**CANADIAN BOARD OF EXAMINERS FOR PROFESSIONAL SURVEYORS**

**SCHEDULE I / ITEM 3** **March 2010**
**ADVANCED SURVEYING**

**Notes : This examination consists of 6 questions on a total of 5 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 for the answer. Otherwise, full marks may not be awarded even though the answer is numerically correct.**

| Q. No | Time: 3 hours | Marks Value | Earned |
|---|---|---|---|
| 1. | There is a dispute about the orientation of the southerly boundary of a parcel that was surveyed in 1995. The contention is that the SW corner is due West of the SE corner within ±5″. In researching the survey, you have found the field notes which show that the SE corner was occupied with reference sights onto the SW corner and sights on Polaris, as follows. The zone clock times of observation are in Pacific Daylight Saving Time (PDT) on 31 May 1995, as noted.<br><br>Observations at Station SE:<br>Station SW / Polaris / PDT, 1995 05 31<br>000°00′00″<br>53°10′40″ 19h 05m 20.0s<br>233°11′15″ 19h 08m 40.0s<br>179°59′55″<br><br>α Ursae Minoris:<br>GHA / Declination<br>1995 05 31, 0h00 UT 211° 29′ 36.3″ 89° 14′ 24.4″<br>1995 06 01, 0h00 UT 212° 28′ 27.3″ 89° 14′ 24.2″<br>1995 06 02, 0h00 UT 213° 27′ 18.7″ 89° 14′ 24.0″<br><br>The SE corner is approximately 122°16′22.2″W and 49°54′26.6″N.<br>a) With substantiation, determine whether the contention is correct.<br>b) Explain what systematic influences could affect a single determination, or set, if a T2 or similar theodolite (with a plate vial having a sensitivity of 20"/div) were used in this situation and how the accuracy would be improved with several sets. | 15<br>5 | |
| 2. | The transfer of elevation from a surface benchmark, through a shaft, to an elevation point on the wall of a drift or tunnel, can be done by using special steel tapes or by using a certain type of total station and accessories. Giving advantages, disadvantages, potential accuracies, and limitations, describe (by listing the sequence of observables) and compare the two possible techniques when the drift or tunnel is 300 m below the surface and;<br>a) there is a sump at the bottom of the shaft, farther down.<br>b) the shaft terminates at the floor of the drift or tunnel. | 10<br>10 | |

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| 3. | In many elementary plane surveying textbooks, the determination of the additive constant, $z_0$, is usually presented in very simple terms, with a unique determination using three points (i.e., no redundancy). Adding a correction to an observation should not unduly increase the uncertainty in the corrected value compared to the uncorrected value.<br>a) Explain how a collinear array of 6 points, with 15 possible one-way distances observed, would improve the uncertainty in the value of $z_0$ compared to the uncertainty of the unique determination.<br>b) If the method of least squares were used in the estimation of $z_0$ using the 15 distances in a collinear array of 6 points, explain how the uncertainty in the estimated overall distance, "$x_6$", would compare with the direct measurement, "$s_{1to6}$" which had been used as an observation in the estimation. | 5<br><br>5 | |
| 4. | A traverse has been measured from two coordinated monuments, through 7 intermediate stations, to a second pair of coordinated monuments. Specifications require that the angular misclosure is not to exceed $n_\beta^{1/2}10''$. "Not to exceed" is to be regarded as being at 99%. The included angles are to be measured in 3 sets. Their average values are to be converted to deflection angles which are then to be used in the traversing calculations, such as misclosure.<br>a) By the propagation of variance, develop an expression for the standard deviation of an average of the sets in terms of the allowable misclosure, and use that expression to determine the value of the standard deviation of an angle average in this case.<br>b) By the propagation of variance, develop an expression for a limit on the discrepancy between sets that would then be used as a quality assurance measure during the gathering of the sets and use that expression to determine the value for the limit in this case. | 10<br><br>5 | |
| 5. | An extensometer mechanically measures the change in a distance to a precision that is much better than if the distance were to be determined in absolute terms.<br>a) With a suggestion of uncertainty for each, give an example of an extensometer that could be used at several locations (i.e., between different pairs of anchor points with varying separations) and of one that would remain *in situ* and explain why in both cases.<br>b) Explain how an extensometer may be used to determine the strain between two reference points and what would be a typical value for the uncertainty in that strain if the two points were 40 m apart.<br><br>Plumb lines can be used to determine the relative horizontal displacement between two points at different levels in a structure.<br>c) Explain how this can be done and calculated and how that displacement can be converted into inclination with a suggestion on the uncertainty that could be expected for the inclination if the observing tables were 20 m apart. | 5<br><br>5<br><br>10 | |

