CANADIAN BOARD OF EXAMINERS FOR PROFESSIONAL SURVEYORS

C-4 COORDINATE SYSTEMS & MAP PROJECTIONS **March 2015**

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.	On an UTM projection, point A is located on the eastern secant line while point B is located on a line where the scale factor is 1.0001 towards the eastern boundary. If the UTM plane bearing of line AB is 45º30´10.5", determine the grid bearing of the line (assuming the Gaussian mean radius of the earth in the region is 6,382,129.599 m).	20	
2.	a) A 3TM zone (with False Easting of 304,800 m and the scale factor of central meridian of 0.99990) and a UTM zone have the same central meridian. Given the 3TM map coordinates of point Q as X = 274,800.000 m, Y = 5,500,000.000 m, calculate the UTM coordinates of the point. b) Explain if the convergence of meridian at point Q in (a) above will be the same in the 3TM and the UTM projections.	7 3	
3.	A new survey point Q was established in the ITRF2008 (epoch 2012.16) using GNSS. After an appropriate transformation, the ITRF96 (epoch 2012.16) coordinates were determined for the point as $X = -4,793,404.167\ m$; $Y = 407,107.994\ m$; $Z = -4,175,081.559\ m$. The velocity model for ITRF2008 (epoch 2012.16) are $v_x = -0.0196\ m/yr$, $v_y = 0.0277\ m/yr$, and $v_z = 0.0250\ m/yr$; and other parameters are zero. a) Calculate the ITRF96 (epoch 2000.0) coordinates of the survey point Q. b) What are the significance of “2008” and “epoch 2012.16” in ITRF2008 (epoch 2012.16)? c) Explain what constitutes an ITRF realization. d) The North American Datum of 1983 (NAD83) is currently aligned with a fixed epoch of an ITRF realization to support most spatial users. Clearly explain one important practical limitation with aligning NAD83 with a fixed epoch.	6 4 2 3	
4.	Answer the following: a) Explain three important reasons why the GPS coordinate values, which are usually presented in the (X, Y, Z) geocentric coordinate system, are inconvenient for use by surveyors. b) What is Tissot indicatrix? Describe the conformal and the equal-area map projections with regard to the possible sizes, shapes and orientations of Tissot indicatrices on them. 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) 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 checks on the correct orientation of the line. Suggest, with reasons, what might be more appropriate bearings to compare.	6 9 6 6	

5.	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. 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.	4 6 4 4	
6.	Your company has just been awarded a project to create a map (using only one projection) showing the route of a pipeline in an area (latitudes 42°N to 84°N and longitudes 92°W to 141°W). Describe a suitable map projection for this project if scale distortions in the area must be kept to a minimum, explaining reasons for your choices. Your description must clearly explain the aspect, distortion characteristic, developable shape, locations of standard lines, locations of central parallel and central meridian, and suggested name of projection type.	10	
		100	

Some potentially useful formulae are given as follows:

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

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

UTM point scale factor, $k_{UTM} = 0.9996\left[1 + \frac{\Delta x^2}{2R_m^2}\right]$, where $\Delta x = x^{UTM} - 500{,}000$

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.

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

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

<u>Distortion Formulas:</u>

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

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

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

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

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

ITRF:

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

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