National Exams December 2018

04-Geom-A3, Geodesy and Positioning

3 hours duration

NOTES:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.

2. This is a CLOSED BOOK EXAM.
   Approved Casio or Sharp calculator permitted.

3. SIX (6) questions constitute a complete exam paper.
   The first six questions as they appear in the answer book will be marked.

4. Each question is of equal value.

5. Most questions require an answer in essay format. Clarity and organization of the answers are very important. The candidate is strongly advised to provide succinct yet precise answers that demonstrate competency in the subject and language aptitude.

1. **Coordinate Systems, Reference Frames and Datums**
   - **a)** Natural Resources Canada (NRCan) maintains the Canadian Spatial Reference System (CSRS), through the use of the North American Datum of 1983 (NAD83CSRS), which is the adopted standard in Canada. NAD83 comes in different versions but two of them are most commonly used, namely NAD83(original) and (NAD83CSRS+epoch).
     - i. Which are the main differences between the above two versions of NAD83?
     - ii. What does the (CSRS+epoch) mean, and what is the importance of "epoch"?
   - **b)** At the heart of the CSRS is the Canadian Active Control System (CACS):
     - i. What is CACS?
     - ii. How does it work?
     - iii. How does it contribute to the definition/realization CSRS?
   - **c)** Internationally, the *International Terrestrial Reference Frame* (ITRF) for positioning has been used. Compare NAD83CSRS+epoch, with the ITRF(epoch) by listing similarities and differences including the order of magnitude of their differences, if any.

2. **Gravity Field and Geoid**
   - **a)** Define *gravity anomaly* in its most generic form. Based on your definition of the gravity anomaly define *refined Bouguer* gravity anomaly.
   - **b)** What is the typical accuracy of modern geoid model and which are the factors that limit its accuracy i.e., what would we need to do to increase its accuracy in the future?
   - **c)** Why do we need a geoid model in the geodetic computations?
   - **d)** Why are the plumb lines of the Earth's gravity field curved? (*2 points*). Can we say the same for the plumb lines of the Earth's gravitational field? Why? (*3 points*).
   - **e)** Define *geoid deflection of the vertical*. Please describe in which common application in survey reductions we use this deflection.

3. **Height systems**

   In 2013, Canada replaced the old vertical datum CGVD28 with the new CGVD2013. Describe and compare both datums by briefly answering the following:
   - a) The fundamental (conceptual) difference between the two and their precision
   - b) The height system (e.g., orthometric, normal, dynamic or normal-orthometric) on which each of them is based
   - c) Provide the type of fundamental measurements needed for the determination of orthometric or dynamic heights by precise geodetic levelling.
   - d) In a mountainous area where the levelled height differences may reach 2 km (e.g., levelling in the Rockies) what would be the magnitude of the orthometric correction that is, the correction you need to apply to the levelled height differences to obtain orthometric heights? What if the levelled height differences do not exceed 100 m (relatively flat area). Please give an order of magnitude.

4. **Map projections**
   Observations made in the field, regardless of how they were obtained (total station, GNSS) must be projected (or reduced) first onto the reference ellipsoid (horizontal datum) and then onto the mapping plane using a specific map projection.
   a) In order to project the distance or GNSS baseline measurements from the terrain (where the measurements are done) onto the ellipsoid, we use what is termed as the "*elevation factor*". Define "*elevation factor*" and explain how it is used.
   b) One of the fundamental reductions (corrections) used to project an azimuth from the terrain to the reference ellipsoid is called *Complete Laplace Correction*. Please indicate the reason we apply this correction and provide an order of magnitude of it.

5. **Space Geodetic Positioning**
   a) GPS positions are referenced to the World Geodetic System of 1984 (WGS84). Are WGS84 and NAD83CSRS+epoch compatible? If yes, at what level of precision are they compatible?
   b) Are the GPS positions in WGS84 compatible with the ITRF? Please justify you answer.
   c) Modern Geodesy relies on the astronomical technique of VLBI (Very Long Baseline Interferometry), as the only technique that is capable of maintaining the long-term stability of the space-based methods, such as GNSS. Please explain how VLBI works and in what sense it is stable as opposed to GNSS. (hint: use the notion of the inertial reference frame).

6. **Horizontal, vertical and three-dimensional networks; pre-analysis and post-analysis**
   After the completion of a least-squares adjustment of a geodetic network, we assess statistically the estimated parameters in order to establish a trust in them; this is known as geodetic network post-analysis. Post-analysis, among others, involves the calculation of confidence ellipses (2-D networks) or confidence ellipsoids (3-D networks). Such confidence ellipses or ellipsoids can be "*standard*", "*95%*" or other.
   a) What is "*standard error ellipse*" and what is "*standard error ellipsoid*?" What is the confidence level they define?
   b) How can we obtain the 95% confidence error ellipse from the standard error ellipse?

7. **Briefly describe the terms below (2-3 sentences for each). Sketches or graphs, wherever possible, are acceptable:**
   a) Polar motion
   b) Atomic time
   c) Sidereal time
   d) GNSS-PPP
   e) Combined factor
   f) Geodetic datum
   g) Canadian Base Network (CBN)
   h) Inertial reference coordinate system
   i) RINEX
   j) IGS