

Solutions Manual

for

Construction Surveying and Layout

Second Edition

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Table of Contents

Chapter	Page
1.....	1
2.....	1
3.....	1
4.....	3 - 4
5.....	5
6.....	5
7.....	5 - 6
8.....	6
9.....	6 - 7
10.....	7
11.....	8
12.....	8
13.....	8 - 9
14.....	9 - 11
15.....	12 - 18
16.....	18 - 23
17.....	23 - 25
18.....	25 - 32
19.....	32
20.....	32 - 33
21.....	33
22.....	33 - 36
23.....	36
24.....	36
25.....	36
26.....	No Questions Presented



Chapter 1 - Scope and Responsibilities

1. Describe what a field engineer is and list the duties and responsibilities of a person in that position.

Reference page 1-3.

2. Discuss why field engineers should not perform property surveys.

Reference page 1-13.

Chapter 2 - Communications and Field Engineering

3. The most important part of communicating is said to be the ability to listen. List some factors that improve the listening ability of field engineers.

Reference page 2-5.

4. What is the number for the following hand signals?

- a) seven
- b) one
- c) three
- d) nine

Reference page 2-14.

5. What are the meanings of the following hand signals?

- a) close to grade
- b) cut
- c) give me line
- d) I want line

Reference page 2-25.

6. What is the tolerance for the following types of construction stakes?

- a) rough grade stakes
- b) slope stakes
- c) curb and gutter

Reference page 2-23.

7. What is wrong with the following control information found on the wall of a construction site?

- a) off of "L" line \Rightarrow North, South, East, or West
- b) feet above floor \Rightarrow Rough or Finish

Reference page 2-28.

Chapter 3 - Getting Started and Organized

8. Identify the most important activity of the field engineer.

"Planning"

9. List the common personal surveying tools used by most field engineers.

Reference page 3-4.

Chapter 4 - Fieldwork Basics

10. List the basic personal protective equipment of field engineers.

Reference page 4-4.



11. Identify the most important factor in the overall safety of the field engineer.
Reference page 4-4.
12. Develop a list of 10 mistakes or blunders that could occur in construction measurement.
Reference page 4-11.
13. Distinguish between errors and mistakes.
Reference page 4-11.
14. Discuss which errors can be eliminated and which errors can only be reduced in size by refined techniques.
Reference page 4-12.
15. What is the basic rule of measurement for a field engineer?
“Do it twice.”
16. State the basic rule of thumb regarding tolerances in construction measurement.
Reference page 4-15.
17. List and discuss the cardinal rules of field book use.
Reference page 4-18.
18. State why erasures are absolutely not allowed in a field book.
Reference page 4-21.
19. State why a combination of the methods of notekeeping is best.
Reference page 4-22.
20. State the simple rules regarding transporting an instrument in a vehicle.
Reference page 4-26.
21. What special storage precautions should be used when the climate is very cold or very hot?
Reference page 4-29.
22. How is the care of electronic instruments different from optical instruments?
Reference page 4-30.
23. Describe how to care for and maintain the following surveying tools: plumb bob, hand level, Gammon reel, chaining pins, range poles prism poles brush clearing equipment, steel chain, cloth chain, level rod, hand-held calculators, ni-cad batteries.
Reference page 4-35.
24. State the left thumb rule for leveling an instrument.
Reference page 4-46.
25. Describe the process used to set up an instrument over a point with a plumb bob.
Reference page 4-52.
26. Describe the process used to “Quick Setup” an instrument over a point with an optical plummet.
Reference page 4-55.



Chapter 5 - Officework Basics

27. List the basic information that should be shown on a site drawing.

Reference page 5-10.

28. State why a graphical scale should be used on all drawings.

Reference page 5-11.

29. Describe the common characteristics of contours.

Reference page 5-16.

30. State the purpose of lift drawings.

Reference page 5-20.

31. Using a set of plans for a building on a slab, prepare a lift drawing of the slab details by following the Lift Drawing Checklist in Chapter 5.

Reference page 5-24.

Chapter 6 - Distance Measurement - Chaining

32. List the tools a field engineer uses to measure a distance by chaining.

Reference page 6-4.

33. Outline the step-by-step procedure for chaining a distance.

Reference page 6-7.

34. State when it is necessary to use a hand level while chaining.

Reference page 6-9.

35. What is the process called when you use lengths shorter than 100 feet to measure between points?

“Breaking chain.”

36. List common mistakes that occur when chaining.

Reference page 6-16.

37. Distinguish between systematic errors and random errors in chaining.

Chapter 7 - Distance Measurement - EDM

38. List potential uses of an EDM in construction.

Layout of building lines.

Sitework layout.

Establishing primary control.

Establishing secondary control.

Layout centerline of road.

etc.

39. What sighting procedure with the EDM can be used to eliminate complicated geometric calculations?

Reference page 7-8.



40. Outline the step-by-step procedure for measuring a distance with an EDM.

Reference pages 7-9.

41. What is the greatest source of error with EDM measurement?

Reference page 7-26.

Chapter 8 - Angle Measurement

42. Illustrate the geometric relationships of any angle turning instrument.

Reference page 8-7.

43. Identify the three basic parts of the transit.

Reference page 8-8.

44. State the basic order of the steps in turning a horizontal angle direct and reverse.

Reference page 8-18.

45. After turning two direct and reverse angles, you read an angle of $241^{\circ} 21' 20''$. What is the average angle turned?

$60^{\circ} 20' 20''$

46. What process allows for systematic errors in a transit's horizontal axis to be eliminated?

"Double centering"

47. Distinguish between zenith angle and vertical angle and state why zenith angle is used on modern theodolites.

Reference page 8-24.

Chapter 9 - Leveling

48. Illustrate the basic theory of differential leveling.

Reference page 9-4.

49. Define the following leveling terms.

- a) Benchmark
- b) Backsight
- c) height of Instrument
- d) Foresight
- e) Turning Point

Reference pages 9-6.

50. Describe the step-by-step differential leveling procedure.

Reference pages 9-7, 9-15.

51. State why the distance from the instrument to the backsight and the instrument to the foresight must be the same. (Balanced)

To eliminate error due to the instrument and earth curvature.



52. Complete the following set of differential leveling notes and perform the arithmetic check.

Closing a Loop from BM #6				
Station	BS	HI	FS	ELEVATION
BM #6				155.375
Station 1	1.255	156.630		
TP 1			3.110	153.52
Station 2	0.465	153.985		
TP 2			2.095	151.89
Station 3	0.13	152.02		
TP 3			0.245	151.775
Station 4	3.765	155.540		
BM#6			0.165	155.375

Arithmetic Check:

$$\text{Starting elevation} + \text{SBS} - \text{SFS} = \text{Ending elevation}$$

$$155.375 + 5.615 - 5.615 = 225.74$$

53. Complete the accompanying set of differential leveling notes and perform the arithmetic check for the following problem.

Station	BS	HI	FS	ELEVATION
BM 65	1.36	578.39		577.03
TP1	2.54	578.61	2.32	576.07
TP2	2.55	578.93	2.23	576.38
TP3	3.01	579.69	2.25	576.68
TP4	3.02	580.36	2.35	577.34
TP5	3.02	581.28	2.10	578.26
TP6	2.98	582.25	2.01	579.27
BM 65			5.24	577.01

Arithmetic Check:

$$\text{Starting elevation} + \text{SBS} - \text{SFS} = \text{Ending elevation}$$

$$577.03 + 18.48 - 18.50 = 577.01$$

Chapter 10 - Total Stations

54. Distinguish between a total station and an EDM.

A total station can measure both angles and distances, but the EDM can measure only distances.

55. List advantages of the total station as compared to a top-mount EDM.

The total station is advantageous because it is a fully integrated unit that can use the angle and distance measurements to easily obtain horizontal distances. A top-mount EDM requires obtaining the distance and angle measurements individually and manually calculating the horizontal distance.

56. Describe how the total station is used for measuring distances and angles.



Reference page 10-11.

57. List the features that are typically available on an Electronic Field Book. *Reference page 10-20.*

Chapter 11 - Construction Lasers

58. What is LASER an acronym for?

Reference page 11-4.

59. List advantages of lasers as a construction tool.

Reference page 11-5.

60. Distinguish between fixed, rotating, and utility lasers.

Reference page 11-6.

