Geological engineering syllabus

Geological engineering examinations

Group A - Compulsory examinations (seven required)

18-Geol-A1 Mineralogy and Petrology

Introduction to crystallography and crystal chemistry. Physical and chemical properties of minerals in hand specimens. Identification of minerals and rocks with the petrographic microscope. Field and laboratory classification of igneous and metamorphic rocks. The nature of magmas and processes of magmatic differentiation. Metamorphic facies concepts. Interpretation of mineral assemblages of igneous and metamorphic rocks in the light of the phase rule and phase relations of relevant mineral assemblages. Textural and physical properties of rocks relevant to engineering problems.

Textbooks (most recent edition is recommended):

- Raymond, L.A., Petrology, The study of igneous, sedimentary, and metamorphic rocks. 2nd Ed., McGraw Hill, 2002.
- Perkins, D. and K. Henke, Minerals in Thin Section. 2nd Ed. Prentice Hall, 2004.
- MacKenzie, W.S. and A.E. Adams, A Color Atlas of Rocks and Minerals in thin Section. J. Wiley, 1994.
- Nesse, William D., Introduction to Optical Mineralogy. Oxford University Press, 2003.
- Philpotts, Anthony R., Petrography of Igneous and Metamorphic Rocks. Prentice Hall, 2003.
- Klein, C., Dutrow, B., The Manual of Mineral Science (after James D. Dana), 23rd Ed., John Wiley and Sons, New York, 20082.
- Blatt, H. and R.J. Tracy, Petrology: Igneous, Sedimentary and Metamorphic. 2nd Ed., W.H. Freeman and Co., 1996.
- Prinz, Martin, George E. Harlow, and Joseph Peters, eds. Simon and Schuster's Guide to rocks and minerals, Simon & Schuster, 1978.

18-Geol-A2 Hydrogeology

Hydrologic cycle: precipitation, evaporation, transpiration, deep and shallow groundwater circulation. Physics of flow through porous media. Hydraulic conductivity and groundwater storage. Occurrence, transmissivity and storage characteristics of surficial and bedrock aquifers. Groundwater exploration methods: geophysics, remote sensing, mapping, borehole investigations. Groundwater flow patterns: recharge, discharge, flow net construction and analysis. Aquifer development and management. Control of pore pressures and groundwater flow in geotechnical engineering.

Textbooks (most recent edition is recommended):

- Freeze, R. Allan, and John A. Cherry, Groundwater, 604 pp. (1979). Online at: http://hydrogeologistswithoutborders.org/wordpress/textbook-project/
- Schwartz, F.W., and H. Zhang, Fundamentals of Ground Water, Wiley, 2003.
- Domenico, P.A., and F.W. Schwartz, Physical and Chemical Hydrogeology. 2nd Ed., Wiley, 1998.

18-Geol-A3 Sedimentation and Stratigraphy

Classification of sedimentary rocks, processes of weathering, erosion, sedimentation and diagenesis. Formation of carbonate, clastic and chemical precipitate rocks. Principles of stratigraphic and paleontological correlation; sedimentary facies: geological and practical significance. Distribution of major Precambrian and Phanerozoic systems. Facies associations; modern and ancient sedimentary environments. The engineering properties and behaviour of sedimentary rocks and the use of stratigraphic principles in the solution of engineering problems.

Textbooks (most recent edition is recommended):

- Boggs, S., Principles of Sedimentology and Stratigraphy. 3rd Ed., Prentice Hall, New York, 2001.

18-Geol-A4 Structural Geology

Stress and strain. Brittle and ductile rock deformation behaviour. Fabric analysis of deformed rocks. Structural features of stable and mobile parts of the crust. Fold and fault development. Mountain building and orogenies. Theories in geotectonics. Methods of structural analysis. Field mapping and graphical data processing; maps, cross-sections, block diagrams, structure contour maps, stereographic projections, equal area nets, and strain indicators. Kinematic and dynamic interpreta*Textbooks (most recent edition is recommended):*tion. The application of structural geology to the solution of engineering problems.

- Fossen, Haakon, Structural geology, Cambridge University Press, 2016.
- van der Pluijm, Ben A., and Stephen Marshak, Earth Structure: An Introduction to Structural Geology and Tectonics. New York, W.W. Norton, 2004.
- Davis, G.H., and S.J. Reynolds, Structural Geology of Rocks and Regions. 2nd Ed., New York, John Wiley and Sons, Inc., 1996.

18-Geol-A5 Rock Mechanics

Engineering properties and classification of intact rocks. Rock mass properties and classification. Laboratory and in-situ testing of rock. In-situ stresses and stress measurement techniques. Stability analysis of rock slopes and excavations. Rock excavation techniques. Design of excavations, slopes, tunnels and shafts. Rock reinforcement and support. Groundwater considerations in rock engineering.

