National Exams May 2015

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.
   A Casio or Sharp model calculator is 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) The modern approach to defining a spatial reference system is to consider a "*kinematical*" definition of its associated coordinate system, as opposed to the "*dynamical*" definition used in the past. What is it meant by "*kinematical*" and what by "*dynamical*?" (*5 points*).

b) Based on the "*kinematical*" approach **define** the coordinate system associated with the *International Terrestrial Reference Frame* ITRF (*5 points*).

c) Which geodetic measurement techniques are used today to define and access the ITRF? Please explain. (*5 points*).

d) In Canada we use NAD83(CSRS+epoch) for positioning and navigation. Compare NAD83(CSRS+epoch) with ITRF by listing similarities and differences including the order of magnitude of their differences, if any (*5 points*).

2. Computations of positions on the ellipsoid

If done correctly, 2-D relative positioning on the reference ellipsoid is equivalent to 3-D (spatial) relative positioning. Please discuss the following points/questions:

a) State the direct problems of 2-D and 3-D relative positioning, i.e., state the "given", the "observed" and "wanted" quantities. (*5 points*)

b) For the each of the problems (2-D and 3-D) list the corrections (reductions) required to the raw observations (as discussed in point (a) above) and indicate whether they are of "physical" or "geometrical" type. (*8 points*)

c) Discuss the complexity of the calculations involved in 2-D and 3-D relative positioning (only the direct problem). (*7 points*)

3. Height systems

a) Define geopotential number. What does it express physically? (*4 points*)

b) Can we determine the geopotential number of a point by observations? How? (*4 points*)

c) Define *dynamic* and *orthometric* heights. (*4 points*)

d) What is the conceptual difference between these two height systems (*4 points*)?

e) Can the orthometric height be calculated accurately? Please justify your answer. (*2 points*)

f) In 2013, Canada replaced the old vertical datum CGVD28 with the new CGVD2013. What is the fundamental (conceptual) difference between the two? (*2 points*)

4. Map projections

Measurements made in the field, regardless of how they were obtained, must be projected onto the mapping plane using a specific map projection.

a) Before the terrain measurements are projected onto the mapping plane are reduced to another intermediate reference surface. Which is this surface? And why do we need this intermediate surface? (*4 points*)

b) In order to project the <u>distance</u> observations from the terrain (where the measurements are done) onto the mapping plane we use what is termed as the "*grid factor*". Define "*grid factor*" and explain how it is used (Note: we often use the term "*combined scale factor*" instead of "*grid factor*"). (*4 points*)

c) What is "central meridian" and what is "standard meridian" in the *Universal Transverse Mercator* (UTM)? How many central meridians and how many standard meridians do we have in a single UTM zone? (*3 points*)

d) Please provide the scale factors within an entire UTM zone. Please justify your answer. (*3 points*)

e) What is "*meridian convergence*"? Is it important to apply the meridian convergence correction to the observed azimuths in UTM projection? Please justify your answer. (*3 points*)

f) What is MTM (3TM)? Name two conceptual differences between UTM and MTM (*3 points*)

5. Satellite Positioning

a) GPS positions are referenced to the World Geodetic System of 1984 (WGS84). Are WGS84 and NAD83(CSRS+epoch) compatible? If yes, at what level of precision are they compatible? (*5 points*)

b) Are the GPS positions in WGS84 compatible with the ITRF? Please justify you answer. (*5 points*)

c) What is GPS-PPP? Please describe briefly the concept of PPP and the field procedure we use to obtain positions. Discuss the accuracy in positioning one can achieve with PPP? (*5 points*)

d) What is a GPS-RTK network? What is the principle of operation of such a network? What positioning accuracies can we achieve? Can you name one such network in Ontario and how a user can access it? (*5 points*)

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, and also "*out-of-context*" or "*in-context.*"

a) What is "*standard error ellipse*" and what is "*standard error ellipsoid*?" What is the confidence level they define? (*8 points*)

b) What is the meaning of "*out-of-context*" and "*in-context*" (or simultaneous) ellipses or ellipsoids? (*8 points*)

c) How can we obtain the 95% confidence error ellipse from the standard error ellipse? (*4 points*)

7. Gravity field and geoid model calculation

The Stokes formula for the calculation of the geoid is given by:

$$N = \frac{R}{4\pi\gamma_0} \iint_s S(\psi)\Delta g ds$$

a) What is the approximation used to derive this formula (3 points) and what is the order of magnitude of the error in the geoid N stemming from this approximation? (*3 points*).

b) Describe briefly all the variables involved in the above formula (*4 points*). Which variable(s) are observables (*2 points*)? Can they be observed directly? (*2 points*). Why do we call $S(\psi)$ a "*kernel function?*" (*2 points*).

c) What other fundamental data set do we need to calculate the geoid that is implicitly included in the above formula. (*4 points*).

8. Definitions/Descriptions

Briefly describe the terms below (2-3 sentences for each). Sketches or graphs, wherever possible, are acceptable (*2 points each*)

a) IERS
b) VLBI
c) SLR
d) CBN
e) Beidu
f) Satellite orbit inclination
g) Right ascension of the ascending node
h) Orbital coordinate system
i) Deflection of the vertical
j) Conformal map
k) Tissot's indicatrix