CANADIAN BOARD OF EXAMINERS FOR PROFESSIONAL SURVEYORS

C-3 ADVANCED SURVEYING — March 2016

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 8 questions on 4 pages. **Marks**

Time: 3 hours

Q. No		Value	Earned
1.	a) According to Donahue and others in their *Guidelines for RTK/RTN GNSS Surveying in Canada*, "working with a public or private Real-Time Network (RTN) can be a very precise and efficient way to perform cadastral and engineering surveys." Answer the following:		
	i. What is RTN? How is it different from RTK? Discuss the issues (including how to solve them) that the surveyors must address a priori in preparation for RTN surveys.	8	
	ii. Provide a checklist of your considerations in the general planning of a RTN survey.	6	
	b) As part of GNSS job specifications for a GNSS survey project, a fixed baseline of approximately 16,697 m in length (between control points A and B) was observed using static surveying procedures with specified accuracy of 5 mm + 1 ppm. The differences between the observed and fixed baseline components are 0.0074 m, 0.0013 m, 0.0050 m respectively for ΔX, ΔY, ΔZ components. If the setup error of 0.0015 m is assumed for each receiver, determine if the surveying procedures are acceptable at 95% confidence level.	4	
	c) A new point is tied to the geodetic control point A in (b) using the same static surveying procedures. If the new point is 5 km away from the control point A which has a published network accuracy of 0.030 m, determine the local accuracy and the network accuracy for the new point.	3	
2.	Deformation measurements can be adjusted in two ways: by coordinate differencing (or two-epoch adjustment) and observation differencing approaches. The displacement field (*d*) resulting from the coordinate differencing approach can be given as $d = \hat{x}_2 - \hat{x}_1$ where $\hat{x}_1$ and $\hat{x}_2$ are the vectors of least squares adjusted coordinates of the monitoring network in epochs 1 and 2, respectively; and the displacement field based on the observation differencing approach is determined directly from $\ell_2 - \ell_1 + V = Ad$ where ℓ_1 and ℓ_2 are the vectors of observations in epochs 1 and 2, respectively; and *V* is a vector of residuals. Answer the following:		
	a) Explain three conditions under which *d* can be determined in the coordinate differencing approach; and discuss two disadvantages of this approach.	5	
	b) Explain three conditions under which the observation differencing approach may be followed and discuss two disadvantages of the approach.	5	
	c) If the monitoring were to be continued over a long period of time, such as decades, explain two concerns that would arise in each of the two approaches and how best to deal with those concerns.	4	
	d) Explain three specific cases (with clear examples) where geotechnical instrumentation is more likely to be used to monitor relative movement than a geodetic survey approach.	3	

3.	a. A leveling instrument that has not been used for over 15 years is to be used for a survey project. The manufacturer claims, following DIN 18723 [or ISO 17123-2], that the equipment has a standard deviation of ±0.2 mm over 1-km double-run leveling. Since there is no record of any testing or calibration of this particular instrument, explain six important quality assurance/quality control measures (with explanations on why the measures) and the field procedure (including the configuration of the test line, number and types of measurements made in the field) that you would recommend following in order to determine whether the level is capable of behaving as the manufacturer claimed.	10	
	b. Explain the quantities that will be determined from the adjustment of the measurements, and the statistical tests (hypotheses, test statistics, etc.) that will be performed on some of the quantities in order to determine whether the level is capable of behaving as the manufacturer claimed.	5	
4.	In the process of calibrating a total station for the effects of tilting and collimation errors, the following circle readings for targets A and B were recorded with the total station.		
	a. Calculate the vertical and horizontal collimation errors and the tilting axis error for this total station.	4	
	b. List and briefly describe (including their causes) two total station errors that cannot be eliminated based only on observing procedures, such as using the mean of the face I and face II angles.	3	
	c. Clearly explain how a total station can be checked in the field for one of the errors listed in question (b) (i.e. to find out if the total station has the error).	2	
5.	a. Some of the specifications for geodetic levelling are such that First Order Levelling should use an optical mechanical instrument [sensitivity of 10"/2 mm, magnification of at least 32×] with a parallel plate micrometer along with double scaled invar rods [usually with range of 10 mm graduations]. Lengths of sight are not to exceed 60 m and are to be balanced within 10 m. Also, the discrepancy between independent forward and backward levellings is not to exceed [at 99% confidence level] ±4mm $\sqrt{k}$ with k in kilometres. Consider each of the following types of levelling equipment and explain (with some numerical substantiation) whether each type is suitable for First Order levelling (where σ_{ISO} is the standard deviation per 1 km of double run levelling according to ISO 17123-2).		
	i. Sokkia B20 automatic level with micrometer [32×, compensator setting accuracy = ± 0.3", σ_{ISO} = ± 0.5 mm] with appropriate rods. ii. Leica DNA03 digital automatic level [24×, compensator setting accuracy = ± 0.3", σ_{ISO} = ± 0.3 mm] with bar coded invar rods.	6	
	b. In order to provide control for a construction project, the Canadian Second Order specifications ($\Delta = 8mm\sqrt{k}$) is to be followed with two Canadian Second Order benchmarks nearby used. The construction site is 471 m away from the nearer of the two benchmarks. If the project requires control of high precision with the average elevation difference for section leveling as ΔH± 1.5 mm or better, explain with numerical substantiation, whether the Second Order procedure is able to achieve this precision. Note that the leveling discrepancy is based on 95% confidence level.	5	