Textbooks (most recent edition is recommended):

- Hoek, Evert and John Bray, Rock Slope Engineering. London: Institution of Mining and Metallurgy, 1981.
- Hoek, Evert and Edwin T. Brown, Underground Excavations in Rock. London: Institution of Mining and Metallurgy, 1982.

18-Geol-A6 Soil Mechanics

Rock weathering and development of soils. Engineering classification of soils. Soil physical properties: porosity, density, capillarity, permeability. Shear strength, consolidation and settlement. Normally and over consolidated soils. In-situ stresses in soil masses. Lateral earth pressures. Mechanics, stability and analysis of soil slopes. Pore water pressure, seepage pressure, groundwater considerations in soil engineering.

Textbooks (most recent edition is recommended):

- Coduto, D.P., Component: Geotechnical Engineering: Principles and Practices. Prentice Hall, NJ, 1999.
- Lambe, T.W., Soil Testing for Engineers. BiTech Publishers, Vancouver, 1991.

18-Geol-A7 Applied Geophysics

Basic principles, interpretation, and limitations of geophysical methods applied to the exploration for coal, oil and natural gas, minerals, groundwater, and for geotechnical studies of the surface and subsurface. Introduction to electrical, electromagnetic, and magnetotelluric surveys; magnetic and gravity surveys; seismic reflection and refraction surveys; radiometric methods. Introduction to geophysical well logging techniques. Case histories of applications to engineering problems.

Textbooks (most recent edition is recommended):

- Sharma, P.V., Environmental and Engineering Geophysics. Cambridge University Press,1997.
- Reynolds, J.M., An Introduction to Applied and Environmental Geophysics. Wiley, 1997.
- Kearey, P., M. Brooks and I. Hill, An Introduction to Geophysical Exploration. 3rd Ed., Blackwell Science, 2002.

Group B - Optional examinations (three required)

18-Geol-B1 Contaminant Hydrogeology

Groundwater geochemistry, isotopes in groundwater. Movement of dissolved species. Diffusion and dispersion regimes. Classification of contaminants. Organic contaminants, introduction to multiphase flow, LNAPLs and DNAPLs. Assessment, control and remediation of contaminants. Waste management. Deep well disposal.

Textbooks (most recent edition is recommended):

- Fetter, C.W., Contaminant Hydrogeology. 2nd Ed., MacMillan Publishing Co., New York,1999.
- Bedient, Philip B., Hanadi S. Rifai, and Charles J. Newell, Ground Water Contamination: Transport and Remediation, 2nd edition. Upper Saddle River, NJ: Prentice Hall, 1999. https://www.amazon.ca/Ground-Water-Contamination-Transport-Remediation/dp/0130138401.
- Council, National Research, Contaminants in the Subsurface: Source Zone Assessment and Remediation, 2004. https://www.nap.edu/catalog/11146/contaminants-in-the-subsurface-source-zone-assessment- and-remediation.
- Domenico, P.A., and F.W. Schwartz, Physical and Chemical Hydrogeology. 2nd Ed., Wiley, 1998

18-Geol-B2 Terrain Analysis

Elements of photogrammetry. Interpretation of aerial photos – recognition elements (tone, pattern, texture, size and shape, occupance). Identification of structures and terrain features. Glacial, fluvial, coastal, and permafrost landforms – identification and engineering characteristics. LANDSAT imagery. Operation, characteristics, and uses of thermal infrared and RADAR remote sensing.

Textbooks (most recent edition is recommended):

- Mollard, J.D. and J.R. Janes, Airphoto Interpretation and the Canadian Landscape. Energy, Mines and Resources Canada, 1984. ISBN 0-660-11591-3

Required Materials for Examination:

- 1 pocket stereoscope + plates from Mollard and Janes (1984) p. 187-399 only.

18-Geol-B3 Site Investigation

Uses and sources of geological and geotechnical information. Methods of site investigation: trial pits, boreholes, sampling, laboratory and in-situ testing, geophysical methods. In-situ instrumentation and post construction monitoring: measurement of stress, deformation and settlement, pore pressures, permeability, groundwater contamination. Design of site investigations and monitoring schemes.

T*extbooks (most recent edition is recommended):*

- Hunt, Roy E., Geotechnical engineering investigation handbook, CRC Press, 2005.
- Hunt, Roy E., Geologic hazards: a field guide for geotechnical engineers, CRC Press, 2007.
- Canadian Geotechnical Society, Canadian Foundation Engineering Manual. 3rd Ed. Canadian Geotechnical Society, Technical Committee on Foundations, BiTech Publishers Ltd., Richmond, British Columbia, 1992.
- Nielsen, David M., (ed.). Practical Handbook of Ground Water Monitoring. Lewis Publishers Inc., Chelsea, Michigan, 1991.

