SYLLABUS FOR
B.S. IN GEOLOGY

Department of Geology
University of Karachi
2024

FIRST SEMESTER [18 Credit Hours]				
Course Cod	**Subject**	**Cr. H.**	**Type**	**Status**
300.1 (U)	Urdu	2	Arts & Humanities (G. Edu)	
300.1 (IS)	Islamic Studies or Ethics (Non-Muslim)	2	Compulsory (G. Edu)	
300.1 (CCE)	Civics and Community Engagement	2	Compulsory (G. Edu)	
300.1 (NS)	Natural Sciences	3	Compulsory (G. Edu)	
301	Interdisciplinary -I	3	Interdisciplinary	Already approved
301	Interdisciplinary -II	3	Interdisciplinary	Already approved
Geol. 301	General Geology I*	2+1	Major 1	Minor modification in content, references updated
		18		

SECOND SEMESTER [18 Credit Hours]				
Course Cod	**Subject**	**Cr. H.**	**Type**	**Status**
300.2 (PS)	Pakistan Studies	2	Compulsory (G. Edu)	
300.2 (ICP)	Ideology & Constitution of Pakistan	2	Compulsory (G. Edu)	
300.2 (FE)	Functional English	3	Compulsory (G. Edu)	
300.2 (Entr)	Entrepreneurship	2	Compulsory (G. Edu)	
300.2 (SS)	Intro to Social Sciences	2	Social Sciences (G. Edu)	
302	Interdisciplinary -I	3	Interdisciplinary	Already approved
302	Interdisciplinary -II	3	Interdisciplinary	Already approved
Geol. 302	General Geology II*	2+1	Major 2	Already approved, content rephrased, references updated
		20		

THIRD SEMESTER [18 Credit Hours]				
Course Cod	**Subject**	**Cr. H.**	**Type**	
400.1 (QR)	Quantitative Reasoning	3	Compulsory (G. Edu)	
400.1 (EW)	Expository writing	3	Compulsory (G. Edu)	
401	Interdisciplinary -I	3	Interdisciplinary	Already approved

401	Interdisciplinary -II	3	Interdisciplinary	Already approved
Geol. 401	Mineralogy*	2+1	Major 3	Already approved, content restructured, references updated
Geol. 403	Stratigraphy and Paleontology	2+1	Major 4	Already approved, content rephrased, references updated
		18		

FOURTH SEMESTER [18 Credit Hours]				
Course Cod	**Subject**	**Cr. H.**	**Type**	**Status**
400.2 (QR)	Quantitative Reasoning	3	Compulsory (G. Edu)	
400.2 (ICT)	Application of Inform. & Communication Technologies	3	Compulsory (G. Edu)	
402	Interdisciplinary -I	3	Interdisciplinary	Already approved
402	Interdisciplinary -II	3	Interdisciplinary	Already approved
Geol. 402	Petrology*	2+1	Major 5	Already approved, content rearranged, references updated
Geol. 404	Economic Geology	2+1	Major 6	Already approved, content rephrased, references updated
		18		

Two years same scheme for Bachelor of Studies Degree (BS) and Associate Degree (AD)

* Courses for both major and interdisciplinary students
Interdisciplinary courses: Physics, Chemistry, Mathematics, Geography, Biostatistics, Botany, Zoology (combinations already given in prospectus)

FIFTH SEMESTER [18 Credit Hours]				
Course Cod	**Subject**	**Cr. H.**	**Type**	**Status**
Geol. 501	Micropaleontology and Biostratigraphy	2+1	Major 7	Already approved, content revised, references updated
Geol. 503	Sedimentology and Sequence Stratigraphy	2+1	Major 8	Code change, content modified, shuffled, references updated
Geol. 505	Geology of Pakistan	2+1	Major 9	Code change, content abridged, shuffled, references updated
Geol. 507	Geochemistry	2+1	Major 10	Already approved, content simplified, references updated
Geol. 509	Field Geology and Geomorphology	2+1	Major 11	Already approved, references updated
Geol. 511	Plate Tectonics and Structure Geology	2+1	Major 12	New course by merging approved old courses
		18		

SIXTH SEMESTER [18 Credit Hours]				
Course Cod	**Subject**	**Cr. H.**	**Type**	**Status**
500.2	Capstone Project	0+3	Compulsory	New
Geol. 502	Hard Rocks Petrogenesis	2+1	Major 13	New; modified from old approved course
Geol. 504	Petroleum Geology	2+1	Major 14	Code change, content modified, shuffled, references updated
Geol. 506	Oceanography	2+1	Major 15	New course
Geol. 508	Geophysics and Hydrogeology	2+1	Major 16	Title and content modified, references updated
Geol. 510	Engineering Geology	2+1	Major 17	Title and content modified, references updated
		18		

SEVENTH SEMESTER [15 Credit Hours]				
Course Cod	**Subject**	**Cr. H.**	**Type**	**Status**
600.1	Field Experience/Internship	0+3	Compulsory	Already approved, references updated
Geol. 601	Renewable Energy Resources	2+1	Major 18	Code change, content modified, references updated

Geol. 603	Well Site Geology and Logging Techniques	2+1	Major 19	Title and content modified, references updated
Geol. 605	Basin Analysis	2+1	Major 20	Already approved, content modified, references updated
Geol. 607	Nano-Geology	2+1	Major	New Course
Geol. 609	Coal Geology	2+1	Major	Already approved
Geol. 6--	Major (elective subject)	2+1	Major 21	Already approved
Geol. 600.3	Thesis (optional)	0+3		Already approved
		15		

Note: From Geol. 601 to Geol. 609; only three courses will be offered during 7th semester.

EIGHTH SEMESTER [15 Credit Hours]				
Course Cod	**Subject**	**Cr. H.**	**Type**	**Status**
Geol. 602	Geological Field Work and Report Writing	2+1	Major 22	Already approved, references updated
Geol. 604	Reservoir and Development Geology	2+1	Major 23	Already approved, references updated
Geol. 606	Environmental Geology	2+1	Major 24	Already approved, references updated
Geol. 608	Remote Sensing and GIS	2+1	Major 25	Already approved, content and references updated
Geol. 6--	Major (elective subject)	2+1	Major 26	Already approved
Geol. 600.2	Project (optional)	0+3		Already approved
Geol. 600.3	Thesis (optional)	0+3		Already approved
		15		

Note: Students can offer a research project (3 credit hours) or thesis (6 credit hours) in lieu of 1 or 2 major courses of seventh and eighth semester respectively.
Course Codes: Odd number courses are for odd number semesters and vice versa.

Total number of courses: **49**

i. General Education: 14 courses
ii. Major: 26 courses
iii. Interdisciplinary/allied courses: 08 courses
iv. Field experience/internship: 01 course
v. Capstone project: 01 course

Total number of credit hours: **140**

i. General Education: 32 credit hours
ii. Major: 78 credit hours
iii. Interdisciplinary/allied courses: 24 credit hours
iv. Field experience/internship: 03 credit hours
v. Capstone project: 03 credit hours

LIST OF ELECTIVE COURSES

Groups	Course Code	Elective Courses	Credit Hour	Status
Group-I Mineralogy	Geol. 611	Ore Geology	2+1	Already approved, content modified, references updated
	Geol. 612	Mining Geology and Mineral Processing	2+1	Already approved, content modified, references updated
	Geol. 613	Industrial Mineralogy and Mineral Economics	2+1	Already approved, content modified, references updated
	Geol. 614	Gemology	2+1	Already approved, content modified, references updated
Group-II Engineering Geology	Geol. 621	Soil Mechanics	2+1	Course Code change, content modified, references updated
	Geol. 622	Geotechnical Investigations	2+1	Course Code change, content modified, references updated
	Geol. 623	Rock Mechanics	2+1	Course Code change, content modified, references updated
Group-III Applied Geophysics	Geol. 631	Seismic Stratigraphy	2+1	Title and content modified, references updated
	Geol. 632	Geomagnetism and Paleomagnetism	2+1	Already approved, references updated
	Geol. 633	Gravity and Magnetic Methods	2+1	Already approved, references updated
	Geol. 634	Applications of Electrical and Radiometric Techniques	2+1	Title and content modified, references updated
Group-IV Marine Geology	Geol. 641	Marine Geology	2+1	New Course
	Geol. 642	Advance Oceanography	2+1	Course Code change, content modified, references updated
	Geol. 643	Geology of Arabian Sea	2+1	Course Code change, content modified, references updated
	Geol. 644	Marine Geochemistry	2+1	Course Code change, content modified, references updated
Group-V Geochemistry	Geol. 651	Geochemical Exploration	2+1	Already approved, references updated
	Geol. 622	Petroleum Geochemistry	2+1	Already approved, references updated
	Geol. 653	Carbonate Geochemistry	2+1	Already approved, references updated
Group-VI Sedimentology	Geol. 661	Clastic Sedimentology	2+1	Already approved, content modified, references updated
	Geol. 662	Carbonate Sedimentology	2+1	Already approved, references updated
	Geol. 663	Sedimentary Petrology	2+1	Already approved, references updated
	Geol. 664	Quaternary Geology	2+1	New Course
Group-VII Hydrogeology	Geol. 671	Climate Change and Water Hazards	2+1	New Course
	Geol. 672	Field Hydrogeology	2+1	New Course
	Geol. 673	Groundwater modeling	2+1	New Course

BS. 1st Year

GEOL. 301: GENERAL GEOLOGY-I*
2+1 Credit Hours

Objectives:
This course is designed to impart basic knowledge of Geology. It will help the students to understand various types of rocks and minerals; sedimentary and structural features and geological processes.

Learning Outcomes:
Through successful completion of this course, students will be able to:
Describe importance and applications of Geology.
Describe relation of Earth and solar system; internal structure of Earth
Understand minerals and rocks
Understand sedimentary and structural features and the processes operating within and on the surface of the earth.

Course Content:
Introduction and scope of Geology, its importance and relationship with other sciences. Earth as a member of the solar system, its origin, age, composition and internal structure. Geological time scale. Agents and processes of weathering, erosion and related landforms. Introduction to minerals and rocks. Introduction to primary and secondary structures of rocks. Introduction to Plate Tectonics and Earthquake.

Lab:
Study of various relief and structural features by using models, topographic and geological maps. Construction of cross-section and interpretation of geological features. Study of selected rocks and minerals in hand specimen. Field visits of selected sites to observe geological features.

Recommended Books:

1. Investigating the Earth: Exercises for Physical Geology by Hauptvogel, D., Sisson, V. and Comas, M. 2024. Press books, Houston, TX: UH Libraries.
2. The IIT-JAM Breaker Series: Geology by Chakrabarti, N. and Nandy, R., 2024. Hindustan Publishing Corporation (India), 9788170751052.
3. A practical guide to introductory geology by Minnett, M., and Daniels, B.G. 2022. Mount Royal University Library.
4. Structural Geology by A.R. Bhattacharya, 2022. Springer Nature Switzerland AG, Springer Nature Switzerland. AG, ISBN: 978-3-030-80794-8.
5. Physical Geology by Plummer, C., Carlsen D. and Hammersely L. 2022. McGraw Hill. ISBN10: 1264408056 | ISBN-13: 9781264408054.
6. Physical Geology by Earle, S. 2019. (2^{nd} ed.), Victoria, B.C: BC campus. Retrieved from https://opentextbc.ca/physicalgeology EBOOK, ISBN: 978-1-77420-028-5.
7. Fundamentals of Physical Geology by Jain, S. 2018. I N: : 9788132237754.
8. Laboratory Manual in Physical Geology by Busch, R.M. 2011. (9^{th} ed.), American Geological Institute, Pearson Education.
9. Earth System History by Stanley, S. M. 2005. W.H. Freeman & Co. San Francisco.

GEOL. 302: GENERAL GEOLOGY-II*
2+1 Credit Hours

Objectives:
This course is designed to develop the concepts of sedimentation and stratigraphy among students. It assists to acquire basic concept of palaeontology and the process of fossilization. It also helps to understand morphological characteristics of fossils.

Learning Outcomes:
After successful completion of this course, students will be able to:
Understand the importance of Palaeontology; their applications and basic concepts.
Distinguish various types of fossils.
Describe concepts of stratigraphy, sedimentation and correlation.
Discriminate between different sedimentary environments.

Course Content:
Fossils and their significance. Modes of fossilization. Introduction to invertebrates (Mollusca), vertebrate and plant fossils. Life through the ages. Introduction to Historical Geology.
Basic principles of stratigraphy and sedimentation. Stratotypes. Classification of stratigraphic units. Correlation. Introduction to sedimentary environments.

Lab:
Preparation of stratigraphic columns and their correlation. Construction of stratigraphic cross-sections and their interpretation. Study of local stratigraphic sections. Study of selected invertebrate (Mollusca), and plant fossils. Field visits of selected sites to study stratigraphic succession and fossils collection.

Recommended Books:

1. Sedimentology and Stratigraphy (3rd ed.) by Nichols, G. 2023., Willy, ISBN: 978-1-119-41727-9.
2. Paleontology: An Illustrated History Hardcover by David, B. 2022. Princeton University Press; ISBN-10: 0691220921.
3. Stratigraphy: A Modern Synthesis by Andrew D. Miall, 2022. Springer Cham, ISBN: 978-3-030-87535-0.
4. Invertebrate Paleontology by Abdelbaset, S. 2020. King Saud University Press, S.A, 9786035073394.
5. Stratigraphy and Historical Geology of Pakistan by Abbasi, I. 2019. Publisher: Department and NCE in Geology, University of Peshawar, Pakistan. ISBN: 978-969-9119.
6. Principles of Sedimentology and Stratigraphy by Boggs, S., 2011. Prentice Hall.
7. Stratigraphy of Pakistan by Geological Survey of Pakistan, 2009. Memoir 22, Geological Survey of Pakistan, Quetta.
8. Stratigraphy and Historical Geology of Pakistan by Kazmi, A.H and Abbasi, I.A., 2008. Graphic Publishers, Karachi, Pakistan.
9. Invertebrate Paleontology and Evolution by Clarkson, E.N. 2007. (4th ed.), Blackwell Publishing Company.
10. Vertebrate Paleontology by Romer, A.S., 1966. University Chicago Press.
11. Stratigraphic Code of Pakistan, Geological Survey of Pakistan, 1962. Memoirs of GSP, V. IV, Part-I.
12. Invertebrate Fossils by Moore, R.C., Lalicker, C.G. and Fischer, A.G., 1952. McGraw-Hill.

BS. 2nd Year

GEOL. 401: MINERALOGY*
2+1 Credit Hours

Objectives:
This course is designed to acquire the knowledge about the properties of various rock forming minerals and related phase diagrams. It will help to get the optical properties of minerals and basic concepts of crystallography and the crystal systems.

Learning Outcomes:
Through successful completion of this course, students will be able to:
Identify silicate and non-silicate minerals.
Use polarizing microscope and determine optical properties of minerals.
Understand basic concepts of crystallography and the crystal systems in which minerals are crystallized.

Course Content:
Introduction to mineralogy and its relationship with allied sciences. Properties and classification of minerals. Rock forming mineral groups. Silicate structures and description of important silicate families such as Olivine, Pyroxene, Amphibole, Feldspar, Quartz, Feldspathoid, Zeolite, Mica and Clay minerals.
Principles of optical mineralogy. Introduction to polarizing microscope. Optical properties of common rock forming minerals.
Introduction to crystallography. Basic concepts of crystal structure and crystal chemistry. Coordinates, parameters, indices, symmetry elements and stereogram of crystals. Description of Normal Class of each crystal system. Twining and its types. Irregularities in crystal growth.