61. Describe how it is possible to establish grade (elevations) with one person, using a lenker rod and Laser.

Reference page 11-11.

Chapter 12 - Equipment Calibration

62. Illustrate with a sketch the following geometric relationships that exist in transits and theodolites.

- a) VA perpendicular to HA.
- b) VA perpendicular to PL.
- c) HA perpendicular to LOS.
- d) VCH perpendicular to HA.
- e) TL parallel to LOS.

Reference page 12-13.

63. The quick peg test is used to check which geometric relationship in a level?

Reference page 12-25.

64. Describe how to calibrate a bull's-eye bubble and a hand level.

Reference pages 12-29 and 12-32.

Chapter 13 - Math Review and Conversions

65. Convert the following feet and decimal parts of a foot to feet, inches, and eighths.

Feet, tenths, hundredths	Feet, inches, eighths
222.20	222 ^c - 2 3/8 ²
125.87	125 ^c - 10 1/2 ²
42.42	42 ^c - 5 ²
110.55	110 ^c - 6 5/8 ²
15.92	15 ^c - 11 ²

66. Convert the following feet, inches, and fractions to feet and decimal parts of a foot.

Feet, inches, eighths	Feet, tenths, hundredths
25' - 4 3/8"	25.36
44' - 11 5/8"	44.97
123' - 6"	123.50
88' - 3 1/4"	88.27



222' - 2 1/2"	222.21
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67. Convert the following degrees, minutes, and seconds to decimal degrees.

Degrees, minutes, seconds	Degrees and decimal
15° 25' 13"	15.42027778°
33° 53' 45"	33.89583333°
77° 23' 59"	77.39972222°
125° 48' 15"	125.8041667°
278° 42' 55"	278.7152778°

68. Convert the following decimal degrees to Degrees, minutes, and seconds.

Degrees and decimal	Degrees, minutes, seconds
33.23456722°	33° 14' 04"
75.34698543°	75° 20' 49"
123.4500392°	123° 27' 00"
289.2222222°	289° 13' 20"
234.2700000°	234° 16' 12"

Chapter 14 - Distance Corrections

69. A field engineer has measured the distance between column lines with a chain which is later discovered to be too long. In order to determine the actual distance between points, how should the correction be applied?

Measuring a distance with a long chain P Add correction to recorded distance.

70. A field engineer used a chain which is too short to lay out a foundation of a large building. If she sets points at the prescribed distances from plans, how should the correction be applied?

Laying out a distance with a short chain P Add correction to plan distance.

71. What is the distance between two building control points measured (recorded) to be 600 feet, if the 100-foot chain was found to be too long by 0.015 feet?

**Recorded (measured) distance = 600 ft.
Chain is too long P Add correction.
+0.015 ft/Chain Length (CL)
Total Correction = 6 * 0.015 = 0.09¢
CORRECTED DISTANCE = 600.09 ft**

72. A chain 100 feet long is laid on ground sloping 5%. What is the horizontal distance if the slope distance is 300 feet?

$$Cg = \frac{h^2}{2 * CL} = \frac{5^2}{2 * 100} = 0.125¢CL$$

**Total correction = 0.375¢
HORIZONTAL DISTANCE = 299.62**



73. A 100-foot steel chain (known to be 99.93 feet) was used to measure between two building points. A distance of 147.44 feet was recorded at a temperature of 43°F. What is the distance after correcting for temperature and chain length error?

Measured distance = 147.44 ft.

① **Chain is too short P Subtract correction.**

$$C_l = (-0.07) * (1.4744) = -0.103$$

② **Temperature (T) = 43°F**

Chain is too short P Subtract correction.

$$C_t = 0.0000645 * (43-68) * 147.44 = -0.024$$

③ **CORRECTED DISTANCE = 147.44 - 0.103 - 0.024 = 147.31**

74. The slope distance between the two points is 24.776 feet and the slope angle is 1° 17'. Compute the horizontal distance.

Slope distance = 24.776

Slope angle = 1° 17'

$$\begin{aligned} \text{Horizontal distance} &= \cos(\text{Slope angle}) * \text{Slope distance} \\ &= \cos(1^\circ 17') * (24.776) \\ &= (.9997492) * (24.776) \end{aligned}$$

HORIZONTAL DISTANCE = 24.770

75. The slope distance between two points is 42.71 feet, and the difference in elevation between them is 3.56 feet. Compute the horizontal distance.

$$\text{HORIZONTAL DISTANCE} = \sqrt{42.71^2 - 3.56^2} = 42.52 \text{ ft}$$

76. A distance of 328 feet was measured along a 2% slope. Compute the horizontal distance.

$$C_g = \frac{h^2}{2 * CL} = \frac{2^2}{2 * 100} \text{ P } C_g = 0.02\%CL$$

$$\text{Total correction} = (0.02) * (3.28) = 0.066\%$$

$$\text{CORRECTED DISTANCE} = 328.00 - 0.066 = 327.93$$

77. It is required to lay out a rectangular building, 75 feet wide by 100 feet long. If the 100' steel chain being used is 99.94 feet long, what distances should be laid out?

Building = 75' x 100'

Tape = 0.06' Short

Required Layout Corrections:

$$(.06) * (.75) = 0.045$$

$$(.06) * (1.00) = 0.06$$

Add Correction P CORRECTED BUILDING DIMENSIONS = 75.045' x 100.06'

78. A concrete slab measuring 10 feet by 85 feet is to be laid out by a chain known to be 100.07 feet long under standard conditions. What distances should be laid out?

① **Layout 10 ft. distance.**

Chain is too long P Subtract correction.

$$-0.07 \text{ ft/CL}$$

$$\text{Corrected Distance} = 10 - (0.07) * (0.1) = 9.99 \text{ ft.}$$

② **Layout 85 ft. distance.**

$$\text{Corrected Distance} = 85 - (0.07) * (0.85) = 84.94 \text{ ft.}$$

③ **DISTANCES TO BE LAID OUT = 9.99' x 84.94'**



79. A 100' steel chain standardized at 99.98' was used to measure a distance between control points of 1275.36 feet when the field temperature was 87°F. The ground was sloping at 5%. What is this distance under standard conditions?

Measured distance = 1275.36 ft.

- ① **Chain is too short P Subtract correction.**
-0.02 ft/CL

$$C_l = (-0.02) * (12.7536) = 0.255$$

- ② **T = 87°F P Add correction.**

$$C_t = 0.0000645 (87-68) (1275.36) = 0.156$$

- ③ **CORRECTED DISTANCE = 268.33 - 0.08 - 0.05 = 268.20 ft**

80. A steel chain known to be 99.94 feet under standard conditions is used to measure the distance between two control points. If a distance of 178.4 feet was recorded at 58°F, what distance should be measured at a temperature of 75°F?

- ① **Tape = 0.06¢ Short P Subtract correction**

Temperature = 58°F P Tape short P Subtract correction

Distance = 178.4

-0.06/Tape Length

$$(58-68) * (0.0000645) * 100 = -0.006/TL$$

total correction/TL = -0.066

$$\text{total correction} = -0.066 * 1.784 = -0.119$$

$$\text{Corrected distance} = 178.4 - 0.119 = 178.281$$

- ② **Tape = 0.06 Short P Add correction**

Temperature = 75°F P Tape long P Subtract correction

+0.06/TL

$$(75-68) * (0.0000645) * 100 = -0.005/TL$$

total correction/TL = +0.055

$$\text{total correction} = 0.055 * 1.78281 = 0.099$$

$$\text{CORRECTED DISTANCE} = 178.281 + 0.099 = 178.38$$

81. A steel chain known to be 100.03 feet is used to measure the distance between two building corners. If the distance between the corners is supposed to be 268.33 feet and the field temperature is 97°F, then what distance should be laid out?

Layout distance = 268.33 ft.

- ① **Chain is too long P Subtract correction.**

-0.03 ft/CL

$$C_l = (0.03) (2.6833) = 0.080$$

- ② **T = 97°F P Chain is too long P Subtract correction.**

$$C_t = 0.0000645 (97-68) (268.33) = 0.050$$

- ③ **CORRECTED DISTANCE = 268.33 - 0.08 - 0.05 = 268.20**

82. Two control points are known to be 487.63 feet apart. Using a 200' chain known to be 199.96 feet under standard conditions, what distance should be measured when the field temperature is 78°F?

