CANADIAN BOARD OF EXAMINERS FOR PROFESSIONAL SURVEYORS

C-3 ADVANCED SURVEYING **October 2010**

Note: This examination consists of 5 questions on 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.	Points A, B, C, D, and E are in a practically straight line. Points A and B have known coordinates and can be considered as errorless. Point E is to be coordinated off points A and B through a traverse having points C and D as intermediate stations. Each point is approximately 200 m from its immediate neighbour. The included angle at B, C, or D is ~ 180° and the line of the five points can be considered as horizontal and parallel to the x coordinate axis.		
	a) If each of the included angles has a standard deviation of ± 3″, what is the lateral random error [i.e., σ_y] associated with the position of point E?	2	
	b) What equipment and procedures would you recommend to achieve a standard deviation of ± 3″ in an angle?	4	
	c) If azimuths, rather than included angles, were observed [± 5″] at points B, C, and D, what would be the random lateral error in the position of point E?	2	
	d) What equipment and procedures would you recommend to achieve a standard deviation of ± 5″ in an azimuth?	4	
	e) Explain what would be the dominant random error influence affecting this traverse: i. when measuring included angles; ii. when measuring azimuths.	4	
	f) Explain why observing azimuths might be preferred over observing included angles in this situation.	4	
2.	Usually, the purpose of a geodetic network [directions, zenith angles, spatial distances] is to determine the three dimensional positions of the stations involved. However, if a network includes points on a sensitive structure and is repeatedly re-observed, the data can be used to monitor the geometric deformation of the structure. And, usually then, the "absolute", rather than "relative", movement of the structure points [the "object points"] can be described with respect to the network stations [the "reference points"]. Monitoring the relative movement of points within the structure usually involves geotechnical instrumentation.		
	a) Explain the concerns that should be regarded when dealing with "absolute" monitoring over the long term [annually for decades] and what is normally done about these concerns.	10	
	b) Explain why geotechnical instrumentation is more likely to be used to monitor relative movement. Provide an example to substantiate your explanation and discuss the uncertainty in relative movement derived from geotechnical instrumentation compared to that derived from coordinates.	10	

3.	A current parcel retracement has resulted in coordinate values for the parcel corners as derived from connecting to four coordinated survey monuments [CSMs]. A traverse was run from two CSMs to the parcel corners and then on to the second pair of CSMs. An earlier survey has parcel corner coordinates resulting from connecting to CSMs that are not the same as those used in the current survey. The two sets of parcel corner coordinates are not the same. a) Explain why they would be different, having regard for both random and systematic errors. b) With a substantiated suggestion [i.e., cite a reference] of an allowable discrepancy, explain how you would determine whether the coordinate differences are statistically significant.	10 10	
4.	Often, provincial or other authorities require that measurements, s_{ij}, by an EODMI or total station be done on a calibration baseline that has known pillar coordinates, $\mathbf{x} = [x_1, x_2, \ldots, x_n]^T$ with $C_\mathbf{x}$. However, some aspects of EODMI behaviour can be investigated by using an *ad hoc* collinear array of points such as a series of tribrachs on tripods. There is an ISO standard that requires 7 points with spacing following the Heerbrugg design, as explained by Rüeger in his <u>*Introduction to EDM*</u>. The spacing is based on the unit length [$U = \lambda_{mod}/2$] of the EODMI and on the overall length of the array, which is usually at least as long as any intended use of the EODMI. Compare the use of a linear array to the use of a calibration baseline under each of the following considerations: a) Information that is known *a priori*; b) What setting out must be done in preparation for measurements by the subject EODMI; c) What is "observed"; d) What corrections are applied as "pre-processing" and why; e) What quantities are estimated and a typical observation equation with an explanation of the variables; f) What statistical testing can be done *a posteriori* [null and alternate hypotheses, statistic, test]; g) How the results are used in subsequent employment of the EODMI; h) The advantages and disadvantages of the linear array rather than the baseline.	2 2 4 4 6 4 2 6	
5.	Although testing and calibration of EODMI seem to be a dominant concern, the behaviour of the angular measurement, or theodolite, portion and optical portion of a total station and of the levelling and optical portions of a differential levelling instrument cannot be neglected. a) Explain what testing or calibration, or both, should be done to: i. theodolites; and ii. levels with an explanation of why and, subsequently, what would be done during normal use of the instruments as a consequence. Normal use of theodolites can be considered as having substantial lengths of sight [several hundreds of metres] and zenith angles ranging from 85° to 95° and, of levels, balanced lengths of backsight and foresight. b) If extreme, rather than normal, conditions were to be experienced such as in an industrial metrology situation, explain what these conditions might be, what concerns would arise, and whether the testing or calibration, or both, would then be different for: i. theodolites; and ii. levels.	3 3 2 2	
	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.