Lab:
Identification and description of various minerals in hand specimen. Study of crystal models of Normal Classes. Study of optical properties of minerals.

Recommended Books:

1. Crystallography and Crystal Chemistry, by Rick U., 2024. Springer Chem. ISBN: 978-3-031-49751-3.
2. Optical Mineralogy, by Claude C. 2024. Discovery Publishing House (India). ISBN-10: 8119523474.
3. Optical Mineralogy by Pramod K.V. 2023. Springer Chem. ISBN: 978-3-031-40764-2.
4. Crystallography, by Celia M. 2022. Springer Nature: ISBN: 978-3-030-96782-6.
5. Mineralogy by Miloš R. 2 22. Institute of Rock tructure and Mechanics, Czech Academy of ciences, Czech Republic, ISBN: 978-1-80355-465-5.
6. Introduction to Crystallography by Hoffmann, F. 2020. Springer| Publication. ISBN-10: 3030351092.
7. Mineralogy: An Introduction to Minerals, Rocks, and Mineral Deposits by Martin O. and Frimmel, H.E. 2020, Springer: ISBN: 978-3-662-57316-7.
8. Minerals and Their Properties: Novel Approach for Applications, by Anup P. Bhat, Bandana Samant, Renu Nayar, Sanjay J. Dhoble (Editors), 2020. Geology and Mineralogy Research Developments (NOVA).
9. The Fundamentals of Crystallography and Mineralogy, by Aretas N.N. 2 8. Spears Media Press. ISBN-10: 1942876246.
10. An Atlas of Minerals in Thin Sections by Schulze, D.J., 2003. CD-RM, Oxford University Press.
11. Minerals in Thin Sections by Perkins, D., 2000. Prentice Hall.
12. Optical Mineralogy by Kerr, P.F., 1959. McGraw-Hill.

GEOL. 402: PETROLOGY*
2+1 Credit Hours

Objectives:
This course is designed to identify the igneous, metamorphic and sedimentary rocks by megascopic and microscopic examination. It also supports to get knowledge about the classification of rocks on the basis of texture and mineral composition.

Learning Outcomes:
Successful completion of this course will make students be able to:
Distinguish between magma and lava and their characteristics.
Understand magmatic, metamorphic and sedimentary processes.
Describe texture, types and classification of rocks.
Describe different sedimentary environments.

Course Content:
Types and characteristics of magma and lava. Magmatic processes. Description, texture, structure and classification of igneous rocks. Metamorphism: agents, processes, zones and facies. Texture, structure and types of metamorphic rocks.
Sedimentary provenance, processes and diagenesis. Description, texture, structure and formation of siliciclastic, precipitated and allochemical sedimentary rocks. Sedimentary environments.

Lab:
Megascopic study of igneous, metamorphic and sedimentary rocks. Geological field visits of selected sites to study different rock types.

Recommended Books:

1. Basics of Metamorphic Petrology by Manickavasagam, R.M. 2024. Atlantic Publishers and Distributors (P) Ltd. ISBN: 13-9788126937295
2. Environment and Geochemistry of Sediments by Marianna, K. and Dmitry, S. (eds), 2023. MDPI Books. ISBN: 978-3-0365-8108-8
3. On the Classification of Sedimentary Rocks by Grabau, A.W. 2023. Legare Street Press, ISBN-10: 1020417552.
4. Sedimentary Petrology (4th ed.) by Stuart J. and Tucker, M.E. 2023. Wiley, ISBN: 978-1-118-78648-2.
5. Principles of Igneous and Metamorphic Petrology, by Philpotts, A.R. and Ague, J.J. 2022. Cambridge University Press, ISBN: 9781108492881.
6. An Introduction to Metamorphic Petrology, by Bruce, Y. and Clare, W. 2020 (2nd ed.). Cambridge University Press; ISBN: 9781108659550.
7. Igneous Petrology by Best, M.G. and Christiansen E.H. 2020. Wiley-Blackwell. ISBN-10: 0865425418.
8. Essentials of Igneous and Metamorphic Petrology by Frost, B.R. 2019. Cambridge University Press. ISBN: 9781108482516.
9. Petrology: Igneous, Sedimentary and Metamorphic by Blatt, H., Tracy, R. and Owens, D., 2005. W.H. Freeman and Co.
10. Petrology of Sedimentary Rocks by Boggs Jr. S., 1992. Merril Publishing Co.

GEOL. 403: STRATIGRAPHY AND PALAEONTOLOGY
2+1 Credit Hours

Objectives:
This course is designed to equip the students with the knowledge about stratigraphic successions formed during different geologic time with special reference to Pakistan. This will help the students to understand stratigraphy and morphological characteristics of fossils.

Learning Outcomes:
After completing this course successfully, students will be able to:
Describe the importance, ecology, evolution and morphology of important invertebrate fossil groups.
Understand concepts of facies, correlation and global cycles.
Comprehend basic concepts of seismic and sequence stratigraphy.
Understand stratigraphic code and stratigraphy of Pakistan.

Course Content:
Concept of facies, regressive and transgressive cycles. Introduction to global cycles. Correlation techniques. Introduction to seismic and sequence stratigraphy. Stratigraphy of Pakistan and study of important type sections. Stratigraphic code of Pakistan.

Detailed morphology, classification, distribution, evolution and paleoecology of important invertebrate fossil groups: Brachiopoda, Trilobita, Coelentrata, Echinodermata. Vertebrate Paleontology. Important index fossils found in Pakistan.

Lab:
Megascopic study of common invertebrate and vertebrate fossil groups. Preparation of facies and correlation maps. Study of global cycle charts.

Recommended Books:

1. Principles of Sequence Stratigraphy by Maravelis, A.G. and Botziolis, C. 2024. Kallipos, Open Academic Editions. ISBN: 978-618-228-234-2.
2. Vertebrate Palaeontology, by Michael, J.B. 2024. Wiley ISBN-10: 1394195087.
3. Paleontology: An Illustrated History Hardcover by David, B. 2022. Princeton University Press; ISBN-10: 0691220921.
4. Principles of equence tratigraphy by Octavian, C. 2 22. Elsevier cience. I N- : 9780444533531.
5. Invertebrate Paleontology by Abdelbaset, S. 2020. King Saud University Press, S.A, 9786035073394.
6. Principles of Sedimentology and Stratigraphy by Boggs, S., 2011. Prentice Hall.
7. Stratigraphy of Pakistan by Geological Survey of Pakistan, 2009. Memoir 22, Geological Survey of Pakistan, Quetta.
8. Stratigraphy and Historical Geology of Pakistan by Kazmi, A.H and Abbasi, I.A., 2008. Graphic Publishers, Karachi, Pakistan.
9. Invertebrate Paleontology and Evolution (4th Edition), by Clarkson, E.N. 2007. Published by Blackwell Publishing Company.
10. Vertebrate Paleontology by Romer, A.S., 1966. University Chicago Press.
11. Stratigraphic Code of Pakistan, Geological Survey of Pakistan, 1962. Memoirs of GSP.
12. Invertebrate Fossils by Moore, R.C., Lalicker, C.G. and Fischer, A.G., 1952. McGraw-Hill.

GEOL. 404: ECONOMIC GEOLOGY
2+1 Credit Hours

Objectives:
This course is designed to acquire the knowledge about the formation of various types of mineral deposits, other natural resources and their significance. It helps to know economic mineral deposits of Pakistan.

Learning Outcomes:
The outcome will make the students able to:
Understand the processes which are involved in the genesis of various ores deposits, hydrocarbons, gemstones and other industrial minerals.
Recognize the important economic mineral deposits of Pakistan.

Course Contents:
Economic Geology: concept and scope. Classification of economic mineral deposits and their uses. Processes of formation of economic mineral deposits. Metallogenic Provinces and Epochs. Brief description of hydrocarbons, coal, gemstones, radioactive, non-metallic and metallic mineral deposits. Economic mineral deposits of Pakistan.

Lab:
Megascopic study of metallic and nonmetallic minerals. Specific gravity and reserve estimation of economic mineral deposits. Industrial visits to mineral processing sites.

Recommended Books:

1. Introduction to mineral deposits geology: (Including Exploration, Mining and Mineral Economics), by Moses, O. 2024. Prescott Publishers. ISBN: ISBN 978-0-578-34652-6.
2. Handbook of Petroleum Geoscience: Exploration, Characterization, and Exploitation of Hydrocarbon Reservoirs, by Soumyajit, M., Swagato, D., Chandan, M., Subhandip, M. and Troyee, D. (Editors), 2023. John Wiley & Sons Ltd. ISBN: 9781119680031.
3. Geology and Mineralogy of Gemstones, by David P., Turner, Lee A. Groat, 2022. Wiley (American Geophysical Union), ISBN: 978-1-119-29987-5.
4. Economic Geology: Economic Mineral Deposits by Prasad, U. (2nd ed.), 2021. ISBN 10: 9788123904603.
5. Economic Geology: Principles and Practice by Walter, L.P. 2020. Schweizerbart Sche Vlgsb. ISBN-10: 3510654412.
6. The World of Mineral Deposits: A Beginner's Guide to Economic Geology, by Florian, N. and Gunnar, R. 2020. Springer Nature Switzerland AG. ISBN: 978-3-030-34345-3.
7. Ore Deposits: Origin, Exploration, and Exploitation, by Sophie, D. and Laurence, R. 2019 (1st ed.), Wiley ISBN: 978-1-119-29055-1.
8. An Introduction to Ore Geology by Evans, A.M., 1987. Blackwell.
9. Economic Mineral Deposits by Jenssen, M.L. and Bateman, A.M., 1972. John Wiley and Sons.
10. Ore Deposits by Park, C.F. and Mac Diarmid, R.A., 1970. W.H. Freemanand Co.
11. Directory of Mineral Deposits of Pakistan by Zaki, A., 1969. Geological Survey of Pakistan.

BS. 3rd Year

GEOL. 501: MICROPALEONTOLOGY AND BIOSTRATIGRAPHY
2+1 Credit Hours

Objectives:
This course is designed to provide basic knowledge of major microfossil groups and their geological applications. Students will be familiar with the basic principle and terminologies related to biostratigraphy. Detailed knowledge of biostratigraphic techniques to utilize microfossils in correlation and petroleum exploration.

Learning Outcomes:
Students who successfully finish this course will be able to:
Identify major microfossil groups and utilize them in geological interpretation.
Understand basic principle of biostratigraphy and their application in developing correlation and in petroleum exploration.

Course Content:
Taxonomy and morphological studies of Foraminifera, Ostracoda, Conodonts, Algae, Pollen and Spores, Microplankton and nano-fossils. Application of microfossils in the field of hydrocarbon exploration, biostratigraphy, paleoecology and paleoclimatology.
Principles and concept of biostratigraphy and its facies. Basic terminologies and models of evolution. Biostratigraphic techniques, sampling method, interpretation and challenges in correlation. Biostratigraphic classification. Tertiary biostratigraphy with special reference to Pakistan. Role of biostratigraphy in Petroleum Geology.

Lab:
Sampling and laboratory techniques. Morphological and taxonomic studies of selected microfossils. Preparation of thin sections and identification of fossils. Preparation of Range Chart, interpretation based on bio-stratigraphic techniques, biocorrelation.

Recommended Books:

1. Applications of Palynology in Stratigraphy and Climate Studies, by Bandana Samant, Deepali Thakre (Editors) 2024. Springer International Publishing AG, ISBN: 9783031518768.
2. Introduction to Microfossil Biostratigraphy by M. Dan Georgescu., 2021. Cambridge Scholars Publishing.
3. Micropaleontology: Principles and applications. By Saraswati, P.K., and Srinivasan, M.S. 2015. Springer.
4. Principles of Sedimentology and Stratigraphy (Fifth edition), by Sam Boggs Jr., 2014. Springer.
5. Stratigraphy of Pakistan, By Shah, S.M.I. 2009. Geological Survey of Pakistan. Memoir, Vol. 22.
6. Microfossils by Howard A. Armstrong and Martin D. Brasier, 2005. Blackwell Publishing.
7. Biostratigraphy by McGowran, Brian. 2005. Cambridge University Press.
8. Introduction to Marine Micropaleontology by Haq and Boersman, 1980. Elsevier.

GEOL. 502: HARD ROCKS PETROGENESIS
2+1 Credit Hours

Objectives:
This course is designed to acquire the knowledge about the origin of magma and the role of magmatic and metamorphic processes in the formation of igneous and metamorphic rocks.

Learning Outcomes:
The learning outcomes include understanding the classification of igneous and metamorphic rocks and their genesis in different tectonic settings.
Recognized the igneous and metamorphic rocks of Pakistan.

Course Content:
Introduction to petrogenesis. Magmatic differentiation Processes. Granitization and hybridization. Tectonics and magmatism. Layered igneous rocks. Ophiolites, mélanges and Calc alkaline igneous complexes of Pakistan. Igneous Monomineralic rocks.
Metamorphism: grades and facies. Equilibrium in metamorphism, phase diagrams. Types of metamorphic reactions. Description of important metamorphic rocks. Development of metamorphic textures. Nucleation, crystal growth and recrystallization. Relationship of metamorphism to tectonic processes. Paired metamorphic belts and their tectonic interpretation. Facies series, metamorphic P-T-t path. Distribution of metamorphic rocks in Pakistan.

Lab:
Microscopic studies of igneous and metamorphic rocks.

Recommended Books:

1. Petrology: Igneous, Sedimentary and Metamorphic by Blatt, H., Tracy, R. and Owens, D., 2005. Freeman & Co.
2. Introduction to Igneous and Metamorphic Petrology by Winter, J. D., 2001. Prentice Hall.
3. Igneous Petrology by Hill, A., 1987. Longman Scientific and Technical.
4. Petrology: Igneous, Sedimentary and Metamorphic by Ehlers, E.G. and Blatt, H.W.H., 1982. W.H. Freeman and Co.
5. Petrology: Igneous and Metamorphic Rocks by Hyndman, D.W., 1972. McGraw-Hill.
6. Igneous and Metamorphic Petrology by Best, M.G., 1982, W.H., 1982. W.H. Freeman and Co.
7. Igneous and Metamorphic Petrology by Turner, F.J. and Verhoogen, J., 1960. McGraw-Hill.
8. Igneous Petrogenesis by Wilson, M., 1989. Unwing Hyman.
9. Igneous Petrogenesis by Carmichael, I.S.E., Turner, F.J. and Verhoogen, J., 1974. McGraw-Hill.
10. Igneous Petrology by McBirney, A.R., 1984. Freeman Cooper and Co.

GEOL. 503: SEDIMENTOLOGY AND SEQUENCE STRATIGRAPHY
2+1 Credit Hours

Objectives:
This course is designed to acquire the knowledge about various types of sedimentary rocks their diagenesis and depositional systems; various types of stratigraphic sequences and their relationship with the sea level changes.

Learning Outcomes:
After completion, the students will become able to apply sedimentological principles and sequence stratigraphic techniques in the various field of Geology.

Course Content:
Introduction to sedimentology, origin, transportation and deposition of sediments. Texture of sedimentary rocks and their statistical parameters. Sedimentary structures, their classification, morphology and significance. Classification and description of sedimentary rocks. Provenance and diagenesis. Concepts of sedimentary facies and facies associations. Physicochemical controls of the sedimentary environments.

Diagnostic features of fluvial, lagoonal, deltaic, tidal and marine environments. Tectonic controls of sedimentation.

