Chapter 02 – Leveling

2.1 *Compute the error due to curvature and refraction for the following distances:*

(a) 500 ft	(c+r) = 0.0206 x (500/1000)2 = 0.005 ft.
(b) 4,000 ft	(c+r) = 0.0206 x (4)2 = 0 ft.
(c) 300 m	(c+r) = 0.0675 x 0.3002 = 0.006 m.
(d) 2.2 mi	(c+r) = 0.574 x 2.22 = 2.78 ft.
(e) 2,800 m	(c+r) = 0.0675 x (2.8)2 = 0.529 m
(f) 3 km	(c+r) = 0.0675 x (3)2 = 0.608m.

2.2 *Determine the rod readings indicated on the foot and metric rod illustrations in Figure 2-32. The foot readings are to the closest 0.01 ft, and the metric readings are to the closest one-half or one-third cm.*

Rod A	i 1.90	ii 1.73	iii 1.57	iv 1.21	v 1.03 (1.04)
Rod B	i 1.185	ii 1.150	iii 1.040	iv 1.000	v 0.930
Rod C	i 3.06	ii 2.85 (2.84)	iii 2.57 (2.56)	iv 2.21	v 1.92
Rod D	i 1.145	ii 1.065	iii 1.000	iv 0.935	v 0.880

2.3 *An offshore drilling rig is being towed out to sea. What is the maximum distance away that the navigation lights can still be seen by an observer standing at the shoreline? The observer's eye height is 5' 0" and the uppermost navigation light is 147 ft. above the water.*

$5.00 = .574\ K1^2$, K1 = √5.00/.574 = 2.95 miles

$147 = .574\ K2^2$, K2 = √147/.574 = 16.00 miles

Maximum visibility distance = 18.95 miles

2.4 *Prepare a set of level notes for the survey in Figure 2-33. Show the arithmetic check.*

STATION	BS	HI	IS	FS	ELEVATION
BM #50	1.27	390.34			389.07
TP #1	2.33	387.76		4.91	385.43
TP #2				6.17	381.59
	BS = 3.60			FS = 11.08	

389.07 +3.60 = 392.67 - 11.08 = 381.59 check

2.5 *Prepare a set of profile leveling notes for the survey in Figure 2-34. In addition to computing all elevations, show the arithmetic check and the resulting error in closure.*

STATION	BS	HI	IS	FS	ELEVATION
BM #61	4.72	401.46			396.74
0+00			4.42		397.04
0+50			4.30		394.16
TP #1	5.11	404.56		2.01	399.45
1+00			4.66		399.90
1+50			3.98		400.58
1+75			1.20		403.36
TP #2				1.80	402.76
	BS = 9.83			FS = 3.81	

E = - 0.02m [small error – no need for adjustments]

396.74 + 9.83 = 406.57 - 3.81 = 402.76 check

2.6 Complete the set of differential leveling notes in Table 2-5, and perform the arithmetic check.

STATION	BS	HI	FS	ELEVATION
BM 100	2.71	317.59		314.88
TP 1	3.62	316.33	4.88	312.71
TP 2	3.51	315.87	3.97	312.36
TP 3	3.17	316.23	2.81	313.06
TP 4	1.47	316.08	1.62	314.61
BM 100			1.21	314.87
	BS = 4.48		FS = 14.49	

314.88 + 14.48 - 14.49 = 314.87, check

2.7 If the loop distance in Problem 2.6 is 1,000 ft,at what order of survey do the results qualify? Use Table 2-1 or Table 2-2.

Error of closure = 0.01 ft.; for 1000 ft., second order (see Table 2.2) permits .035 √1000/5280 = 0.015; therefore, results qualify for **second order** accuracy.

2.8 Reduce the set of differential leveling notes in Table 2-6, and perform the arithmetic check

STATION	BS	HI	IS	FS	ELEVATION
BM 20	8.27	186.04			177.77
TP 1	9.21	192.65		2.60	183.44
0+00			11.3		181.4
0+50			9.6		183.1
0+61.48			8.71		246.65
1+00			6.1		249.3
TP 2	7.33	195.32		4.66	187.99
1+50			5.8		252.2
2+00			4.97		253.06
BM 21				3.88	191.44
	BS =24.81			FS = 11.14	

177.7 + 24.81 - 11.14 = 191.44 Check!

