CANADIAN BOARD OF EXAMINERS FOR PROFESSIONAL SURVEYORS

C-4 COORDINATE SYSTEMS & MAP PROJECTIONS **October 2013**

Although programmable calculators may be used, candidates must show all formulae used, the substitution of values into them, and any intermediate values to 2 more significant figures than warranted by the answer. Otherwise, full marks may not be awarded even though the answer is numerically correct.

Note: This examination consists of 6 questions on 3 pages. **Marks**

Time: 3 hours

Q. No		Value	Earned
1.	Explain each of the following (with a clear demonstration of your understanding of each of the terms involved): a) Main difference between datum transformation and coordinate transformation b) Main difference between reference system and reference frame c) Main differences between Hybrid datum and CGVD28	 3 4 5	
2.	According to Torge in his *Geodesy*, Celestial Reference System (CRS) is an approximation to an inertial system. a) What is an inertial system? Explain the need for it in Geomatics. b) Describe the three-dimensional Cartesian coordinate system and the spherical coordinate system, for CRS. c) Give an example of CRS and explain how it is being realized for practical positional applications.	 4 6 5	
3.	a) Explain two fundamental roles of time in positioning applications. b) Explain the differences between the Local Astronomic coordinate system and the Horizon coordinate system with regard to their origins, fundamental planes, and how an object can be positioned in each. c) Explain what natural coordinates are and how they can be determined for a point in space. d) Explain three important points for and three important points against, the use of geodetic coordinates (Latitude, Longitude) as nation-wide grid reference system.	4 6 4 6	
4.	a) Sketch the graticule as it appears on the Universal Transverse Mercator (UTM) projection of a specific zone and specify the following on the sketch: Zone Number, Longitude of Central Meridian, Equator, False Northing and False Easting coordinates, Latitude limits, Longitudes of zone boundaries, scale factor at the Central Meridian. b) Using well-labeled sketches only, illustrate the Mercator and the polar Stereographic projections in the Northern hemisphere; give one sketch for the Mercator projection and the other sketch for the polar Stereographic projection. The sketches must show the representations (in dotted lines) of **loxodrome with bearing 90˚**, and the projections (in bold lines) of the **Equator**, **Central Meridian**, **parallels** and **meridians** with the appropriate relationship between the lines of the graticule clearly illustrated.	10 16	

5. The point scale factor (k) at any given point (x, y) on a Transverse Mercator (TM) projection can be approximated using the following formula:

$$k = k_0\left[1 + \frac{(\Delta x)^2}{2R^2}\right]$$

where k_0 is the scale factor at the central meridian; Δx is the distance (in km) from the central meridian to the mapping boundary; and R (in km) is the mean radius of the earth. In a large-scale cadastral mapping of a region (with 360 km East-West extent), a linear distortion factor of 1:10,000 is required and a Modified Transverse Mercator (MTM) projection (similar to UTM) is to be used. The mean radius of the earth (R) in the region can be taken as 6,371 km.

a) Determine (by calculation) the number of zones needed to cover the region so that the linear distortion factor remains within 1:10,000. 6

b) If a single zone is used for the whole mapping region, determine the worst linear distortion factor (in ratio form) for the zone, assuming the scale factor determined for the central meridian in (a) is adopted for the central meridian in this case. 5

c) If the linear distortion factor is 1:10,000, calculate the difference between actual lot area and the projection lot area for a lot 100 m by 100 m. 4

6. Given the Universal Transverse Mercator (UTM) map coordinates of points B and C as follows:

Station	Easting (m)	Northing (m)
B	564,702.284	5,588,965.983
C	563,836.008	5,580,487.376

The other parameters of the map projection are as follows:

- Geodetic coordinates of point B are Latitude = 50° 26′ 56.8740″N, Longitude = 122° 05′ 19.1800″W; Longitude of the Central Meridian = 123°W; T-t correction from B to C = -1.4″;
- Mean radius of the earth for the region, R_m = 6,382,129.599 m.

Calculate the geodetic azimuth of line BC (to the tenth of a second), and explain the steps and the quantities needed to transform the geodetic azimuth into an astronomic azimuth. 12

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Some potentially useful formulae are given as follows:

$$T - t = \frac{(y_2 - y_1)(x_2 + 2x_1)}{6R_m^2}$$

where $y_i = y_i^{UTM}$; $x_i = x_i^{UTM} - 500{,}000$; R_m is the Gaussian mean radius of the earth; and x_i^{UTM} and y_i^{UTM} are the UTM Easting and Northing coordinates respectively, for point i.

UTM average line scale factor, $\bar{k}_{UTM} = 0.9996\left[1+\frac{x_u^2}{6R_m^2}\left(1+\frac{x_u^2}{36R_m^2}\right)\right]$;

where $x_i = x_i^{UTM} - 500{,}000$; $\quad x_u^2 = x_1^2 + x_1 x_2 + x_2^2$

Grid convergence, $\gamma_B = \Delta\lambda \sin\phi\left[1+\frac{\Delta\lambda^2 \cos^2\phi}{3(20265)^2}\right]$; where $\Delta\lambda = (\lambda - \lambda_0)$ (in arc-seconds) for any given longitude λ with central longitude at λ_0.

$$x = (N+h)\cos\phi\cos\lambda$$
$$y = (N+h)\cos\phi\sin\lambda$$
$$z = \left[\left(1-e^2\right)N+h\right]\sin\phi$$

$$X_f = X_G \times K_f + X_0$$
$$Y_f = Y_G \times K_f$$

$$\Delta r^{LG} = R_3(\eta_0 \tan\phi_0)R_2(-\xi_0)R_1(\eta_0)\times\Delta r^{LA}$$
$$\Delta r^{G} = R_3(\pi-\lambda_0)R_2(\frac{\pi}{2}-\phi_0)P_2\times\Delta r^{LG}$$
$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} x_0 \\ y_0 \\ z_0 \end{bmatrix} + (1+\delta k)\begin{bmatrix} 1 & \gamma & -\beta \\ -\gamma & 1 & \alpha \\ \beta & -\alpha & 1 \end{bmatrix}\begin{bmatrix} x \\ y \\ z \end{bmatrix}$$

$$\alpha_{ij} = A_{ij} - \eta_i \tan\phi_i - \left(\xi_i \sin\alpha_{ij} - \eta_i \cos\alpha_{ij}\right)\cot Z_{ij}$$