CANADIAN BOARD OF EXAMINERS FOR PROFESSIONAL SURVEYORS

SCHEDULE I / ITEM 3 **October 2009**

ADVANCED SURVEYING

Notes : This examination consists of 7 questions on a total of 5 pages.

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 for the answer. Otherwise, full marks may not be awarded even though the answer is numerically correct.

Q. No	Time: 3 hours	Marks Value	Marks Earned

1.	There is a dispute about the orientation of the side boundary of a parcel that was surveyed in 1996. The contention is that the NW corner is due North of the SW corner within ±5″. In researching the survey, you have found the fieldnotes which show that the SW corner was occupied with reference sights onto the NW corner and sights on Polaris, as follows. The zone clock times of observation are in Mountain Daylight Saving Time [MDT] on 12 May 1996, as noted.
	
	Observations at Station SW:
	Station NW Polaris MDT, 1996 05 12
	000°00′12″
	  358°53′56″ 20h 16m 21.5s
	  178°53′22″ 20h 19m 36.1s
	180°00′16″
	
	α Ursae Minoris:
	  GHA Declination
	1996 05 12, 0h00 UT 193°18′56.4″ 89°14′43.04″
	1996 05 13, 0h00 UT 194°17′57.5″ 89°14′42.73″
	1996 05 14, 0h00 UT 195°16′57.1″ 89°14′42.41″
	
	The SW corner is approximately 117°38′13.1″W and 50°48′50.2″N. Determine whether the contention is correct.
		15	

2.	Last February, a crew was to lay out a 1600 m distance from one survey marker to set a second survey marker. Even though the temperature was − 30 C, they did not apply a meteorological correction but simply used the display value of "1600.000". You are now reviewing a remeasurement between the two markers done in August and the uncorrected display, using the same instrument [± 3 mm and ± 2 ppm; group refractive index: 1.000294497; design refractive index number or design refractivity: 282.106 at 12 C and 760 mmHg or 1013.25 mb] and reflector, is "1599.910" with an ambient temperature of + 25 C. Determine the current separation of the markers in August and whether there is a significant difference, at 80 %, between the separation of the markers in August compared to last February, assuming standard pressure.	10	

3.	The transfer of elevation from the surface, through a shaft, to a tunnel or drift, can be done using special steel tapes or using a total station. Giving advantages, disadvantages, potential accuracies, and limitations, compare the two possibilities when the drift or tunnel is 300 m below the surface and there is a sump at the bottom of the shaft, farther down.	20	
4.	In many elementary plane surveying textbooks, the determination of the additive constant, z_0, is usually presented in very simple terms, with a unique determination using three points [i.e., no redundancy]. Adding a correction to an observation should not unduly increase the uncertainty in the corrected value compared to the uncorrected value. a) Explain how the unique determination of z_0 would increase the uncertainty in the corrected distance and by how much, if the distance to be corrected was $\pm \sigma_s$ and the distances in the unique determination were also $\pm \sigma_s$. b) Explain how a collinear array of 6 points would improve the uncertainty in the value of z_0. c) If the method of least squares were used in the estimation of z_0 using a collinear array of 6 points, explain how the uncertainty in the estimated overall distance would compare with the direct measurement, which had been used in the estimation, along with the other 14 one-way distances.	15	
5.	A traverse has been measured from two coordinated monuments, through 7 intermediate stations, to a second pair of coordinated monuments. Specifications require that the angular misclosure is not to exceed $n_\beta^{1/2}10''$. "Not to exceed" is to be regarded as being at 99%. The angles are to be measured in 3 sets with the averages then used in the traversing. a) By the propagation of variance, develop an expression relating the standard deviation of an average of the sets, based on the allowable misclosure, and use that expression to determine the standard deviation of an average in this case. b) By the propagation of variance, develop an expression for a limit on the discrepancy between sets that would then be used as a quality assurance measure during the gathering of the sets and use that expression to determine the value for the limit in this case.	10	
6.	The only access to a 3 m diameter drift that is 400 m below the surface is through a vertical shaft that is 4 m in diameter and is at one end of the drift. There are local grid-coordinated points on the surface. The sump is 500 m below the surface. A traverse has been run along the drift with points attached to one side of the wall, spaced every 200 m, to a total of 2000 m from the shaft in an approximately E/W direction. The activity is at a latitude of 63°N. a) Suggest a method [observables, equipment, procedures] for transferring the local grid azimuth from the surface to the course joining the last two stations of the drift traverse. b) Explain what geodetic "corrections" would have to be applied to the observations in order to result in a proper grid azimuth and suggest their magnitudes. c) Explain what would contribute to the random uncertainty of that azimuth with some suggestion of the magnitude associated with each contribution.	10 5 5	