18-Geol-B4 Geomorphology and Pleistocene Geology

Basic geomorphological concepts: formation and composition of landforms, geomorphologic cycles. Weathering and soils. Mass wasting. Fluvial processes and landforms. Coastal processes and landforms. Glacial geomorphology and landforms. Frozen-ground phenomena. Karst geomorphology. Physical geology of Canada. Quaternary geology of selected areas of Canada. Influence of geomorphology on human activity.

Textbooks (most recent edition is recommended):

- Easterbrook, D.J., Surface Processes and Landforms. 2nd Ed., Prentice-Hall, 1999.
- Trenhaile, AS, Geomorphology: A Canadian Perspective. Oxford University Press, 1998.ISBN 0-19-541277-X
- Fulton, RJ, (ed.), Quaternary Geology of Canada and Greenland. Geological Survey of Canada, 1989. ISBN 0-660-13114-5 (Any one section of Part I (Sect. 1-5), and Part II: Sect. 11, 12.)

18-Geol-B5 Environmental Geology

Geological hazards, volcanoes, landslides, earthquakes, subsidence, floods, erosion. Preparation of hazard maps. Return period concepts and risk assessment. Environmental considerations for landfills, deep cavern and deep well disposal of wastes. Mining reclamation. Acid rock drainage. Control of sediment and dissolved contaminants. Preservation and restoration of soils, landscaping and contour restoration, revegetation and erosion control. Preparation of environmental impact statements. Laws and procedures pertaining to environmental assessments.

Textbooks (most recent edition is recommended):

- Keller, Edward A. (2001) Environmental Geology (9th ed.) Pearson.
- Merritts D, Menking K, and Dewet A (2014) Environmental Geology: An Earth Systems Approach (2nd ed.) Macmillan.

18-Geol-B6 Resource Geology (Select ONE from)

18-Geol-B6-1 Petroleum Deposits

Physical properties, geochemistry, origin, migration, accumulation, and history of oil and natural gas, and their associated waters. Geological conditions of oil and gas entrapment. Structural and stratigraphic factors controlling the distribution of reservoir rocks, porosity, permeability and fluid saturations. Environmental problems associated with the development of hydrocarbons.

Textbooks (most recent edition is recommended):

- Gluyas, J.G. and R.E Swarbrick, Petroleum Geoscience. Blackwell, 2004.
- Hunt, J.M., Petroleum Geochemistry and Geology. 2nd Edition, Freeman, New York, 1996.

18-Geol-B6-2 Coal Deposits

Coal depositional environments and their significance. Nature, origin, diagenesis, metamorphism, and classification of organic sediments. Rank, physical, and petrological properties of coal. Glacial and tectonic deformation effects on rank and seam dimensions. Trace element geochemistry of coal. Stratigraphic and geographic occurrence of Canadian (and world) coals. Properties of environmental and mining significance.

Textbooks (most recent edition is recommended):

- No Referenced Textbooks

18-Geol-B6-3 Metallic and Industrial Mineral Deposits

Nature, mode of occurrence and processes of formation of metallic and industrial minerals including minerals deposited from magmas, high-temperature vapours and aqueous solutions; formed by evaporation or precipitation in surface waters; formed by mechanical accumulation or accumulated by residual weathering. Processes of element/mineral migration and concentration. Stratigraphic and structural controls on occurrence. Solution geochemistry and isotopic characteristics of ore bearing fluids and ore deposits. Illustrative case histories for important deposits of sulphides, oxides, native elements, silicates, and ionic salts.

Textbooks (most recent edition is recommended):

- Evans, Anthony M., Ore Geology and Industrial Minerals - An Introduction. 3rd Ed., Blackwell Science, Oxford, UK, 1993.

18-Geol-B7 Petroleum Development

Drilling equipment, controls and techniques. Circulation systems and well completions. Drilling problems associated with overpressure, underpressure, permafrost, evaporites, sour-gas, loss of circulation. Reservoir fluid phase behaviour. Material balance equations. Porosity and permeability characteristics of reservoirs. Steady and transient flow of oil, water and gas through porous media. Well stimulation. Capillary pressure and multiphase flow. Segregated and diffuse flow regimes. Oil and gas well testing and analysis. Natural drive mechanisms. Secondary and tertiary oil recovery. Introduction to history matching and numerical simulators. Conventional and geostatistical methods of oil and gas reserve estimation.

Textbooks (most recent edition is recommended):

- Dake, L.P., The Practice of Reservoir Engineering. Elsevier, 1994.

