CANADIAN BOARD OF EXAMINERS FOR PROFESSIONAL SURVEYORS

C-4 COORDINATE SYSTEMS & MAP PROJECTIONS **March 2018**

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.	Answer all of the following. a) Explain the terms "Central Meridian" and "Standard Meridian" and how many of them are present in a single Universal Transverse Mercator (UTM) zone. b) 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. c) Discuss 2 important advantages of computing geodetic positions on a conformal projection plane as compared to computing them on an equal-area projection.	2 7 4	
2.	Explain and give the important applications of the following as used in Coordinate Systems and Map Projections. a) Gaussian fundamental quantities b) Cauchy –Riemann equations c) Reference frame d) Natural coordinates e) Isometric latitude f) Time scale g) Footpoint latitude	 3 2 2 3 3 3 3	
3.	Given the UTM map coordinates of points B and C as follows: (see table below) The other parameters of the map projection are as follows: • Geodetic coordinates of point B are Latitude = 50° 26′ 56.8740″, Longitude = -122° 05′ 19.1800″; • Mean radius of the earth for the region, R_m = 6,382,129.599 m; • Ellipsoidal parameters, a = 6378137.0000 m; e^2 = 0.006694380025; and e'^2 = 0.006739496780. Answer the following: a) Calculate the geodetic azimuth of line BC (to the tenth of a second). b) Calculate the ellipsoidal distance between points B and C, and explain the steps and the quantities needed to transform this distance into a mark to mark distance on the ground surface. c) Discuss two conceptual differences between UTM and MTM (or 3TM).	 16 8 2	

Station	Easting (m)	Northing (m)
B	564,702.284	5,588,965.983
C	563,836.008	5,580,487.376

4.	Answer all of the following. a) Explain if Z-axis of the International Terrestrial Reference System (ITRS) will move due to polar motion. b) Assume that the (X, Y, Z) axes of a global geodetic coordinate system are parallel to the (X, Y, Z) astronomic coordinate system. Explain if the geodetic and astronomic meridian planes for a given point on the Earth's surface are also parallel. Your explanation must demonstrate that you understand what the two meridian planes are. c) Given the (X, Y, Z) right ascension system, determine which of the following would affect the curvilinear coordinates of a star in this system (justifying your answer for each item): i) a translation of the coordinate origin of the (X, Y, Z) system; ii) a general rotation of the (X, Y, Z) system; iii) rotation of X and Y axes about Z-axis; iv) precession and nutation of the rotation axis. d) The GPS coordinate values, which are usually presented in the (X, Y, Z) geocentric coordinate system, are inconvenient for use by surveyors. Explain 3 important reasons why.	2 3 6 3	
5.	a) 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. b) Two of the important considerations in the choice of a suitable map projection for navigation purposes, are how the projection represents bearings in relation to navigation compass bearings and how it distorts scale. With regard to these two considerations, discuss the suitability of the Mercator projection and the Polar Stereographic projection for navigational purposes in the Canadian Arctic region (North of the 68th parallel). c) 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.).	16 6 6	
		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) $L = \left(\lambda - \lambda_0\right)$ (in radians) for a given longitude λ; and λ_0 is the longitude of the central meridian.

Grid convergence (in arc sec.), $\gamma = \Delta\lambda\sin\phi\left[1 + \frac{\Delta\lambda^2\cos^2\phi}{3\left(206265\right)^2}\right]$; where $\Delta\lambda = (\lambda - \lambda_0)$ (in arc-seconds) for any given longitude λ with central longitude at λ_0.

$$Sf = \frac{R_m}{R_m + H_m}$$

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 $\mathbf{t}_0$.