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| 6. | A flat hanging traverse is to be measured with uniform sight lengths of 100 m ±2 mm. There are two "fixed" stations, "A" and "B", plus seven traverse stations, "P1" to "P7" so that "B" and "P1" to "P6" would be occupied while "A" and "P7" would be sighted. One approach is to measure the included horizontal angles (values near 180°) with $\sigma_\beta$ = ±5". An alternative method is to occupy certain stations and to observe the azimuth to the next station using a gyro attachment so that $\sigma_A$ = ±15". | | |
| | a) If only included angles were observed, explain the dominant influence on the random uncertainty at the end point of the traverse, "P7", and suggest a value and orientation of the uncertainty. | 5 | |
| | b) If azimuths rather than included angles were observed, explain the dominant influence on the random uncertainty at the end point of the traverse, "P7", and suggest a value and orientation of the uncertainty. | 5 | |
| | c) Consider the traverse, as mentioned above, to be running along, 0.4 m in front of the south face of buildings, across several city blocks. The observations were done during late morning and early afternoon on a clear day, with an ambient temperature of −20 C at 2 m away from the buildings with a typical brick temperature of +3 C. Explain the dominant influence on the uncertainty at the end point of the traverse, "P7", and suggest a value and direction of the uncertainty as it affects the traverse of:<br>i) included angles only;<br>ii) azimuths only. | 5 | |
| | **Total Marks:** | 100 | |

Percentiles of the $\chi^2$ 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 are given below.

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

$$\sin Z = -\frac{\sin t\cos\delta}{\cos h}; \qquad \sin Z = \frac{\sin p}{\cos\varphi}$$

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

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

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

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

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

$$\sigma_{s}^{2} = a^{2} + b^{2}s^{2}$$

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

1 atm = 1013.25 mb = 101.325 kPa = 760 torr = 760 mmHg
0 C = 273.15 K

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

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

$$n_a = 1 + \frac{0.359474(0.0002945)p}{273.15 + t}$$

$$n_a = 1 + \frac{0.359474(0.0002821)p}{273.15 + t}$$

$$\Delta N_1 = 294.5 - \frac{0.29065p}{1 + 0.00366086t}$$

$$\Delta N_1 = 282.1 - \frac{0.29065p}{1 + 0.00366086t}$$

$$\varepsilon_A = \frac{206264.8}{b}\sqrt{e_1^{2} + e_2^{2}}$$

$$e_i^{2} = \left[\frac{e}{2}\right]^{2} + [2r]^{2} + [0.2mm]^{2}$$

$$\Delta H = \frac{PH}{aE};$$ $E = 2.1\text{x}10^{6}$ kgcm$^{-2}$

$$T = 2\pi\sqrt{\frac{H}{g}};\qquad \text{g} = 980\ \text{cms}^{-2}$$

$$e = \frac{30hHdv^2}{P}$$

$$r_0 = r_2 - \frac{P_1(r_1 - r_2)}{P_2 - P_1}$$

$$r = \frac{\pi d^4 E}{64RP}$$

$$\theta = \frac{d\tan\phi\left(1 - \varepsilon^2\sin^2\phi\right)^{\frac{1}{2}}}{a}$$

$$\Delta\gamma = \frac{\Delta E\tan\phi}{R}$$

6378206.4 m, 0.0822718948; 6378137.0 m, 0.081819191

$$\varepsilon = \frac{\Delta\ell}{\ell}$$

$$d_x = r_{x_1} - r_{x_2};\quad d_y = r_{y_1} - r_{y_2}$$

$$\theta_x = \frac{d_x}{s};\quad \theta_y = \frac{d_y}{s}$$

$$c = [N_0 - N_a]s$$

$$c_{cal} = \frac{s_{std} - s_{obs}}{s_{std}}s_i$$

$$c_{align} = -\frac{d^2}{2s}$$

$$c_{temp} = \alpha(t - t_0)s$$

$$c_{tens} = \frac{P - P_0}{aE}s$$

$$c_{sag} = -\frac{s^3}{24}\left(\frac{mg\cos\theta}{P}\right)^2\left(1 \pm \frac{mgs\sin\theta}{P}\right)$$

$$c_{sea} = \frac{H}{R + H}s$$