CANADIAN BOARD OF EXAMINERS FOR PROFESSIONAL SURVEYORS

C-3 ADVANCED SURVEYING **March 2018**

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.

Note: This examination consists of 7 questions on 4 pages. **Marks**

Q. No	Time: 3 hours	Value	Earned
1.	A closed-loop horizontal traverse of 4 points is to be run in a fairly flat and homogeneous terrain using Leica 802 total station with specified standard deviation of 2″ according to ISO 17123-3 Standard. Assume each traverse leg is approximately 100 m long; the included angle at each traverse point is approximately 90°; the targets and total station are to be centered on tripods using tribrachs with optical plummets; heights of targets and instrument are to be set at 1.6 m and the included angle at each traverse point is to be measured in one set. With consideration for leveling, centering, pointing and reading errors at each setup point, determine if the traverse will satisfy the allowable angular misclosure of 15″ at 95% confidence level.	15	
2.	Answer the following: a) Briefly describe 3 theodolite errors whose effects on a horizontal circle reading will not change when the telescope direction is changed horizontally with the zenith angle reading locked, and explain how these effects can be minimized. b) Clearly explain how a theodolite can be checked in the field for plate bubble error. c) Explain one method of checking (in the field) if a theodolite has a standing axis error. How will you minimize the effect of this error on horizontal direction measurements? d) Explain the procedure for calibrating a total station for the effects of tilting and collimation errors, providing appropriate supporting formulae and a discussion on how the calibrating parameters are determined internally by the total station.	4 2 3 5	
3.	A survey contract requires determining local benchmark elevations following First Order procedure with the discrepancy between independent forward and backward levellings not exceeding ±4 mm $\sqrt{L}$ at 99% confidence level (with L in kilometres). A height difference is the average of the forward and backward levellings. Answer the following: a) Derive an expression, based on the discrepancy and as a function of L, for the standard deviation of a height difference. b) Using modern total stations [angular accuracy of ± 1″ and a distance accuracy of ± 1 mm ± 1 ppm according to ISO Standards] has the potential for competing with traditional differential levelling. Assuming the total station is used in a trigonometric levelling procedure with imposed sight length (60 m) and balanced sight length (within 10 m) limitations of First Order levelling procedure, determine numerically (stating any assumptions made) whether the levelling result will satisfy the First Order specification. [Let the average slope of the terrain (covered with the same material) be +1.5°] c) Discuss five important advantages of trigonometric levelling over the traditional precise differential levelling.	5 15 5	

4.	Answer the following in regard to correlation survey in an underground mine: a) If the entrance into the mine is through an adit, suggest an appropriate type of correlation survey and explain (with clear reasons) 3 main sources of error in the survey. b) Two mechanical methods of mine correlation surveys are the Weisbach and Weiss quadrilateral methods. Answer the following: i) Explain why the effects of centering errors are critical in Weiss quadrilateral methods of mine correlation surveys using one total station instrument. Clearly explain how you will minimize these effects. ii) Explain two important limitations of Weisbach triangulation method.	4 4 2	
5.	The two commonly used methods of precise azimuth determination are based on the use of Global Navigation Satellite System (GNSS) and gyrotheodolite/gyro station equipment (e.g. follow-up method). Answer the following: a) GNSS validation procedure and the gyro station calibration for the alignment constant are the important field calibration processes commonly required prior to field observation. Discuss briefly these calibration processes (providing simple explanation of the procedure, the purpose and how often it should be done in each method). b) Discuss the sources of errors (systematic and random) in the azimuth determination in both methods and how they are minimized (providing 2 sources of errors for each method). c) What steps and corrections are required in each method to transform the determined azimuths to grid azimuths (specifying the type of azimuth determined in each method)?	6 4 4	
6.	Answer the following in regard to deformation monitoring and analysis: a) What is the *observation differencing* approach? Explain the conditions under which this approach may be used and discuss two disadvantages of the approach. b) Clearly explain the main problem of deformation analysis based on isolated (local) coordinate system. c) Discuss the important limitations in using terrestrial laser scanners in deformation monitoring surveys.	6 2 2	
7.	Two survey crews A and B measured the length of a horizontal baseline using the same EODMI instrument (with precision ± 3 mm ± 2 ppm and the reference refractivity as 281.949). Crew A measured the whole baseline and obtained the overall length of the baseline (corrected wrongly for meteorological condition using refractivity of 300.000 instead of the correct value of 305.520) as 1799.921 m. Crew B measured the baseline in two equal sections (with each section measured independently) and obtained the meteorologically corrected overall length of the baseline as 1799.931 m. Answer the following, assuming each of the crews was able to center their instrument to an accuracy of 0.8 mm and their target to 0.8 mm. a) Determine if there is any significant difference (at 99% confidence level) between the two lengths obtained by crews A and B. b) With consideration for both random and systematic errors, explain which of the baseline lengths should be adopted [length by crew A or by crew B] and why.	10 2	
		100	

Some potentially useful formulae are given as follows:

$$v = \frac{Z_I + Z_{II} - 360}{2} \qquad \bar{z} = \frac{Z_I + (360 - Z_{II})}{2}$$

$$\frac{c}{\sin(z)} = \frac{Hz_I - (Hz_{II} - 180)}{2} \qquad \frac{t}{\tan(z)} + \frac{c}{\sin(z)} = \frac{Hz_I - (Hz_{II} - 180)}{2}$$

$$Corrected\ direction = Measured\ direction - \frac{(NR - NL) \times v''}{2\tan z}$$

$$i_v = z - z' \text{ or } \quad i_v = i\cos\alpha\,; \qquad i_T = Hz - Hz' \text{ or } \quad i_T = \frac{i\sin\alpha}{\tan z}$$

