Geomatics engineering syllabus

Geomatics engineering examinations

Group A - Compulsory examinations (seven required)

18-Geom-A1 Surveying

Basic principles; instruments and procedures for angle, distance and height measurements; plane coordinate computations such as intersections, resections, traverses; coordinate transformation; simple horizontal and vertical curves; area and volume computations; cross-sections and profiles; setting-out surveys; pre-analysis, design and planning of precise surveys for horizontal and vertical control; principles of electronic distance and angle measurements; total stations; propagation of EM energy in the atmosphere and its application to EM ranging; theodolite observations and precise positioning systems; sources of errors in angle, distance and precision levelling surveys; influence of atmospheric refraction. Systematic and random errors, design, processing and analysis of angle, distance, and height difference measurements. Route survey and design; surveys for route planning, setting-out and as-built surveys, easement curves, alignment and grade for roads, sewers and pipelines, bridges, buildings, dams, tunnels, mining.

Textbooks (most recent edition is recommended):

- Anderson, M.J., and E.M. Mikhail, <u>Surveying: Theory and Practice</u>. McGraw Hill, (5th Edition), 2017.
- Wolf, P.R., and C.D. Ghilani, <u>Elementary Surveying. An Introduction to Geomatics</u>. Prentice Hall, New Jersey (10th Edition), 2002.
- Moffitt, F.H. and H. Bouchard, <u>Surveying</u>. 9th edition. Harper & Row Publishers, 1992. ISBN 0065000595.

- Brinker, R.C. and P. Wolf, <u>Elementary Surveying</u>. 9th edition. Harper-Row, 1984. ISBN 0065003993.
- Kissam, P., <u>Surveying for Civil Engineers</u>. 2nd edition. McGraw-Hill Book Co. Inc., 1981. ISBN 0070348820.
- Kavanagh, B.F., <u>Surveying Principles and Applications</u>. Prentice Hall, New Jersey (6th Edition), 2003. Surveying for Engineers, 5th Editing 2010

18-Geom-A2 Adjustment of Observations and Data Analysis

Geomatics engineering methodology and estimation. Accuracy and precision; errors and their propagation. Classes and combination of mathematical models; undetermined, uniquely determined and over determined models. Weight matrix; variance factor; covariance propagation. Least squares methods: parametric, condition and combined cases. Problem formulation and solution: theory of errors and adjustment of observations, problems with a priori knowledge of the parameters, step by step methods, sequential solution methods, summation of normals, examples. Uni- and multi-variate statistical testing. Data classification, analysis and bias identification. Kalman filtering and real-time data analysis. Introduction to signal processing, time series analysis and FFT techniques and examples of Practical applications of data analysis and processing in Geomatics engineering.

Textbooks (most recent edition is recommended):

- Mikhail, E.M., <u>Observations and Least-squares</u>. Thomas Y. Crowell, New York, 1976.
- Mikhail, E.D., and G. Gracie, <u>Analysis & Adjustment of Survey Measurements</u>. Van Nostrand Reinhold, 1981.
- Wolf, P.R., and C.D. Ghilani, <u>Adjustment Computations</u>. John Wiley & Sons Inc., 1997, ISBN 0-471-16833-5.
- Krakiwsky, E.J. (Ed.), <u>Papers for the CISM Adjustment and Analysis Seminars</u>. 2nd edition. Canadian Institute of Geomatics, Ottawa, 1987.

18-Geom-A3 Geodesy and Positioning

Concepts of geodesy; size and shape of the Earth; geoid and ellipsoid; terrestrial, celestial and orbital coordinate systems; coordinate transformations; computations of positions in three dimensions; computations of positions on the ellipsoid and on a conformal mapping plane; azimuthal, conic and cylindrical projections, UTM and 3TM; Canadian horizontal and vertical datums; height determination. Static and kinematic positioning with the Global Positioning System (GPS). Elements of inertial positioning; time systems; astronomic positioning; VLBI positioning; orbit computations; satellite laser ranging. Horizontal, vertical and three-dimensional networks; pre-analysis and post-analysis; theory of heights; gravimetry; global and local geoid determination; astrogeodetic, gravimetric and combined methods; levelling by GPS and the geoid. Introduction to Global Navigation Satellite Systems GNSS concepts.

