ASSOCIATION OF CANADA LANDS SURVEYORS - BOARD OF EXAMINERS
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SCHEDULE I / ITEM 3 — ADVANCED SURVEYING

March 2006

Notes: This examination consists of 8 questions on a total of 4 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 by the answer.

Time: 3 hours

Q. No		Marks Value	Marks Earned
1	If the maximum allowable angular misclosure in a traverse of n_β angles is M_β [at 99%], determine the standard deviation, σ_β, of each individual angle [i.e., the average from several sets], considering that each would contribute equally to the actual misclosure m_β.	5	
2	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 parallel to the x coordinate axis. a) If each of the included angles has a standard deviation of ± 5″, what is the lateral random error [i.e., σ_y] associated with the position of point E? b) What equipment and procedures would you recommend to achieve a standard deviation of ± 5″ in an angle? 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? d) What equipment and procedures would you recommend to achieve a standard deviation of ± 5″ in an azimuth? e) Explain what would be the dominant error influence affecting this traverse i) in a random manner, ii) in a systematic manner. f) Explain why observing azimuths might be preferred over observing included angles in this situation.	20	

3	Station AT [89°26’00”W; 43°05’24”N] was occupied with observations to station RO and α Ursae Minoris [Polaris] as follows. The zone clock times of observation are in Central Standard Time [CST] on 3 December 2000, as noted. From this one set of observations, determine the azimuth from AT to RO. Observations at Station AT: Station RO Polaris CST, 2000 12 03 000°00’00” 51°09’15” 20h 30m 49s 231°07’14” 20h 31m 31s 180°00’01” α Ursae Minoris: GHA Declination 2000 12 03, 0h00 UT 33° 35’ 22.8” 89° 16’ 09.70” 2000 12 04, 0h00 UT 34° 34’ 44.4” 89° 16’ 10.04” 2000 12 05, 0h00 UT 35° 34’ 06.4” 89° 16’ 10.36”	20	
4	Canadian Special Order Levelling procedures require that “difference between backsight and foresight distances at each set-up and their total for each section not to exceed 5 m” with maximum lengths of sight of 50 m. Normally, invar double scale rods and a level [M ≥ 40X, sensitivity ≤ 10”/div] with parallel plate micrometer are used. How well would the lengths of sight have to be determined [i.e., σ_s]? How would they be measured? Interpret “not to exceed” as being at 99%.	15	
5	For visible and near infra-red radiation and neglecting the effects of water vapour pressure, the refractivity correction, ΔN, can be determined by $\Delta N_i = N_D - N_i = 281.8 - \left\lfloor \frac{0.29065\,p}{1 + 0.00366086\,t} \right\rfloor$ The meteorological correction is in the sense that $s = s' + c_{met}$, with $c_{met} = \Delta N_i s'$. a) Temperature and pressure are to be measured at each end of a 1600 m distance, the refractivity correction at each end will be calculated, and the average value of ΔN_i will be used to determine the meteorological correction, c_{met}. The instrument being used has a design $n_D = 1.0002818$ [so that $N_D = 281.8$] and the average temperature and pressure during the measurements are expected to be +30°C and 1000 mb. What would be the largest values of σ_t and σ_p that, together with equal contribution to $\sigma_{\Delta N}$, would result in a meteorological correction that would contribute uncertainty of no more than 2 ppm to the corrected distance? b) What equipment should be used and what procedures should be followed in order to ensure that the required precisions in temperature and pressure are met? c) If the accuracy [not “precision”] of a distance is to be degraded by no more than 2 ppm as a result of the meteorological correction, what concerns would you have in deciding on equipment and procedures?	10	

6	Observations on α *Ursae Minoris*, are done at $\Phi \geq 50°$ in many locations in Canada. As with any other angular measurement, averaging the determinations, by the hour angle method, from several sets improves the precision of the azimuth. The accuracy of the determination would also be improved with several sets. Assuming that an instrument comparable in precision to a Wild T2 [micrometer: 1"; 28X; plate vial: 20"/div; index vial: 30" with coincidence viewing] were being used and that the RO is at least 250 m away, explain what systematic influences would affect a single determination, or set, and how the accuracy would be improved with several sets.	10	
7	The additive constant [or system constant or zero correction], z_0, is a correction that is applied to the output of an EODMI, $s = s' + z_0$, to account for the offset between the electronic and mechanical centres of an instrument and reflector combination. The magnitude of z_0 can be as high as 35 mm to 90 mm depending on the reflector mounting and EODMI/reflector combination. a) Explain how z_0 can be uniquely determined. b) If each distance involved in the unique determination of z_0 is ± 0.002 m, what is the consequent uncertainty in z_0? c) If the same EODMI as in part b is used elsewhere, say s_i' ± 0.002 m, what is the uncertainty in the corrected distance, s_i? d) Normally corrections are expected to not significantly contribute to the uncertainty of the quantity that they are correcting. In what way could the uncertainty in z_0 be improved? e) i. What type of error contaminates an uncorrected distance, s', if z_0 is not applied? ii. How would that error affect the accuracy and the precision of a traverse involving n_d distances between two pairs of control points? iii. How would it affect the accuracy and the precision of a traverse involving n_d distances in a loop?	10	
8	A repetition instrument [theodolite or total station] can be used as a direction instrument if its lower motion remains clamped. Even so, a crusty older party chief insists that the repetition method is better than the direction method since it is faster in observing and is more precise. Consequently, he has decided to use the repetition method with the instrument even though the specifications say that the angles are to be measured as directions. Explain whether he is justified in doing so.	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 on the following page.

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

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

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

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

$$-\frac{\Delta^2}{2S}$$

$$\sigma_c = \pm 0.5mm\,h; \quad \sigma_l = \pm 0.2\,div$$

$$\sigma_{\delta_c}^2 = \frac{\sigma_{c_{AT}}^2 + \sigma_{c_{TO}}^2}{s^2}; \quad \sigma_{\delta_l}^2 = \sigma_l^2\tan^2 v$$

$$\sigma_{\delta_p}^2 = \frac{1}{2}\left[\pm\frac{45''}{M}\right]^2; \quad \sigma_{\delta_r}^2 = \frac{1}{2}[\pm 2.5''\,div]^2$$

$$\sigma_{\beta_c}^2 = \frac{\sigma_{c_{FROM}}^2}{s_{FROM}^2} + \frac{\sigma_{c_{TO}}^2}{s_{TO}^2} + \left[\frac{1}{s_{FROM}^2} + \frac{1}{s_{TO}^2} - \frac{\cos\beta}{s_{FROM}s_{TO}}\right]\sigma_{c_{AT}}^2$$

$$\sigma_{\beta_l}^2 = \sigma_l^2\left[\tan^2 v_{FROM} + \tan^2 v_{TO}\right]$$

$$\sigma_{\beta_p}^2 = \left[\pm\frac{45''}{M}\right]^2; \quad \sigma_{\beta_r}^2 = [\pm 2.5''\,div]^2$$

$$\sigma_{\beta_{rep}}^2 = \frac{2\sigma_s^2}{n^2} + \frac{2\sigma_p^2}{n}; \quad \sigma_{\beta_{dir}}^2 = \frac{2\sigma_s^2}{n} + \frac{2\sigma_p^2}{n}$$

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

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

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

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

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