Layout distance = 487.63 ft.

- ① **Chain is too short P Add correction.**

+0.04 ft/CL

$$C_l = (0.04) (2.438) = 0.098$$

- ② **T = 78°F P Chain is too long P Subtract correction.**

$$C_t = 0.0000645 (78-68) (487.63) = 0.031$$

- ③ **CORRECTED DISTANCE = 487.63 + 0.098 - 0.031 = 487.70 ft**



Chapter 15 - Traverse Computations

83. What is the angular closure for the following interior field angles of traverse ABCDEF, measured with equal precision?
84. Using the angles in the previous problem, how much adjustment is needed for each angle?

$87^{\circ} 54' 12''$	\cancel{D}	$87^{\circ} 54' 09''$
$90^{\circ} 32' 54''$	\cancel{D}	$90^{\circ} 32' 51''$
$102^{\circ} 43' 31''$	\cancel{D}	$102^{\circ} 43' 28''$
$99^{\circ} 24' 44''$	\cancel{D}	$99^{\circ} 24' 41''$
$156^{\circ} 01' 56''$	\cancel{D}	$156^{\circ} 01' 53''$
<u>$183^{\circ} 23' 01''$</u>	\cancel{D}	<u>$183^{\circ} 22' 58''$</u>
$720^{\circ} 00' 18''$		$720^{\circ} 00' 00''$

85. Using adjusted angles from above, and a direction for line AB of 247° , what is the direction for each line?

Line	Azimuth
AB	$247^{\circ} 00' 00''$
BC	$336^{\circ} 27' 09''$
CD	$53^{\circ} 43' 41''$
DE	$134^{\circ} 19' 00''$
EF	$158^{\circ} 17' 07''$
FA	$154^{\circ} 54' 09''$

86. Provide the back azimuth for the following azimuths:

- a) $132^{\circ} 12' 07'' + 180^{\circ} = \underline{\underline{312^{\circ} 12' 07''}}$
 b) $56^{\circ} 52' 17'' + 180^{\circ} = \underline{\underline{236^{\circ} 52' 17''}}$
 c) $311^{\circ} 32' 42'' - 180^{\circ} = \underline{\underline{131^{\circ} 32' 42''}}$

87. Convert the following azimuths into bearings:

- a) $351^{\circ} 43' 52'' = \underline{\underline{N 8^{\circ} 16' 08'' W}}$
 b) $11^{\circ} 32' 59'' = \underline{\underline{N 11^{\circ} 32' 59'' E}}$
 c) $326^{\circ} 32' 52'' = \underline{\underline{N 33^{\circ} 27' 08'' W}}$

88. Given two successive azimuths of a traverse $69^{\circ} 21'$ followed by $320^{\circ} 11'$, what is the counterclockwise interior angle between them?

$$69^{\circ} 21' + 180^{\circ} = 249^{\circ} 21'$$

$$\text{Az. } 320^{\circ} 11' - 249^{\circ} 21' = 70^{\circ} 50'$$

$$\text{CCW Interior Angle} = \underline{\underline{70^{\circ} 50'}}$$

89. Given two successive bearings of a traverse N $41^{\circ} 35'$ E followed by S $87^{\circ} 36'$ E, what is the interior angle between them?

$$\underline{\underline{\text{Interior angle} = 41^{\circ} 35' + 87^{\circ} 36' = 129^{\circ} 11'}}$$

90. A 400' line bears N $88^{\circ} 11' 07''$ E. What is the latitude and departure of the line?

$$\underline{\underline{\text{Latitude} = 400 * \cos(88^{\circ} 11' 07'') = 12.67'}}$$

$$\underline{\underline{\text{Departure} = 400 * \sin(88^{\circ} 11' 07'') = 399.80'}}$$

91. A 656' line bears S $52^{\circ} 53' 42''$ W. What is the latitude and departure of the line?

$$\underline{\underline{\text{Latitude} = 656 * \cos(52^{\circ} 53' 42'') = -395.75'}}$$



$$\underline{\text{Departure}} = 656 * \sin(52^\circ 53' 42") = \underline{-523.18c}$$

92. A 736.32' line has an azimuth of 78° 52' 13". What is the latitude and departure of the line?

$$\underline{\text{Latitude}} = 736.32 * \cos(78^\circ 52' 13") = \underline{142.13c}$$

$$\underline{\text{Departure}} = 736.32 * \sin(78^\circ 52' 13") = \underline{722.47c}$$

93. A 1333.45' line has an azimuth of 203°24'. What is the latitude and departure of the line?

$$\underline{\text{Latitude}} = 1333.45 * \cos(23^\circ 24') = \underline{-1223.78c}$$

$$\underline{\text{Departure}} = 1333.45 * \sin(23^\circ 24') = \underline{-529.58c}$$

94. The closure in latitudes of a loop traverse is N 0.36 feet; the closure in departures is W 0.25 feet. What is the linear error of closure?

$$\underline{\text{L.E.O.C.}} = \sqrt{0.36^2 + 0.25^2} = \underline{0.4383}$$

95. The unbalanced latitudes and departures of a closed traverse, and the lengths of the sides are given below. What is the precision?

Course	Length	Latitude	Departure
AB	357.65	N 326.41	W 146.18
BC	329.22	N 58.27	E 324.02
CD	423.6	S 384.52	W 177.70

Answer: Latitudes, Departures and Closure

Line	Distance	North Latitude	South Latitude	East Departure	West Departure
AB	357.65	326.41			146.18
BC	329.22	58.27		324.02	
CA	423.60		384.52		177.70
TOTAL	1110.47	384.68	384.52	324.02	323.88
		Closure =	0.16	Closure =	0.14

Answer: L.E.O.C and Precision

$$\underline{\text{L.E.O.C.}} = \underline{0.213}$$

$$\underline{\text{Precision}} = \underline{0.213/1110.47 = 1/5223}$$



96. For the following traverse WXYZ, what is the corrected departure of XY?

Course	Direction	Length	Latitude	Departure
WX	N 68° 12' E	340.2	126.3	345.9
XY	S 7° 54' E	261.7	259.2	36.0
YZ	S 51° 06' W	413.5	259.7	321.8
ZW	N 4° 25' W	377.9	376.6	31.6

Answer: Latitudes, Departures and Closures

Line	Distance	North Latitude	Corr.	South Latitude	East Departure	Corr.	West Departure
WX	340.2	126.3	+0.02		315.9	+0.02	
XY	261.7		-0.02	259.2	36.0	+0.02	
YZ	413.5		-0.03	259.7		-0.03	321.7
ZW	393.7	392.5	+0.03			-0.03	30.3
TOTAL	1110.47	518.8		518.9	351.9		352.0
		Closure = 0.10			Closure = 0.10		

Answer: Adjusted Latitudes & Departures

Line	North Latitude	South Latitude	East Departure	West Departure
WX	126.32		315.92	
XY		259.18	36.02	
YZ		259.67		321.67
ZW	392.53			30.27

97. A four-sided closed traverse ABCD has the following angles and distances.

A = 88° 30' AB = 262.76'
 B = 90° 22' BC = 955.63'
 C = 87° 00' CD = 250.49'
 D = 94° 08' DA = 944.47'

The direction of AB is an azimuth of 88°.

- Perform a check for angular closure. $88^{\circ}30' + 90^{\circ}22' + 87^{\circ}00' + 94^{\circ}08' = 360^{\circ}00'$
- Compute the direction for all sides. (Azimuths)
- Compute the latitudes and departures.

Line	Azimuth	Dist.	North Lat.	Corr.	South Lat.	East Dep.	Corr.	West Dep.
AB	88° 00'	262.76	9.17	-0.02		262.60	+0.01	
BC	177° 38'	955.63		+0.07	954.81	39.46	+0.05	
CD	270° 38'	250.49	2.77	-0.02			-0.01	250.47
DA	356° 30'	944.47	942.71	-0.07			-0.05	57.66
TOTAL		2413.35	954.65		954.81	302.06		308.13
			Closure = 0.16			Closure = 6.07		



- d) Compute the linear error of closure and the precision ratio.

$$\mathbf{L.E.O.C. = \sqrt{.16^2 + 6.07^2}}$$

$$\mathbf{Precision = L.E.O.C./2413.35 = \frac{1}{397}} \quad \text{(Terrible Precision! Return to the}$$

field and remeasure. For the sake of seeing how the compass rule works, the given data is used in the following adjustments.