Sequence stratigraphy and its historical development. Hierarchy of sequences and sequence boundaries, sedimentary processes and depositional environment. Global cycle chart and eustatic sea level changes. Facies analysis and determination workflows. High Resolution Sequence Stratigraphy: integration of outcrops, core, well logs and seismic data. Age determination techniques, Sequence formation, depositional architecture, behavior of sedimentary successions during subsidence. Tectonic processes and structures. Accommodation and shoreline shifts, Stratigraphic surfaces, Systems tracts, Sequence models, Time attributes of stratigraphic surface,

Lab:
Grain size analysis, grain morphology. Microscopic study of sedimentary rocks. Separation and identification of heavy minerals. Study of sedimentary structures and paleocurrent analysis. Strip Logs, correlation and Facies analysis. Wheelers model. Interpretation of stratigraphic and seismic cross section. Application of different software.

Recommended Books:

1. Sedimentology and Stratigraphy (3rd ed.) by Nichols, G. 2023. Willy. ISBN: 978-1-119-41727-9.
2. Sedimentary Petrology by. Tucker, M. E., and Jones. S.J., 2023. 4th Edition. Wiley.
3. Principles of sequence stratigraphy by Catuneanu, Octavian, and Newnes, 2022.
4. Stratigraphy: A Modern Synthesis by Miall, A.D. 2022. Springer Chem, ISBN: 978-3-030-87535-0.
5. Principles of Sedimentology and stratigraphy (5th ed.) by Boggs, Jr.S., 2012. Pearson Publishing Co.
6. Sedimentology and stratigraphy by Nichols, G. 2009.John Wiley & amp Sons,
7. Sequence stratigraphy by Emery, Dominic, and Keith Myers, (Editors), 2009. John Wiley &amp Sons.
8. Sequence Stratigraphy and Facies Association by Posamentier, H.W., et al., 1993. Blackwell.
9. Silici-clastic Sequence Stratigraphy in Well Logs, Cores and Outcrops by Van Wagoner, J. C., et al., 1990, AAPG Meth Expl. Ser.No: 7.
10. Applied Sedimentology by Selly, R.C., 1988. Chapman and Hall.
11. Sea-level Changes an Integrated Approach by Wilgus, B.S., et al., 1988. SEPM.
12. Sedimentary Environment and Facies by Reading, H.G., 1986. Blackwell.

GEOL. 504: PETROLEUM GEOLOGY
2+1 Credit Hours

Objectives:
This course is designed to acquire the knowledge of processes involved in the formation, migration and accumulation of petroleum. This will help the students to learn the occurrences and distribution of oil and gas in Pakistan.

Learning Outcomes:
Once they have finished this course successfully, students will be able to:
Understand concepts of petroleum geology and aspects of petroleum system.
Distinguish source, reservoir and seal rocks and their characteristics.
Understand Petroleum geology of Pakistan and the application of knowledge in the exploration and development of the country's energy resources.

Course Content:
Basic concepts of Petroleum Geology. Historical review of petroleum exploration. Petroleum system and its types. Source rock: characteristics, productivity and preservation of organic matter, formation and maturation

of kerogen, types of organic matter. Expulsion and migration mechanism. Conventional Reservoirs: Sandstone and carbonate reservoirs, effects of diagenesis on reservoir quality, reservoir continuity. Traps and its types. Seal rock and its characterization. Unconventional reservoirs. Drive mechanism, energy and pressure maintenance, Enhanced oil recovery techniques. Petroleum geology of Pakistan. Case studies of selected oil and gas fields of Pakistan.

Lab:
Preparation of various types of subsurface maps and cross sections. Preparation of fence diagrams. Visits to well/drilling sites.

Recommended Books:

1. Fundamentals of reservoir rock properties (2nd ed.) by Alyafei, N., 2021. Hamad Bin Khalifa University Press.
1. Petroleum Geology, Basin Architecture and Stratigraphy of Pakistan by Siddiqui, N.K. 2016. Publisher Nusrat K. Siddiqui, ISBN 9692313301, 9789692313308
2. Nontechnical guide to petroleum geology, exploration, drilling, and production (3rd ed.) by Norman J. H., 2012. Penn Well Corporation.
3. Petroleum Geoscience: From Sedimentary Environments to Rock Physics by Bjørlykke, K., 2010, Springer.
4. Traps, Seals and Petroleum System by Surdam, R.C., 2008, AAPG Memoir 67.
5. Elements of Petroleum Geology by Selley, R.C. 1998. Acad. Press.
6. Hydrocarbon Exploration and Production by Jahn, F., Cook, M. and Graham, M. 1998. Elsevier.
7. Geology and Tectonics of Pakistan by Kazmi, A.H. and Jan, M.Q., 1997. Graphic Publishers.
8. Geology of Pakistan by Bender, F.K. and Raza, H.A., (Editors) 1995. Gebruder Borntraeger.
9. Petroleum Geology of Pakistan by Kadri, I.B., 1995. Pakistan Petroleum Limited (PPL).
10. Petroleum Geology by North, F.K., 1985. Allen and Unwin.
11. Petroleum Formation and Occurrence by Tissot, B.P. and Welte, D.H. 1984. Springer-Verlag.
12. Geology of Petroleum by Leverson, A.I., 1970. W. H. Freeman and Co.

GEOL. 505: Geology of Pakistan
2+1 Credit Hours

Objectives:
This course is designed to equip the students with the knowledge of geology of Pakistan. It will help the students to understand the important geological and tectonic features of Pakistan. It supports to comprehend the distribution of rocks, minerals and other natural resources associated with these geological features.

Learning Outcomes:
After finishing this course successfully, students will be able to:
Understand the geology of Pakistan and its importance.
Describe various structural and tectonic features of Pakistan and associated resources.

Course Content:
Tectono-geomorphic divisions of Pakistan. Stratigraphy of sedimentary basins of the Indian and Eurasian plates with reference to Pakistan. Geology of igneous and metamorphic complexes of Pakistan with special reference to Chagai magmatic arc, ophiolitic belt and Kohistan arc.
Geology of Salt Range, Kohat-Potwar Plateaus, Swat-Hazara Region, and Kirthar-Sulaiman Fold Belt.
Chaman Transform Zone, Syntaxes of Pakistan and Makran Subduction Complex.

Lab:
Study and interpretation of geological maps of Pakistan. Construction of cross sections on Hunting Survey Corporation and Salt Range maps. Geological field visit to Salt Range and adjoining areas, report writing.

Recommended Books:

1. Petroleum Geology, Basin Architecture and Stratigraphy of Pakistan by Siddiqui, N.K. 2016. Publisher Nusrat K. Siddiqui, ISBN: 9692313301, 9789692313308.
2. Stratigraphy and Historical Geology of Pakistan by Kazmi, A.H and Abbasi, I.A., 2008. Graphic Publishers, Karachi, Pakistan.
3. Metallogeny and Mineral Deposits of Pakistan by Kazmi, A.H., and Abbasi, S.G., 2001. Orient Petroleum Incorporation.
4. Geology and Tectonics of Pakistan by Kazmi, A.H. and Jan, M.Q., 1997. Graphic Publishers.
5. Geology of Pakistan by Bender, F.K. and Raza, H.A. (Editors), 1995. Gebruder Borntraeger.
6. Geochronology of pre-Himalayan and Himalayan tectonic events, northwest Himalaya, Pakistan, Baig, M.S., 1991. Kashmir Journal of Geology, Kashmir, Vol:8 and 9, pg: 197.
7. 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. Vol: 125, No. 1, pg: 83-86.
8. Geodynamics of Pakistan by Farah, A. and DeJong, K.A. (Editors.), 1979. Geological Survey of Pakistan.
9. Geology of Himalaya by Gansser. A. 1964. John Wiley and Sons.
10. Reconnaissance Geology of West Pakistan, 1961. Hunting Survey, Report.

GEOL. 506: Oceanography
2+1 Credit Hours

Objectives:
This course is designed to impart knowledge about basic concepts of oceanography and its impact on global climate. It also introduces the scope of Marine Geology and helps the students to learn about application of various instruments for data acquisition in marine realm.

Learning Outcomes:
Through successful completion of this course, students will be able to:
Understand the basic concepts of oceanography and its impact on global climate.
Understand the scope and applications of marine geology.
Describe ocean floor topography and exploration methods.
Define offshore natural resources of Pakistan.

Course Content:
Basic concepts of oceanography, oceanographic processes include plate tectonics. Oceanographic tools and technology. History of the development of paleoceanography. Marine ecology. Marine sediments and sedimentation. Relationship of oceanographic processes to other components and human activities that impact ocean resources. Global climate variability and viability.
Introduction and applications of branches of oceanography; Biological Oceanography: the distribution of organisms in the ocean, the types and abundance of organisms found in specific locations, relationship with micropaleontology. Chemical Oceanography: origin, concentration, vertical and horizontal distribution of various chemicals constituents, biogeochemical cycles. Geological oceanography (Marine geology): ocean floor topography, geological materials and processes. Major ocean basins, seas and gulfs. Physical oceanography: physical movement of the oceans; waves, tides, and water currents. Physical processes occurring along the shore and interactions between the ocean and the atmosphere.

Lab:
Exercises of Marine Charts, navigation and bathymetry, acoustic seismic profiling. Geography of the marine environments. Sea floor spreading and plate tectonics. Marine sediments.

Recommended Books:

1. Geology of the Oceans by Rao, C.S.P. and Rao, R.R.K. 2023. Wiley. ISBN: 978-1-119-57986-7.
2. Marine Geology and Geotechnology by Mukherjee, P.K. and Dutta, P.N. 2022. Elsevier. ISBN: 978-0-12-818225-4.
3. The Sea Floor: A Natural Laboratory for Marine by O'Connor, J.A.C. and Lee, L.M.W. (Editors) 2022. Springer.
4. Introduction to Oceanography, by Pinet, P.R., 2000. Jones & Bartlett Publishers.
5. Laboratory Exercises in Oceanography, (2nd ed.) by Popkin, B.W, Grosline, D.S and Hammond, D. E., 1987. W. H. Freeman and Company. New York.
6. The Sea Floor: An Introduction to Marine Geology (2nd ed.) by Seibold, E. and Berger, W.H., 1993. Heidelberg, Germany: Springer-Verlag.
7. Oceanography by Gross, M.G., 1986. Prentice Hall. 106.
8. Submarine Geology by Shepard, P.P., 1983. Harper and Row.
9. Essentials of Oceanography by Thurman, H.V., 1983. University of Mecill

GEOL. 507: GEOCHEMISTRY
2+1 Credit Hours

Objectives:
This course is designed to provide the basic understanding about geochemistry and distribution of elements in minerals and rocks within different prevailing environments. How the geochemical signatures provide the heterogeneity that leads to useful geochemical proxies / tools.

Learning Outcomes:
After successful completion of this course, students will be able to:
Understand the basic concepts of geochemistry, branches and their applications.
Describe geochemical cycles and distribution of elements in spheres of Earth.
Collect and utilize geochemical data for different fields.

Course Content:
Introduction to geochemistry and basic geochemical principles. Geochemistry and classification of elements. Geochemical composition of solar system. Geochemical cycle of selected elements. Geochemical data and rock types. Distribution of trace elements in minerals. Geochemical associations, mobility and dispersion of elements at the earth surface. Geochemical anomalies.
Introduction to petroleum geochemistry, hydrogeochemistry, medical geology, isotope geochemistry**.**

Lab:
Geochemical sampling, preparation and dissolution procedures. Introduction to quantitative chemical analyses (rocks, sediments, water). CIPW calculations of igneous rocks.

Recommended Books:

1. Geochemistry: Concepts and applications, by Boddula, R., Ahamed, M.I., Altalhi. T., 2021. John Wiley & Sons.
2. Using Geochemical Data: To Understand Geological Processes (2nd ed.) by Rollinson, H. R., Pease, V., 2021. Cambridge University Press.
3. Geochemistry (2nd ed.) by White, W.M., 2020.Wiley-Blackwell.

4. Applied Geochemistry: Advances in Mineral Exploration Techniques, by Macheyeki, A., Kafumu, D., Li, X., Yuan, F., 2020.Elsevier.
5. Introduction to Geochemistry: Principles and Applications, by Kula, C. Misra, K.C., 2010. Wiley-Blackwell.
6. Geochemistry: An Introduction (2nd ed.) by Albarèd, F., 2009. Cambridge University Press.
7. Essentials of Geochemistry (2nd ed.) by Walther, J.V., 2008. Jones & Bartlett Publishers, Inc.
8. Treatise on Geochemistry, by Holland, H.D. and Turekian, K.K. 2005. Elsevier.
9. Introduction to Geochemistry, by Krauskopf, K.B., 2003. McGraw-Hill.
10. Geochemistry, by Brownlow, A.H., 1996. Prentice Hall.
11. Geochemistry in Mineral Exploration, by Rose, A.W., Hawkes, H.H. and Webb, J.S., 1983. WhitstableLitho. Ltd.

GEOL. 508: GEOPHYSICS AND HYDROGEOLOGY
2+1 Credit Hours

Objectives:
This course is designed to acquire knowledge about the hydrogeology, and subsurface geology (aquifers) based on different geophysical methods, with an aim to understand the structure of the earth, exploration of resources, and assessment of aquifers.

Learning Outcomes:
After successful completion of this course, students will be able to:
Describe the basic concepts of geophysics and hydrogeology; and their applications.
Understand various geophysical techniques employed for the exploration of resources, groundwater and engineering works.
Recognize groundwater resources of Pakistan.

Course Content:
Basic concepts and relation of geophysics with other sciences. Geophysical concepts of forces and impact on various types of rocks. Introduction to various geophysical techniques for the exploration of hydrocarbon, minerals, groundwater and engineering works. Acquisition, Processing, and interpretation of data.
Introduction to Hydrogeology. The hydrologic cycle. Groundwater and surface water interaction. Recharge and discharge of groundwater. Geological, geophysical and hydraulic properties of aquifers. Formation of aquifer systems. Hydraulic gradient and hydraulic conductivity. Steady and transient flow in aquifers. Groundwater flow equations. Groundwater quality and pollution. Fluctuation of watertable. Groundwater resources of Pakistan.

Lab:
Time and depth structure maps. Quantitative and Qualitative interpretation of geophysical data. Derivation of different formula for thickness measurement, two-way time and intercept time. Calculation of subsurface characteristics of the rock.
Collection and interpretation of hydrogeological data. Laboratory analyses of major water quality parameters. Construction of water table maps, drainage maps and flow nets. Geophysical survey methods for groundwater.

Recommended Books:
1. Hydrogeology by Hölting, B., Coldewey, W.G. 2018. Springer Berlin, Heidelberg.
2. Hydrogeology, Principles and Practice (2nd ed.) by Kevin M.H. and Victor F.B. 2014. John Willey & Sons.
3. Gravity and Magnetic Exploration: Principal, Practices, and Application by William J. Hinze, W.J., von Frese, R.B. and Saad, A.H. 2013. Cambridge University Press.

4. Fundamentals of Hydrology by Tim Davie. 2012. Rourledge for Taylor and Francis Group, USA.
5. Hydrogeology Lab Manual by Lee. 2010. Prentice Hall, USA.
6. Whole Earth Geophysics: An Introductory Textbook for Geologists and Geophysicists by Lillie, R.J. 2008. Prentice Hall.
7. Hydrogeology, Principles and Practice by Geofluids, S.Q.L., 2005. Blackwell Synergy.
8. An Introduction to Geophysical Exploration by Kearey, P., and Brooks, M., 1991. Osney Mead.
9. Field Hydrogeology by Brassington, R., 1988. John Wiley & Sons.
10. Basic Exploration Geophysics by Robinson, E.S. and Coruh, C., 1988. John Wiley & Sons.
11. Geophysical Methods in Geology by Sharma, P.V., 1987. Elsevier.

