CANADIAN BOARD OF EXAMINERS FOR PROFESSIONAL SURVEYORS

C-4 COORDINATE SYSTEMS & MAP PROJECTIONS **October 2017**

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.	Answer all of the following: a) Surveyors usually project their field measurements from the terrain onto some mapping plane (using some specific map projections) before using them in their computations. Explain how distance and azimuth measurements would be projected onto a mapping plane in order to obtain their equivalent values on this plane (stating the surfaces involved, types of reductions in each surface, and the typical distortion property of the commonly used projections). b) Discuss briefly the concept of Tissot indicatrix and clearly describe its practical applications using conformal and equal-area mappings 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.	6 10 6	
2.	a) Discuss two conceptual differences between UTM and MTM (or 3TM). b) What are the ellipsoidal (latitude and longitude) coordinates of the points where the meridian convergence values are minimal and maximal in UTM projections? Calculate the meridian convergence values corresponding to those points. c) Determine the longitude coordinates (along the Equator) of the points where the scale factor distortion is minimal in UTM projections. What is that scale factor distortion? d) 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 (MTM) projection is to be used. Determine (showing your computational steps) the scale factor (to 6 decimal places) and the number of projection zones for the region so that the scaling accuracy ratio remains within 1/10,000. The radius of the earth in the region can be taken as 6,371 km.	2 10 5 6	
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) 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 precession and nutation of the rotation axis of the Earth would affect them.	2 3 5	

5.	a) You are to transform the cadastral map coordinates of the Province of New Brunswick from the stereographic double projection [NAD27] to UTM projections [NAD83 (CSRS)]. Explain step by step how to best carry out this transformation (without providing any specific formulae, but clearly describing in each step the input and output data, types of transformation equations, etc.). b) If the map coordinates to be transformed in (a) are in the stereographic projection [NAD83 (CSRS)], explain what you would change in your steps in (a).	6 3	
6.	Answer the following (while explaining the differences, do not be tempted to state, for example, that one is … and the other is not): 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 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. d) Describe the relationship between a reference system and a reference frame.	7 6 4 3	
		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 $\Delta x = x^{UTM} - x_0$

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

k_0 is scale factor of Central Meridian and x_0 is the False easting value (or 500,000 m)
$L = (\lambda - \lambda_0)$ (in radians) for a given longitude λ; and λ_0 is the longitude of the central meridian.

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 $\mathbf{t}_0$.