- e) Using the compass rule, compute the adjustments for latitudes and departures and apply the adjustments. See above table.

ADJUSTED LATITUDES & DEPARTURES

Line	North Latitude	South Latitude	East Departure	West Departure
AB	9.19		263.26	
BC		954.75	41.86	
CD	2.79			249.84
DA	942.77			55.28

- f) Assuming coordinates of North 1000 and East 1000 for point A, compute the coordinates of B, C, and D.

Point	Northing	Easting
A	1000.00	1000.00
B	1009.19	1263.26
C	54.44	1305.12
D	57.23	1055.28

- g) Using the computed coordinates, compute the area in acres enclosed by the traverse.

Area = cross multiplication of the listed coordinates
 Area = 487,119/2 ft²
Area = 5.59 acres

98. A four-sided closed traverse LMNO has the following angles and distances.

$$\begin{array}{ll} \mathbf{L = 110^\circ 38c} & \mathbf{LM = 470.52} \\ \mathbf{M = 82^\circ 56c} & \mathbf{MN = 402.06} \\ \mathbf{N = 90^\circ 37c} & \mathbf{NO = 488.34} \\ \mathbf{O = 75^\circ 50c} & \mathbf{OL = 349.91} \end{array}$$

The direction of LM is an azimuth of North 0°.

- a) Perform a check for angular closure.

$$\begin{array}{l} \mathbf{110^\circ 38c + 82^\circ 55c + 90^\circ 37c + 75^\circ 50c = 360^\circ 01c} \\ \mathbf{110^\circ 38c + 82^\circ 54c + 90^\circ 37c + 75^\circ 50c = 360^\circ 00c \checkmark} \end{array}$$

- b) Compute the direction for all sides. (Azimuths)
 c) Compute the latitudes and departures.



Line	Azimuth	Distance	North Latitude	South Latitude	East Departure	West Departure
LM	00° 00'	470.52	470.52		---	
MN	97° 05'	402.06		49.58	398.99	
NO	186° 28'	488.34		485.23		55.00
OL	290° 38'	349.91	123.30			327.46
TOTAL		1710.830	593.82	534.81	398.99	382.46
			Closure = 59.01		Closure = 16.53	

d) Compute the linear error of closure and the precision ratio.

$$L.E.O.C. = \sqrt{59.01^2 + 16.53^2} = 61.28$$

Precision = L.E.O.C./1630.83 = $\frac{1}{28}$ (Terrible Precision Again. Return to the field and remeasure. For the sake of seeing how the compass rule works, the given data is used in the following adjustments.

e) Using the compass rule, compute the adjustments for latitudes and departures and apply the adjustments.

Line	Distance	North Latitude	Corr.	South Latitude	East Departure	Corr.	West Departure
LM	470.52	470.52	-16.23		---	-4.55	
MN	402.06		+13.87	49.58	398.99	-3.88	
NO	488.34		+16.84	485.23		+4.72	55.00
OL	349.91	123.30	-12.07			+3.38	327.46
TOTAL	1710.830	593.82		534.81	398.99		382.46
		Closure = 59.01		Closure = 16.53			

Adjusted Latitudes & Departures

Line	North Latitude	South Latitude	East Departure	West Departure
LM	454.29			4.55
MN		63.45	395.11	
NO		502.07		59.72
OL	111.23			330.84

f) Assuming coordinates of North 1000 and East 1000 for point L, compute the coordinates of M, N, an O.

Point	Northing	Easting
L	1000.00	1000.00
M	1454.29	995.45
N	1390.84	1390.56
O	888.77	1330.84



g) Using the computed coordinates, compute the area in acres enclosed by the traverse.

Area = 175,977 ft²

AREA = 4.04 acres

99. For the traverse shown, what is the distance and direction for each line? What is the area?

Solution needed

100. For the traverse shown, what is the distance and direction for each line? What is the area?

Solution needed

101. For the closed traverse ABCD, answer the following questions.

Course	Bearing	Length	Latitude	Departure
AB	S 77° 48' E	76	14.8	74.3
BC	S 68° 14' W	135	50.1	125.4
CD	N 10° 26' W	42	41.3	7.6
DA	N 53° 00' W	50	30.1	39.9

a) What are the corrected departures?

See table below

b) What are the corrected latitudes?

Line	Azimuth	Distance	North Latitude	Corr.	South Latitude	East Departure	Corr.	West Departure
AB	102° 12'	76.00		+0.01	16.06	74.28	+0.01	
BC	248° 14'	135.00		+0.01	50.06		-0.01	125.37
CD	349° 34'	42.00	41.30					7.60
DA	67° 03'	63.71	24.84			58.67		
TOTAL		316.71	66.14		66.12	132.95		132.97
				Closure =	0.02	Closure =		0.02

Adjusted Latitudes & Departures

Line	North Latitude	South Latitude	East Departure	West Departure
AB		16.07	74.29	
BC		50.07		125.36
CD	41.30			7.60
DA	24.84		58.67	

c) What is the error of closure?

L.E.O.C. = $\sqrt{.02^2 + .02^2} = 0.02828$

d) What is the approximate precision?

Precision = L.E.O.C./316.71 = $\frac{1}{11200}$



- e) Assuming starting coordinates of North 1000 and E 1000 for point A, what are the coordinates of the other traverse points?

Point	Northing	Easting
L	1000.00	1000.00
M	983.93	1074.29
N	933.86	948.93
O	975.16	941.33

- f) What is the area of Figure ABCD?

Area = 4173 ft²

AREA = .09580 acres

102. For the following coordinates, calculate the area using the coordinate method:

Point	Northing	Easting
A	1200	1400
B	1300	1100
C	1100	1200
D	1000	1000

Area = 25,000 ft²

AREA = 0.574 acres

103. For the adjusted latitudes and departures given below and with coordinates of Point A being North 1000 East 1000, calculate the coordinates of Point C:

Course	Latitude	Departure	Point	N	E
			A	1000	1000
AB	S 350	E 160			
			B	650	1160
BC	N 310	E 120			
			C	960	1280
CA	N 40	W 280			
			A	1000	1000

Chapter 16 - Coordinates in Construction

104. Given the North and East coordinates of Point A (400, 100), and Point B (60, 470), what are the distance and bearing from A to B?

Bearing = $\tan^{-1}(340/370) = N 42^\circ 35' W$

Distance = $\sqrt{370^2 + 340^2} = 502.5'$



The next two questions are based on the information in the following table. The athletic department has decided to construct a tunnel from the basement of the new athletic building to the playing field in the football stadium. The distance and direction of the tunnel is needed for design purposes. Given the following traverse information, calculate the length and bearing for the tunnel from point basement to point field:

Side	Direction	Distance	N	S	E	W
Field - #1	N 65° 20' E	165.00	68.90		149.90	
#1 - #2	S 75° 15' E	110.90		28.00	106.40	
#2 - Basement	S 59° 15' W	270.00		138.00		232.00
Basement - Field	unknown	unknown	97.10			24.30

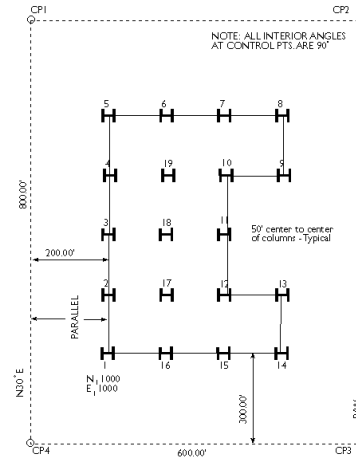
105. What is the bearing from basement to field?

