *Enigma of Political Development.* Kent England: WmDawson and sons Ltd, 1980.
9. Zahid, Ansar. *History and Culture of Sindh.* Karachi: Royal Book Company, 1980.
10. Afzal, M. Rafique. *Political Parties in Pakistan,* Vol. I, II and III. Islamabad: National Institute of Historical and cultural Research, 1998.

11. Sayeed, Khalid Bin. *The Political System of Pakistan.* Boston: Houghton Mifflin, 1967.
12. Aziz, K.K. *Party, Politics in Pakistan,* Islamabad: National Commission on Historical and Cultural Research, 1976.
13. Muhammad Waseem, Pakistan Under Martial Law, Lahore: Vanguard, 1987.
14. Haq, Noor ul. *Making of Pakistan: The Military Perspective.* Islamabad: National Commission on Historical and Cultural Research, 1993.

Course Title: **Islamic Studies /Ethics (Compulsory) (Isl. St./Eth. 401)**
Course Code: **----------**
Credit Hours: **2**
Course Type: **Core**
Prerequisite: **----------**

Objectives:

This course is aimed at to provide basic information about Islamic Studies, to enhance understanding of the students regarding Islamic Civilization, to improve Students skill to perform prayers and other worships and to enhance the skill of the students for understanding of issues related to faith and religious life.

Course Contents:

The main course contents are **Introduction to Quranic Studies** (1. Basic Concepts of Quran, 2. History of Quran, 3. Uloom-ul -Quran). **Study of Selected Text of Holly Quran** (**1**. Verses of Surah Al-Baqra Related to Faith (Verse No-284-286), 2. Verses of Surah Al-Hujrat Related to Adab Al-Nabi (Verse No-1-18), 3. Verses of Surah Al-Mumanoon Related to Characteristics of faithful (Verse No-1-11), 4. Verses of Surah al-Furqan Related to Social Ethics (Verse No.63-77), 5. Verses of Surah Al-Inam Related to Ihkam (Verse No-152-154). **Study of Selected Text of Holly Quran (1.** Verses of Surah Al-Ihzab Related to Adab al-Nabi (Verse No.6,21,40,56,57,58.), 2. Verses of Surah Al-Hashar (18,19,20) Related to thinking, Day of Judgment, 3. Verses of Surah Al-Saf Related to Tafakar,Tadabar (Verse No-1,14).) **Seerat of Holy Prophet (S. A. W) (**1. Life of Muhammad Bin Abdullah (Before Prophet Hood), 2. Life of Holy Prophet (S. A. W) in Makkah, 3. Important Lessons Derived from the life of Holy Prophet in Makkah). **Seerat of Holy Prophet (S. A. W) II (**1. Life of Holy Prophet (S.A.W) in Madina, 2. Important Events of Life Holy Prophet in Madina, 3. Important Lessons Derived from the life of Holy Prophet in Madina). **Introduction To Sunnah (1.** Basic Concepts of Hadith, 2. History of Hadith, 3. Kinds of Hadith, 4. Uloom–ul-Hadith, 5. Sunnah and Hadith, **6.** Legal Position of Sunnah).

Selected Study from Text of Hadith. Introduction to Islamic Law and Jurisprudence (1. Basic Concepts of Islamic Law and Jurisprudence**, 2.** History and Importance of Islamic Law and Jurisprudence**, 3.** Sources of Islamic Law and Jurisprudence, **4.** Nature of Differences in Islamic Law**, 5.** Islam and Sectarianism)

Islamic Culture and Civilization (1. Basic Concepts of Islamic Culture and Civilization**, 2.** Historical Development of Islamic Culture and Civilization, **3.** Characteristics of Islamic Culture and Civilization, **4.** Islamic Culture and Civilization and Contemporary Issues)

Islam and Science (1. Basic Concepts of Islam and Science, **2.** Contributions of Muslims in the Development of Science**, 3.** Quranic and Science)**. Islamic Economic System (1.** Basic Concepts of Islamic Economic System, **2.** Means of Distribution of wealth in Islamic Economics**, 3.** Islamic Concept of Riba**, 4.** Islamic Ways of Trade and Commerce)**. Political System of Islam (1.** Basic Concepts of Islamic Political System**, 2.** Islamic Concept of Sovereignty, **3.** Basic Institutions of Govt. in Islam).