$$\sqrt{\sigma_c^2} \approx \pm 0.001h$$
$$\sqrt{\sigma_c^2} = \pm 0.0005h$$
$$\sqrt{\sigma_c^2} \leq \pm 0.0005h$$
$$\sqrt{\sigma_c^2} \leq \pm 0.0001$$

$$\sigma_{\delta_c}^2 = \frac{\sigma_{c_F}^2 + \sigma_{c_T}^2}{s_{FT}^2}$$

$$\sigma_{\beta_C}^2 = \frac{\sigma_{c_F}^2}{s_F^2} + \frac{\sigma_{c_T}^2}{s_T^2} + \left[\frac{1}{s_F^2} + \frac{1}{s_T^2} - \frac{2}{s_F s_T}\cos\beta\right]\sigma_{c_A}^2$$

$$\sigma_l = \pm 0.2div$$

$$\sigma_l = \pm 0.02div$$

$$\sigma_l \leq \pm 0.5''$$

$$\sigma_{\beta_l} = \pm\sigma_l\sqrt{\cot^2 z_i + \cot^2 z_j}$$

$$\pm\frac{30''}{M} \leq \sigma_p \leq \pm\frac{60''}{M}$$

$$b = 2a + c$$
$$a = \frac{120}{206264.8}\frac{D}{M}$$
$$2'' \leq c \leq 4''$$

$$\sigma_r \geq \pm 0.3div$$
$$\sigma_r = \pm 0.3div$$
$$\sigma_r = \pm 2.5div$$
$$\sigma_r = \pm 0.6''$$

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

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

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

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

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

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

1 atm = 1013.25 mb = 101.325 kPa = 760 torr = 760 mmHg
0 C = 273.15 K

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

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

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

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

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

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

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

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

$$\Delta H = \frac{PH}{aE}; \qquad E = 2.1\text{x}10^6 \text{ kgcm}^{-2}$$

$$T = 2\pi \sqrt{\frac{H}{g}}; \qquad g = 980 \text{ cms}^{-2}$$

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

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

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

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

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

6378206.4 m, 0.0822718948; 6378137.0 m, 0.081819191

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

$$d_x = r_{x_1} - r_{x_2}; \quad d_y = r_{y_1} - r_{y_2}$$

$$\theta_x = \frac{d_x}{s}; \quad \theta_y = \frac{d_y}{s}$$

$$c = [N_0 - N_a]s$$

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

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

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

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

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

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

$$\frac{s^2}{\sigma^2} \le \frac{1}{\nu}\chi^2_{\nu,1-\alpha} ?$$

$$\frac{1}{F_{\nu_1,\nu_2,1-\frac{\alpha}{2}}} \le \frac{s_1^2}{s_2^2} \le F_{\nu_1,\nu_2,1-\frac{\alpha}{2}} ?$$

$$\frac{a_\mu}{s_{a_\mu}} \le t_{\nu,1-\frac{\alpha}{2}} ?$$

$$C_x = \sigma_0^2\left[C_{x_S}^{-1} + \left(A^T P A\right)_U\right]^{-1}$$