GEOL. 509: FIELD GEOLOGY AND GEOMORPHOLOGY
2+1 Credit Hours

Objectives:
In this course students will learn the use of field equipments, identification of geological features, data acquisition and preparation of geological maps and cross-sections.

Learning Outcomes:
After completion of course the students will be able to:
Recognize geological features, collect data in field and writing of geological field report.
Describe basic concepts of geomorphology; geomorphic processes and formation of various related landforms of the earth.

Course Content:
Introduction to field geology and reconnaissance survey. Preparation and safety measures, and instruments used in the field. Field identification of sedimentary, igneous and metamorphic rocks. Methods of rock section measurements. Recognition and interpretation of structural features. Methods and techniques of surface geological mapping. Geological field report writing.
Fundamental concepts of Geomorphology. Geomorphic agents and cycles. Impact of climate on geomorphology. Fluvial geomorphology, drainage patterns and their significance. Aeolian, Glacial and Coastal processes and related landforms.

Lab:
Study and observation of rocks, primary and secondary structures in the field. Measurements of distance, height, thickness, attitude of planes and lines. Location and contact marking. Interpretation of topographic maps. Field visits to various geological sections around Karachi.

Recommended Books:
1. Fundamentals of geomorphology by Huggett, R. and Shuttleworth, E. 2022. Routledge.
2. Field Guide Book of Geology of Kutch (Kachchh) Basin, Gujarat, India by Biswas, S.K., Mahender, K., & Chauhan, G.D. 2022. Springer.
3. Sedimentary rocks in the field, A Colour Guide by Stow, D.A.V. 2021. Manson Publishing
4. Fluvial processes in geomorphology by Leopold, L.B, Wolman, M.G, Miller, J.P, and Wohl, E.E. 2020. Courier Dover Publications.
5. Geological field techniques. By Coe, Angela L., 2010. John Wiley & Sons.
6. Process Geomorphology, by Ritter, D.F., Kochel, R.C. and Miller, J.R., 2006. Waveland Press.
7. Introduction to Field Geology. Bevier, M.L., 2006. McGraw-Hill Ryerson.
8. Fundamentals of Geomorphology, by Huggett, R., 2002. Routledge.
9. Principles of Geomorphology, by Thornbury, W.D., 1991. John Wiley & Sons.
10. Basic Geological Mapping, by Barnes, W.J., 1991. Open University Press.
11. Geomorphology of Earth Surface Processes and Forms, by Aharma, V.K., 1986. McGraw-Hill.

12. Geology in the Field by Compton, R.R., 1985. John Wiley and Sons.
13. Structural Geology of Rocks and Regions, by Davis, G.H., 1984. John Wiley & Sons.
14. Field Geology by Lahee, F.H., 1961. McGraw-Hill.

GEOL. 510: ENGINEERING GEOLOGY
2+1 Credit Hours

Objectives:
This course elaborates the fundamental concepts of engineering geology and its application to solve the problems in civil engineering. This course helps to get knowledge about soil mechanics and site investigation for civil structures.

Learning Outcomes:
After finishing this course successfully, students will be capable to:
Understand the engineering properties and classification of soil and rocks and their applications.
Describe geology of sites for civil structures.

Course content:
Fundamentals of soil mechanics and site investigation. Estimation of index properties of soil with the help of three phase diagram. Soil Identifications and Classification. Soil Structure and Clay Minerals. Principles of Soil Compaction. Effective Stress, Capillarity and Permeability. Compressibility of Soil. Shear Strength of Soil. Geology of site for dams, tunnels, reservoirs, buildings, highways, bridges, and flyovers. Building materials. Groundwater and its impact on civil structures, water logging and salinity.
Introduction to rock engineering, Index properties of rock. Engineering classification of rocks, Factors controlling behavior of rock materials, In-situ stresses in rock. Applications of rock engineering to rock slopes, Applications of rock engineering to Foundation and underground openings. Rocks as an aggregate.

Lab:
Determination of Physical properties of rocks, soils and aggregates.

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. Engineering Geology by F.G. Bell., 2007. Buttersworth.
4. Foundations of Engineering Geology by Waltham, T., 2002.
5. Engineering Geology by Goodman, R.E., 1993, John Wiley and Sons.
6. Rock Slope Stability Analysis by Gian Paolo Giani., 1992. Amazon.
7. Principles of Engineering Geology by Johnson, R.B. and Degraff, J.V., 1989. John Willey & Sons.
8. Measuring Engineering Properties of Soil by Wray, W. K., 1986. Prentice Hall.
9. Engineering Geology by Beavis, F.C., 1985. Blackwell Scientific Publications.
10. Geology and Engineering by Legget, R.F., 1962. McGraw-Hill.

GEOL. 511: PLATE TECTONICS AND STRUCTURAL GEOLOGY
2+1 Credit Hours

Objectives:
This course is designed to acquire the knowledge of plate tectonics, various types of plate boundaries. This will help the students to understand mountain building phenomenon, seismicity, volcanism and metallogeny. It helps to become familiar with structural elements in the earth crust. This course will equip the student with types of illustration used in structural analysis.

Learning Outcomes:
After completion of this course the students will be able to:
Understand fundamentals of plate tectonics, types of forces and resultant features.
Carry out structural analysis in various types of terrains.
Prepare and interpret different types of surface and subsurface maps and cross sections.

Course Content:
Earthquake seismology - first motion analysis, velocity structure of earth. Theories of plate tectonic. Framework of plate tectonics: plate and plate margins and distribution of earthquakes. Oceanic ridges and continental rifts. Transform versus transcurrent faults and ocean fracture zones. Subduction zone related tectonics. Types of mountain ranges.

Fundamental concepts of forces, stress and strain. Rheological relationships of rocks. Joints: arrays, origin and interpretation. Deformation processes. Veins. Fault: geometry, displacement, classification and relation to stresses. Fault system. Fold: classification, systems, geometry, mechanics and kinematic models. Foliation and lineation types, origin and tectonic interpretation. Fold and thrust belts in regional context and mechanics. Thrust geometry and thrust related folding.

Lab:
Map exercises and construction of geological cross-sections. Orthographic and stereographic Projections, balanced cross-sections.

Recommended Books:

1. Elements of Structural Geology by Hills, E.S., 2024. Routledge.
2. Structural Geology and Tectonics Field Guidebook by Mukherjee, S., 2023. Springer.
3. Structural Geology by Bhattacharya, A.R., 2022. Springer.
4. An Integrated Framework for Structural Geology: Kinematics, Dynamics, and Rheology of Deformed Rocks by Wojtal, S., Blenkinsop, T., and Tikoff, B., 2022. Wiley.
5. Plate Tectonics: Essential Concepts by Morrison, F., 2022. Murphy & Moore Publishing.
6. Regional Geology and Tectonics: Principles of Geologic Analysis (2^{nd} ed.) by Scarselli, N., Adam, J., Chiarella, D. (Editors) 2020. Elsivere.
7. Structural Geology: A Quantitative Introduction by Pollard, D.D., and Martel, S.J., 2020. Cambridge University Press.
8. Tectonics and Structural Geology: Indian Context by Mukherjee, S., 2019. Springer.
9. Plate Tectonics by Brown, F.Y., 2018. (Great Discoveries in Science).
10. Global Tectonics, by Kereay, P., Klepeis, K.A. and Vine, F.J., 2009. Blackwell Scientific Publications.
11. Earth Structure: An Introduction to Structural Geology, by Puljim, B.A. and Marshak, S., 2004. WCB/McGraw-Hill.
12. Applied Subsurface Geological Mapping by Tearpook, D.J. and Bischke, R.E., 1991. Prentice Hall.
13. Basic Methods of Structural Geology by Marshak, S. and Mitra, S., 1988. Prentice Hall.

BS Fourth Year

GEOL. 601: RENEWABLE ENERGY RESOURCES
2+1 Credit Hours

Objectives:
This course is designed to acquire knowledge about the importance of renewable energy resources. It helps to get awareness about sources of various renewable energy resources; their environmental and socio-economic impacts in Pakistan.

Learning Outcomes:
After successful completion of this course, students will be able to:
Describe the renewable energy resources in context of geology.
Recognize renewable energy resources of Pakistan.
Define techniques, possible impacts and hazard issues associated with utilization of these resources.
Student will also be able to conduct research or development project in renewable energy systems.

Course Content:
Introduction to renewable energy resources. Global and local shares. Promising renewable energy sources of Pakistan, their potential availability and present status. Introduction to waves, tides and current energy resources, techniques and their socio-economic impacts. Geothermal gradient: occurrences and potentials of thermal springs and geysers, extraction techniques, applications; water and space heating power generations, problems, environmental effects. Nuclear energy: role of radioactive minerals in nuclear energy, safety and hazards issue.
Hydalpower: Global resources, and their assessment, classification, sources and principles of energy conversion; micro to small power systems, environmental impact. Solar energy: Solar constant atmospheric effects, global distribution, effects of tilt angle, daily and seasonal variations, resource estimation. Wind: Global distribution resource assessment. Role of geology and structure in the formation of wind corridors. Wind corridors of Pakistan.

Lab:
Case studies of selected renewable resource projects of Pakistan. Visits to renewable resource sites.

Recommended Books:

1. Renewable Energy Sources. Panwar, N.L. 2023. NIPA Genx Electronic Resources & Solutions P. Limited. ISBN: 9788119072118, 8119072111.
2. Renewable Energy and Green Technology, Principles and Practices. Kumar, A., Hukum Singh, H., Kumar, N. (Editors), 2021. CRC Press. ISBN: 9781000484489, 1000484483.
3. Fundamentals of Renewable Energy by Panwar N.L. and Narendra, R.S. 2021. New India Publishing Agency.
4. Renewable and Alternative Energy Resources by Hanif, M.A., Nadeem, F., Tariq, R. and Rashid, U. 2021. Elsevier Science. ISBN: 9780128181508, 0128181508.
5. Renewable Energy: Resources, Challenges and Applications. Ahmad El-Kharouf, Hakan Serhad Soyhan, Mansour Al Qubeissi (Editors), 2020. United Kingdom: Intech Open. ISBN: 9781789842838, 1789842832.
6. Fundamentals and Source Characteristics of Renewable Energy Systems by Radian Belu, R. 2019. CRC Press, Taylor and Francis Group.
7. Wind Energy: Renewable Energy and the Environment, Second Edition by Vaughn Nelson. 2013. CRC Press, Taylor and Francis Group.
8. Renewable Energy Sources Their Impact on Global Warming and Pollution. Abbasi T, Abbasi S.A., 2011. Prentice Hall India Pvt., Limited. ISBN:9788120339941, 8120339940.

9. Geothermal Energy Resources for Developing Countries by D. Chandrasekharam, J. Bundschuh (editors). 2010. CRC Press, Taylor and Francis Group.
10. Sustainable Energy: Choosing Among Options by Jefferson W. Tester. 2005. MIT Press, USA.

GEOL. 602: GEOLOGICAL FIELD WORK AND REPORT WRITING
0+3 Credit Hours

Objectives:
Aim of this course is to identify various rock types, stratigraphic features, fossils, primary and secondary structures and landforms in the field. It also includes the construction of profiles and cross sections, out crop sketches and geological mapping techniques.

Learning Outcomes:
Students will be able to carry out geological field work, sample collection, section measurement and mapping.

Course Content:
Two weeks field work in the areas of geological interest: Reconnaissance Survey and traverse marking. Section measurement. Field photography, collection of rock samples and field data related to geomorphology, stratigraphy, sedimentology, paleontology and structure. Geological mapping of area and submission of field report.

Recommended Books:
1. Sedimentary Rocks is the Field, A Colour Guide, by Stow, D.A.V., 2005. Manson Publishing.
2. Geology and Tectonics of Pakistan, by Kazmi, A.H. and Jan, M.Q., 1997. Graphic Publishers.
3. Geology of Pakistan, by Bender, F.K. and Raza, H.A., 1995. Gebruder Borntraeger.
4. Computing Information Age, by Stem, N. and Stern, R.A., 1993. John Wiley & Sons.
5. Basic Geological mapping, by Barnes, W.J., 1991. Open University Press.
6. Mapping of Geological Structures by McClay, K.R., 1988. Open University Press.
7. Field Geology by Lahee, F.H., 1987. McGraw-Hill.
8. Geology in the Field by Compton, R.R., 1985. John Wiley & Sons.
9. Stratigraphy of Pakistan by Shah, S.M.I., 1977. Geological Survey of Pakistan, Memoirs 12.
10. Hunting Survey Corporation, 1961. Reconnaissance Geology of Part of West Pakistan, Colombo plan.

GEOL. 603: WELL SITE GEOLOGY AND LOGGING TECHNIQUES
2+1 Credit Hours

Objectives:
This course furnishes knowledge of well site geology, types of rig and drilling fluids. It also educates students about the well logging techniques and their interpretation.

Learning Outcomes:
After finishing this course successfully, students will be able to:
Describe well site geology, type of rig and drilling fluids.
Define well logging techniques.
Determine petrophysical properties of rocks.
Interpret of various logs for exploration of hydrocarbon.

Course Content:
Introduction to well site geology. Types and components of rigs and bits, types and composition of drilling muds. Fundamentals of well logging. Petrophysical properties. Resistivity concepts and invasion profile. Mud logging techniques. Wire line logging methods and interpretation. Spatial correction on Logs. Spontaneous

Potential (SP) and Resistivity measuring tools. Induction and Laterolog, Permeability relationship. Matrix sensitivity logs: GR, SGR Pe. calipers and image logs. Density-Resistivity cross plots. Advanced Log (FMI, FMI-HD, ECS, and CMR etc), dip meter logs and their applications. Cased hole logs (Cement and Corrosion Log). Study of depositional environments using wire line logs.

Lab:
Correlation and interpretation of different log types. Estimation of petrophysical properties of reservoir rocks. Integration of core data with petrophysical logs. Visit to well site.

Recommended Books:

1. The Imperial College Lectures in Petroleum Engineering (An Introduction to Petroleum Geosciences), Vol: 1, by Michael Ala, 2017. World Scientific.
2. Principles and application of Well Logging, by Hongqi Liu, 2017. Springer Berlin.
3. Well's First Principles of Geology. Wells, D.A., 2016. A Textbook for Schools, Academies and Colleges. Creative Media Partners, LLC. ISBN: 9781359034717, 1359034714
4. Petrophysics. Cannon, S., 2015. A Practical Guide. John Wiley & Sons, Inc. ISBN: 9781119117636, 1119117631.
5. Nardone, P.J., 2009. Well Testing Project Management Onshore and Offshore Operations. Elsevier Science. ISBN: 9780080879079, 0080879071
6. Serra, O., 2008. Well Logging Handbook. Technip. ISBN: 9782710809128, 2710809125.
7. Fundamentals of Formation Testing by Schlumberger, 2006. Schlumberger Marketing Communications.
8. Basic Log Interpretation, by Schlumberger, 2005. Schlumberger Educational Services.
9. Basic well log analysis, by Krygowski, D., 2004. Amer. Assn. of Petroleum Geologist.

GEOL. 604: RESERVOIR AND DEVELOPMENT GEOLOGY
2+1 Credit Hours

Objectives:
This course is design to impart the knowledge about Reservoir rock types. Fluid contacts; reservoir zonation and mapping techniques of reservoirs, Reserve calculation and Appraisal and development techniques.

