ASSOCIATION OF CANADA LANDS SURVEYORS - BOARD OF EXAMINERS
WESTERN CANADIAN BOARD OF EXAMINERS FOR LAND SURVEYORS
ATLANTIC PROVINCES BOARD OF EXAMINERS FOR LAND SURVEYORS

SCHEDULE I / ITEM 3 — ADVANCED SURVEYING

March 2005

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	a) 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 for a traverse from one pair of control monuments to a second, different pair of monuments. b) 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	
2	The transfer of orientation, i.e., azimuth, from the surface to a level underground, e.g., to a tunnel or an adit, can be done down a single shaft using a pair of plumblines, P_1 and P_2. Two ways in which this can be done are the Weisbach or pair of adjacent triangles method and the Hause or quadrilateral method. The surface connections to P_1 and P_2 are the same but the underground connections differ between the two methods. Compare the two methods with respect to a) observables and optimal geometry; b) computational effort; and c) advantages, disadvantages, and limitations.	14	

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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 Pacific Daylight Saving Time [PDT] on 12 May 1991, as noted. From this one set of observations, determine the azimuth from AT to RO.

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Observations at Station AT:
Station RO    Polaris       PDT, 1991 05 12
000°00'12"
              314°25'28"    19h 16m 21.5s
              134°24'58"    19h 19m 36.1s
180°00'16"

α Ursae Minoris:
                     GHA               Declination
1991 05 12, 0h00 UT  193°59'34.2"      89°13'33.00"
1991 05 13, 0h00 UT  194°58'30.1"      89°13'32.67"
1991 05 14, 0h00 UT  195°57'24.0"      89°13'32.36"
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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?
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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 1600 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 +35°C and 1000 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?
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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 [lengths and inclinations of sight]? 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.	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?	12	
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 both faster in observing and 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 useful formulae are given on the following page.

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

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

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

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

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

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

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

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

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

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

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

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

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