Islamic History (1. Period of Khlafat-E-Rashida**, 2.** Period of Ummayyads**, 3.** Period of Abbasids). **Social System of Islam (1.** Basic Concepts of Social System of Islam**, 2.** Elements of Family, **3.** Ethical Values of Islam)

Recommended Books:

1. Hameed ullah Muhammad, "Emergence of Islam" , IRI, Islamabad.
2. Hameed ullah Muhammad, "Muslim Conduct of State".
3. Hameed ullah Muhammad, 'Introduction to Islam'.
4. Mulana Muhammad Yousaf Islahi,".
5. Hussain Hamid Hassan, "An Introduction to the Study of Islamic Law" leaf
6. Publication Islamabad, Pakistan.
7. Ahmad Hasan, "Principles of Islamic Jurisprudence" Islamic Research
8. Institute, International Islamic University, Islamabad,1993.
9. Mir Waliullah, "Muslim Jrisprudence and the Quranic Law of Crimes"
10. Islamic Book Service, 1982.
11. H.S. Bhatia, "Studies in Islamic Law, Religion and Society" Deep and Deep
12. Publications New Delhi, 1989.
13. Dr. Muhammad Zia-ul-Haq, "Introduction to Al Sharia Al Islamia" Allama
14. Iqbal Open University, Islamabad, 2001.

Annexure - D

COMPULSORY MATHEMATICS COURSES FOR BS (4 YEARS) GEOLOGY

Course Title: **Mathematics I (Algebra)** **(Math. 301)**
Course Code: **----------**
Credit Hours: **3**
Course Type: **Core**
Prerequisite: **Mathematics at Secondary Level**

Objectives:

Prepare the students, not majoring in mathematics, with the essential tools of algebra to apply the concepts and the techniques in their respective disciplines.

Course Contents:

The main contents are **Preliminaries** (Real-number system, complex numbers, introduction to sets, set operations, functions, types of functions). **Matrices** (Introduction to matrices, types, matrix inverse, determinants, system of linear equations, Cramer's rule. **Quadratic Equations** (Solution of quadratic equations, qualitative analysis of roots of quadratic equations, equations reducible to quadratic equations, cube roots of unity, relation between roots and coefficients of quadratic equations). **Sequences and Series** (Arithmetic progression, geometric progression, harmonic progression. **Binomial Theorem** (Introduction to mathematical induction, binomial theorem with rational and irrational indices). **Trigonometry (**Fundamentals of trigonometry, trigonometric identities).

Recommended Books

1. Dolciani MP, Wooton W, Beckenback EF, Sharron S, *Algebra 2 and Trigonometry*, 1978, Houghton and Mifflin,Boston (suggested text).
2. Kaufmann JE, College *Algebra and Trigonometry*, 1987, PWS-Kent Company, Boston Swokowski EW, *Fundamentals of Algebra and Trigonometry* (6th edition), 1986, PWS-Kent Company, Boston.

Course Title: **Mathematics II (Calculus)** **(Math. 302)**
Course Code: **----------**
Credit Hours: **3**
Course Type: **Core**
Prerequisite: **Mathematics I (Algebra)**

Objectives:

Prepare the students, not majoring in mathematics, with the essential tools of calculus to apply the concepts and the techniques in their respective disciplines.

Course Outline:

The main contents are **Preliminaries** (Real-number line, functions and their graphs, solution of equations involving absolute values, inequalities). **Limits and Continuity** (Limit of a function, left-hand and right-hand limits, continuity, continuous functions). **Derivatives and their Applications** (Differentiable functions, differentiation of polynomial, rational and transcendental functions, derivatives). **Integration and Definite Integrals** (Techniques of evaluating indefinite integrals, integration by substitution, integration by parts, change of variables in indefinite integrals).

Recommended Books:

1. Anton H, Bevens I, Davis S, *Calculus: A New Horizon* (8th edition), 2005, John Wiley, New York.
2. Stewart J, *Calculus* (3rd edition), 1995, Brooks/Cole (suggested text).
3. Swokowski EW, *Calculus and Analytic Geometry*, 1983, PWS-Kent Company, Boston.
4. Thomas GB, Finney AR, *Calculus* (11th edition), 2005, Addison-Wesley, Reading, Ma, USA.

Course Title: **Chemistry I** **(Chem. 301)**
Course Code: **----------**
Credit Hours: **3**
Course Type: **Core**
Prerequisite: **----------**

Objectives:

Prepare the students with tools of chemistry to apply the concepts and the techniques in their respective discipline.

Course Contents:

Phase rule for one and two component system and Distribution laws; first and second laws of thermodynamics with applications; brief introduction to nuclear chemistry: nuclear fission and fusion, nuclear reactors, uses of isotopes and radioisotopes; Metallurgy: major steps involved in metallurgy of iron, copper, nickel, chromium, gold and platinum. metallurgy raw materials; cement preparation; solutions: types, Eubulioscopic constant, distribution law and various properties of solutions; Complexometric Methods: titration and its various types, concept of mono, di and plydentateligoinds.

Labs:

Qualitative analysis of a mixture containing four radicals; Refractive Index of various liquids.