Learning Outcomes:
After completion of course, students will be able to:
Understand Reservoir rock types and properties.
Understand fluids and its characters.
Describe Reserve calculation and Appraisal and development techniques

Course Content:
Introduction to reservoir development geology. Reservoir rock types: clastics, carbonates and non-marine reservoirs. Reservoir properties, depositional and diagenetic controls. Rock and fluid properties and their saturation in reservoir. Hydrocarbon distribution and fluid contacts. Migration from source to reservoir rock. Reserve estimation methods: Volumetric, Material Balance, Decline Curve and Enhanced oil. Pressure and temperature regimes in the subsurface. Origin of different pressures and their testing techniques. Drive mechanisms and recovery efficiencies. Well spacing design criteria. Naturally Fractured reservoirs. Rock types and its impact on production. Economic projections and decline curves. Secondary and enhanced oil recovery. Brief introduction of Reservoir modeling.

Lab:
Exercises on measurements of rock and fluid properties, reserve estimation and oil recovery. Specified assignments/projects.

Recommended Books:

1. Reservoir Development. Islam, R., 2021. (ebook), Elsevier Science. ISBN: 9780128204160, 0128204168.
2. Petroleum Reservoir Management Considerations and Practices. Pathak, 2021. (ebook), CRC Press. ISBN: 9781000429329, 1000429326.
3. Water flooding Sandstone Reservoirs: Methods, Design and Analysis. ebook, Springer. Wang, J., 2021. ISBN: 9789811603495, 9811603499.
4. Enhanced Oil Recovery Field Planning and Development Strategies. Alvarado, V., and Manrique, E., 2010. (ebook), Elsevier Science. ISBN: 9781856178563, 1856178560.
5. Applied subsurface mapping, by Tearpock, D.J. and Bischke, R.E., 2007, Prentice Hall.
6. Geostatistical Reservoir Modeling by Clayton, V. Deutsch, 2002. Oxford, University Press.
7. Principles of Petroleum Development Geology by Laudon, R., 1996. Prentice Hall
8. Basics of Reservoir Engineering by Coss, R., 1993. Editions Technip.
9. 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.
10. Reservoir Characterization by Lake, L.W. and Carrol Jr, H.B., 1986. Academic Press.
11. Well Log Formation Evaluation by Richard H. Merkel, 1986. AAPG course notes #14.

GEOL. 605: BASIN ANALYSIS
2+1 Credit Hours

Objectives:

This course provides knowledge about sedimentary basins, their types and classification, mechanism for the formation of sedimentary basins, eustatic and relative sea level changes.

Learning Outcomes:

After completing this course successfully, students will be able to:
Classify sedimentary basin.
Describe mechanism for the formation of sedimentary basins.
Recognize sedimentary basins of Pakistan.

Course Content:

Basin classification and model concepts. Mechanics of sedimentary basin formation in different tectonic settings. Factors controlling basin stratigraphy. Origin of basin, subsidence, basin fills and petroleum systems. Basin modeling. Sedimentary architecture and burial and thermal history of basins. Petroleum basins of the world. Role of basin analysis in hydrocarbon play assessment. Sedimentary basins of Pakistan.

Lab:

Construction of burial history and time-temperature index plots. Exercises related to basin evaluation and classification, basin modeling. Application of related geological softwares' for basin evaluation.

Recommended Books:

1. Petroleum Geology, Basin Architecture and Stratigraphy of Pakistan by Siddiqui, N.K. 2016. Publisher Nusrat K. Siddiqui, ISBN 9692313301, 9789692313308
2. Basin analysis: Principles and Applications to Petroleum Play Assessment byAllen, P.A., and Allen, J.R., 2013. John Wile & Sons.
3. Principles of Sedimentary Basin Analysis by Miall,A.D. 2010. Springer Berlin, Heidelberg.
4. Stratigraphy and Historical Geology of Pakistan by Kazmi, A.H and Abbasi, I.A., 2008. Graphic Publishers, Karachi, Pakistan
5. Tectonics of Sedimentary Basins. By Busby, C.J., and Ingersoll, R.V. (Editors), 1995. Blackwell Science, pg: 579.
6. Sedimentary Basin Evolution, Facies and Sediment Budget by Einsle, G., 1992.

7. Sedimentary Basin Evolution, Facies and Sediment Budget by Einsle, G., 1991. Springer-Verlag.
8. Principles of sedimentary Basin Analysis by Andrew D. Mial, 1990. Springer-Verlag, New York Inc.
9. Sedimentary Environment and Facies by Reading, H.G., 1986. Blackwell Scientific Publications.

GEOL. 606: ENVIRONMENTAL GEOLOGY
2+1 Credit Hours

Objectives:
Main objective of this course is to impart knowledge about the role of geological processes in the environmental degradation. This will also help the students to learn how various geological processes and related human activities are involved in harming our ecosystem.

Learning Outcomes:
After completing this course successfully, students will be able to:
Describe role and importance of environmental geology.
Become environmental manager to mitigate the impacts of natural disasters.

Course Content:
cope of environmental geology. Earth's materials and dynamic system. Relationship between processes and risk assessment. Geohazards and their mitigations. Environmental impacts of mineral development and geotechnical projects and remedial measures. Air pollution. Environmental impact assessment studies.
Water pollution and soil contamination. Renewable and cleaner sources of energy. Global warming, desertification and sea level changes. Coastal hazards and marine pollution. Integrated waste management. Geogenic diseases.

Lab:
Sampling methods for water, sediments and air. Assigned projects and field visits.

Recommended Books:
1. Environmental Law by Malik, S., 2008 Eastern Book company Publishing (P) Ltd, Lucknow, India
2. Manual of Environmental Laws in Pakistan with guideline for development of green belts and International Conventions Protocols by Badar-ul-Amir, 2006. Khyber law Publishers, Lahore.
3. LAL' commentary on Water and Air Pollution with environment (4th ed.), by Mc Mehta, 2007. Delhi Law house Delhi, India
4. Introduction to Environmental Geology, by Keller, E.A., 2005, Pearson Prentice Hall.
5. Environmental geology by Montgomery, C.W., 2005, McGraw-Hill
6. Pakistan's Environmental laws and their compliance by Qadar, S. and Dogar, A.R., 2002, Lahore Law Times Publications.
7. Environmental geology by Keller, E: A., 2000, Charles E. Merrill Publishing Co.
8. Environmental Engineering, by Kiely, G., 1998, McGraw-Hill.
9. Toxic Substances in the Environment, by Magnus, F. B., 1994, John Wiley & Sons.
10. Environmental Geology by Merritt, et al. (Editors), 1998, Freeman & Co.

GEOL. 607: NANO-GEOLOGY
2+1 Credit Hours

Objectives:
This course is designed to equip students with the knowledge of Nano geoscience, determination and characterization methods of Nano composites.

Learning Outcomes:
At the end of the course the student will able to:
Understand of concepts, principles and theories Nano-geoscience and their application towards the solution of problems of an unfamiliar nature.
It will augment the study skills needed for continuing professional development and to interact with others on inter or multidisciplinary problems.

Course Content:
Introduction to Nano geoscience. Occurrence and distribution of Nano minerals and mineral nanoparticles in oceans. Occurrence and distribution of Nano minerals and mineral nanoparticles in surface waters. Occurrence and distribution of Nano minerals and mineral nanoparticles in soils structure, chemistry and properties of mineral nanoparticles. Naturally occurring amorphous nanomaterial**.** Nanoparticles in the atmosphere and their effects on climate and human health**.** Nanoparticles in soils and rocks**.** The effect of organic nanoparticles and microorganisms on weathering Nanomaterial beyond earth. The interdisciplinary character of Nano geoscience. Industrial and environmental applications of nanoparticles**.** Identification and characterization methods in Nano geoscience (XRD, SEM, DTA-TG, FT-Raman, Raman, FTIR, NMR).

Lab:
Synthesis and characterization of nano-particles of minerals and metals using top down and bottom up approach.

Recommended Books:

1. Nano and Micro Diamond Formation in Nature: Ultrafine Carbon Particles on Earth and Space by Simakov, S., Scribano, V., Melnik, N., Pechnikov, V., Drozdova, I., Vyalov, V., Novikov, M. 2023. Springer International Publishing, Germany.
2. Nano Mineralogy by Michael F., Hochella, Jr., Quan Wan, Yiwen Ju. 2020. MDPI Publishers, Switzerland.
3. Nano-mineralogy by Hochella, M.F., Ju Y., Wan, Q. (Editors), 2020. MDPI AG Publishers, Switzerland.
4. Concise Concepts of Nanoscience and Nanomaterials by Kumar, N. and Kumbhat, S., 2018. Scientific Publishers, India.
5. Bio-Nano-Geo Sciences: The Future Challenge by Srivastava, A. and Roy, I. 2016. Springer Berlin Heidelberg, Germany.
6. Actinide Nanoparticle Research by Denecke, M.A. and Kalmykov, S.N. (Editors), 2011. Springer Berlin Heidelberg, Germany.
7. Nanoscopic Approaches in Earth and Planetary Sciences by Brenker, F.E and Jordan, G. (Editors), 2010. European Mineralogical Union.

GEOL. 608: REMOTE SENSING AND GIS
2+1 Credit Hours

Objectives:
The basic aim of the course is to provide basic knowledge regarding GIS, RS and different types of data sets and data models.

Learning Outcomes:
Understand the concepts of RS and satellite image processing techniques.
Data digitization and analyze spatial data.
Run GIS software.

Course Content:
Scope and development of remote sensing. Types of remote sensing. Electromagnetic spectrum, sources and sensors. Imaging and non-imaging systems. Digital image processing. Interaction of different wavelengths with the earth's surface. Types of platforms, satellite types and their functions emphasizing on ERT . Application of remote sensing in earth sciences.
Introduction to GIS. Geo referencing and map digitization. GIS data model. Evolution and applications of GIS data models (raster and vector data). Data acquisition, transformation, visualization and classification techniques. Digital elevation model (DEM) and terrain analysis. Map layout and thematic mapping.

Lab:
Study of aerial photographs and satellite imageries. Photogeological mapping techniques. Digital analyses of satellite data. Introduction to GIS and satellite data software. Data display, digitization. Coordinate based mapping.

Recommended Books:

1. Basics of Geographic Information System (GIS) by Atulkar, M., and Waikar, M.K. 2024. B P International.
2. Remote Sensing by Khorram, S., Koch, F.H., et al. 2012. Springer.
3. Introduction to Geographic Information Systems by Kang-Tsung Chang. 2010. McGraw-Hill Publishers.
4. Remote Sensing of the Environment by Jensen, J.R. 2009. Amazon publishers.
5. GIS: Fundamentals, Applications and Implementations by Elangovan. 2006. McGraw-Hill Publishers.
6. Foundations of Geographic Information Science, by Duckham, M., Goodchild, M.F. and Worboys, M.F. 2003, Tylor and Francis, New York, USA.
7. Fundamentals of Geographic Information System, by Demers, M.N. 2002, John Wiley & Sons, Inc., Singapore.
8. Introduction to Geographic Information Systems, by Chang, K. 2002, McGraw-Hill Company, New York, U.S.A.
9. Physical Principles of Remote Sensing by Rees, W.G. 2001, Cambridge University Press, United Kingdom. ISBN: 0521669480. 38
10. GIS for Beginners, by Shrestha, A. and Bajracharya, B. 2000,ICIMOD, Kathmandu, Nepal.
11. Remote Sensing and Image Interpretation by Lilles, T.M. and Kiefer,R.W. 2000, John Wiley & Sons.

GEOL. 609: COAL GEOLOGY
2+1 Credit Hours

Objectives:
The objectives of this course are to introduce the students to coal, its characteristics, classification, origin, distribution, and problems in exploitation.

Learning Outcomes:
Upon successful completion of this course, students will able to:
Describe origin, structure, texture, distribution of coal and its characteristics.
Do resource estimation.
Identify the problems associated with coal exploitation with special emphasis to Pakistan.

Course Content:
Introduction to coal and its origin. Coal petrology. Geological and geographical distribution. Coal Classification and ranks of coal. Coalification process and its causes; Lithotypes, microlithotypes and macerals: their physical, chemical and optical properties. Mineral and organic matter in coal.
Resource estimation and reserve calculation. Proximate and ultimate analyses. Uses of coal for various industries e.g. carbonization, liquefaction, power generation, gasification and coal-bed methane production.

Introduction to Geology of different Tertiary and Gondwana coalfields of Indian Plate. Coal-bearing sequences of Pakistan, coal mining and its environmental issues with special reference to Thar coal field.

Lab:
Visit to coal mine sites. Study of macerals groups. Proximate and ultimate analyses. Classification of coal. Geological study of coal core samples. Standard exercises related to reserve estimation of coal.

Recommended Books:

1. Coal Geology (3rd ed.) by Thomas, L. 2020. John Wiley & Sons Ltd. ISBN:9781119424130 |Online ISBN:9781119424307 |DOI:10.1002/9781119424307
2. Coal Gasification and its applications by Bell, D.A., Towler, B.F. and Fan, M. 2010. Elsevier.
3. Significance of Coal Resources of Pakistan by Kazmi, A.H. and Raza, H.A., 1990, Geological Survey of Pakistan.
4. Coal Combustion and Gasification by Smoot, L.D. and Smith P.J.,1985, Plenum Press.
5. International Handbook of Coal Petrology by International Committee for Coal Petrology, 1985, University of Newcastle upon Tyne.
6. Sedimentology of Coal and Coal Bearing Sequences by Rehmani, R.A. and Flores, R.M., 1984, International Association of Sedimentologists, Blackwell.
7. Coal Geology and Coal Technology by Ward, C. R., 1984, Blackwell.
8. Terrigenous Clastic Depositional Systems, Application to Petroleum, Coal and Uranium Exploration by Galloway, W. E. and Hobday, D. K., 1983, Springer-Verlag.
9. tach's Textbook of Coal Petrology by Stach, E., et al., 1982, GebruderBorntraeger.
10. Coal: Typology, Chemistry, Physics and Constitution by Van Krevelen, D.W., 1981, Elsevier.

ELECTIVE PAPERS

GROUP I: MINERALOGY

GEOL. 611: ORE GEOLOGY
2+1 Credit Hours

Objectives:
This course provides an introduction to the key features of several major classes of economically important mineral deposits.

Learning outcomes:
This will be enabling them to take their place as professional geologists in industry or government organizations; to recognize alteration in host-rock sequences; characterize ore textures; recognize the importance and role of structure in the formation and modification of ore deposits.

Course Content:
Introduction to tectonic setting and mineralization. Magmatic deposits: ultramafic-mafic Cr-Ni-PGE deposits, ultramafic-mafic Fe-Ni-Cu sulphide deposits, quartz monzonite-granodiorite Cu-Mo sulphide deposits and anorthosite-gabbro Fe-Ti deposits. Ore associated with carbonatites. Hydrothermal vein deposits. Iron and manganese deposits of sedimentary origin. Stratiform and Stratabound ores of sedimentary affiliation. Ores formed by metamorphic processes. Metallogeny and important ore deposits of Pakistan

Lab:
Petrography of ore minerals. Visits to mining sites and report submission.