Textbooks (most recent edition is recommended):

- Vanicek, P. and E.J. Krakiwsky, <u>Geodesy: The Concepts</u>, (Parts IV and V). E.J. North Holland Publishing Co., 1986. ISBN 0444877770.
- Heiskanen W.A., and H. Moritz, <u>Physical Geodesy</u>. Technical University, Gratz (reprint), 1979.
- Moritz, H., <u>Advanced Physical Geodesy</u>. Abacus Press, Tunbridge Wells, U.K, 1980.
- Torge, W., <u>Geodesy</u>. Walter de Gruyter, Berlin (3rd Edition), 2001.

18-Geom-A4 Photogrammetry

Airborne, space and terrestrial data acquisition systems. Metric and non-metric cameras, digital cameras, linear sensors, and non-conventional imagery. Fundamental coordinate systems and mathematical relationships between image, model and object space. Direct and inverse problems of projective and similarity coordinate transformations. Correction of photogrammetric measurements. Geometry of vertical and tilted aerial photographs. The collinearity and coplanarity conditions; analytical space resection and space intersection. Interior and exterior orientation; relative and absolute orientation of single model; stereomodel formation and error analysis. Flight project planning. Multi-image processing, mathematical models for image-triangulation for strip and block adjustment including self calibration and direct georeferencing. Concepts of terrain extraction from airborne sensors. Principles of digital photogrammetry, digital image acquisition, scanning and sampling; resampling, image enhancement; image matching, spatial filtering, stereo-vision techniques; digital rectification and orthorectification and their error analysis.

Textbooks (most recent edition is recommended):

- Mikhail E., J. Bethel, and J.C. McGlone, <u>Introduction to modern photogrammetry</u>. Wiley, 2001.
- McGlone C. (Ed.), E. Mikhail & J. Bethel (Associate Editors), <u>Manual of Photogrammetry</u>. 5th Edition, Published by the American Society for Photogrammetry and Remote Sensing, 2004.
- Schenk T., <u>Digital photogrammetry</u>. TerraScience, 1999.
- Konecny G., <u>Geoinformation: remote sensing, photogrammetry and geographic information systems</u>. Taylor & Francis, 2003.
- Ghosh S.K., <u>Analytical Photogrammetry</u>. 2nd ed, Pergamon Press, 1988.
- Wolf P.R, and B.A. Dewitt, <u>Elements of photogrammetry: with applications in GIS</u>. 3rd ed, McGraw- Hill, 2000.
- Kraus K., <u>Photogrammetry</u>, Vol 1 and 2. 4th rev. ed, Ferd. Dümmlers Verlag, 1993.
- Ghosh S.K., <u>Phototriangulation</u>. Lexington Books, 1975.

18-Geom-A5 Remote Sensing and Image Analysis

Basic physical principles of electro-optical, infra-red and microwave remote sensing; space- and air-borne sensor systems, active and passive sensors; properties of digital image data; radiometric processing including correction of instrumental artifacts and atmospheric corrections; geometric corrections and registration. Concepts of terrain extraction from space-borne sensors. Image statistics. Radiometric enhancement including histogram matching; Fourier representation of image data; image pyramids; geometric enhancement including spatial filtering, edge detection and enhancement; multispectral transformations including IHS, principle component analysis and vegetation indices; overview of remote sensing image interpretation; thematic classification and clustering; supervised classification including minimum distance and maximum likelihood classification; accuracy assessment of classification. Concepts of hyderspectral image analysis.

Textbooks (most recent edition is recommended):

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- Lillesand T.M., and R.W. Kiefer, <u>Remote sensing and image interpretation</u>. 4th ed, John Wiley & Sons, 2000.
- Ryerson R.A., (ed.), <u>Manual of remote sensing</u>. 3rd ed, Wiley, 1996.
- Avery T.E., and G.L. Berlin, <u>Fundamentals of remote sensing and airphoto interpretation</u>. 5th ed, Maxwell Macmillan International, 1991.
- Jensen J.R., <u>Introductory digital image processing: a remote sensing perspective</u>. 2nd ed. Prentice Hall, 1996.
- Richards J.A., and X. Jia, <u>Remote sensing digital image analysis: an introduction</u>. 3rd ed. Springer, 1999.

- Mather P.M., <u>Computer processing of remotely-sensed images: an introduction</u>. Wiley, 1988.
- Schowengerdt R.A., <u>Remote sensing - models and methods for image processing</u>. 2nd ed., Academic Press. 1997.
- Leberl F.W., <u>Radargrammetric image processing</u>. Artech House, 1989.

