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

October 2004

Notes : This examination consists of 8 questions on 3 pages, plus 1 page of formulae.

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.	The ratio of misclosure [“RoM”] in a traverse for horizontal positioning is often called the “precision” of the traverse. By addressing the sources and types of errors that contribute to the uncertainty associated with the RoM, explain whether using the word “precision” is correct in each of the following cases. a) a traverse from one pair of control monuments to a second, different pair of monuments. b) a traverse from one pair of control monuments back onto the same pair [i.e., a loop].	10	
2	In a three dimensional traverse, measured by a total station, face left and face right VCRs were recorded at a setup in order to obtain the zenith angle, z, that would then be used to reduce the slope distance, d_S, to the horizontal, d_H, and to calculate the value of V, the simple [non-geodetic] height difference from the total station to the reflector. The target design was centered on the centre of the reflector and the EODMI optics were symmetric to the telescope. There was a new set-up for each occupation by total station and by reflector [i.e., no “forced centering” using tribrachs]. Between a pair of points A and B, this would result in values of instrument and reflector/target heights of HI_A^F and HR_B^F in one direction [“forward”, from A to B] and of HI_B^R and HR_A^R in the other direction [“backward”, from B to A]. a) Explain why the values of d_S^F, z^F, V^F [in one direction] and d_S^R, z^R, V^R [in the opposite direction] cannot necessarily be compared directly as checks on the measurements. b) Suggest, with reasons, what might be more appropriate quantities to compare. c) A typical set-up involved, in one direction, z = 110° ± 5”; HI = 1.6 m ± 0.002 m, HR = 1.8 m ± 0.002 m; d_S = 200.0 m ± 0.003 m. What is the uncertainty in the height difference [ground mark to ground mark] derived from such a set-up? d) Explain and show how the uncertainty would be expected to improve for the value of the height difference between ground marks when averaged from both directions along a leg such as in part c.	10	
3	Station AT [119°38′12.6″W; 37°48′50.2″N] was occupied with observations to station RO and α Ursae Minoris [Polaris] as follows. The zone clock times of observation are in Mountain Daylight Saving Time [MDT] on 12 May 1996, as noted. From this one set of observations, determine the azimuth from AT to RO.	20	

	Observations at Station AT:
	Station RO Polaris MDT, 1996 05 12
	000°00′12″
	    314°25′28″ 20h 16m 21.5s
	    134°24′58″ 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″		

4	Designing a survey scheme [i.e., deciding on the best choice of equipment and procedures] for horizontal positioning can often involve the process of pre-analysis or simulation, with the standard deviations of potential observables [$\sigma_{\beta i}$ for angles; σ_{si} for distances], potential geometry [expressed as approximate coordinates, $\mathbf{x}^0$] and a relative positioning tolerance [limit on relative ellipses at 95% of a_{95}]. a) With reference to the appropriate equations and matrix expressions, explain how a simulation is performed. b) How would you ensure that the intended $\sigma_{\beta i}$ and σ_{si} are realized during the observations [i.e., give details of what field checks would be performed]?	14	
5	For visible and near infra-red radiation and neglecting the effects of water vapour pressure, the refractive index, n, can be determined by $$n - 1 = \frac{0.269578[n_0 - 1]}{273.15 + t} p$$ The meteorological correction is in the sense that s = s' + c_{met}, with $c_{met} = k_{met}s'$ with $k_{met} = [n_0 - n]/n$. a) Temperature and pressure are to be measured at each end of a 1700 m distance, the refractive index at each end will be calculated, and the average value of n will be used to determine the meteorological correction, c_{met}. The instrument being used has n_0 = 1.000294497 and the average temperature and pressure during the measurements are expected to be +30°C and 950 mb. What would be the largest values of σ_t and σ_p that, together with equal contribution to σ_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?	14	

6	a) Explain why a direction observed in one set using a "single second" theodolite, e.g., a Wild T2, does not have a standard deviation of ± 1". Suggest what might be a more realistic value for sights to 500 m and inclinations to +/- 30°. b) If a single direction has a standard deviation of σ_δ in one set, what is the standard deviation, σ_β, of the mean value of an angle, β, measured in n_s sets by the same theodolite under the same conditions? c) Determine the allowable discrepancy between any two of the n_s sets in part b, so that the mean, β, would have the expected standard deviation, σ_β. d) If the maximum allowable angular misclosure in a traverse of n_β angles is M_β, 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.	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 contol points? iii. How would it affect the accuracy and the precision of a traverse involving n_d distances in a loop?	12	
8	The normal levelling of a non-electronic theodolite, using the plate vial, may not be sufficient when considering the effect of the inclination of the standing axis on the HCR of a steeply inclined sight. a) Explain why in the context of a single setup. In this context also, explain whether there is any benefit in taking the average from face left and face right VCRs. b) Suggest at least one way in which the levelling of the instrument could be improved. c) Explain the technique and the calculation of at least one way in which a correction to the HCR for mis-levelment could be determined.	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 useful formulae are given on the following page.

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

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

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

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

$$C_x = \sigma_0^2\left[A^T PA\right]^{-1}$$

$$P = Q^{-1}$$

$$C_l = \sigma_0^2 Q$$

$$p_1 = \frac{\sigma_x^2 + \sigma_y^2}{2}$$

$$p_2 = \sqrt{\frac{\left(\sigma_x^2 - \sigma_y^2\right)^2}{4} + \left(\sigma_{xy}\right)^2}$$

$$a_s = \sqrt{p_1 + p_2}$$

$$b_s = \sqrt{p_1 - p_2}$$

$$2\alpha_{a_s} = \arctan\left[\frac{2\sigma_{xy}}{\sigma_y^2 - \sigma_x^2}\right]$$

$$a_{1-\alpha} = k_{1-\alpha}a_s; \quad b_{1-\alpha} = k_{1-\alpha}b_s; \quad k_{1-\alpha} = \sqrt{\chi^2_{2,1-\alpha}}$$

$$\sigma^2_{\Delta x} = \sigma^2_{x_1} + \sigma^2_{x_2} - 2\sigma_{x_1x_2}$$

$$\sigma_{\Delta x\Delta y} = \sigma_{x_1y_1} + \sigma_{x_2y_2} - \sigma_{x_1y_2} - \sigma_{x_2y_1}$$

$$\sigma^2_{\Delta y} = \sigma^2_{y_1} + \sigma^2_{y_2} - 2\sigma_{y_1y_2}$$

$$c_{HCR} = e_i\cot z = e_i\tan v = i\sin\alpha\tan v$$

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