Recommended Books:

1. Introduction to mineral deposits geology: (Including Exploration, Mining and Mineral Economics), by Moses, O. 2024. Prescott Publishers. ISBN: ISBN 978-0-578-34652-6.
2. Economic Geology: Mineral Systems, Earth Evolution, and Global Metallogeny by David, I.G. and Santosh, M. 2023. Elsevier, ISBN 978-0-443-21684-8
3. Economic Geology: Economic Mineral Deposits by Prasad, U. (2nd ed.), 2021. ISBN 10: 9788123904603.
4. Ore Deposits: Origin, Exploration, and Exploitation by Laurence Robb, L. and Decrée, S. (Editors) 2019. John Wiley & Sons, Inc. USA.
5. The Geology of Ore Deposits by John M. Guilbert, J.M. and Park, C.F. 2007. Waveland Press, USA.
6. Ore Deposits Geology, by Edwards, R. and Atkinson, K. 1986, Chapman & Hall.
7. Mineral Deposits in Relation to Plate Tectonics, by Sawkins, F.J. 1984, Springer-Verlag.
8. Mineral Deposits and Global Tectonic Settings, by Mitchell, A.H.J. and Garson, M.S. 1981, Academic Press.
9. An Introduction to Ore Geology, by Evans, A.M. 1980, Blackwell Scientific Publications.

GEOL. 612: MINING GEOLOGY AND MINERAL PROCESSING
2+1 Credit Hours

Objectives:
Main objectives of this course is to equip the students with the application of engineering principles to minerals processing operations and the application of process control and safety in the mineral industry will be introduced.

Learning Outcomes:
On successful completion of this course students will be able to:
Explain the principles governing a range of processes applied in the minerals industry.
Describe typical unit processes and flow-sheets for production of a number of metals.
Produce conceptual designs for simple extraction processes.

Course Content:
Terms and definitions of mine workings. Selection criteria of mining methods and modes of extraction. Openings through adits, shafts, inclines, vertical cross cuts. Structural controls in mining: bedding, fractures, joints, faults and folds. Rock pressure and support for the mine and safety measures. Surface and underground mapping methods. Impact of mining on land, water, air and biological resources. Remedies, long term planning and rehabilitation.
Scope and principles of mineral processing. Measures of efficiency of mineral separations. Sampling systems and sampling errors. Particle size measurement. Mineral liberation techniques and classification. Mineral concentration using gravity, magnetic and other separating methods. Use of reagents, collectors, frothers, depressants and activators. Precious and other metals recovery methods. Dewatering techniques, thickening, filtering, drying, flocculants and filter aids.

Lab:
Specified assignments/projects. Visits to the operative/model mines and mineral processing plants.

Recommended Books:

1. SME Mining Engineering Handbook, by Hartman, H.L., 1992, Society of Mineral Exploration.
2. Coal Preparation, by Leonard, J.W., 1997, SME, Littleton Co.
3. Mining Geology, by McKinstry, H.B., 1948, Prentice Hall.
4. Mineral Processing Handbook, by Weiss, N. (Editor.), 1985, SME. Littleton Co.
5. Exploration and Mining Geology, by Peters, W.C., 1978, John Wiley & Sons.

GEOL. 613: INDUSTRIAL MINERALOGY AND MINERAL ECONOMICS
2+1 Credit Hours

Objectives:
The main objective of this course is to explore and exploit mineral resources on economic basis.

Learning Outcomes:
The outcome of this course includes making of feasibility reports, evaluating mineral/metal resources through calculating resource grades, exploitation cost and market value etc. This course is designed to introduce students to common rocks/minerals being utilized in the industries.

Course Content:
Physical and chemical properties of industrial rocks and minerals. The geological setting, exploration methods and uses. Natural abrasive raw materials and their properties. Mineralogy and chemistry of raw materials for ceramics, cement, glass, agriculture, chemicals and refractories.
Estimation of ore reserves. Factors affecting mine size, grade and distribution of ore body. Prediction and estimation of cost of mine development and operation. Revenue calculation. Taxable income, income tax, net profit. Risk minimization, sensitively analysis and risk management, limiting financial losses. Development decisions based on economic evaluation.

Lab:
Estimation of specific gravity and ore reserves. Visit to different mineral based industries. Specified assignments/projects.

Recommended Books:

1. Introduction to mineral deposits geology: (Including Exploration, Mining and Mineral Economics), by Moses, O. 2024, Prescott Publishers ISBN: ISBN 978-0-578-34652-6
2. Geology and Mineralogy of Gemstones, by David P., Turner, Lee A. Groat, 2022, Wiley (American Geophysical Union), ISBN: 978-1-119-29987-5
3. Economic Geology Economic Mineral Deposits by Prasad, U. (2nd ed.), 2021, ISBN 10 / 9788123904603
4. Economic and Applied Geology: An Introduction, by Shackleton, W.G. 2020, Taylor & Francis, ISBN-10:0367207192
5. Economic Mineralization, by Shrivastava, K.L., 2008, Scientific Publishers.
6. Mineral Economics, by Gordon, R.L. and Tilton, J.E., 2008, Elsevier.
7. An Introduction to Mineral Economics, Chatterjee, K.K, 2004, New age International Publications.
8. Mineral Resources, Economics and the Environment, by Kesler, S.E., 1994, MacMillian College Publisher Co.
9. Mineral Economics: Developments in Economic Geology, by Rudawsky, O., 1986, Elsevier.

GEOL. 614: GEMOLOGY
2+1 Credit Hours

Objectives:
The core objective of this course is to deliver the knowledge about formation of gemstones. The importance of physics of colors and be familiarity with semi-precious and precious gemstones. To share the knowledge about various gemstone testing methods.

Learning outcomes:
Students will be able to:
Understand the fundamentals of various precious and semiprecious gem stones.
Know their formation, classifications, basic qualities of gemstones, description of their various physical properties.
Recognize different techniques involved in identification of natural and synthetic gemstones.

Course Content:
Introduction of gems and gemology. Crystallography of gemstones, Physical, chemical and optical properties of gemstones. Identification and classification of gemstones. Synthetic gemstones, methods of manufacturing, methods of differentiation between natural, synthetic and imitation gemstones. Synthetic diamonds and their methods of manufacturing and methods of identification. Inclusions in gemstones.
Introduction to gemstone mining methods and gemological instruments. Gemstone treatment, methods of gemstone enhancements, dyeing and irradiation, heat treatment principles and practices, various types of diffusion and other types of enhancement. Gem cuts. Global and local deposits. Gem industry of Pakistan

Lab:
Introduction to gemological instruments, visits to gemological labs and gems mining sites. 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. Gem Identification Made Easy (6th ed.): A Hands-On Guide to More Confident Buying & Selling by Matlins, A. and Bonanno, A.C. 2016. Gemstone Press.
2. Gemstone Tumbling, Cutting, Drilling & Cabochon Making: A Simple Guide to Finishing Rough Stones by Magnuson, J., Carver, V. and Wood, C. 2015. Adventure Publications.
3. Decorative Stones: The complete source book by Price, M.T. 2007. Thames and Hudson.
4. Gems (6th ed.) by O'Donoghue, M. 2 6. Butterworth Heinemann.
5. Gemology (3rd ed.) by Read, P.G., 2005. Elsevier.
6. Gems and Precious stones by Lyman, K. 2005. A Fireside Book.
7. Identification of Gemstones by O'Donoghue, M. 2 3. utterworth Heinemann.
8. Gems: Their source, Description and Identification (4th ed.) by Webster, Are, 1983, Butterworth Heinemann.
9. Synthetic, limitation and Treated Gemstones by O'Donoghue, M. 997. Butterworth Heinemann.
10. The Spectroscope and Gemology by Andarson, B. 1998. Gemstone Press.
11. Gemstones of the World by Schumann, W. 1997. Sterling Publishing Co.
12. Gem Identification Made Easy by Matlins, A. L. 1989. Gemstone Press.

GROUP II: ENGINEERING GEOLOGY

GEOL. 621: SOIL MECHANICS
2+1 Credit Hours

Objectives:

The course is design to learn concepts governing the mechanical properties of soil through integrated lectures, readings, exercise and laboratory experience.

Learning Outcomes:

By studying soil mechanic, students can:
Determine the physical properties of soil.
Analyze how different types of soil may affect the stability of a civil structure.

Course Content:

Concepts of soil mechanics. Soil formation and classifications. Analysis of stress and strain. Compression and swelling. Survey and sampling techniques. Behavior of soil before failure. Geotechnical properties of soil: shearing strength, basic principle relating to friction between solid bodies, coulomb's law, shear strength parameters, shearing strength of granular and cohesive soils, shearing strength tests and their results, effect of strain, rate and drainage conditions on shearing strength and consolidation; mechanics of consolidation, one-dimensional consolidation equation, coefficient of consolidation, compression index, consolidation tests and graphical representation of data, degree of consolidation. Determination of pre-consolidation pressure, swelling clays and clay-shale. Slope stability and bearing capacity.

Lab:

Determination of index properties of soil and report writing.

RECOMMENDED BOOKS:

1. Soil Mechanics and Foundation Engineering: Fundamentals and Applications by Sivakugan, N. 2021. McGraw Hill.
2. Soil Mechanics Fundamentals and Applications by Hazarika, H. and shibashi, I. 2015. CRC Press
3. Soil Mechanics and Foundation Engineering, by Murthy, V.N.S. 2007. CBS Publishers.

4. An Introduction to Mechanics of Soils and Foundations, by Atikson, J. 1993. McGraw-Hill.
5. Engineering Geology, by Beavis, F.C. 1985. Blackwell Scientific Publications.
6. Physical and Geotechnical Properties of soils, by Bowles, J.E. 1984. McGraw-Hill.

GEOL. 622: GEOTECHNICAL INVESTIGATIONS
2+1 Credit Hours

Objectives:
The purpose of this course is to provide the student with an in-depth knowledge and understanding of different method of geotechnical investigation of a proposed site for any civil structure.

Learning Outcomes:
Learning of different techniques of site investigation creates power of decision and confidence in students'.

Course Content:
Geological and geophysical surveys. Application of aerial photographs and satellite data. Drilling and other exploratory methods. Well log interpretation, disturbed and undisturbed samples. Field testing and applications: site investigations for dam and other civil structures. Case histories of various heavy structures in Pakistan. Analysis of slope stability and protection. Foundation analyses and evaluation of the design parameters.
Methods of tunnel excavation in different materials. Evaluation of sub-grade materials, highways and building aggregates.

Lab:
Geotechnical mapping techniques and geotechnical report writing.

Recommended Books:
1. Earth Manual Part I, by Earth Sciences and Research Laboratory. 2000. Geotechnical Research, Technical Services Centre, Scientific Publisher.
2. Essentials of Soil Mechanics and Foundations, by McCarthy, D.F., 1998. Prentice Hall Publishers.
3. Engineering Geology, by Goodman, R.E. 1993. John Wiley & Sons.
4. Modern Geotechnical Engineering, by Singh, A. 1992. CBS Publishers.
5. Engineering Geology, by Beavis, F.C. 1985. Blackwell Scientific Publications.
6. Fundamentals of Engineering Geology, by Bell, F.A.G. 1983. Butter Worth.
7. Geotechnical Engineering Handbook by Carter, M. 1983. Pentech.

GEOL. 623: ROCK MECHANICS
2+1 Credit Hours

Objectives:
The main objective of this course is to understand the behaviour of rocks when used in civil engineering projects such as buildings road dam and tunnels.

Learning outcomes:
After completion of course, a student will be able to:
Apply knowledge of rock mechanics while designing infrastructure like dams, roads, etc.
Know about slope protection and it's crucial role in manning and tunneling.
Understanding rock behaviour in the surface and designing safe and efficient excavation methods

Course Content:
Fabric and mechanical nature of rocks. Determination of rock quality for engineering purpose. Stress and strain behavior of different rock types. Rock mass strength. Theories of failure. Types of fractures. Rock

deformation under compression. Factors controlling mechanical behavior of rocks. Excavation methods of rocks. Distribution of stresses around underground excavations. Measurement of in situ stresses. Dynamic models. Use of photoelasticity in rock mechanics. Wave propagation in rocks.

Lab:
Determination of physical and mechanical properties of rocks. Specified assignments/projects.

Recommended Books:

1. Fundamentals of Rock Mechanics, by Jeager J.C., Cook, N.G.W. and Zimmerman, R.W. 2008. Blackwell Scientific Publishers.
2. Rock Engineering, by Franklin, J.A. and Dusseault, M.B. 1989. McGraw-Hill.
3. Engineering Geology, by Beavis, F.C. 1985. Blackwell Scientific Publishers.
4. Rock Mechanics for Underground Mining, by Brady, B.H.G. and Brown, E.T. 1985. Allen & Unwin.

GROUP III: GEOPHYSICS

GEOL. 631: SEISMIC STRATIGRAPHY
2+1 Credit Hours

Objectives:
This course is design to impart knowledge about the fundamentals of seismic techniques, method and their applications. It also provides concepts of seismic stratigraphy and geological interpretation of seismic sequences and facies.

Learning Outcomes:
Once they have finished this course successfully, students will be able to:
Understand concepts of seismic stratigraphy.
Use different types of seismic surveying methods and instruments
Interpret seismic data.

Course Content:
Seismic waves. Seismic energy sources. Types of seismic surveying methods and instruments. Factors influencing velocity of seismic waves in rocks. Integration of seismic data with geology. Data acquisition, processing, and interpretation, 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. Seismic facies analysis. Reflection character analysis. Geologic interpretation, of structural and stratigraphic traps.

Lab:
Assignments on data processing, analysis and interpretation.

RECOMMENDED BOOKS:

1. Applied Geophysics by Telford, W.M., Geldart. L.P. and Sheriff, R.E. 1990. Cambridge University Press
2. Introduction to Geophysical Prospecting by Kearey, P. and Brooks, M. 1991. Osney Mead.
3. Field Geophysics by Milson, J. 1989. Open University Press.
4. Introduction to Geophysical Prospecting by Dobrin, M.B. and Savit, C.H., 1988, McGraw-Hill
5. Basic Exploration Geophysics by Robinson, E.S. and Coruh, C., 1988, John Wiley & Sons.
6. Geophysical Methods in Geology, by Sharma, P.V., 1987, Elsevier.
7. Seismic Exploration, by Al-Sadi, H.N., 1980, Birkhauser-Verlag.
8. Seismic Stratigraphic Interpretation and Petroleum Exploration by Brown, Jr., L.F. and Fisher, W.L.

1982. AAPG, CNS 16.

GEOL. 632: GEOMAGNETISM AND PALEOMAGNETISM
2+1 Credit Hours

Objectives:
This course provides information about the principles of geomagnetism and paleomagnetism and their applications in geology.

Learning Outcomes:
After studying this course, students will be able to:
Understand concepts of geomagnetism and paleomagnetism.
Apply paleomagnetism in the field of geology.

Course Content:
Principles of magnetism, geomagnetism and paleomagnetism. Present geomagnetism, secular variation, geomagnetic field reversal. Physical and chemical bases of paleomagnetism. Origin of natural remnant magnetization, mineralogy of magnetic minerals. Environmental magnetism. Applications of paleomagnetism in earth sciences.

Lab:
Exercises on data acquisition, processing and interpretation. Specified assignments /projects.

Recommended Books:
1. Introduction of Geomagnetic Fields, by Campbell, W., 2008, National Centre for Atmospheric Research.
2. Magnetic Approaches to Geological Sciences, by Yoshida, M., Khadmi, I.M. and Ali, M., 1994, Part I, II and III, GSP-JICA.
3. Paleomagnetism: Magnetic Domains to Geologic Terranes, by Butler, R.F., 1992, Blackwell Scientific Publishers.
4. Practical Handbook of Physical Properties of Rocks and Minerals, by Carmichael, R.S., 1984, CRC Press.
5. Ferromagnetism, by Bozorth, R.M., 1951, Van Nostrand Publishers.

GEOL. 633: GRAVITY AND MAGNETIC METHODS
2+1 Credit Hours

Objectives:
This purpose of this course is to provide knowledge about the principles of gravity and magnetic geophysical techniques. It also helps to understand the gravity/magnetic anomalies and their applications in geology.