French Textbooks:

- Bonn & Rochon, <u>Précis de télédétection, volume 1: Principes et méthodes</u>. Presses de l'Université du Québec, 1992.
- Caloz & Collet, <u>Précis de télédétection, volume 3: Traitements numériques d'images de télédétection</u>. Presses de l'Université du Québec, 2001.
- Girard & Girard, Traitement des données de télédétection. DUNOD, Paris, 1999.
- Henri Maitre, <u>Le traitement des images</u>. Hermès Sciences, Paris, 2002.

18-Geom-A6 Cadastral Studies

Legal, economic and social concepts of land tenure; land ownership and land registration; fiscal, judicial and multipurpose cadastral systems; the proprietary land unit; use, valuation and management of land resources; the role of the cadastral surveyor, liability of surveyors; the Dominion Land Survey System, history, detailed description and calculations; land registration systems in Canada; Introduction to other Legal Survey Systems; descriptions of land. History of Cadastres. Essential Elements of a modern cadastre.

Textbooks (most recent edition is recommended):

- Teskey, W.F., T.C. Swanby, W.D. Usher, and A. Hittel, <u>Cadastral Studies Lecture Notes. A Division of Surveying Engineering</u>, University of Calgary, 1983.
- <u>Survey Law in Canada</u> (Note: Now out of print, but approved photocopies may be obtained through the offices of the Canadian Council of Land Surveyors in Ottawa)
- Dale, P.F. and J.D. McLaughlin, <u>Land Information Management: An Introduction with Special Reference to Cadastral Problems in Third World Countries</u>, Oxford University Press 1988.

18-Geom-A7 Geospatial Information Systems

Design and implementation of geospatial information systems (GIS) and their role in digital mapping and spatial data management including: concept of information and GIS; spatial data management systems; georeferencing; spatial data modelling; spatial representation; geoprocessing; input/output operations; file storage; database management systems and distributed processing. Techniques involved in project specification, design and implementation and the selection of computer hardware and software for GIS. GIS data models and structures. Spatial indexing. Algorithms for data manipulation, transformation. Spatial analysis and visualization. Strategies and steps on GIS design and implementation. Data standards and metadata management. Concepts of data fusion and interoperability, including internet-based handling of spatial data and web-based geo-information services.

Textbooks (most recent edition is recommended):

- Longley, P.A., M.F. Goodchild, D.J. Maguire, and D.W. Rhind, <u>Geographic Information Systems and Science</u>. Wiley Ed. ISBN 0-471-89275-0, 2001.
- Date, C.J., <u>Introduction to Database Systems</u>. 8th edition. Addison-Wesley, Reading Mass., 2003. ISBN: 0321197844.
- Groot R. and J. McLaughlin, (eds) <u>Geospatial data infrastructure: concepts, cases, and good practice</u>. Oxford University Press, 2000.

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- Monmonier, M.S., Computer Assisted Cartography: Principles and Prospects. Prentice Hall, 1982.
- Keates J.S., Cartographic Design and Production. 2nd edition. Halsted Press, 1989.
- Robinson, A.H. et al., Elements of Cartography. 6th edition. John Wiley and Sons, 1995. ISBN 0471555797.
- Maling, D.H., Coordinate Systems and Map Projections. 2nd edition. George Philip and Son Ltd., London, 1992. ISBN 0080372341.
- Molenaar M., An introduction to the theory of spatial object modelling for GIS. Taylor & Francis, 1998.
- Burrough P.A. and R.A. McDonnell, Principles of geographical information systems. University Press, 1997.
- Kraak M.-J. and F. Ferjan Ormeling, Cartography: visualization of spatial data. Longman, 1996.
- Green D. and T. Bossomaier, Online GIS and spatial metadata. Taylor & Francis, 2002.
- Aronoff S., Geographic information systems: a management perspective. WDL Publications, 1989.
- Goodchild M. and R. Jeansoulin (eds) Data quality in geographic information: from error to uncertainty. Hermès, 1998.