2.9 If the distance leveled in Problem 2.8 is 1,000 ft, for what order of survey do the results qualify if the elevation of BM 21 is known to be 191.40? See Tables 2-1 and 2-2.

Error of closure = 0.04 ft.; for 1000 ft., third order (see Table 2.2) permits ± 0.10√1000/5280 = 0.044; therefore results qualify for **third order** accuracy.

2.10 Reduce the set of profile notes in Table 2-7, and perform the arithmetic check.

STATION	BS	HI	IS	FS	ELEVATION
BM 22	1.203	182.425			181.222
0+00					
℄			1.211		181.214
10M LT.,			1.430		180.995
10M RT.,			1.006		181.419
0+20					
10M LT.,			2.93		179.50
7.3M LT.			2.53		179.90
4M LT.			2.301		180.124
℄			2.381		180.044
4M RT.			2.307		180.118
7.8M RT.			2.41		180.02
10M RT.			2.78		179.65
0+40					
10M LT.			3.98		178.45
6.2M LT.			3.50		178.9
4M LT.			3.103		179.322
℄			3.187		179.238
4M RT.			3.100		179.325
6.8M RT.			3.37		179.06
10M RT.			3.87		178.56
TP 1				2.773	179.65

2.11 Reduce the set of municipal cross-section notes in Table 2-8.

STATION	BS	HI	IS	FS	ELEVATION
BM 41	4.11	307.104			302.994
TP 13	4.10	310.314		0.89	306.214
12+00					
50 ft. lt.			3.9		306.4
18.3 ft. lt.			4.6		305.7
℄			6.33		303.98
20.1 ft. rt.			7.9		302.4
50 ft. rt.			8.2		302.1
13+00					
50 ft. lt.			5.0		305.3
19.6 ft. lt			5.7		304.6
℄			7.54		302.77
20.7 ft. rt.			7.9		302.4
50 ft. rt.			8.4		301.9
TP 14	7.39	316.584		1.12	309.194
BM S.22				2.41	314.174
	BS = 15.60			FS = 4.42	

302.994 + 15.60 - 4.42 = 314.174 check!

2.12 Complete the set of highway cross-section notes in Table 2-9.

STATION	BS	HI	FS	ELEV.	LEFT		℄	RIGHT	
BM 37	7.20	385.17		377.97					
					50	26.7		28.4	50
5+50					4.6	3.8	3.7	3.0	2.7
					380.6	381.4	381.5	382.2	382.5
					50	24.1		25.0	50
6+00					4.0	4.2	3.1	2.7	2.9
					381.2	381.0	382.1	382.5	382.3
					50	26.4		23.8	50
6+50					3.8	3.7	2.6	1.7	1.1
					381.4	381.5	382.6	383.5	384.1
TP 1			6.71	378.46					

2.13 Complete the set of highway cross-section notes in Table 2-10.

STATION	BS	HI	FS	ELEV.	LEFT		℄	RIGHT	
BM 107	7.71	406.87		399.16					
					60	28		32	60
80+50					9.7	8.0	5.7	4.3	4.0
					397.2	398.9	401.2	402.6	402.9
					60	25		30	60
81+00					10.1	9.7	6.8	6.0	5.3
					396.8	397.2	400.1	400.9	401.6
					60	27		33	60
81+50					11.7	11.0	9.2	8.3	8.0
					395.2	395.9	397.7	398.6	398.9
TP 1			10.17	396.70					

2.14 A level is set up midway between two wood stakes that are about 300 ft apart. The rod reading on stake A is 8.72 ft, and it is 5.61 ft on stake B. The level is then moved to point B and set up about 6 ft or 2 m away. A reading of 5.42 ft is taken on the rod at B. The level is then sighted on the rod held on stake A, where a Reading of 8.57 ft is noted.