Learning Outcomes:
After completion of this course, students will be able to:
Understand concepts of gravity and magnetic methods of geophysical surveying.
Identify Gravity/magnetic anomalies.
Do 2D and 3D modeling.

Course Content:
Physical principles and theories. Instrumentation. Planning of the survey and evaluation of errors. Different survey methodologies. Rock densities/susceptibilities and their measurements. Data acquisition and reduction. Gravity/magnetic anomalies. Interpretation: Regional fields and residual anomalies, Derivatives, continuation of the field, 2D and 3D modeling. Application and case histories.

Lab:
Problems on data acquisition, processing and interpretation /specified assignments /projects.

Recommended Books:

1. An Introduction to Applied Geophysics by Burges, R.H., Jones, C., Shoehan, A., Sheehan, A.F. and Jones, C.H. 2006. Norton & Co.
2. An Introduction to Geophysical Exploration by Kearey, P. and Brooks, M. 1991. Osney Mead.
3. Applied Geophysics, by Telford, W.M., Geldart. L.P. and Sheriff, R.E, 1990. Cambridge University Press.
4. Field Geophysics, by Milson, J. 1989. Open University Press.
5. Introduction to Geophysical Prospecting, by Dobrin, M.B. and Savit, C.H. 1988. McGraw-Hill.
6. Basic Exploration Geophysics, by Robinson, E.S. and Coruh, C. 1988. John Wiley & Sons.
7. Geophysical Methods in Geology, by Sharma, P.V. 1987. Elsevier.
8. Theory of the Earth's Gravity Field, by Pick, M., Picha, J. and Vyskocil, V. 973. Elsevier.

GEOL. 634: APPLICATIONS OF ELECTRICAL AND RADIOMETRIC TECHNIQUES
2+1 Credit Hours

Objectives:
This course is design to impart knowledge about the fundamentals of electrical and radiometric techniques, procedures and their applications.

Learning Outcomes:
Once they have finished this course successfully, students will be able to:
Understand concepts of gravity and radiometric techniques.
Use gravity and radiometric surveying methods and instruments
Interpret resistivity and radiometric data.

Course Content:
Fundamentals of current flow in the earth. Electrode arrangements and field procedures. 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 of radiometric method. Radioactivity of rocks. Radioactive dating methods. Field surveys and instruments. Data processing, interpretation, and applications.

Lab:
Assignments on data acquisition, processing, and interpretation.

Recommended Books:

1. An Introduction to Applied Geophysics by Burges, R.H., Jones, C., Shoehan, A., Sheehan, A.F. and Jones, C.H. 2006. Norton & Co.
2. An Introduction to Geophysical Exploration by Kearey, P. and Brooks, M. 1991. Osney Mead.
3. Applied Geophysics, by Telford, W.M., Geldart. L.P. and Sheriff, R.E, 1990. Cambridge University Press.
4. Field Geophysics, by Milson, J. 1989. Open University Press.
5. Introduction to Geophysical Prospecting, by Dobrin, M.B. and Savit, C.H. 1988. McGraw-Hill.
6. Basic Exploration Geophysics, by Robinson, E.S. and Coruh, C. 1988. John Wiley & Sons.
7. Geophysical Methods in Geology, by Sharma, P.V. 1987. Elsevier.

GROUP IV: MARINE GEOLOGY

GEOL. 641: MARINE GEOLOGY
2+1 CREDIT HOURS

Objectives:
This course will provide a comprehensive overview of marine geological processes and their implications, analysis of sediment types and their depositional environments. It also familiarize students with marine geological research methodologies.

Learning Outcomes:
Students will be able to:
Describe key concepts in marine geology, including ocean floor geology, sedimentology, and marine geohazards.
Identify and classify different types of marine sediments and understand their depositional environments.
Understand marine geological fieldwork techniques, including sediment sampling, surveying, data collection and interpretation.

Course Content:
Introduction Scope, history and application to Marine Geology. Bathymetry/ Hypsometry. Ocean floor topography. Ocean basins and geographical features. Evolution and structure of important oceans; especially Indian Ocean. Methods of exploring the ocean floor: sub bottom geological sampling equipments and corers. Oceanic expeditions: Challenger expedition, Deep Sea drilling Project (DSDP), Ocean drilling Programme (ODI), Joint Global Flux Studies (JGOFS), and Integrated Ocean Drilling Programme (IODP). Plate tectonics and marine geology. Marine sediments and analysis techniques. Marine Geohazards. Coastal geology and sediment dynamics. Paleoceanography. Marine resources. Impact of climate change on marine geology. Introduction and classification of marine natural resources. Offshore natural resources of Pakistan.

Lab:
Collection of coastal sediments, their grain size analysis and mineralogical studies.

Recommended Books:

1. Geology of the Oceans by Rao, C.S.P. and Rao, R.R.K. 2023. Wiley. ISBN: 978-1-119-57986-7.
2. Marine Geology and Geotechnology by Mukherjee, P.K. and Dutta, P.N. 2022. Elsevier. ISBN: 978-0-12-818225-4.
3. The Sea Floor: A Natural Laboratory for Marine by O'Connor, J.A.C. and Lee, L.M.W. (Editors) 2022. Springer.
4. Marine Geology: A Global Perspective by Carleton, G.D. 2021. Springer. ISBN: 978-3-030-67810-5.
5. Paleoceanography and Paleoclimatology: The Role of the Oceans in Global Climate Change by Wang, R.H. and Dutton, J.A.T. (Editors) 2020. CRC Press. ISBN: 978-0-367-36785-0.

Geol. 642: Advance Oceanography
2+1 Credit Hours

Objectives:
This course is design to impart knowledge about chemical and physical properties of sea water, oceanic circulations and major oceanography events in the Cenozoic Era.

Learning Outcomes:
After completion of this course, students will be able to:

Understand oceanic circulation and upwelling zones.
Interpret paleoceanographic proxies.
Describe oceanographic events of Cenozoic time.

Course Content:
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. Major oceanography events in the Cenozoic, Opening and closing of the gateways. The Law of the sea. Paleoceanographic proxies: their usefulness and limitations (Proxies for temperature, sea level, nutrient contents, thermocline thickness, productivity, OMZ intensity and denitrification). Reconstruction of paleoceanographic history with special reference to the Indian Ocean. Oceanographic tools and technology.

Lab:
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. Geology of the Oceans by Rao, C.S.P. and Rao, R.R.K. 2023. Wiley. ISBN: 978-1-119-57986-7.
2. The Sea Floor: A Natural Laboratory for Marine by O'Connor, J.A.C. and Lee, L.M.W. (Editors) 2022. Springer.
3. Introduction Introduction to Physical Oceanography by Stewart, R.H. 2007. Texas A and M University.
4. Introduction to Oceanography by Pinet, P.R. 2000, Jones & Bartlett Publishers.
5. Sea water: Its Composition, Properties and Behavior, by Gerry, B. (ed.), 1989, Pergamon Press & Open University Press.
6. Laboratory Exercises in Oceanography, by Popkin, B.W., Grosline, D.S. and Hammond, D.E., 1987, Freeman & Co.
7. Coastal Environments by Carter, R.W.G., 1988. Academic Press.
8. A workbook in Oceanography by Dudley, W.C. and Min Lee, 1982. Burgess Co.
9. The Sea, by Emiliani, C. 1981, John Wiley & Sons.

GEOL. 643: GEOLOGY OF THE ARABIAN SEA
2+1 Credit Hours

Objectives:
This course makes students familiar with the evolution, characteristics and natural resources of Arabian Sea. It also imparts knowledge about sedimentary record of climatic variations and Himalayan orogeny.

Learning Outcomes:
Once they have finished this course successfully, students will be able to:
Understand geological evolution of Arabian Sea.
Describe sedimentary record of climatic variations and Himalayan orogeny.
Delineate offshore hydrocarbon and mineral resources of Pakistan.

Course Content:
Geological evolution of Arabian Sea. Physiographic and structural features of Arabian Sea. Geo-dynamics 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 resources.

Lab:
Exercises based on national and international geological research cruises data of Arabian Sea**.**

Recommended Books:

1. The Tectonic and Climatic Evolution of the Arabian Sea Region by Clift, P.D., Kroon, D., Gaedicke, C. and Craig, J. 2005. Geological Society London Special Publication No.195.
2. Seismic Facies and Sedimentary Processes of Submarine Fans and Turbidite Systems, by Weimer, P. and Link, M.H. (Editors), 1991, Springer.
3. Marine Geology and Oceanography of Arabian Sea and Coastal Pakistan, by Haq, B.U. and Milliman, J.D. (Editors) 1984. Van Nostrand Reinhold.
4. Trench and Fore-arc Geology: Sedimentation and Tectonics on Modern and Ancient Active Plate Margin, by Legget, J.K. (Editor), 1982, Blackwell Scientific Publishers.
5. Initial Reports of the Deep-sea Drilling Project, Vol. 23. By Whitmarsh, R.D. (Editor), 1975, U.S. Government Printing Office.

GEOL. 644: MARINE GEOCHEMISTRY
2+1 Credit Hours

Objectives:
This course is design to impart knowledge about the fundamentals of geochemical cycle and the composition of ocean water. It also helps to understand the geochemistry of marine sediments, marine carbonates and geochemical models.

Learning Outcomes:
After studding this course, students will be able to:
Understand geochemical composition of ocean water and marine sediments.
Explain geochemical models of oceans.

Course Content:
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. Geochemical models.

Lab:
Exercises on determination of salinity, residence time and reactivity of major elements. Calculation of chemical fluxes, paleoproductivity and interpretation of geochemical proxies. Geochemical analysis of marine sediments.

Recommended Books:

1. Marine Geochemistry, by Schulz, H.D. and Zabel, M. (Editors), 2002, Springer.
2. Methods of Seawater Analysis, by Grasshoff, K., Kremling, K. and Ehrhardt, M. 1999. Wiley-VCH.
3. Organic Matter: Productivity,Accumulation and Preservation in Recent and Ancient Sediments, by Whelan, J.K. and Farrington, J.W. (Editors), 1992, Columbia University Press.
4. Modern and Ancient Continental Shelf Anoxia by Tyson, R.V. and Pearson, T.H. (Editors), 1991,

Geological Society London Special Publication No. 58.
5. Marine Geochemistry, by Chester, R. 1990. Chapman & Hall.
6. Sea water: Its Composition, Properties and Behavior by Gerry, B. (Editor), 1989, Pergamon Press & Open University Press.
7. Coastal Upwelling: Its Sedimentary Record, by Thiede, J. and Suess, E. (Editors), 1983, Part B: Sedimentary Records of Ancient Coastal Upwelling, Plenum Press.

GROUP V: GEOCHEMISTRY

GEOL. 651: GEOCHEMICAL EXPLORATION
2+1 Credit Hours

Objectives:
The course will provide comprehensive information on geochemical exploration, skilling a student to learn basic techniques of sampling, analysis, and interpretation of anomaly. The course will help to plan a geochemical exploration program to prospect ore and mineral deposits on the right lines.

Learning Outcomes:
Through successful completion of this course, students will be able to:
Understand principles of geochemical exploration and geochemical environment.
Describe metallogenic provinces of Pakistan and types of mineral deposits.
Design geochemical exploration surveys for minerals.

Course Content:
Principles of geochemical exploration. Primary and secondary geochemical environments. Geochemical dispersion, mobility and association of elements. Metallogenic provinces and epochs. Geochemical anomalies: types of anomalies in bed-rock, drainage sediments and natural waters. Role of path finder elements in mineral exploration. Decay pattern in stream sediments and waters.
Application of different geochemical prospecting and exploration methods for minerals. Regional and detailed lithogeochemical, hydrogeochemical, geobotanical and biogeochemical surveys. Presentation, statistical treatment and interpretation of data.

Lab:
Introduction to instrumental techniques. Analysis of geochemical samples and report writing.

Recommended Books:
1. Advanced Integrated Methods in Mineral Exploration: Applied Geochemistry, Geophysics and Remote Sensing by Shirazy, A. , Shirazi, A. and Hezarkhani, A. 2022, Lambert Academic Publishing.
2. Applied Geochemistry: Advances in Mineral Exploration Techniques by Macheyeki, A.S., Kafumu, D.P. and Li, X. 2020, Elsevier
3. Geochemical Exploration and Modelling of Concealed Mineral Deposits by Talapatra, A.K. 2020. Springer
4. Geochemistry (2nd ed.) by White, W.M. 2020. Wiley-Blackwell
5. Using Geochemical Data (2nd ed.) by Rollinson, H. 2021. Cambridge University Press
6. Statistics and Data Analysis in Geochemical Prospecting by Howarth, R.J. 2013. Elsevier
7. Biogeochemistry in Mineral Exploration by Dunn, C.E 2011 Elsevier Science
8. Geochemical Anomaly and Mineral Prospectivity Mapping in GIS by Carranza, E.J.M. 2008. Elsevier Science
9. Elements of Geochemistry, Geochemical Exploration and Medical Geology by Randive, K.R. 2012. Research Publishing Services
10. Geochemistry in Mineral Exploration, by Rose, A.W., Hawkes, H.E. and Webb, J.S., 1981, Academic

Press.
11. Geochemical Exploration, by Elliott, I.L. and Letcher, W.K., 1974, Elsevier.
12. Exploration Geochemistry, by Bradshaw, P.M.D., Clew, D.R. and Walker, J.L. 1973. Barringer Research.

GEOL. 652: PETROLEUM GEOCHEMISTRY
2+1 Credit Hours

Objectives:
This course is an advanced level course that has been deliberate in the group of geochemistry specialization in the BS final year. The course is designed to acquire knowledge about the formation, migration and accumulation of petroleum in the rocks.

Learning Outcomes:
The disseminated awareness of the subject will capable a student to:
Understand characteristics and quality of Kerogen and yield hydrocarbons.
Work in the oil and gas industry globally.

Course Content:
Types of biogenic matters and their composition. Impacts of paleogeography and sedimentary environment on production of organic matter. Geochemical conditions for the accumulation and formation of hydrocarbons. Source rock assessment; organic richness, potential and thermal maturity parameters. Temperature, time and quantitative modeling of maturity for systems with unconformities, changing gradients and faulting. Kerogen and its types, generation and composition of petroleum. Source rock-oil-gas relationships. Expulsion efficiency. Physicochemical and geochemical assessment of primary migration. Efficiency and direction of secondary migration.

Lab:
Estimation of important geochemical parameters (TOC, EOM and Kerogen) for the assessment of source rock.

Recommended Books:
1. Advanced Methods in Petroleum Geochemistry by Ostadhassan, M. and Hazra, B. 2024. Springer Cham
2. Unconventional Methods for Geoscience, Shale Gas and Petroleum in the 21st Century by Watada, J., Tan, S.C., Lin, P.C., et.al. 2023. IOS Press
3. Elements of Petroleum Geology (4th ed.) by Selley, R.S. and Sonnenberg, S.A. 2022. Academic Press
4. Practical Petroleum Geochemistry for Exploration and Production (2nd ed.) by Dembicki, H. 2022. Elsevier
5. Applied Geoscience in Shale Exploration and Production by Bartok, P. 2018. Pennwell Books
6. Oilfield Survival Guide, by Hatami, M.J. 2017. Oilfield Books
7. Organic Geochemistry Applications in Petroleum Exploration: Principals and Applications by El Nady, M. 2015, LAP LAMBERT Academic Publishing
8. Insights into Petroleum Geochemistry by Bernard, C., 2004, Lavoisier.
9. Petroleum Geochemistry and Exploration, in the Afro-Asian Region by Garg, A.K., Dwivedi, P., Swamy, S.N. and Banerji, V. (Editors) 2000. B.R. Publishing Corporation.
10. Elements in Petroleum Geology by Selley, R.C., 1998, Academic Press.
11. Petroleum Geology and Geochemistry by Hunt, J., 1995, Freeman & Co.
12. Petroleum Formation and Occurrences by Tissot, B.P. and Welte, D.H., 1984, Springer-Verlag.