Group B - Optional examinations (three required)

18-Geom-B1 Digital Terrain Modelling

Digital Terrain Modelling (DTM) and Digital Elevation Modelling (DEM) concepts, their implementation and applications in geomatics engineering and other disciplines. Methods for DTM generation from optical and SAR stereo-imagery, digitisation of cartographic sources, hydrographic surveys, Interferometric SAR (InSAR), laser altimetry (LIDAR) and other capturing methods. Mathematical techniques and automation for terrain extraction, LIDAR and InSAR systems. Sampling, soft and hard breaklines. Structures of DTM (Contours, Grid, and TIN). Types of DEM (eg. CDED, DTED). Processing, storage, and manipulation of DTM. Surface representation from point data using moving averages, linear projection, and Kriging techniques. Grid resampling methods and search algorithms used in gridding and interpolation. DTM derivatives (slope maps, aspect maps, viewsheds, and watershed). Applications of DTM in orthoimage generation, volume computation, and drainage networks, telecommunications, flood prediction, data fusion, and 3D models and visualization. DEM error analysis and impact on DEM-based derived products.

Textbooks (most recent edition is recommended):

- Petrie, G. and T. J. M. Kennie (edit). Terrain modelling in surveying and civil engineering. New York: McGraw-Hill, 1991.
- Maune, D.F. (Editor). Digital Elevation Model Technologies and Applications, the DEM Users Manual. Published by the American Society for Photogrammetry & Remote Sensing, 2001.
- McGlone C. (Editor), E. Mikhail & J. Bethel (Associate Editors), Manual of Photogrammetry. 5th Edition, Published by the American Society for Photogrammetry and Remote Sensing, 2004.
- Greve C. (Editor). An Addendum to the Manual of Photogrammetry. Published by the American Society for Photogrammetry and Remote Sensing, 1996.
- Leberl F.W., Radargrammetric image processing. Artech House, 1989.
- Davis, John C., Statistics and data analysis in geology. New York, Wiley, 2nd ed, 1986.
- Lodwick G.D., Digital Terrain Modelling. University of Calgary, Publication No. 10007, 1983.

18-Geom-B2 Satellite Navigation

Performance requirements, mathematical models, observation methods, processing strategies, uncertainties and other characteristics associated with moving marine, land airborne, and space vehicle positioning, orientation and attitude applications. Description of GPS signal structure and derivation of observables; characteristics of instrumentation; analysis of atmospheric, orbital, random and non-random effects; derivation of mathematical models used for absolute and differential static and kinematic positioning; pre-analysis methods and applications; software considerations; introduction to GPS quality control; static and kinematic survey procedures and operational aspects; integrated GPS-INS systems. Global navigation satellite system.

Textbooks (most recent edition is recommended):

- Wells et. al., Guide to GPS Positioning. Canadian GPS Associates, Fredericton, N.B., 1986.

- Torge, W., <u>Geodesy</u>. Walter de Gruyter. Berlin (3rd Edition), 2001.
- Vanicek P. and E. Krakiwsky, <u>Geodesy: The Concepts</u>. North Holland, Amsterdam (2nd Edition). (Chapters 15 and 16), 1986.
- Leick, A., <u>GPS Satellite Surveying</u>. 2nd edition. Wiley, 1995. ISBN 0471306266.
- El-Rabbany, A., <u>Introduction to GPS, the Global Positioning System</u>. Artech House, Boston, 2002.

18-Geom-B3 Networks and Precise Engineering Surveys

Network concepts and their implementation. Reference systems and surfaces, datum, and fiducial networks. Special surveying and photogrammetric methods and instrumentation used for precise engineering and mining surveying; applications of lasers; deformation measurements and analysis; preanalysis including reliability and sensitivity of engineering surveys; testing and laboratory calibration of surveying instruments; mapping of open pits and underground mines; shaft plumbing; use of lasers and gyrotheodelites; rock deformation measurements; underground construction surveys; tunnelling; subsidence measurements; special instruments and methods for high precision measurements, optical tooling, electronic theodolite and total station systems. Geotechnical measurements of tilt, strain, stress, etc. New network concepts. Wide Area Differential WADGPS and the concept of dynamic networks.