18-Geol-B8 Resource Economics & Valuation

Growth of mining and petroleum industries. Estimation of future demands. Significance of the resource sector in the Canadian economy. Prices, exchanges and futures markets. Types and grades of concentrates, smelter charges and returns. Properties, specifications and markets for industrial rocks and minerals. Relative value of hydrocarbon fractions. Evaluation of mining and oil prospects; mining and oil law, taxes and tariffs, labour, transportation, technical factors, property acquisition and claims, development methods, production estimates. Evaluation of geological engineering and commercial aspects of developed properties. Feasibility reports. Costs: access; transportation; mining; milling; well development, well stimulation; primary, secondary and tertiary recovery. Capital costs, amortization and depreciation, rate-of-return on investment calculations.

Textbooks (most recent edition is recommended):

- Gentry, D.W. and T.J. O'Neill, Mine Investment Analysis. Society of Mining Engineers, American Institute of Mining, Metallurgical, and Petroleum Engineers, New York, 1984.
- Rudenno, V., The Mining Valuation Handbook. Wrightbooks, Australia, 1998.

18-Geol-B9 Exploration & Mining Geology

Planning and execution of exploration programs. Sampling methods. Legal aspects of exploration in Canada. Principles of geochemistry in mineral exploration. Field analytical techniques. Primary and secondary dispersion patterns, weathering, soil formation. Anomalies in residual and transported overburden, stream waters, stream sediments, vegetation. Factors affecting relative mobility of elements. Background values, threshold values, orientation surveys. Application, planning and interpretation of geophysical surveys. Planning surface drilling programs. Logging, sampling, analysis and interpretation of drill core data. Mineralogical study of ore and recommendations for beneficiation. Introduction to mining methods, equipment selection, layout, environmental logistics during life of mine and at closure, and integration of these with a clear understanding of their compatibility with the geological and geotechnical parameters of the site materials. Mapping and sampling underground. Planning subsurface drilling programs. Structural interpretation and analysis of underground drilling. Quality control aspects of mining and milling. Conventional and geostatistical methods of ore-deposit reserve estimation.

Textbooks (most recent edition is recommended):

- Evans, Anthony M., Ore Geology and Industrial Minerals – An Introduction. 3rd Ed., Blackwell Science, Oxford, UK, 1993.
- Evans, Anthony M., and William L. Barrett, Introduction to Mineral Exploration. Blackwell Publications, UK, 1995.
- Peters, W.C., Exploration and Mining Geology. 2nd Ed., John Wiley & Sons, Inc, 1987.

18-Geol-B10 Geophysical Exploration Methods (Select ONE from)

18-Geol-B10-1 Gravity and Magnetic Fields

Theory and quantitative interpretation of the gravity and magnetic fields in geophysical exploration. Interpretation of regional gravity and magnetic maps. Identification of local anomalies. Data acquisition and data reduction for gravimeters and magnetometers. Design and conduct of field surveys. Potential field, Fourier, forward modeling and inversion methods in data interpretation and analysis.

Textbooks (most recent edition is recommended):

- Telford, W.M., L.P. Geldart, and R.E. Sheriff, Applied Geophysics. Cambridge University Press, 1990.
- Sharma, P.V., Environmental and Engineering Geophysics. Cambridge University Press, 1997.

18-Geol-B10-2 Electrical Methods

Theory and quantitative interpretation of electrical, electromagnetic and magnetotelluric data in geophysical exploration. Electrical properties of rocks. Self-potential, induced polarization, electromagnetic induction and magnetotelluric methods. Operation of field instrumentation, data reduction. Design and conduct of field surveys. Potential field, forward modeling and inversion methods for data interpretation.

Textbooks (most recent edition is recommended):

- Telford, W.M., L.P. Geldart, and R.E. Sheriff, Applied Geophysics. Cambridge University Press, 1990.
- Sharma, P.V., Environmental and Engineering Geophysics. Cambridge University Press, 1997.

18-Geol-B10-3 Exploration Seismology

Theory of elasticity and elastic properties of rock. Wave propagation in elastic media. Interaction of waves with boundaries. Body-wave seismology. Surface waves. Earthquake source studies. Artificial energy sources. Refraction and reflection methods. Theory of operation and selection of seismometers. Design and conduct of field refraction and reflection surveys. Fundamentals of digital processing: static corrections, velocity analysis and corrections, Fourier analysis and filtering, stacking, migration. Interpretation of refraction and reflection seismograms.

Textbooks (most recent edition is recommended):

- Telford, W.M., L.P. Geldart, and R.E. Sheriff, Applied Geophysics. Cambridge University Press, 1990.
- Sharma, P.V., Environmental and Engineering Geophysics. Cambridge University Press, 1997.