Deformation: $1_2 - 1_1 + V = Ad$; $\quad d = \hat{x}_2 - \hat{x}_1$

$$F_c = \frac{\hat{d}^T Q_{\hat{d}}^{-1} \hat{d}}{\hat{\sigma}_0^2 u_d} < F(\alpha_0, u_d, df_p);$$

$$F_c = \frac{\hat{d}^T Q_{\hat{d}}^{-1} \hat{d}}{\hat{\sigma}_0^2 u_d} < \frac{\chi^2_{\alpha_0, df = u_d}}{u_d}$$

EDM:

$$n_a = 1 + \frac{(n_g - 1)273.16p}{(273.16 + t)1013.25} \quad \text{(for } p \text{ in mb and } t \text{ in °C)}$$

$$N = (n-1) \times 10^6 \qquad \delta' = (N_{REF} - N_a)d' \times 10^{-6}$$

Standard pressure: 760 mmHg or 1013.25 mb; 0°C or 273.15 K

$$\hat{C} = \frac{M - (m_1 + m_2 + m_3 + m_4 + \ldots + m_n)}{n - 1}$$

Levelling: $\pm 3mm\sqrt{L}$ $\quad \pm 4mm\sqrt{L}$ $\quad \pm 8mm\sqrt{L}$ $\quad \pm 24mm\sqrt{L}$ $\quad \pm 120mm\sqrt{L}$

Statistics:

$$\Delta = \sigma_\Delta \sqrt{\chi^2_{df,\alpha}} \qquad \Delta \le z_{\alpha/2}\sigma_\Delta \qquad \Delta \le t_{df,\alpha/2}\sigma_\Delta$$

$$\hat{\sigma} \le \sqrt{\frac{\chi^2_{\alpha,df}(\sigma)}{df}}$$

7. $\sigma_{dp} = \frac{\sigma_p}{\sqrt{2n}}$ $\qquad \sigma_{dp} = \frac{60}{M}$ $\qquad \sigma_{\theta p} = \frac{\sigma_P}{\sqrt{n}}$

$$\sigma_{dr} = \frac{\sigma_r}{\sqrt{2n}} \qquad \sigma_{dr} = 2.5 \text{ div} \qquad \sigma_{\theta r} = \frac{\sigma_r}{\sqrt{n}}$$

$$\sigma_L = \sigma_v \cot z, \qquad \sigma_v = 0.2v'' \qquad \sigma_r = 2.5d''$$

$$\sigma_{\theta L} = \sigma_v \sqrt{\cot^2(Z_b) + \cot^2(Z_f)}$$

$$\sigma_i = \frac{(206265")\sigma_{c3}}{S_1} \qquad \sigma_t = \frac{(206265")\sigma_{c1}}{S_1} \qquad \sigma_{dc} = \frac{206265}{S}\sqrt{\sigma_{c3}^2 + \sigma_1^2}$$

$\sigma_c = \pm 0.5 mm/\text{m} \times \text{HI}\,(\text{m})$ $\qquad \sigma_c = \pm 0.1$ mm $\qquad \sigma_c = \pm 0.1$ mm/m × HI (m)

$$\sigma_{\theta i} = (206265")\sigma_{c3}\sqrt{\left[\frac{S_1^2 + S_2^2 - 2S_1S_2\cos\theta}{S_1^2S_2^2}\right]}$$

$$\sigma_{\theta i+t} = (206265")\sqrt{\frac{\sigma_{c1}^2}{S_1^2} + \frac{\sigma_{c2}^2}{S_2^2} + \frac{\sigma_{c3}^2}{S_1^2S_2^2}\left[S_1^2 + S_2^2 - 2S_1S_2\cos\theta\right]}$$

$$\sigma_P = \frac{45}{206265 \times M}S; \quad \sigma_L = \left(\frac{\sigma_v}{206265}\right)S; \quad \sigma_r = \frac{\lambda}{2}\left(\frac{v_r}{206265}\right)^2$$

Table 1: Normal Distribution table (upper tail area):

α	0.001	0.002	0.003	0.004	0.005	0.01	0.025	0.05	0.10
z_α	3.09	2.88	2.75	2.65	2.58	2.33	1.96	1.64	1.28

Table 2: Chi-Square Distribution table (lower tail area)

α	0.025	0.05	0.10	0.90	0.95	0.975	0.99	0.995
Degrees of freedom								
1	0.001	0.004	0.016	2.705	3.841	5.024	6.635	7.879
2	0.051	0.103	0.211	4.605	5.991	7.378	9.210	10.597
3	0.216	0.352	0.584	6.251	7.815	9.348	11.345	12.838
11	3.816	4.575	5.578	17.275	19.675	21.920	24.725	26.757
12	4.404	5.226	6.304	18.549	21.026	23.337	26.217	28.300
13	5.009	5.892	7.041	19.811	22.362	24.736	27.688	29.819
14	5.629	6.571	7.790	21.064	23.685	26.119	29.141	31.319
15	6.262	7.261	8.547	22.307	24.996	27.488	30.578	32.801

Table 3: Table for Student-t distribution (α is upper tail area)

	t_α			
Degree of freedom	$t_{0.10}$	$t_{0.05}$	$t_{0.025}$	$t_{0.01}$
1	3.08	6.31	12.7	31.8
2	1.89	2.92	4.30	6.96
3	1.64	2.35	3.18	4.54
4	1.53	2.13	2.78	3.75
5	1.48	2.01	2.57	3.36
6	1.49	1.94	2.45	3.14
11	1.363	1.796	2.201	2.718
12	1.356	1.782	2.179	2.681
13	1.350	1.771	2.160	2.650
14	1.345	1.761	2.145	2.624
15	1.341	1.753	2.131	2.602