Textbooks (most recent edition is recommended):

- Anderson, M.J., and E.M. Mikhail, <u>Surveying: Theory and Practice</u>. McGraw-Hill, (7th Edition). 1998.
- Kuang, S., <u>Geodetic Network Analysis and Optimal Design: Concepts and Applications</u>. Ann Arbor Press, Inc., Chelsea, Michigan, 1998.
- Caspary, W.F., <u>Concepts of Network and Deformation Analysis</u>. Monograph 11, School of Surveying, The University of New South Wales, Kensington, N.S.W., Australia, 183 pp, 1988.
- Teskey, W.F. (editor), <u>Proceedings of 7th International FIG Symposium on Deformation Measurements and 6th Canadian Symposium on Mining Surveying</u>. Canadian Institute of Geomatics, Ottawa, 1993.
- Wolf, P.R. and C.D. Ghilani, <u>Adjustment Computations</u>. John Wiley & Sons Inc., 1997, ISBN 0-471-16833-5.

18-Geom-B4 Hydrography

Objectives and basic principles of physical oceanography and hydrography surveying; tides, water levels and vertical reference surfaces. Hydrography positioning including mathematical models, optical and radio techniques, radio propagation, satellite, acoustic and self-contained techniques. Depth determination including underwater acoustics, single and multi-beam systems, sea water properties, acoustic and nonacoustic techniques, sea tides, sea surface topography and sea bed properties. Data visualization and standards for safety of navigation.

Textbooks (most recent edition is recommended):

- Ingham, A.E. <u>Hydrography for the Surveyor and Engineer</u>. 3rd edition. Wiley, 1994. ISBN 0632029439.
- Bowditch, N., <u>American Practical Navigator</u>, Volumes I and II. Topographic Centre, United States Defence Mapping Agency, 1976. ISBN 0403089948.
- De Jong, C.D., G. Lachapelle, S. Skone, and I. Elema, <u>Hydrography</u>. Delft University Press, 2002.
- Appleyard, S.F. et al., <u>Marine Electronic Navigation</u>, 2nd edition. Routledge & Kegan Paul, 1988.
- Forrester, W. D., <u>Canadian Tidal Manual. Department of Fisheries and Oceans</u>, Canadian Hydrographic Service, 1983. ISBN 0660113414.

18-Geom-B5 Survey Law

The Canadian Legal System: sources of law, statutes, regulations, rules; case law and precedent; common law; civil law in Quebec; administration of law and justice in Canada. Real Property Law: estates and tenures; legal and equitable interests; encumbrances; leases; mortgages; covenants; land use controls and rights in land; easements and rights of way; reservation; prescription; possession; freehold fee simple; adverse possession; limitation of actions; registration of deeds; registration of title; conveyancing. Boundary Law: nature of boundaries; creation of boundaries; principles of evidence; creation of evidence; retracement; artificial boundaries; natural boundaries; riparian rights; littoral boundaries; high and low water mark; erosion and accretion; dedication and acceptance; navigable waters; descriptions of land; offshore

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boundaries; leases at sea.

Textbooks (most recent edition is recommended):

- Ziff, Bruce, <u>Principle of Property Law</u>, 3rd edition, CARSWELL, 2000.
- <u>Survey Law in Canada</u> (Note: Now out of print, but approved photocopies may be obtained through the offices of the Canadian Council of Land Surveyors in Ottawa)

18-Geom-B6 Land Use Planning and Environmental Management

The evolution of urban planning in Canada; its present institutional, administrative and legal arrangements and its application. Site analysis prior to planning and design; criteria that are applicable to the design of residential site and subdivision plans. Resource management including environmental and ecological concerns that relate to resource development especially in remote areas. Contributions of geomatics technologies such as Geographic Information Systems (GIS), remote sensing, and ocean mapping to environmental engineering. Earth systems modelling, climate change, sustainable development and the general impacts of anthropogenic activity. Water quantity and quality issues; inland, costal, and ocean environments; and atmospheric and land-based processes are presented with applications of how geomatics technology supports monitoring and modelling efforts.

Textbooks (most recent edition is recommended):

- Chapin, F.S. and E.J. Kaiser, <u>Urban Land Use Planning</u>. 4th edition. University of Illinois Press, 1995. ISBN 0252021010.
- Ratcliffe, J. <u>An Introduction to Town and Country Planning</u>. 2nd edition. Longwood Publication Group, 1984.
- Lynch, <u>Site Planning</u>, 3rd edition. M.I.T. Press, 1984. ISBN 0262121069.
- So, F.S. et al. (editors), <u>The Practice of Local Government Planning</u>, 2nd edition. Planners Press, 1988. (International City Management Association in cooperation with APA. ISBN 0873260775.

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