Bearing = N 14° 03' E

106. What will the length of the tunnel be?

Length = 100.09'

Use the illustration of the building to determine answers for problems 107, 108, and 109:



107. The coordinates for the building corners and interior columns.

Point	Northing	Easting
1	1000.00	1000.00
2	1043.30	1025.00
3	1086.60	1050.00
4	1129.90	1075.00
5	1173.20	1100.00
6	1148.20	1143.30
7	1123.20	1186.60
8	1098.20	1229.90
9	1054.90	1204.90
10	1079.90	1161.60
11	1036.60	1136.60
12	993.30	1111.60
13	968.30	1154.90



14	925.00	1129.90
15	950.00	1086.60
16	975.00	1043.30
17	1018.30	1068.30
18	1061.60	1093.30
19	1104.90	1118.30

108. The coordinates of the control points.

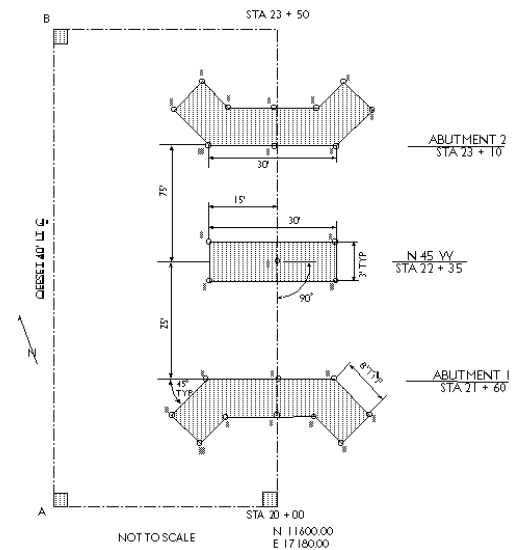
Point	Northing	Easting
CP1	1533.01	1076.79
CP2	1233.01	1596.41
CP3	540.19	1196.41
CP4	840.19	676.79

109. The layout data (angle right and distance) to each of the building points if an instrument is set on CP4 and backsighted with $00^{\circ} 00' 00''$ on CP1.

Instrument @ CP4		
B.S. CP1 w/ $00^{\circ} 00' 00''$		
Point	Angle Right	Distance
1	$33^{\circ} 41' 24''$	360.56
2	$29^{\circ} 44' 42''$	403.11
3	$26^{\circ} 33' 54''$	447.21
4	$23^{\circ} 57' 45''$	492.44
5	$21^{\circ} 48' 05''$	538.52
6	$26^{\circ} 33' 54''$	559.02
7	$30^{\circ} 57' 50''$	583.10
8	$34^{\circ} 59' 31''$	610.33
9	$37^{\circ} 52' 30''$	570.09
10	$33^{\circ} 41' 24''$	540.83
11	$36^{\circ} 52' 12''$	500.00
12	$40^{\circ} 36' 05''$	460.98
13	$45^{\circ} 00' 00''$	494.97
14	$49^{\circ} 23' 55''$	460.98
15	$45^{\circ} 00' 00''$	424.26
16	$39^{\circ} 48' 20''$	390.51
17	$35^{\circ} 32' 16''$	430.12
18	$32^{\circ} 00' 19''$	471.70
19	$29^{\circ} 03' 17''$	514.78



Use the illustration for the bridge to determine answers for 110, 111, and 112:



110. The coordinates for the corners on the abutments and the pier.

Abutment 1

Point	Northing	Easting
1	11723.74	17274.53
2	11723.74	17282.53
3	11713.14	17293.14
4	11702.53	17303.74
5	11694.53	17303.74
6	11694.53	17300.74
7	11701.29	17300.74
8	11711.02	17291.01
9	11720.74	17281.29
10	11720.74	17274.53

Center Pier

Point	Northing	Easting
1	11777.84	17336.62
2	11756.62	17357.84
3	11754.50	17355.72
4	11775.72	17334.50
5	11766.17	17346.17

Abutment 2

Point	Northing	Easting
1	11837.81	17388.60
2	11837.81	17391.60
3	11831.05	17391.60
4	11821.32	17401.32
5	11811.60	17411.05



6	11811.60	17417.81
7	11808.60	17417.81
8	11808.60	17409.81
9	11819.20	17399.20
10	11829.81	17388.60

111. The coordinates of the control points on centerline and the offset points A and B.

Point	Northing	Easting
STA.20+00	11600.00	17180.00
STA.23+50	11847.49	17427.49
A	11628.28	17151.72
B	11875.77	17399.20

112. The layout data (angle right and distance) to each of the bridge points if an instrument is set on Point A and backsighted with $00^{\circ} 00' 00''$ on Point B.

Instrument @ Point A
B.S. Point B w/ $00^{\circ} 00' 00''$

Abutment 1

Point	Angle Right	Distance
1	$7^{\circ} 08' 36''$	155.55
2	$8^{\circ} 52' 50''$	161.94
3	$14^{\circ} 02' 10''$	164.92
4	$18^{\circ} 58' 13''$	169.19
5	$21^{\circ} 27' 17''$	165.83
6	$21^{\circ} 02' 01''$	163.09
7	$18^{\circ} 54' 05''$	165.95
8	$14^{\circ} 17' 37''$	162.01
9	$9^{\circ} 29' 22''$	159.18
10	$8^{\circ} 01' 34''$	153.73

Center Pier

Point	Angle Right	Distance
1	$6^{\circ} 02' 03''$	237.82
2	$13^{\circ} 05' 31''$	242.81
3	$13^{\circ} 15' 15''$	239.89
4	$6^{\circ} 06' 40''$	234.83
5	$9^{\circ} 39' 36''$	238.38

Abutment 2

Point	Angle Right	Distance
1	$3^{\circ} 30' 24''$	316.25
2	$3^{\circ} 51' 51''$	318.50
3	$4^{\circ} 47' 33''$	314.10
4	$7^{\circ} 16' 58''$	315.54
5	$9^{\circ} 44' 44''$	317.58
6	$10^{\circ} 26' 13''$	323.12
7	$10^{\circ} 52' 39''$	321.43
8	$10^{\circ} 03' 38''$	314.84



9	7° 21' 09"	312.57
10	4° 36' 38"	311.01

Chapter 17 - Horizontal Curve

113. Calculate the missing curve parts in the following table.

Curve #	"I"	Radius	° of Curve	Tangent	Length	External	Middle Ordinate	Long Chord
1	18° 54'	357.25	16° 02' 17"	59.46	117.84	4.91	4.85	117.31
2	10° 51' 22"	2291.83	2° 30'	217.78	434.25	10.32	10.28	433.60
3	51° 16' 55"	250.00	22° 55' 06"	120.00	223.76	27.31	24.62	216.36
4				200.00				350.00
5	2° 55'	8857.65	0° 38' 49"	225.50	450.90	2.87	2.87	450.85

114. Given PI @ 9+87, "I" angle = 32°14', R = 800; compute tangent (T), the length of arc (L), and compute the stationing of the PC and PT.

$$T = R \cdot \tan(I/2) = 231.16$$

$$Da = 5729.58/R = 7.162^\circ = 7^\circ 09' 43''$$

$$L = 100 \cdot I/Da = 450.06$$

$$PC = PI - T = 9+87.00 - 231.16 = 7+55.84$$

$$PT = PC + L = 7+55.84 + 450.06 = 12+05.90$$

115. Given PI @ 12+73, "I" angle = 6° 19', Da = 7°, compute the stationing of the PC and PT.

$$R = 5729.58/Da = 818.51$$

$$T = R \cdot \tan(I/2) = 45.16$$

$$PC = PI - T = 1273 - 45.16 = 12+27.84$$

$$L = 100 \cdot I/Da = 90.24$$

$$PT = PC + L = 1227.83 + 90.24 = 1318.07$$

116. Given PI @ 15+55, "I" angle of 20°, R = 700, Compute the parts of the curve. T, L, LC, Da, E, MO, Stationing of the PC and PT.

117. Given PI @ 55+24.776, "I" angle = 13° 54', and R = 400 feet, compute the deflection at every half-station.

Solutions for parts of the curve:

T = 48.76	E = 2.96
L = 97.04	M.O. = 2.94
LC. = 96.80	PC = 54+76.02
Da = 14° 19' 26"	PT 55+73.056

Deflections

Station	Arc Length	Deflection Increment	Total Deflection	Short Chord	Long Chord
55+73.056	23.056	1° 39' 04"	6° 57' 00"	23.05	96.80
55+50	50	3° 34' 52"	5° 17' 56"	49.97	73.88
55+00	23.984	1° 43' 04"	1° 43' 04"	23.98	23.98
54+76.016	0	0	0	0	0



118. Given PI @ 11+52.42, "I" angle = $25^{\circ} 52' 12''$, R = 2978 feet, compute the deflection at every 100' station.