(a) What is the correct difference in elevation between the tops of stakes A and B?
(b) If the level had been in perfect adjustment, what reading would have been observed at A from the second setup?
(c) What is the line-of-sight error in 300 ft?
(d) Describe how you would eliminate the line-of-sight error from the telescope.

a) True difference = 8.72 - 5.61 = 3.11 ft.
b) Correct rod reading = 5.42 + 3.11 = 8.53 ft.; on A
c) Error is +0.04 in 300 ft., or .00001 ft/ft
d) Cross hair adjusted downward from 8.57 to read 8.53, on A

2.15 A pre-engineering baseline was run down a very steep hill (see Figure 2-35). Rather than measure horizontally downhill with the steel tape, the surveyor measures the vertical angle with a theodolite and the slope distance with a 200-ft steel tape. The vertical angle is -21° 26' turned to a point on a plumbed range pole that is 4.88 ft above the ground. The slope distance from the theodolite to the point on the range pole is 148.61 ft. The theodolite's optical center is 4.66 ft above the upper baseline station at 110 + 71.25.

(a) If the elevation of the upper station is 318.71, what is the elevation of the lowerstation?

(b) What is the stationing chainage of the lower station?

a) V=148.61 Sin 21O26' = 54.30 ft Elevation of lower station = 318.71 +4.66 -54.30 -4.88 = 264.19 ft.

b) H = 148.61 Cos (21° 26') = 138.33 ft lower station at 110+71.25 +138.33 = 112+09.58

2.16 You must establish the elevation of point B from point A (elevation 216.612 m). A and B are on opposite sides of a 12-lane highway. Reciprocal leveling is used, with the following results:

Setup at A side of highway:

Rod reading on A = 0.673 m

Rod readings on B = 2.416 and 2.418 m

Setup at B side of highway:

Rod reading on B = 2.992 m

Rod readings on A = 1.254 and 1.250 m

(a) What is the elevation of point B?

(b) What is the leveling error?

a) First elevation difference = 2.417- 0.673 = 1.744

Second elevation difference = 2.992 - 1.252 = 1.740

Average elevation difference = 1.742

Elevation B = 216.612-1.742 = 214.870

b) The leveling error is 0.004m

2.17 Reduce the set of differential leveling notes inTable 2-11, and perform the arithmetic check.

(a) Determine the order of accuracy (seeTable 2-1 or Table 2-2).

(b) Adjust the elevation of BM K110. The length of the level run was 780 m, with setups that are equally spaced. The elevation of BM 132 is 187.536 m.

STATION	BS	HI	FS	ELEVATION
BM 130	0.702	189.269		188.567
TP 1	0.970	189.128	1.111	188.158
TP 2	0.559	189.008	0.679	188.449
TP 3	1.744	187.972	2.780	186.228
BM K110	1.973	188.277	1.668	186.304
TP 4	1.927	188.416	1.788	186.489
BM 132			0.888	187.528
	BS = 7.875		FS = 8.914	

188.567 + 7.875 - 8.914 = 187.528, check

a) error = 187.536 – 187.528 = - 0.008 m.
Using specifications from Table 2.1, Third order accuracy, allowable error = .012√.780 = 0.011 m. This error of 0.008 thus qualifies for **third order** accuracy (in both Tables 2.1 and 2.2)

b)

STATION	CUMULATIVE DISTANCE	ELEVATION	CORRECTION	ADJUSTED ELEVATION
BM 130		188.567		188.567
TP 1	130	188.158	130/780 x.008 = +.001	188.159
TP 2	260	188.449	260/780 x.008 = +.003	188.452
TP 3	390	186.228	390/780 x.008 = +.004	186.232
BM K110	520	186.304	520/780 x.008 = +.005	186.309
TP 4	650	186.489	650/780 x.008 = +.007	186.496
BM 132	780	187.528	780/780 x.008 = +.008	186.536

C = 187.536 – 187.528 = - 0.008

The adjusted elevation of BM K110 is 186.309m