CANADIAN BOARD OF EXAMINERS FOR PROFESSIONAL SURVEYORS

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

Q. No	Time: 3 hours	Value	Earned
1.	a) Explain what time scale and time epoch mean in time systems. b) Discuss three classes of time scales, including the natural observable phenomenon that each relates to. c) Describe the curvilinear coordinates of right ascension system and explain how each of the following would affect them: i) a translation of the coordinate origin in (X, Y, Z) of the right ascension system; ii) a general rotation of the (X, Y, Z) axes of the right ascension system; iii) precession and nutation of the rotation axis of the Earth. d) Explain what natural coordinates are and how they can be determined for a point.	2 3 7 4	
2.	In a large-scale cadastral mapping of a region (with 360 km East-West extent), a scaling accuracy ratio of 1/10,000 is required and a modified Transverse Mercator projection (similar to UTM) is to be used. The radius of the earth in the region can be taken as 6,371 km. Answer the following questions: a) Determine the number of zones (showing the computational steps followed) and the scale factor (to 6 decimal places) to be used at the central meridian so that the scaling accuracy ratio remains within 1/10,000. b) If a single zone is used for the whole mapping region of 360 km, determine the worst scaling accuracy ratio for the zone, assuming the scale factor determined in a) is adopted for the central meridian. c) With regard to your answers in a) and b), discuss two important considerations for the choice of a suitable conformal projection for a large-scale cadastral mapping of a region, indicating a possible consequence of each consideration.	5 4 3	
3.	Using well labelled 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 projections of the **loxodrome with bearing 90°**, **Equator**, **Central Meridian**, **parallels** and **meridians** with the appropriate relationship between the lines of the graticule clearly illustrated.	16	

4.	a) On a UTM Zone 12 projection, calculate the grid convergence (γ) (to the nearest arc second) for point A with latitude (ϕ = 53° 42′ 28″ N) and longitude (λ = 112° 18′ 29″W). (Refer to the formula sheet for the appropriate grid convergence formula) b) What would be the longitude of a point with the same numeric value for convergence, but opposite algebraic sign? c) 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. Calculate the UTM coordinates of the point whose 3TM map coordinates are X = 274,800.000 m, Y = 5,500,000.000 m.	9 2 5	
5.	Answer the following: a) A typical cadastral survey plan usually shows, among other details, the horizontal ground-level distances and the corresponding astronomic bearings of boundaries of a given land parcel; these distances and bearings are different from the plotted corresponding distances and bearings on the plan. Explain the differences and provide the theoretical and practical procedures for making the quantities equivalent. b) Discuss briefly the concept of Tissot indicatrix and clearly describe its practical applications using conformal and equal-area mapping as examples. c) Discuss three important advantages of computing geodetic positions on a conformal projection plane as compared to computing them on an equal-area projection.	7 10 6	
6.	Answer the following: a) Explain how an orbital coordinate system is defined (describing the origin and coordinate axes) and describe three of the important parameters needed to convert coordinates in an orbital system to geocentric coordinate system. b) 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). c) 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.	7 6 4	
		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 $x_i = x_i^{UTM} - x_0$; $x_u^2 = x_1^2 + x_1 x_2 + x_2^2$

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, $\gamma = L\left(1 + \frac{L^2}{3}\left(1 + 3\eta^2\right)\cos^2\phi\right)\sin\phi$

where $\eta^2 = e'^2\cos^2\phi$; e'^2 =0.006739496780; $L = (\lambda - \lambda_0)$ (in radians); and λ_0 is the longitude of the central meridian.

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

Transformation Formulas:

$$X_{(target)} = k_{0(target)} X_G + X_{0(target)}$$
$$Y_{(target)} = k_{0(target)} Y_G$$
$$X_G = \frac{\left[X_{(original)} - X_{0(original)} \right]}{k_{0(original)}}$$
$$Y_G = \frac{Y_{(original)}}{k_{0(original)}}$$

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 $\mathbf{t}_0$.