CANADIAN BOARD OF EXAMINERS FOR PROFESSIONAL SURVEYORS

C-4 COORDINATE SYSTEMS & MAP PROJECTIONS

October 2011

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 8 questions on 3 pages. **Marks**

Time: 3 hours

Q. No		Value	Earned
1.	Coordinate systems, datums, and map projections are needed to represent the Earth's surface on a flat map. Clearly explain how these three components are related. Under what conditions will a coordinate system become a conventional terrestrial reference system (CTRS)?	8	
2.	Different provinces in Canada use different map projections for surveying and the compilation of engineering maps, for example, Nova Scotia uses Modified Transverse Mercator projection and Prince Edward Island uses Stereographic Double projection. Describe the map projections used in these two provinces with regard to their aspects, distortion characteristics, developable shapes, and types of standard parallel or standard meridian used. Give one important reason why different map projections are being used in the two provinces.	6	
3.	The map projection equations relating map projection coordinates (x, y) with the corresponding geographic coordinates (ϕ, λ) can be given as $x = R\lambda$ $\quad\quad$ $y = R\sin\phi$ where R is the mean radius of the spherical earth. Answer the following questions: a) Calculate the area distortion factor and indicate if this projection is equal-area. b) Determine the maximum angular distortion at any point in the map projection, and calculate the latitude where the maximum angular distortion reaches 40° on the projection.	 7 5	
4.	Explain the differences in the following coordinate systems in respect to their origin and orientation of their axes in space: (X, Y, Z) coordinate system used in GPS networks, (x, y, z) coordinate system used in engineering micro-networks, and (Easting, Northing, Orthometric Height) coordinate system used in topographic mapping.	12	
5.	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	 3 2 2 4	

6.	Answer all of the following. a) Maps that cover large areas of the globe usually have stated scale called the nominal scale. However, on such maps one simply cannot measure the distance from any point on a map to another, multiply by the nominal scale, and expect to have obtained a correct distance. Explain why. Clearly explain how you would obtain a correct distance from such maps. b) A map's distortion can be conveniently shown by the *Tissot indicatrices*, drawn at regular intervals on the graticule of the map. i. Discuss briefly the concept of Tissot indicatrix and suggest how it can be used in practice. ii. Describe the conformal and the equal-area map projections with regard to the possible sizes, shapes and orientations of Tissot indicatrices on them. c) Discuss three important advantages of computing geodetic positions on a conformal projection plane as compared to computing them on an equal-area projection.	8 5 6 6	
7.	Sketch a typical map plane (with an x-y grid system) upon which two points A and B have been mapped from an ellipsoid. The sketch must also include a projected meridian, a projected parallel, the projected geodesic from point A to B, the geodetic azimuth of projected geodesic, the grid azimuth of projected geodesic, the grid azimuth of chord, and the meridian convergence. (**Note:** Every element on your sketch must be clearly labeled with its appropriate name in order to earn the full marks.)	11	
8.	The scale factor (*k*) at any point (*x*, *y*) on a UTM projection can be determined using the following formula: $$k = k_0\left[1+\frac{(x-x_0)^2}{2R^2}\right]$$ where k_0 and x_0 are the scale factor and the false Easting coordinate at the central meridian, respectively, and R is the mean radius of the earth. 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. 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) What is the distance between the two secant lines in a zone while still maintaining the scaling accuracy of 1/10,000 in the region? c) If a single zone is used for the whole mapping region, what would the worst scaling accuracy ratio for the zone be, assuming the scale factor determined in (a) is adopted for the central meridian?	6 5 4	
	Total Marks:	100	

Some potentially useful formulae are given as follows:

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

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

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

$$\sin A'_p = \frac{f_\lambda g_\phi - f_\phi g_\lambda}{\sqrt{(f_\lambda g_\phi - f_\phi g_\lambda)^2 + (f_\phi f_\lambda + g_\phi g_\lambda)^2}}$$

$$\tan \mu_m = \frac{f_\varphi}{g_\varphi}$$

$$\tan \mu_s = \frac{g_\phi \cos\phi \cos A + g_\lambda \sin A}{f_\phi \cos\phi \cos A + f_\lambda \sin A}$$

$$\tan(180^\circ - A') = \frac{\tan \mu_m - \tan \mu_s}{1 + \tan \mu_m \tan \mu_s}$$

$$\sin\left(\frac{\omega}{2}\right) = \frac{(a-b)}{(a+b)}$$

$$x = (N+h)\cos\phi \cos\lambda$$
$$y = (N+h)\cos\phi \sin\lambda$$
$$z = \left[(1-e^2)N + h\right]\sin\phi$$