Table for question 4:

	TARGET A	TARGET B
Horizontal circle reading in face I	12°23′30″	74°33′40″
Horizontal circle reading in face II	192°23′50″	254°34′10″
Vertical circle reading in face I	60°59′30″	89°59′30″
Vertical circle reading in face II	298°59′30″	-----

6.	A horizontal open traverse is to be measured with uniform sight lengths of 110.000 m ± 2 mm. There are two "fixed" stations, "A" and "B", plus six traverse stations, "P1" to "P6" so that "B" and "P1" to "P5" would be occupied while "A" and "P6" would be sighted. The order of the stations is A, B, P1, P2, …P6. All are at practically the same elevation. One approach is to measure the included horizontal angles [values near 180°] with standard deviation of ±5" at each of the 6 occupied stations. An alternative method is to occupy the same stations and to observe the azimuth to the next station using a gyro attachment with standard deviation of azimuth determination as ±15". a) If only included angles were observed, explain the dominant component of the random positional uncertainty at the end point of the traverse, "P6", and suggest a value and orientation of the uncertainty. b) If azimuths rather than included angles were observed, explain the dominant component of the random positional uncertainty at the end point of the traverse, "P6", and suggest a value and orientation of the uncertainty. c) If the traverse were along a tunnel, close to one wall, explain what would be the dominant systematic influence and whether included angles or azimuths should be observed.	5 4 2	
7.	A recently repaired gyrotheodolite (e.g. GAK1) is to be used for orientation transfer in an underground mine. A number of control points in a local plane rectangular coordinate system were already established near the shaft of the mine so that surface observations reduced to the horizontal would be in the mapping plane. Explain clearly what procedure you would follow (including corrections to be applied and an explanation on the reasons for the corrections) in order to determine the accurate grid azimuths (in this local coordinate system) at a horizontal drift running approximately in a westerly direction at a level of 1000 m below the surface. Assume that the gyrotheodolite setup point is close to the shaft and the transit (time) method of gyro observations will be adopted.	8	
8.	Last July, a crew was to lay out a 1500 m distance from one survey marker to set a second survey marker. Even though the temperature was + 30°C, they did not apply a meteorological correction but simply used the display value of "1500.000". You have just measured between the two markers and the uncorrected display, using the same electro-optical EDM instrument [± 3 mm and ± 2 ppm; group refractive index: 1.000294497, manufacturer refractive index number or refractivity is 282.106] and reflector, is "1500.095" with an ambient temperature of - 20°C. Determine the current distance between the markers now and whether there is a significant difference, at 90% confidence between the distance now compared to last July, assuming standard atmospheric pressure.	8	
		100	

Some potentially useful formulae are given as follows:

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

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

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

$$\sigma_{X_n}^2 = \sum_{i=1}^{n-1} (Y_n - Y_i)^2 \sigma_{\beta_i}^2 + \sum_{i=1}^{n-1} \left(\frac{X_{i+1} - X_i}{\ell_i} \right)^2 \sigma_{\ell_i}^2 \qquad \sigma_{X_n}^2 = \sum_{i=1}^{n-1} (Y_{i+1} - Y_i)^2 \sigma_{\alpha_i}^2 + \sum_{i=1}^{n-1} \left(\frac{X_{i+1} - X_i}{\ell_i} \right)^2 \sigma_{\ell_i}^2$$

$$\sigma_{Y_n}^2 = \sum_{i=1}^{n-1} (X_n - X_i)^2 \sigma_{\beta_i}^2 + \sum_{i=1}^{n-1} \left(\frac{Y_{i+1} - Y_i}{\ell_i} \right)^2 \sigma_{\ell_i}^2 \qquad \sigma_{Y_n}^2 = \sum_{i=1}^{n-1} (X_{i+1} - X_i)^2 \sigma_{\alpha_i}^2 + \sum_{i=1}^{n-1} \left(\frac{Y_{i+1} - Y_i}{\ell_i} \right)^2 \sigma_{\ell_i}^2$$

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

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

$\Delta = \sigma_\Delta \sqrt{\chi^2_{df,1-\alpha}}$ $\qquad$ $\Delta \le z_{\alpha/2} \sigma_\Delta$ $\qquad$ $\Delta \le t_{df,\alpha/2} \sigma_\Delta$

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

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
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