Parts of the curve:

<ul style="list-style-type: none"> • T = 683.97 • L = 1344.62 • LC = 1333.22 • Da = $1^{\circ} 55' 26''$ 	<ul style="list-style-type: none"> • E = 77.54 • MO = 75.57 • PC @ 108+45.454 • PT @ 121+90.074
---	---

Deflections, short chords, and Long chords:

	Station	Arc (ft)	Deflection Increment	Total Arc (ft)	Total Deflection	Short Chord (ft)	Long Chord (ft)
PT	121+90.074	90.074	$0^{\circ} 51' 59''$	1354.546	$12^{\circ} 56' 04''$	90.06	1333.17
	121+00	100	$0^{\circ} 57' 43''$	1254.546	$12^{\circ} 04' 05''$	99.99	1245.24
	120+00	100	$0^{\circ} 57' 43''$	1154.546	$11^{\circ} 06' 22''$	99.99	1147.28
	119+00	100	$0^{\circ} 57' 43''$	1054.546	$10^{\circ} 08' 39''$	99.99	1049.00
	118+00	100	$0^{\circ} 57' 43''$	954.546	$9^{\circ} 10' 56''$	99.99	950.43
	117+00	100	$0^{\circ} 57' 43''$	854.546	$8^{\circ} 13' 13''$	99.99	851.58
	116+00	100	$0^{\circ} 57' 43''$	754.546	$7^{\circ} 15' 30''$	99.99	752.50
	115+00	100	$0^{\circ} 57' 43''$	654.546	$6^{\circ} 17' 47''$	99.99	653.20
	114+00	100	$0^{\circ} 57' 43''$	554.546	$5^{\circ} 20' 04''$	99.99	553.72
	113+00	100	$0^{\circ} 57' 43''$	454.546	$4^{\circ} 22' 21''$	99.99	454.09
	112+00	100	$0^{\circ} 57' 43''$	354.546	$3^{\circ} 24' 38''$	99.99	354.32
	111+00	100	$0^{\circ} 57' 43''$	254.546	$2^{\circ} 26' 55''$	99.99	254.46
	110+00	100	$0^{\circ} 57' 43''$	154.546	$1^{\circ} 29' 12''$	99.99	154.52
	109+00	54.546	$0^{\circ} 31' 29''$	54.546	$0^{\circ} 31' 29''$	54.54	54.54
PT	108+45.454	0	0	0	0	0	0

119. Given Da = 2.000 degrees, L = 432.62', and PC 11+43.42, find the remaining components of the curve.

I = $8^{\circ} 39' 09''$ R = 2864.79 T = 216.72 LC = 432.21	E = 8.18 MO = 8.16 PI @ 13+60.14 PT @ 15+76.04
--	---

120. Two highway tangents intersect with a right deflection I angle of $31^{\circ} 15' 00''$ at PI sta. 22+22. A $3^{\circ} 30' 00''$ horizontal curve (Da) is to be used to connect the tangents. Compute R, T, L, E, LC, and MO for the curve. Compute in tabular form the deflection angles to layout the curve at half stations. Compute the short and long chords.

Parts of the curve:

R = 1637.02 T = 457.83 L = 892.86	E = 62.82 LC = 881.83 MO = 60.50
---	--

Deflection angles, short and long chords:

	Station	Deflection angle	Short chord	Long chord
PC	17+64.17	0	0	0
	18+00	$0^{\circ} 37' 37''$	35.83	35.83
	18+50	$1^{\circ} 30' 07''$	49.99	85.82
	19+00	$2^{\circ} 22' 39''$	49.99	135.79
	19+50	$3^{\circ} 15' 07''$	49.99	185.73
	20+00	$4^{\circ} 07' 37''$	49.99	235.63



	20+50	5° 00' 07"	49.99	285.47
	21+00	5° 52' 37"	49.99	335.24
	21+50	6° 45' 07"	49.99	384.94
	22+00	7° 37' 37"	49.99	434.54
	22+50	8° 30' 07"	49.99	484.05
	23+00	9° 22' 37"	49.99	533.44
	23+50	10° 15' 07"	49.99	582.71
	24+00	11° 07' 37"	49.99	631.84
	24+50	12° 00' 07"	49.99	680.82
	25+00	12° 52' 37"	49.99	729.65
	25+50	13° 45' 07"	49.99	778.31
	26+00	14° 37' 37"	49.99	826.78
	26+50	15° 30' 07"	49.99	875.06
PT	26+57.03	15° 37' 30"	7.03	881.83

121. If a simple circular curve has a length of curve 210', and the degree of curvature (Da) is known to be 21.000°, and the station of the PI is 125+79.62, what is the central angle of this curve?

$$L = 100 * (I/Da)$$

$$210 = 100 * (I/21)$$

$$I = 44.10000^\circ$$

$$I = 44^\circ 06' 00''$$

122. Two parallel highways 3000' apart are to be joined by a reverse curve made up of two circular curves of equal radius. These curves are to have a (Da) of 3°. Determine all parts of these curves.

Da = 3°	L = 2586.93
R = 2864.79	LC = 2393.65
I = 8° 39' 09"	E = 540.89
T = 1535.78	MO = 421.52

Chapter 18 - Vertical Curves

123. Compute the gradient for each tangent of a pipeline profile and the elevation of each full station on the tangents.

Point	Station	Curve Elevation
PVI - A	25+00	501.00
PVI - B	31+00	455.00
PVI - C	35+50	498.00
PVI - D	39+00	463.00
PVI - E	43+60	481.00

$$\text{Gradient}_{AB} = \frac{455.00 - 501.00}{3100 - 2500} = -7.667\%$$

$$\text{Gradient}_{BC} = \frac{498.00 - 455.00}{3550 - 3100} = +9.556\%$$

$$\text{Gradient}_{CD} = \frac{463.00 - 498.00}{3900 - 3550} = -10.000\%$$



$$\text{Gradient}_{DE} = \frac{481.00 - 463.00}{4360 - 3900} = +3.913\%$$

Gradient or Length	Point	Station	Gradient Elevation
-7.667%	PVI-1	25+00	501.00
		26+00	493.33
		27+00	485.67
		28+00	478.00
		29+00	470.33
9.556%	PVI-2	30+00	462.67
		31+00	455.00
		32+00	464.56
		33+00	474.11
		34+00	483.67
-10.000%	PVI-3	35+00	493.22
		35+50	498.00
		36+00	493.00
		37+00	483.00
		38+00	473.00
3.913%	PVI-4	39+00	463.00
		40+00	466.91
		41+00	470.83
		42+00	474.74
		43+00	478.65
		43+60	481.00

124. Determine the gradients between the points on the following highway profiles to three decimal places.

A.

PI	EL	Gradient
20+50	501.00	
		-0.909%
22+70	499.00	
		+2.414%
25+60	506.00	

B.

PI	EL	Gradient
51+00	818.00	
		-20.000%
52+30	792.00	
		+6.786%
55+10	811.00	
		+4.210%
57+00	819.00	



125. Given the following information, calculate the vertical curve and provide curve elevations.

Point	Station	Elevation	Length of Curve
PVI	10+00	611.32	
PVI	14+00	609.11	500'
PVI	21+00	611.58	500'
PVI	27+00	604.10	700'
PVI	32+52.57	617.302	

See the table on the following page for a summary of the results of the computations.



