CANADIAN BOARD OF EXAMINERS FOR PROFESSIONAL SURVEYORS

C-4 COORDINATE SYSTEMS & MAP PROJECTIONS **March 2016**

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 (giving a clear explanation of each of the terms involved; do not be tempted to state, for example, that one is … and the other is not):		
	a) One main difference between a datum transformation and a coordinate transformation.	3	
	b) One main difference between a reference system and a reference frame.	3	
	c) One main difference between a horizontal geodetic datum and a coordinate reference system.	3	
	d) The differences and the relationship between a map projection and its map grid (including the definition of their possible origins, coordinate axes and units of measurements).	8	
2.	a) Sketch the graticule appearance of the Universal Transverse Mercator (UTM) projection for Zone 10 and label the following on the sketch: longitude of Central Meridian, Equator, False Northing and False Easting coordinates, latitude limits, longitudes of zone boundaries, scale factor at the Central Meridian.	12	
	b) Given the Universal Transverse Mercator (UTM) map coordinates (in UTM Zone 10) 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 Gaussian mean radius of the earth in the region, R_m = 6,382,129.599 m. Answer the following:		
	i) Calculate the geodetic azimuth of line BC (to the tenth of a second) if the convergence of meridian at point B is 1°29′00.0″.	12	
	ii) Calculate the ellipsoidal distance BC.	5	
3.	Answer the following with regard to Transverse Mercator (TM) projection of an ellipsoid onto a plane.		
	a) Explain two specific conditions that the projection must satisfy along the Central Meridian with regard to the *x* and *y* projection coordinates.	3	
	b) Explain how the meridian convergence and scale factor variations in Transverse Mercator projections mathematically relate to those in the Universal Transverse Mercator projections.	2	
	c) Explain how the *x* and *y* coordinates in Transverse Mercator projections mathematically relate to those in the Universal Transverse Mercator projections.	3	

4.	Answer the following: a) Clearly explain why the plane bearing of a line P-Q in a Stereographic double projection and the plane bearing of the same line in a UTM projection cannot necessarily be compared directly as a check on the correct orientation of the line. Suggest, with reasons, what might be more appropriate bearings to compare. b) Explain how orbital coordinate system is defined (describing the origin and coordinate axes) and describe three of the important parameters needed to convert coordinates in orbital system to geocentric coordinate system. c) Clearly explain two important differences between CGVD28 and CGVD2013 (do not be tempted to state, for example, that one is … and the other is not). d) According to Torge in his *Geodesy*, the Celestial Reference System (CRS) is an approximation to an inertial system. What is an inertial system? Explain the need for it in Geomatics. e) What is isometric latitude? Describe how it compares with the geodetic latitude from the Equator to the Pole and explain its important uses in a map projection.	4 7 6 4 6	
5.	a) Explain two fundamental roles of time in positioning applications. b) Define the Local Astronomic coordinate system with regard to its origin and the orientation of its axes. c) Explain what natural coordinates are and how they can be determined for a point.	4 2 4	
6.	In the *Conformal Map Projections in Geodesy* by Krakiwsky (1973), the modified direct mapping equations for a Lambert conformal conic projection can be given as $x = r \sin \ell\lambda$ $y = r_0 - r \cos \ell\lambda$ where x and y are the map projection coordinates. a) Clearly explain, with regard to the two equations, what r, r_0, ℓ and λ represent, including their possible uses. What types of territories are most suitable for conic projections? b) Describe the magnitude of convergence of meridians in a conic projection.	7 2	
		100	

Some potentially useful formulae are given as follows:

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

where $y_i = y_i^{UTM}$; $x_i = x_i^{UTM} - x_0$; 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, $\bar{k}_{UTM} = k_0\left[1+\frac{x_u^2}{6R_m^2}\left(1+\frac{x_u^2}{36R_m^2}\right)\right]$;

where $x_i = x_i^{UTM} - x_0$; $x_u^2 = x_1^2 + x_1x_2 + x_2^2$

UTM point scale factor, $k_{UTM} = k_0\left[1+\frac{\Delta x^2}{2R_m^2}\right]$, where $\Delta x = x^{UTM} - x_0$

$$k_{UTM} = k_0\left[1+\frac{\Delta\lambda^2}{2(206265)^2}\cos^2\phi\right]$$

k_0 is scale factor of Central Meridian and x_0 is the False easting value (or 500,000 m)

Grid convergence, $\gamma_B = \Delta\lambda\sin\phi\left[1+\frac{\Delta\lambda^2\cos^2\phi}{3(206265)^2}\right]$; where $\Delta\lambda = (\lambda - \lambda_0)$ (in arc-seconds)

for any given longitude λ with central longitude at λ_0.

Geodetic bearing: $\alpha = t + \gamma + (T - t)$

Distortion Formulas:

Given: $X = f(\phi,\lambda)$ $Y = g(\phi,\lambda)$

$m_1^2 = \frac{f_\phi^2 + g_\phi^2}{R^2}$; $m_2^2 = \frac{f_\lambda^2 + g_\lambda^2}{R^2\cos^2\phi}$; $p = \frac{2(f_\phi f_\lambda + g_\phi g_\lambda)}{R^2\cos\phi}$

$\frac{d\Sigma'}{d\Sigma} = m_1 \times m_2 \sin A'_p$

$\sin A'_p = \frac{f_\lambda g_\phi - f_\phi g_\lambda}{\sqrt{(f_\lambda g_\phi - f_\phi g_\lambda)^2 + (f_\phi f_\lambda + g_\phi g_\lambda)^2}}$; $\tan\mu_m = \frac{f_\varphi}{g_\varphi}$

$\tan\mu_s = \frac{g_\phi\cos\phi\cos A + g_\lambda\sin A}{f_\phi\cos\phi\cos A + f_\lambda\sin A}$; $\tan(180^\circ - A') = \frac{\tan\mu_m - \tan\mu_s}{1+\tan\mu_m\tan\mu_s}$

ITRF:

$\mathbf{r}(t) = \mathbf{r}_0 + \dot{\mathbf{r}}(t - t_0)$

where $\mathbf{r}_0$ and $\dot{\mathbf{r}}$ are the position and velocity respectively at $\mathbf{t}_0$.