CANADIAN BOARD OF EXAMINERS FOR PROFESSIONAL SURVEYORS

C-4 COORDINATE SYSTEMS & MAP PROJECTIONS **March 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 5 questions on 3 pages. **Marks**

Q. No	Time: 3 hours	Value	Earned
1.	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.).	6	
	b) If the map coordinates to be transformed in a) are all in the same stereographic projection [NAD83 (CSRS)], explain what you would change in your steps in a).	3	
	c) What would you change in your steps in a) if the map coordinates to be transformed relate to a small city (with relatively flat terrain) and the map projection on which the coordinates are based is unknown?	3	
	d) Explain one important difference between a datum transformation and a coordinate transformation.	3	
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) 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.	10	
	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?	5	
	d) Explain how the x and y coordinates in Transverse Mercator projections mathematically relate to those in the Universal Transverse Mercator projections.	3	
	e) Explain how the meridian convergence and scale factor variations in Transverse Mercator projections mathematically relate to those in the Universal Transverse Mercator projections.	2	
3.	a) Explain what time scale and time epoch mean in time systems.	2	
	b) Discuss three classes of time scales, including the natural observable phenomenon that each relates to.	3	
	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.	5	

4.	Answer all of 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 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.	7 10 6	
5.	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 $x_i = x_i^{UTM} - x_0$; $x_u^2 = x_1^2 + x_1x_2 + x_2^2$

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

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

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

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 $\mathbf{t}_0$.