CANADIAN BOARD OF EXAMINERS FOR PROFESSIONAL SURVEYORS

C-3 ADVANCED SURVEYING **March 2019**

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.	The standard deviation specification for Leica TC705 total station horizontal (Hz) and vertical (V) angle measurements is 5″ (based on ISO17123-3 standard) and the compensator setting accuracy is 1.5″. Answer the following with regard to this total station (clearly showing all of the necessary formulas, substitution of values into them, and steps of your calculations for full marks). a) Determine the standard deviation of a horizontal angle derived from two direction measurements using only one face (Face I or Face II) of the telescope. b) Determine the number of times an angle in Question (a) must be measured in order to achieve a mean horizontal angular standard deviation of 5″. c) Normally, the realistic standard deviation of an angle measurement with the total station will be higher than the 5″ specified. Explain why (suggesting what the other sources of error would be, including steps and formulas for estimating their effects).	3 3 6	
2.	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). 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 how these calibration processes are done (providing necessary details on the procedure, the purpose and how often it should be done, for each method).	8	
3.	a) What does the term "Correlation" mean with regard to mining surveying? Explain two important reasons why it is important. b) Briefly describe the possible observables you would measure in a resection process (in one setup) while extending controls in the underground mining surveys using a total station. Explain two important advantages for the resection process. c) If the entrance into a mine is through an adit, suggest an appropriate type of correlation survey and explain (with clear reasons) three main sources of error in such a survey.	4 4 4	
4.	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.	14	

5.

In order to provide control for a construction project, some leveling readings were taken over a section based on a three-wire leveling procedure with the leveling run made in both directions. The Canadian second order specifications were followed with two Canadian second order benchmarks nearby used, and the C-factor of the instrument determined as +0.02 mm/m. The following were determined from the leveling field notes:

	Forward Run (m)	**Backward Run (m)**
Sum of BS rod readings	7.1013	12.0164
Sum of FS rod readings	11.5465	7.5753
Sum of BS distances	232.0	234.1
Sum of FS distances	236.8	239.1

a) Calculate the elevation difference for each run (corrected for the effect of collimation error) and the mean elevation difference (in m to four decimal places) for the section. 5

b) Determine if the leveling run satisfies the Canadian second order specification. 3

c) Discuss three important skills needed in three-wire leveling procedure that are not needed in electronic leveling with any modern digital level equipment (justifying each answer). 6

d) Discuss four important aspects of the Canadian first order vertical control specifications that must be satisfied (including the types of errors minimized) at each instrument setup in three-wire levelling procedure. 8

e) Explain why surveyors prefer orthometric height system to leveled height (uncorrected differential leveling height) system. 3

6.

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. Determine if there is any significant difference (at 99% confidence level) between the two lengths obtained by crews A and B. 10

7.

Answer the following with regard to deformation monitoring and analysis.

a) Computed displacement vector and its covariance matrix determined from coordinate-difference approach of deformation analysis should not be taken directly as representing deformation because of possible datum differences between epochs. Explain with suitable examples three different cases in which a datum for deformation monitoring may change from one epoch to another. 6

b) In two-epoch method of deformation analysis, what statistical test(s) must be performed on each epoch measurements and in the deformation analysis (naming the statistics and providing their purposes)? 5

c) Surveyors usually claim that their geodetic level can be used as a geotechnical instrument such as a tiltmeter. Explain how, including the observables and necessary formulas in each case and two specific situations in which the use of one instrument is preferred to the other. 8

100

Some potentially useful formulae are given as follows:

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

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

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

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

Deformation: $\ell_2 - \ell_1 + V = Ad$; $\qquad d = \hat{x}_2 - \hat{x}_1$

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

$\alpha = \frac{\delta \Delta h}{s}$ where $\delta\Delta h = \Delta h_{12t2} - \Delta h_{12\,t1}$.

$\sigma_\alpha = \frac{\sigma_{\delta\Delta h}}{s}$ where $\sigma_{\delta\Delta h} = \sqrt{\sigma^2_{\Delta h1} + \sigma^2_{\Delta h2}}$

EDM:

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

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

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:

$$|\Delta| = \sigma_\Delta \sqrt{\chi^2_{df,\alpha}} \qquad |\Delta| \le z_{\alpha/2}\sigma_\Delta \qquad |\Delta| \le t_{df,\alpha/2}\sigma_\Delta \qquad \hat{\sigma} \le \sqrt{\frac{\chi^2_{\alpha,df}(\sigma)}{df}}$$

$$\sigma_{dp} = \frac{\sigma_p}{\sqrt{2n}} \qquad \sigma_{dp} = \frac{60}{M} \qquad \sigma_{\theta P} = \frac{\sigma_P}{\sqrt{n}} \qquad \sigma_{dr} = \frac{\sigma_r}{\sqrt{2n}} \qquad \sigma_{dr} = 2.5 \text{ div} \qquad \sigma_{\theta r} = \frac{\sigma_r}{\sqrt{n}}$$

$$\sigma_L = \sigma_v \cot z \, , \qquad \sigma_v = 0.2v'' \qquad \sigma_r = 2.5d'' \qquad \sigma_{\theta L} = \sigma_v \sqrt{\cot^2(Z_b) + \cot^2(Z_f)}$$

$$\sigma_i = \frac{(206265'')\sigma_{c3}}{S_1} \qquad \sigma_t = \frac{(206265'')\sigma_{c1}}{S_1} \qquad \sigma_{dc} = \frac{206265}{S}\sqrt{\sigma^2_{c3} + \sigma^2_1}$$

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

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

$$\sigma_{\theta i+t} = (206265'')\sqrt{\frac{\sigma^2_{c1}}{S_1^2} + \frac{\sigma^2_{c2}}{S_2^2} + \frac{\sigma^2_{c3}}{S_1^2 S_2^2}\left[S_1^2 + S_2^2 - 2S_1S_2\cos\theta\right]}$$

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

$$\sigma_d = \frac{S}{2R} \sigma_{k_h} \qquad \sigma_{ref} = \frac{S}{2R} \sigma_{k_V}$$

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