Gradient or Length	Point	Station	Gradient Elevation	y [y=r(x ²)]	Curve Elevation	
-0.553%	PVI-0	10+00	611.32			
		10+50	611.04			
		11+00	610.77			
500	BVC-1	11+50	610.49	0.0000	610.49	
		12+00	610.22	-0.0226	610.24	
		12+50	609.94	-0.0905	610.03	
		13+00	609.66	-0.2037	609.87	
		13+50	609.39	-0.3621	609.75	
0.353%	PVI-1	14+00	609.11	-0.5658	609.68	
		14+50	609.29	-0.3621	609.65	
		15+00	609.46	-0.2037	609.67	
		15+50	609.64	-0.0905	609.73	
		16+00	609.82	-0.0226	609.84	
		EVC-1	16+50	609.99	0.0000	609.99
		17+00	610.17			
		17+50	610.35			
500	BVC-2	18+00	610.52			
		18+50	610.70	0.0000	610.70	
		19+00	610.87	0.0400	610.83	
		19+50	611.05	0.1600	610.89	
		20+00	611.23	0.3599	610.87	
		20+50	611.40	0.6398	610.76	
-1.247%	PVI-2	21+00	611.58	0.9997	610.58	
		21+50	610.96	0.6398	610.32	
		22+00	610.33	0.3599	609.97	
		22+50	609.71	0.1600	609.55	
		23+00	609.09	0.0400	609.05	
		700 EVC-2/BVC-3	23+50	608.46	0.0000	608.46
		24+00	607.84	-0.0649	607.90	
		24+50	607.22	-0.2597	607.48	
		25+00	606.59	-0.5843	607.18	
2.389%	PVI-3	25+50	605.97	-1.0388	607.01	
		26+00	605.35	-1.6232	606.97	
		26+50	604.72	-2.3373	607.06	
		27+00	604.10	-3.1814	607.28	
		27+50	605.29	-2.3373	607.63	
		28+00	606.49	-1.6232	608.11	
		28+50	607.68	-1.0388	608.72	
		29+00	608.88	-0.5843	609.46	
		29+50	610.07	-0.2597	610.33	
		30+00	611.27	-0.0649	611.33	
		EVC-3	30+50	612.46	0.0000	612.46
PVI-4	32+52.57	31+00	613.66			
		31+50	614.85			
		32+00	616.05			
		32+50	617.24			
		32+52.57	617.302			



126. A +1.512% grade meets a -1.785% grade at station 31+50, elevation 562.00. Vertical curve = 700 feet.
Calculate all parts of the vertical curve at full stations.

Gradient or Length	Point	Station	Gradient Elevation	y [$y=r(x^2)$]	Curve Elevation
1.512%	BVC	28+00	556.71	0.0000	556.71
		29+00	558.22	0.2355	557.98
		30+00	559.73	0.9420	558.79
		31+00	561.24	2.1195	559.12
700	PVI	31+50	562.00	2.8849	559.12
		32+00	561.11	2.1195	558.99
		33+00	559.32	0.9420	558.38
		34+00	557.54	0.2355	557.30
-1.785%	EVC	35+00	555.75	0.0000	555.75

127. A -2.148% grade meets a +2.485% grade at station 21+50, elevation 435.00. Vertical curve = 800 feet.
Calculate all parts of the vertical curve at half station intervals.

Gradient or Length	Point	Station	Gradient Elevation	y [$y=r(x^2)$]	Curve Elevation
-2.148%	BVC	17+50	443.59	0.0000	443.59
		18+00	442.52	-0.0724	442.59
		18+50	441.44	-0.2896	441.73
		19+00	440.37	-0.6515	441.02
		19+50	439.30	-1.1583	440.45
		20+00	438.22	-1.8098	440.03
		20+50	437.15	-2.6061	439.75
		21+00	436.07	-3.5471	439.62
800	PVI	21+50	435.00	-4.6330	439.63
		22+00	436.24	-3.5471	439.79
		22+50	437.49	-2.6061	440.09
		23+00	438.73	-1.8098	440.54
		23+50	439.97	-1.1583	441.13
		24+00	441.21	-0.6515	441.86
		24+50	442.46	-0.2896	442.74
		25+00	443.70	-0.0724	443.77
2.485%	EVC	25+50	444.94	0.0000	444.94

128. A grade of -3.3% intersects a grade of -1.412% at station 70+00 whose elevation 512.85 feet and the distance back to the BVC is 500 feet and the distance to the EVC is 550 feet. Compute the elevations of the full stations on this unequal tangent vertical curve.

See the table on the following page.



Gradient or Length	Point	Station	Gradient Elevation	y [$y=r(x^2)$]	Curve Elevation
2.512%	BVC	15+50	417.69	0.0000	417.69
		16+00	418.95	0.0867	418.86
		17+00	421.46	0.7800	420.68
		18+00	423.97	2.1667	421.81
600	PVI	18+50	425.23	3.1200	422.11
		19+00	424.41	2.1667	422.24
		20+00	422.76	0.7800	421.98
		21+00	421.11	0.0867	421.02
-1.648%	EVC	21+50	420.29	0.0000	420.29

129. Given that $L = 400$ feet, $g_1 = -2.3\%$, $g_2 = +1.6\%$, PVI at $30+20$, and elevation = 425.23 , determine the location and elevation of the low point and elevations on the curve at even stations.

Gradient or Length	Point	Station	Gradient Elevation	y [$y=r(x^2)$]	Curve Elevation	
-2.300%	BVC	28+20	429.83	0.0000	429.83	
		29+00	427.99	-0.3120	428.30	
		30+00	425.69	-1.5795	427.27	
400	PVI	30+20	425.23	-1.9500	427.18	
		Low point	30+56	425.80	-1.3128	427.12
		31+00	426.51	-0.7020	427.21	
1.600%	EVC	32+00	428.11	-0.0195	428.13	
		32+20	428.43	0.0000	428.43	

130. Given the following vertical curve data: PVI at $21+00$, $L = 700$ feet, $g_1 = +1.6\%$, $g_2 = -1.0\%$, elevation of PVI = 722.12 feet, compute the elevations of the curve summit, and of even full stations.

Gradient or Length	Point	Station	Gradient Elevation	y [$y=r(x^2)$]	Curve Elevation	
1.600%	BVC	17+50	419.63	0.0000	419.63	
		18+00	420.43	0.0464	420.38	
		19+00	422.03	0.4179	421.61	
		20+00	423.63	1.1607	422.47	
700	PVI	21+00	425.23	2.2750	422.96	
		High point	21+81	424.42	1.3462	423.08
		22+00	424.23	1.1607	423.07	
		23+00	423.23	0.4179	422.81	
-1.000%	EVC	24+00	422.23	0.0464	422.18	
		24+50	421.73	0.0000	421.73	

131. Sketch a vertical curve and label all of its parts.

Reference page 18-12.



132. A +2.512% grade meets a -1.648% grade at station 18+50, elevation 445.00. Vertical curve = 600 feet.
Calculate all parts of the vertical curve at full stations.

Gradient or Length	Point	Station	Gradient Elevation	y [$y=r(x^2)$]	Curve Elevation
2.512%	BVC	15+50	417.69	0.0000	417.69
		16+00	418.95	0.0867	418.86
		17+00	421.46	0.7800	420.68
		18+00	423.97	2.1667	421.81
600	PVI	18+50	425.23	3.1200	422.11
		19+00	424.41	2.1667	422.24
	High point	19+12	424.20	1.9586	422.24
		20+00	422.76	0.7800	421.98
		21+00	421.11	0.0867	421.02
-1.648%	EVC	21+50	420.29	0.0000	420.29

133. A -3.667% grade meets a +1.732% grade at station 45+00, elevation 312.00. Vertical curve = 700 feet.
Calculate all parts of the vertical curve at half stations. Calculate the station and elevation of the low point of the curve.

Gradient or Length	Point	Station	Gradient Elevation	y [$y=r(x^2)$]	Curve Elevation
-3.667%	BVC	41+50	324.83	0.0000	324.83
		42+00	323.00	-0.0964	323.10
		43+00	319.33	-0.8677	320.20
		44+00	315.67	-2.4103	318.08
700	PVI	45+00	312.00	-4.7241	316.72
		46+00	313.73	-2.4103	316.14
	Low point	46+25	314.17	-1.9447	316.12
		47+00	315.46	-0.8677	316.33
		48+00	317.20	-0.0964	317.29
1.732%	EVC	48+50	318.06	0.0000	318.06

134. A -1.153% grade meets a -2.432% grade at station 12+00, elevation 452.00. Vertical curve = 500 feet.
Calculate all parts of the vertical curve at full stations. What are the station and elevation of the summit of the curve?

Gradient or Length	Point	Station	Gradient Elevation	y [$y=r(x^2)$]	Curve Elevation
-1.153%	BVC	9+50	314.88	0.0000	314.88
	High point	4+99	320.08	2.5985	317.48
		10+00	314.31	0.0320	314.27
		11+00	313.15	0.2878	312.87
500	PVI	12+00	312.00	0.7994	311.20
		13+00	309.57	0.2878	309.28
		14+00	307.14	0.0320	307.10
	-2.432%	EVC	14+50	305.92	0.0000



135. A +5.32% grade meets a -1.432% grade at station 63+00, elevation 345.00. Vertical curve = 900 feet.
Calculate all parts of the vertical curve at full stations. Calculate the high point station and elevation.