7.	An extensometer mechanically measures the change in a distance to a precision that is much better than if the distance were to be determined in absolute terms. a) Give an example of an extensometer that could be used at several locations [i.e., between different pairs of anchor points] and of one that would remain *in situ* and explain why in both cases. b) Explain how an extensometer may be used to determine the strain between two reference points and what would be a typical value for the uncertainty in that strain if the two points were 40 m apart.	10	
	Total Marks:	100	

Percentiles of the χ^2 distribution:

	0.50	0.70	0.80	0.90	0.95	0.975	0.99	0.995
1	0.455	1.07	1.64	2.71	3.84	5.02	6.63	7.88
2	1.39	2.41	3.22	4.61	5.99	7.38	9.21	10.60
3	2.37	3.66	4.64	6.25	7.81	9.35	11.34	12.84

Some potentially useful formulae are given below.

$$\tan Z = \frac{-\sin t}{\tan\delta\cos\varphi - \sin\varphi\cos t}$$

$$\sin Z = -\frac{\sin t\cos\delta}{\cos h}$$

$$\sin Z = \frac{\sin p}{\cos\varphi}$$

$$\cos Z = \frac{\sin\delta}{\cos h\cos\varphi} - \tan h\tan\varphi$$

$$\sin\beta_1 = \frac{b_1\sin\alpha_1}{a}; \quad \sin\beta_2 = \frac{b_2\sin\alpha_2}{a}$$

$$\sigma_\beta^2 = \frac{\tan^2\beta}{b^2}\sigma_b^2 + \frac{\tan^2\beta}{a^2}\sigma_a^2 + \left(\frac{b^2}{a^2\cos^2\beta} - \tan^2\beta\right)\sigma_\alpha^2$$

$$\sigma_{y_n}^2 = \sum_{i=1}^{n-1}(x_n - x_i)^2\sigma_{\beta_i}^2$$

$$\sigma_{y_n}^2 = \sum_{i=1}^{n-1}(x_{i+1} - x_i)^2\sigma_{\alpha_i}^2$$

$$\sigma_s^2 = a^2 + b^2s^2$$

$$d\delta = 8'' \frac{pS}{T^2}\frac{dT}{dx}$$

$$T = \frac{\sum_{i=1}^{n}\left[(h_{i+1} - h_i)(T_i + T_{i+1})\right]}{2(h_n - h_1)}$$

$$\Delta h_w = \frac{w}{aE}\left(Lh - \frac{h^2}{2}\right)$$

$$n_a = 1 + \frac{0.359474(0.0002945)p}{273.15 + t}$$

$$n_a = 1 + \frac{0.359474(0.0002821)p}{273.15 + t}$$

$$\Delta N_1 = 294.5 - \frac{0.29065p}{1 + 0.00366086t}$$

$$\Delta N_1 = 282.1 - \frac{0.29065p}{1 + 0.00366086t}$$

$$\varepsilon_A = \frac{206264.8}{b}\sqrt{e_1^2 + e_2^2}$$

$$e_i^2 = \left[\frac{e}{2}\right]^2 + [2r]^2 + [0.2mm]^2$$

$$\Delta H = \frac{PH}{aE}$$

$E = 2.1 \text{x} 10^6$ kgcm^{-2}

$$T = 2\pi\sqrt{\frac{H}{g}}$$

g = 980 cms^{-2}

$$e = \frac{30hHdv^2}{P}$$

$$r_0 = r_2 - \frac{P_1(r_1 - r_2)}{P_2 - P_1}$$

$$r = \frac{\pi d^4 E}{64RP}$$

$$\theta = \frac{d \tan\phi \left(1 - \varepsilon^2 \sin^2\phi\right)^{\frac{1}{2}}}{a}$$

$$\Delta\gamma = \frac{\Delta E \tan\phi}{R}$$

6378206.4 m, 0.0822718948

6378137.0 m, 0.081819191

$$\varepsilon = \frac{\Delta\ell}{\ell}$$

$$c = \left[N_0 - N_a\right]s$$

$$c_{cal} = \frac{s_{std} - s_{obs}}{s_{std}} s_i$$

$$c_{align} = -\frac{d^2}{2s}$$

$$c_{temp} = \alpha\left(t - t_0\right)s$$

$$c_{tens} = \frac{P - P_0}{aE} s$$

$$c_{sag} = -\frac{s^3}{24}\left(\frac{mg\cos\theta}{P}\right)^2\left(1 \pm \frac{mgs\sin\theta}{P}\right)$$

$$c_{sea} = \frac{H}{R + H} s$$