GEOL. 653: CARBONATE GEOCHEMISTRY
2+1 Credit Hours

Objectives:
This course focuses on the geochemistry of the carbonate rocks. Abundance, distribution and significance of trace elements in carbonate minerals.

Learning Outcomes:
Upon completion of the course, the student should be competent enough to perform independent research on the carbonate rocks.
Also, able to develop skills and working knowledge in the fields of petroleum geology, mineralogy and economic geology.

Course Content:
Mineralogy, crystal chemistry and geochemistry of sedimentary carbonate minerals. Mineral dissolution-precipitation, saturation index, solubility diagrams, stability diagrams, adsorption, ion exchange, and surface complexation. Kinetic controlled mineral dissolution-precipitation, solid solutions and phase relationship. Abundance, distribution and significance of trace elements in carbonate minerals. Major controls on carbonate sedimentation. Depositional processes and facies in carbonate rocks. Carbonate depositional systems. Chemical diagenetic processes. Chemistry of interstitial water. Nomenclature and classification of dolostones. Dolomitization reactions and models.

Lab:
Chemical analysis of carbonate rocks. Interpretation of depositional environments. Staining, calcimetry and XRD techniques.

Recommended Books:

1. Carbonate Sediments and Rocks: A Manual for Earth Scientists and Engineers by Braithwaite, C.J.R. 2024. Whittles Publishing
2. Deposition, Diagenesis, and Geochemistry of Carbonate Sequences by Mehrabi, H. and Tavakoli, V. (Editors) 2024. MDPI Books
3. Geochemistry of Carbonate Sediments and Sedimentary Carbonate Rocks, Vol. 2: Sedimentary Carbonate Rocks, by Graf, D.L. 2019. Forgotten Books
4. Carbonates: Mineralogy and Chemistry: Reviews in Mineralogy & Geochemistry by Reeder, R.J. (Editor), 2019. De Gruyter Publisher
5. Dolomite: Formation, Characteristics and Environmental Impact by Pokrovsky, O.S. (Editor) 2017, NOVA
6. Origin of Carbonate Sedimentary Rocks by James,N.P. and Jones,B. 2015, Wiley
7. Sediments, Diagenesis, and Sedimentary Rocks by Mackenzie, F.T., 2005, Volume 7: Treatise on Geochemistry, Elsevier.
8. Carbonate Depositional Environments by Scholle, P.A., Bebout, D.G. and Moore, C.H., 1993, AAPG Memoir 33.
9. Carbonate Sedimentology, by Tucker, M.E. and Wright, V.P., 1990, Blackwell Scientific Publications.

GROUP VI: SEDIMENTOLOGY

GEOL. 661: CLASTIC SEDIMENTOLOGY
2+1 Credit Hours

Objectives:
This course is design to acquire the knowledge of formation and evaluation of clastic rocks.

Learning Outcomes:
After completion, Students will be able to:
Understand the sedimentological techniques to evaluate clastic rocks
Understand the aspects of diagenesis and its impact on the characterization of rocks
Able to apply clastic sedimentology in different field of geology

Course Content:
Origin of terrigenous-clastic sediments. Mineral and Chemical composition. Texture, Sedimentary structures and paleo-current analysis. Fluid mechanics in sediment transport and deposition. Classification and Petrography of clastic rock. Provenance. Clastic depositional system, facies and models. Diagenesis: Types, physical and chemical diagenetic processes and its effects. Para-genesis. Plate tectonics and sedimentary accumulation.

Lab:
Laboratory methods and techniques for the study of clastic sedimentary rocks: Thin section analysis, SEM, XRD, XRF etc. Textural, mineralogical and diagenetic study of various types of clastic sedimentary rocks in hand specimens and thin sections.

Recommended Books:

1. Sedimentology and Stratigraphy (3rd ed.) by Nichols, G. 2023, Willy, ISBN: 978-1-119-41727-9
2. Sedimentary Petrology (4th ed.) by Tucker, M.E. and Jones. S.J. 2023. Wiley.
3. Sandstone Petrography, Petrology and Modeling by Taylor, T.R., Lander, R.H., Bonnell, L. M. 2022. United States: SEPM Society for Sedimentary Geology.
4. A Color Guide to the Petrography of Sandstones, Siltstones, Shales and Associated Rocks by Ulmer-Scholle, D.S., Scholle, P.A., Schieber, J., Raine, R.J. 2014. United States: American Association of Petroleum Geologists.
5. Petrology of Sedimentary Rocks by Boggs Jr. S. 1992. Merril Publishing Co.
6. Sedimentary Environments and Facies by Reading, H.G. 1986. Blackwell Scientific Publications.
7. Sedimentary Petrology: An Introduction by Tucker, M.E. 1981. Blackwell Scientific Publications.
8. Depositional Sedimentary Environments by Renieck, H.E. and Singh, I.B. 1980. Springer-Verlag.
9. Principles of Sedimentolog, by Friedman, G.M. and Sanders, J.E. 1978. John Wiley & Sons.
10. Sand and Sandstones by Pettijohn, F.J., Potter, P.E. and Sever, R. 1972. Springer-Verlag.

GEOL. 662: CARBONATE SEDIMENTOLOGY
2+1 Credit Hours

Objectives:
This course is design to acquire the knowledge of formation and evaluation of Carbonate rocks.

Learning Outcomes:
After completion, Students will be able to:
Understand the sedimentological techniques to evaluate carbonate rocks
Understand the aspects of diagenesis and its impact on the characterization of carbonate rocks
Able to apply carbonate sedimentology in different field of geology

Course Content:
Texture and mineralogy of carbonate rocks. Classification of carbonate rocks. Modern carbonate systems. Dolomites and dolomitization models. Facies models of carbonates. Controls on carbonate sedimentation: biogenic and physicochemical. Environments of carbonate sedimentation and tectonics. Reef and their development. Diagenesis processes, products and environments. Geological records of carbonate rocks.

Lab:
Identification of carbonate sediments in hand specimen and thin-sections. Microfacies analysis. Staining and XRD techniques.

Recommended Books:

1. A color guide to the petrography of carbonate rocks: grains, textures, porosity, diagenesis by Scholle, P.A., Ulmer-Scholle, D.S. 2003. United States: American Association of Petroleum Geologists.
2. Microfacies of Carbonate Rocks; Analysis, Interpretation and Application by Flugel, E. 2004. Springer-Verlag.
3. Carbonate Depositional Environments by Scholle, P.A., Bebout, D.G. and Moore, C.H. 1993. AAPG Memoir 33.
4. Carbonate Sedimentology by Tucker, M.E. and Wright, V.P. 1990. Blackwell Scientific Publications.
5. Carbonate Sedimentology and Petrology by Scholle, P.A., James, N.P., Read, J. F. 1989. United Kingdom: American Geophysical Union.
6. Marine Carbonate by Milliman, J.D. 1974. Springer-Verlag.
7. Carbonate Sediments and their Diagenesis by Bathurst, R.G. 1964. Elsevier.

GEOL.663: SEDIMENTARY PETROLOGY
2+1 Credit Hours

Objectives:
This course is designed to acquire the knowledge about various types of sedimentary rocks their diagenesis and depositional systems.

Learning Outcomes:
After completion, the students will become able to:
Apply sedimentological principles and techniques in the various field of Geology.

Course Content:
Classification of sedimentary rocks. Fabric and framework geometry of sedimentary rocks. Classification, texture, composition and diagenesis of carbonates, rudaceous, arenaceous, argillaceous and other rock types. Provenance of sedimentary rocks. Fluid inclusions. Heavy minerals.

Lab:
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. Sedimentary Rock and the Rock Cycle, by Mattern, J. 2006. Rosen Publishing Group
2. Sedimentary Rocks in the Field by Tucker, M.E., 2003. John Wiley & Sons.
3. Sedimentary Rocks by Cefrey, H. 2003. Rosen Publishing Group.
4. Sedimentary Petrology by Tucker, M.E. 2001. Blackwell Science Publications.
5. Petrology of the Sedimentary Rocks by Greensmith, J.T. 1988. George, Allen & Unwin.
6. Sedimentary Rocks by Pettijohn, F.J., 1975. Harper & Row.
7. Sand and Sandstones by Pettijohn, F.J., Potter, P.E. and Sever, R. 1972. Springer-Verlag.

GEOL.664: QUATERNARY GEOLOGY
2+1 Credit Hours

Objectives:
The main objective of this course is to introduce students to the fundamental concepts of Quaternary Geology and related processes.

Learning Outcomes:
After completing this course, students will be able to:
Understand the techniques, suitable for analyzing different sediment types.
Apply the acquired knowledge in any project or thesis work to elaborate paleoclimatic and eustatic changes to correlate with recent ones.

Course Content:
Outline of Quaternary stratigraphy and geology. Quaternary Period and subdivisions. Quaternary dating techniques. Origin and composition of quaternary sediments. Geological and geomorphic phenomena during the Quaternary period, formation of landforms due to climate, glaciation, and sea-level changes. Neotectonics and their applications to natural hazard assessment. Impact of glacial and interglacial cycles of plant and animal life. Quaternary stratigraphy and climatic studies and their morphological settings with reference to Pakistan. Economic resources of quaternary deposits.

Lab:
Construction of stratigraphic columns of important Quaternary deposits. Study of geomorphic forms and drainage patterns.

Recommended Books:

1. Principles of Quaternary Geology and Environmental Study by Goswami, A.B. 2014. Books Way, Kolkata
2. Quaternary Glaciations - Extent and Chronology by Ehlers, J. Gibbard, P.L. and Philip D. Hughes, P.D. 2011. Elsevier
3. History of Geomorphology and Quaternary Geology by Grapes, R.H., Oldroyd, D. and Grigelis, A. 2008. Geological Society of London
4. Quaternary Geology and the Environment by Jean, R., 2002. Springer
5. Quaternary Geology, Thamer Al-Ameri, 2000. Baghdad University Press, Iraq

GROUP VII: HYDROGEOLOGY

GEOL. 671: CLIMATE CHANGE AND WATER HAZARDS
2+1 Credit Hours

Objectives:
This course is designed to make the students able to understand different processes and interplay between climate system and the global water cycle. To understand the climate change influences on water resources and the associated vulnerabilities and risks. To understand the concept of Integrated Water Resources Management in relation to climate change.

Learning Outcomes:
At the end of the course, students will be able to understand climate science and its relationship with development goals and aspirations.

Course Content:
Climate change and global warming. Global water cycle. Paleoclimatic changes. Impacts of climate change on the quantity and quality of water. Glaciers melting, floods, drought and the risks related to changing water resources. Glacial lake outburst floods, extreme precipitation events and urban flooding. Impact of water hazards on hydropower, agriculture, aquatic ecosystems and health. Water management, strategies and interventions in response to changing climate.

Lab:
Specified projects/assignments

Recommended Books:

1. Climate Change, Urbanization, and Water Resources by Chang, H. and Ross, A.R. 2024. Springer Link.
2. Climate Risk and Sustainable Water Management by Tang, Q. (Editor). 2022. Cambridge University Press.
3. Water and climate Change by Letcher, T. (Editor). 2022 Elsevier.
4. Introduction to Hydrogeology, Denning, D., 2002. McGraw-Hill.
5. Applied Hydrogeology, Fetter, C.W., 2000. Prentice Hall.
6. Groundwater Hydrology, by Todd, D.K., 1995. John Wiley & Sons.
7. Groundwater, by Ragunath, H.M., 1992. Wiley Eastern Ltd.
8. Groundwater Hydrology by Bouwer, H., 1988. McGraw-Hill.
9. Hydrology and Groundwater Resources of NWFP by Kruseman, G.P., 1988. WAPDA.
10. Introduction to Groundwater by Michael, P., 1985. George, Allen & Unwin.

Geol. 672: Field Hydrogeology
2+1 Credit Hours

Objectives:
This course will develop a solid understanding of fundamental hydrogeological principles and processes. It will provide opportunity for learning various field techniques for groundwater investigation, including sampling, monitoring, and data collection.

Learning Outcomes:
After this course, students will be able to:
Explain key hydrogeological concepts, including aquifer types, groundwater flow, and contaminant transport.
Demonstrate proficiency in field techniques such as groundwater sampling, well installation, and geophysical surveys.
Analyze and interpret groundwater data, including water quality tests and hydrographs.

Content:
Groundwater exploration techniques. Aquifer hydraulics. Field evaluation of aquifers. Field methods to determine groundwater and surface water exchange. Borehole drilling methods. Well drilling and well completion. Pumping tests. Application of well logging techniques in hydrogeology. Field surveys and water samples collection, storage and analysis. Hydrogeological report writing.

Lab:
Collection of hydrogeological data in the field and hydrogeological report writing. Visit to well drilling sites.

Recommended Books

1. Groundwater in the Environment: A Scientific Approach. E.D. 2023. Springer.
2. Hydrogeology: Principles and Practice (3rd ed.) by Anderson, M.P. and Woessner, W.W. 2022. Wiley.

3. Field Hydrogeology: A Guide to Groundwater Sampling and Analysis by D.F.W. 2022. Wiley.
4. Introduction to Hydrogeology by DeSimone, L.A., and Dyer, J.A. 2021. CRC Press.
5. Applied Hydrogeology (5th ed.) by Fetter, C.W. 2020. Pearson.
6. Field Hydrogeology by Brassington, R., 1988. John Wiley & Sons.

GEOL. 673: GROUNDWATER MODELING
2+1 Credit Hours

Objectives:
This course provides an overview of groundwater modeling principals using numerical tools. It also offers gaining practical experience in using groundwater modelling software: MODFLOW, FEFLOW.

Learning Outcomes:
Students will be able to understand numerical methods and their applications in groundwater flow and contaminant transport modeling.
Students develop skills in using popular groundwater modeling software (e.g., MODFLOW, FEFLOW).
Studying this course equip students to address complex groundwater challenges in both academic and professional contexts.

Course Content:
Introduction to groundwater modeling. Conceptual hydrogeological model development. Designing mathematical models. Data collection and conceptualization for groundwater modeling. Key equations for groundwater flow modelling and contaminant transport. Aquifer boundary conditions. Groundwater flow models and its key components. Grid design, calibration and parameter optimization. Principles of contaminant transport in groundwater and modelling non-reactive and reactive contaminant transport in groundwater. Application of GIS techniques in groundwater modeling.

Lab:
Introduction to hydrogeological software MODFLOW and FEFLOW.

Recommended Books:
1. Advances in Groundwater Modeling: Applications and Challenges by Fitts, C.R. (Editor). 2023. CRC Press.
2. Groundwater Hydrology: Engineering, Planning, and Management by Thomas, H.F., and Ranjan, M. 2023. Springer.
3. Groundwater Modeling: A Practical Approach by Celia, M.A., and van der Zee, R.L.B.W. 2022. Wiley.
4. Numerical Groundwater Modeling by Bear, J., and Cheng, A.H.D. 2021. Springer.
5. Integrated Groundwater Management: The Role of Hydrogeology in the Sustainable Management of Groundwater Resources by Koundouri, P., and Pashardes, P. 2020. Routledge.