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 2003

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 values than warranted by the answer.

Marks

Q. No	Time: 3 hours	Value	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 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. There was a new set-up for each occupation by total station and by reflector [i.e., no “forced centering” using tribrachs]. The target design was centered on the centre of the reflector and the EODMI optics were symmetric to the telescope. This would result in values of HI^F and HR^F in one direction [“forward”] and in HI^R and HR^R in the other direction [“backward”], along any one leg of the traverse. a) Explain why the values of d_S^F, z^F, V^F and d_S^R, z^R, V^R 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 ± 0.003 $_S$ = 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 when averaged from both directions along a leg such as in part c.	10	

<table>
<tr>
<td>3</td>
<td>Station AT [79°21′00″W; 43°47′30″N] was occupied with observations to station RO and α Ursae Minoris [Polaris] as follows. The local clock times of observation have already been converted to UTC on 6 August 2002, as noted. From this one set of observations, determine the azimuth from AT to RO.

Observations at Station AT:
Station RO   Polaris   UTC, 2002 08 06
000°00′00″
  46°02′21″   0h 10m 00s
  226°02′41″   0h 10m 40s
179°59′56″

α Ursae Minoris:
  GHA   Declination
2002 08 05, 0h00 UT   274°47′45.2″   89°16′08.70″
2002 08 06, 0h00 UT   275°46′23.9″   89°16′08.83″
2002 08 07, 0h00 UT   276°45′03.9″   89°16′08.98″</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>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 pre-analysis is performed.
b) How would you ensure that the intended $\sigma_{\beta i}$ and σ_{si} are realized during the observations?</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>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?</td>
<td>14</td>
<td></td>
</tr>
</table>

6	The geometric deformation of a structure [in two dimensions ("horizontal")] is to be monitored by repeated surveys of a network of strategically placed monuments. Some monuments are to serve as reference points [assumed to not be moving] and some are to serve as object points [purposely placed where deformation is expected]. They have coordinates $[(x_1, y_1, x_2, y_2, ...)^T]$ represented in the vectors, $\mathbf{x}_{ref}$ and $\mathbf{x}_{obj}$, all in an isolated arbitrary local system [i.e., defined by assuming coordinate values for some of the $\mathbf{x}_{ref}$]. Each campaign of measurements will result in the least squares estimates of $\mathbf{x}_i = [\mathbf{x}_{ref} \ \ \mathbf{x}_{obj}]^T$ and the deformation analysis will entail differencing each new j^{th} campaign with the first, i.e., $\mathbf{d}_j = \mathbf{x}_j - \mathbf{x}_1$. What caution should be exercised when the $\mathbf{d}_j$ are based on such an isolated coordinate system in two dimensions?	10	
7	The additive constant [or system constant or zero correction], z_0, is a correction that is applied to the output of an EDMI to account for the offset between the electronic and mechanical centres of an instrument and reflector combination. a) Explain how z_0 can be uniquely determined. b) If each distance involved in the unique determination of z_0 is ±0.003 m, what is the consequent uncertainty in z_0? c) 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?	12	
8	The normal levelling of a theodolite or total station, using the plate vial, may not be sufficient when considering the effect of the inclination of the standing axis on the HCR of an inclined sight. a) Explain why in the context of a single setup. 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 could be determined.	10	
	Total Marks:	100	

Percentiles of the X2 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.

$$\tan Z = \frac{-\sin t}{\tan d \cos j - \sin j \cos t}$$

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

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

$$\cos Z = \frac{\sin d}{\cos h \cos j} - \tan h \tan j$$

$$C_x = s_0^2 \left[A^T PA\right]^{-1}$$
$$P = Q^{-1}$$
$$C_l = s_0^2 Q$$

$$p_1 = \frac{s_x^2 + s_y^2}{2}$$
$$p_2 = \sqrt{\frac{\left(s_x^2 - s_y^2\right)^2}{4} + \left(s_{xy}\right)^2}$$
$$a_s = \sqrt{p_1 + p_2}$$
$$b_s = \sqrt{p_1 - p_2}$$
$$2a_{a_s} = \arctan\left[\frac{2s_{xy}}{s_y^2 - s_x^2}\right]$$

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

$$s_{\Delta x}^2 = s_{x_1}^2 + s_{x_2}^2 - 2s_{x_1 x_2}$$
$$s_{\Delta x \Delta y} = s_{x_1 y_1} + s_{x_2 y_2} - s_{x_1 y_2} - s_{x_2 y_1}$$
$$s_{\Delta y}^2 = s_{y_1}^2 + s_{y_2}^2 - 2s_{y_1 y_2}$$

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

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