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SCHEDULE I / ITEM 3
ADVANCED SURVEYING

March 2002

Note: This examination consists of 8 questions on 3 pages.

Time: 3 hours

Q. No		Marks Value	Marks Earned
1	The ratio of misclosure [“RoM”] in a traverse is often called the “precision” of the traverse. By addressing what contributes to the uncertainty associated with the RoM, explain whether using the word “precision” is correct.	5	
2	The distance between points A and B was measured in three sections, with intermediate points P1 and P2 under the assumption that both P1 and P2 were in line with A and B. Subsequent alignment by theodolite in the direction from A to B revealed that P1 was 1.500 m to the left of the line AB and that P2 was 2.000 m to the right of the line AB. The measured distances were as follows. A to P1: 300.050 m P1 to P2: 299.950 m P2 to B: 300.147 m a) What are the corrections, to be added to each of the observed distances, to account for the mis-alignment of the intermediate points [P1 and P2]? b) If the uncertainty in any of the three alignment corrections is to be no more than ±0.001 m, how well would the two lateral offsets have to be determined [i.e., σ_{offset}] and how might measuring the offsets be done to that precision? c) If the alignment had been done by observing angles at A from B to each of P1 and P2, how well would the angles have to be observed [i.e., σ_{β}] to result in alignment corrections that are ±0.001 m [i.e., compatible with those in part b]?	10	

3	Station AT [122°16’22.2” W; 37°54”26.6” 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 1 June 1995, as noted. From this one set of observations, determine the azimuth from AT to RO.
	
	Observations at Station AT:
	Station RO Polaris UTC, 1995 06 01
	000°00’00”
	    53°10”40” 2h 05m 20.0s
	    233°11’15” 2h 08m 40.0s
	179°59’55”
	
	α Ursae Minoris:
	    GHA Declination
	1995 06 01, 0h00 UT 212°28’14.8” 89°14’24.30”
	1995 06 02, 0h00 UT 213°27’06.5” 89°14’24.10”
		20	

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, 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?	20	
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 1600 m distance, the refractive index at each end will be calculated, and the average 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 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?	10	
6	The geometric deformation of a structure [in one dimension ("vertical") or 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 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., $\mathbf{dx}_j = \mathbf{x}_j - \mathbf{x}_1$. What caution should be exercised when the $\mathbf{dx}_j$ are based on such an isolated coordinate system in one dimension? ... 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?	15	
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) Suggest at least one way in which a correction to the HCR could be determined	10	
	Total Marks:	100	

Some useful formulae follow.

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

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

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

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

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

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

$$C_l = s_0^2 Q$$

$$p_1 = \frac{s_x^2 + s_y^2}{2}$$

$$p_2 = \sqrt{\frac{\left(s_x^2 - s_y^2\right)^2}{4} + \left(s_{xy}\right)^2}$$

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

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

$$2a_{a_s} = \arctan\left[\frac{2s_{xy}}{s_y^2 - s_x^2}\right]$$

$$s_{\Delta x}^2 = s_{x_1}^2 + s_{x_2}^2 - 2s_{x_1x_2}$$

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

$$s_{\Delta y}^2 = s_{y_1}^2 + s_{y_2}^2 - 2s_{y_1y_2}$$

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