Recommended Books:

1. Physical Chemistry for BSc students by Ghulam Nabi and P. A Khokar (Latest edition).
2. Chromatography by Dr. Nasar-ud-din (Latest edition).
3. See also relevant updated books.

Course Title: **Chemistry II**
Course Code: **----------**
Credit Hours: **2**
Course Type: **Core**
Prerequisite: **----------**

Objectives:

Prepare the students with tools of chemistry to apply the concepts and the techniques in their respective discipline.

Course Content:

Gravimetric and volumetric method of analysis; chromatography, TLC, PC, CC ion exchange procedure and application of all these techniques; solvent extraction, classification, important terms involved, types of extraction and factor influencing the extraction system; electro-analytical method; basic principles and elementary techniques; conductometer ; potentiometry; PH and

EH measurement; atomic absorption techniques, neutron activation technique and mass spectrometry.

Labs:

Volumetric analysis; calorimetric analysis of Ni. Fe and Mn; PH and EH measurements; atomic absorption, neutron activation and mass spectrometry analyses.

Recommended Books:

1. Physical Chemistry for BSc student by Gulam Nabi and P. A. Khokar (Latest edition).
2. Chromatography by Nasar-ud-din (Latest edition).
3. See also relevant updated books.

Course Title: **Physics I** **(Phy. 301)**
Course Code: **----------**
Credit Hours: **3**
Course Type: **Core**
Prerequisite: **---------**

Objectives:

Prepare the students with tools of physics to apply the concepts and the techniques in their respective discipline.

Course Contents:

Vector: Vector notation, vector addition, vectors in the Cartesian coordinate system, scalar product (of two vectors) vector product (of two vectors), scalar of triple product, vector triple product, gradiset of a scalar, divergence of a vector, divergence theorem and Stock's theorem; **conservation of energy:** concept of conservation laws, conservation of energy, worked and kinetic energy, power, conservation forces, rotational energy, potential energy in an electric and gravitational field; dynamics of rigid bodies, center of mass, conservation of angular momentum, equation of motion of rotating body, moment of inertia, perpendicular axes and parallel axis theorems; calculation of moment of inertia for a disc and solid sphere; Euler's theorem, Gyroscope cortolis forces; **Inverse Square Law of forces:** Newton laws, ficlitioris forces, Newton law of Universal Gravitation b/w point mass and solid spheres, Kepler's laws, satellite in circular orbit escape velocity; **Electrostatics:** electro charges as source of electric flux, Gauss's theorem, Electrostatic potential, Poisson's equation, Laplace Equation Potential due to: (a) Point Charge (b) dipole capacity of spherical condenser, dielectrics.

Labs:

Surface tension by capillary rise; value of 'g' by compound pendulum; modulus of rigidity by Maxwell's Needle method; use of sextant and measurement of longitude.

Recommended Books:

1. Physics by Holiday, Resnik and Krane (Latest edition). Mechanics by A. B. Pal (Latest edition).
2. B.Sc. Physics by A.B. Paul (Latest edition).
3. See also updated relevant books.

Course Title: **Physics II** **(Phy. 30)**
Course Code: **----------**
Credit Hours: **2**
Course Type: **Core**
Prerequisite: **----------**

Objectives:

Prepare the students with tools of physics to apply the concepts and the techniques in their respective discipline.

Course Contents:

Magnetism: Explanation of dia, pura and ferromagnetism on atomic structure of an atom, magnetic circuit, relation b/w susceptibility and permeability, Hysteresis determination of B-H curve using a Ballistic galvanometer, Magnetic Shell and Ampere's law and method of measuring magnetic field; **Current Electricity:** Magnetic flux density B. Ampher's law and calculation of B due to current in (a) Long Straight, (b) Solenoid, (c) Toriod, Biot and Sarvat's lawand calculation of B, unit of current carrying conductor in a magnetic field, theory and construction of moving coil and magnetic galvanometer; definition of different system of units C.G.S Electrostatic and C.G.S Electro-magnetic system of units, practical units, Gavssion System of units; **Optics:** Reflection and refraction, Sertent wave theory, Interference, Biprism and Michelin interferometer determination of wave length and thickness by using Michelin's interfero - meter, diffraction, diffraction by single and double and "N" slits; **Radio Activity:** Natural radio activity, mature and charge of Alpha, Beta and Gama rays, radioactive series, laws of radioactive decay, Half life and artificial radio activity and transuranic elements.

Labs:

Conservation of pointer galvanometer into a voltmeter and in ammeter; Frequency of A.C supply; Low resistance by carry foster bridge; B-H curve by Magnetometer; Measurement of H.

Recommended Books:

1. Physics by Holiday, Resnik and Krane (latest edition).
2. BSc. Physics by A. B. Paul (latest edition).
3. See also updated books.