CANADIAN BOARD OF EXAMINERS FOR PROFESSIONAL SURVEYORS
ATLANTIC PROVINCES BOARD OF EXAMINERS FOR LAND SURVEYORS

SCHEDULE I / ITEM 3 — ADVANCED SURVEYING

March 2007

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	The maximum allowable angular misclosure in a traverse of n_β angles is stated as M_β at 99%. a) Determine the standard deviation, σ_β, of each of the n_β angles, considering that each would contribute equally to the actual misclosure m_β. b) If the average from n_s sets of an angle has a standard deviation of $\pm\ \sigma_\beta$, determine the allowable discrepancy, δ_s, between individual sets that would be used as a quality check at the time of observation.	10	
2	Monitoring a structure over an extended period of time involves the repetition of observations that may be used to determine the geometric state at a particular epoch t_i ($\mathbf{x}_{ti}$), and then again at t_j ($\mathbf{x}_{tj}$), or to determine how the geometric state has changed over an interval, Δt_{ij} ($\boldsymbol{\Delta}\mathbf{x}_{ij}$). Explain how repeated geodetic observations might be used to describe the "tilt" of a structure. With some explanation, compare the achievable precision of a geodetic observable with a corresponding geotechnical observable [e.g., creating a "long base" tiltmeter between two floor level benchmarks, 20 m apart, by repeated levelling using a Wild N3 (42X, setting accuracy: ± 0.2″, micrometer: 0.1 mm), set up in between, and invar double scale staves].	10	
3	During a city survey, it was necessary to run a traverse line at ~ 0.4 m away from the south face of several buildings over a distance of ~ 270 m. The temperature at the building face was about 40 C and, at ~ 1 m away, was 30 C. This line is one of the four supposedly closing around the block. Explain what might affect the angular misclosure and suggest by how much and whether the misclosure would appear to be larger or smaller than it would be without the influence. What would you do about it?	10	

4	Station AT [122°16′22.2″W; 49°54′26.6″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 Time [PDT] on 31 May 1995, as noted.
	a) From this one set of observations, determine the azimuth from AT to RO.
	
	Observations at Station AT:
	Station RO Polaris PDT, 1995 05 31
	000°00′00″
	    53°10′40″ 19h 05m 20.0s
	    233°11′15″ 19h 08m 40.0s
	179°59′55″
	
	α Ursae Minoris:
	    GHA Declination
	1995 05 31, 0h00 UT 211° 29′ 36.3″ 89° 14′ 24.4″
	1995 06 01, 0h00 UT 212° 28′ 27.3″ 89° 14′ 24.2″
	1995 06 02, 0h00 UT 213° 27′ 18.7″ 89° 14′ 24.0″
	
	b) Explain what systematic influences could affect a single determination, or set, if a T2 were used and how the accuracy would be improved with several sets.
		25	

5	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%.	10	
6	For visible and near infra-red radiation and neglecting the effects of water vapour pressure, the refractivity correction, ΔN, can be determined by $\Delta N_i = N_D - N_i = 281.8 - \left[\frac{0.29065\,p}{1+0.00366086\,t} \right]$ 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 for measuring temperature and pressure?	10	

7	a) The transfer of position (x,y "horizontal") and orientation (azimuth in the x,y plane) from the surface via a single shaft to a tunnel or an adit can be done using either a pair of plumblines or optical methods. Briefly explain the advantages and limitations of each method for i) position transfer and for ii) orientation transfer. b) The transfer of elevation from surface benchmarks via a single shaft to underground stations can be done using a steel tape or an EODMI (total station). i) Briefly explain the advantages and limitations of each method. ii) With a brief explanation, compare the corrections applied to the tape in elevation transfer to the corrections normally applied when a tape is used to determine horizontal distances.	15	
8	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, independent of any other information. b) If each distance involved in the unique determination of z_0 is ± 0.002 m, what is the consequent random 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 random uncertainty in the corrected distance, s_i [with the value of z_0 is applied]? d) Normally corrections are expected to not significantly contribute to the uncertainty of the quantity that they are correcting. In what way could the random uncertainty in z_0 be improved? e) What type of error contaminates an uncorrected distance, s', if z_0 is not applied? Explain how its effect might be misinterpreted if all of the distances, in a traverse between control points, were about the same length.	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 follow.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$\sigma_{pr} = \pm\frac{30''}{M}d; \quad \sigma_c = \pm\sigma_l d$$