Gradient or Length	Point	Station	Gradient Elevation	y [y=r(x ²)]	Curve Elevation	
5.230%	BVC	58+50	321.47	0.0000	321.47	
		59+00	324.08	0.0925	323.99	
		60+00	329.31	0.8328	328.48	
		61+00	334.54	2.3132	332.23	
		62+00	339.77	4.5339	335.24	
900	PVI	63+00	345.00	7.4948	337.51	
		64+00	343.57	4.5339	339.03	
		65+00	342.14	2.3132	339.82	
		High point	65+57	341.33	1.3851	339.94
			66+00	340.70	0.8328	339.87
			67+00	339.27	0.0925	339.18
		EVC	67+50	338.56	0.0000	338.56

Chapter 19 - Excavations

136. For the road area shown, calculate the volume that was excavated between 32+00 and 35+00.

$$\begin{aligned}
 \textcircled{1} \quad & \text{STA. 32+00} \quad \text{AREA} = 332.5 \text{ ft}^2 \\
 & \text{STA. 32+21} \quad \text{AREA} = 303.7 \text{ ft}^2 \\
 & \text{Volume} = \left(\frac{21}{27}\right) * \left(\frac{332.5 + 303.7}{2}\right) = 247.411 \text{ CY} \\
 \textcircled{2} \quad & \text{Volume} = \left(\frac{79}{27}\right) * \left(\frac{303.7 + 357.1}{2}\right) = 966.726 \text{ CY} \\
 \textcircled{3} \quad & \text{Volume} = \left(\frac{100}{27}\right) * \left(\frac{357.1 + 457.0}{2}\right) = 1507.593 \text{ CY} \\
 \textcircled{4} \quad & \text{Volume} = \left(\frac{100}{27}\right) * \left(\frac{457.0 + 357.0}{2}\right) = 1507.407 \text{ CY} \\
 & \text{TOTAL VOLUME FROM 32+00 TO 35+00} = 4229.137 \text{ CY}
 \end{aligned}$$

137. If station 22+00 has an end area of 245 square feet and station 23+00 has an end area of 334 square feet, what is the volume between the stations in cubic yards?

$$\text{Volume} = (100\text{ft}) * \frac{(245 + 334) \text{ft}^2}{2} * \frac{\text{CY}}{27\text{CF}} = 1072 \text{ CY}$$

138.

Chapter 20 - Distance Meas. Applications

138. You have been assigned to pace a length across an open field. Along a given 600 feet distance, you pace 165, 164, 162, and 166 paces, respectively. Upon determining your pace length, you pace 205, 208, 206, 208, 206, and 207 paces, in walking an unknown distance AB. What is the length of AB?

① @600 ft.

# Paces	165	164	162	166
Distance/pace	3.64	3.66	3.70	3.61



Average distance/foot = 3.65ft/pace = Pace length
 ② Unknown distance AB = Average # paces for AB * Pace length
 Average # of paces = (205 + 208 + 206 + 208 + 206 + 207)/6 = 207.17
 Distance AB = 207.17*3.65 = 756.2 ft.

140. Pick any survey point and reference it to four points. Prepare field notes for this activity.

Chapter 21 - Angles and Direction Applications

141. List two instances where bucking in on-line would be needed by the field engineer.

Building floor lines, on top of hill.

142. List five construction layout activities that require “double centering.”

Prolonging line, any building points.

Chapter 22 - Leveling Applications

143. Typically, rod readings taken during the process of profile leveling, or cross-sectioning, need to be read to the nearest_____.

tenth

144. Complete the accompanying set of profile leveling notes and perform an arithmetic check for the following problem. **Plot the profile.**

Point	BS	HI	IS	FS	Elevation
BM 67	10.33	214.89			204.56
TP 1	9.55	220.55		3.89	211.00
TP2	7.63	225.08		3.10	217.45
0+00			2.60		222.48
0+50			2.50		222.58
1+00			0.20		222.88
TP 3	5.98	228.21		2.85	224.88
1+50			1.50		222.23
2+00			1.42		226.79
2+50			0.04		228.17
BM 68				2.47	225.74

Arithmetic Check:

Starting elevation + SBS - SFS = Ending elevation
204.56 + 33.49 - 12.31 = 225.74

145. Complete the accompanying set of profile leveling notes and perform the arithmetic check for the following problem. **Plot the profile.**

Point	BS	HI	IS	FS	Elevation
BM 101	10.65	218.97			208.32
TP 1	9.47	224.12		4.32	214.65
TP 2	7.36	227.63		3.85	220.27
0+00			2.50		225.13
0+50			2.10		225.53
1+00			0.50		227.13



1+50			1.60		226.03
TP 3	5.40	230.18		2.85	224.78
2+00			1.30		228.88
2+14.23			1.72		228.46
2+50			0.90		229.28
BM 102				2.54	227.64

Arithmetic Check

Starting elevation + SBS - SFS = Ending elevation
208.32 + 32.88 - 13.56 = 227.64

146. Complete the accompanying set of cross section leveling notes and perform the arithmetic check for the following problem.

Point	BS	HI	IS	FS	Elevation
BM 21	4.25	575.93			571.68
TP3	6.22	575.48		6.67	569.26
6+00					
50 FT LEFT			3.10		572.38
25 FT LEFT			3.50		571.98
10 FT LEFT			3.20		572.28
CL			2.90		572.58
10 FT RIGHT			2.91		572.57
25 FT RIGHT			2.70		572.78
50 FT RIGHT			2.40		573.08
TP4	6.23	576.30		5.41	570.07
BM 22				7.11	569.19

Arithmetic Check:

Starting elevation + SBS - SFS = Ending elevation
 $571.68 + 16.7 - 19.19 = 569.19$

147. Complete the following borrow pit leveling notes. The borrow pit grid is 50'. Plot the grid and the points and draw 1' contours.

Point	BS	HI	IS	FS	Elevation
BM 45	4.56	624.56			620.00
A-1				5.70	618.86
A-2				7.30	617.26
A-3				9.50	615.06
A-4				8.20	616.36
B-1				4.30	620.26
B-2				8.00	616.56
B-3				8.10	616.46
B-4				7.50	617.06
C-1				2.70	621.86
C-2				7.50	617.06
C-3				7.40	617.16
C-4				5.70	618.86



D-1				1.10	623.46
D-2				7.30	617.26
D-3				6.30	618.26
D-4				4.00	620.56
BM 45			4.56		620.00

Chapter 23 - Construction Layout

148. Develop a layout plan for a “T” shaped house. Use random dimensions.

Recommend drawing on 8 1/2 by 11

149. Develop a layout plan for a Strip Mall that is 1000’ by 70’.

Recommend drawing on 8 1/2 by 11

150. Develop a layout plan for the layout of 10 small (30’ by 30’ or smaller) buildings on the same site.

Recommend drawing on 8 1/2 by 11

151. If the dimensions of a building are 57’ 4 3/4” by 34’ 7 1/2”, what is the length of the diagonal?

$$\text{Diagonal} = \sqrt{(57'-4.75'')^2 + (34'-7.5'')^2} = \mathbf{70.83c = 70c-9\ 7/8''}$$

152. A building has sides of 40’ and 78’. What is the diagonal?

$$\text{Diagonal} = \sqrt{40^2 + 78^2} = \mathbf{87.66c = 87c-7\ 7/8''}$$

153. Determine the minimum amount of lumber needed to build “portable” batterboards.

7 - 2x4 x 4’

5 - 2x4 x 3’

2 - 2x4 x 5 c

Chapter 24 - Building Control and Layout

154. Distinguish between primary, secondary, and working control.

Reference page 24-9

155. Outline the process involved in establishing primary control on a building site.

Reference page 24-5.

156. Using any available set of plans, develop the location of primary control and secondary control.

Recommend using a set of plans for a small commercial building.

157. List ten construction activities in laying out a manufacturing plant that would need working control.

Field layout of: anchor bolts, interior walls, equipment pads, stairways, doors, hallways, closets, . . .

Chapter 25 - One Person Surveying Techniques

158. Develop a system for a field engineer working alone to measure the dimensions of a 40’ by 50’ building to lay out the corners.

See Chapter 25



159. Develop a procedure for a field engineer working alone to set and mark elevations on the inside of wall forms.

See Chapter 25