

October 2025

Marks

4.	Answer the following regarding 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) three main sources of error in the survey. b) Explain why the effects of centering errors are critical in Weiss quadrilateral method of mine correlation surveys using one total station instrument. Clearly explain how you will minimize these effects.	4	
5.	A closed-loop horizontal traverse of 4 points is to be run in a 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	
6.	Answer the following regarding deformation monitoring and analysis. a) What is the <i>observation differencing</i> 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.	Answer the following. a) Validation procedure is one of the important GNSS field procedures that may be required prior to a GNSS campaign. Explain the key elements of the GNSS measurement validation procedure, purpose, how often it is done, and explain a typical statistical test to check if validation is passed (including necessary statistical formulae with well-defined symbols, and the expected degrees of freedom and confidence level). b) List six important factors that will impact the accuracy of GNSS equipment calibration/tests. c) The standard deviation expected for a GNSS baseline determined using static surveying procedure can be estimated as $\sigma_{baseline} = \sqrt{2\sigma_s^2 + a^2 + (k \times ppm)^2}$ where $\sigma_s = 0.0015$ m, is the receiver setup error; $a + k ppm$ is the receiver manufacturer's specified accuracy with $a = 5$ mm and $k = 1$. Check if the misclosure of the baseline measurements of 0.07662 m is acceptable at 95% confidence level assuming the total length of the loop is 50,000 m with 5 baselines involved (with each baseline measured independently). d) If the horizontal error (RMSE_x) and vertical error (RMSE_z) reported for a map (with expected drawing scale of 1:1000 and 0.5 m contour interval) are 0.382 m and 0.152 m, respectively, determine the accuracy values to be reported according to NSSDA standards. e) Discuss two main differences between NMAS and ASPRS accuracy standards.	10 3 5 3 2	
		100	

Some potentially useful formulae are given as follows:

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

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

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

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

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

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

EDM:

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

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

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

Map Accuracy:

$$\text{Accuracy}_x = SE \times \sqrt{\chi_{df, 1-\alpha}^2} \quad \text{Accuracy}_y = SE \times \sqrt{\chi_{df, 1-\alpha}^2}$$

$$\text{Accuracy}_z = SE \times z_{1-\alpha/2} \quad \text{CMAS} = SE \times \sqrt{\chi_{df, 1-\alpha}^2} \quad (SE = RMSE)$$

$$\text{VMAS} = CI/2 \quad \text{VMAS} = SE \times z_{1-\alpha/2}$$

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

Collimation correction due to collimation factor C: $C \times (\sum_1^n d_{BS_i} - \sum_1^n d_{FS_i})$

$$\Delta \bar{h} = \frac{\Delta h_f - \Delta h_b}{2} \quad \Delta = \Delta h_f + \Delta h_b \quad \sigma_{\Delta h} = \sigma_{ran} \sqrt{L}$$

Statistics:

$$\chi^2 = \frac{s^2(df)}{\sigma^2} \quad \Delta = \sigma_{\Delta} \sqrt{\chi_{df, \alpha}^2} \quad \hat{\sigma} \leq \sqrt{\frac{\chi_{\alpha, df}^2(\sigma)}{df}} \quad \Delta \leq z_{\alpha/2} \sigma_{\Delta}$$

$$\Delta \leq t_{df, \alpha/2} \sigma_{\Delta} \quad y = d\hat{x}^T C_{\hat{x}\hat{x}}^{-1} d\hat{x} \quad y \leq \chi_{1-\alpha, df}^2$$

$$\sigma_{dp} = \frac{\sigma_p}{\sqrt{2n}} \quad \sigma_{dp} = \frac{60}{M} \quad \sigma_{\theta p} = \frac{\sigma_p}{\sqrt{n}} \quad \sigma_{dr} = \frac{\sigma_r}{\sqrt{2n}}$$

$$\sigma_{dr} = 2.5 \text{ div} \quad \sigma_{\theta r} = \frac{\sigma_r}{\sqrt{n}} \quad \sigma_L = \sigma_v \cot z, \quad \sigma_v = 0.2v'' \quad \sigma_r = 2.5d''$$

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

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

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

$$\sigma_{\theta t} = (206265'')\sigma_{c3} \sqrt{\frac{S_1^2 + S_2^2 - 2S_1S_2 \cos \theta}{S_1^2 S_2^2}}; \quad \sigma_{\theta t} = 206265 \sqrt{\left(\frac{\sigma_{c1}}{S_1}\right)^2 + \left(\frac{\sigma_{c2}}{S_2}\right)^2}$$

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

Refraction Error: $d\delta = 8'' \frac{PS}{T^2} \left(\frac{dT}{dx}\right)$ T = (273.15 + t°C); p (mb) and S (m)

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