

## Chapter 2 Solutions

2-1. Precision =  $0.27/4826.55 = 1/17,876$

2-2. Precision =  $0.38/6432.81 = 1/16,928$

2-3. A probable error or 50% error is the magnitude of an error for which there is a 50% chance that a particular measurement contains an error of lesser magnitude and a 50% chance that it contains a larger one.

2-4. When a single quantity is measured several times or when a series of quantities is measured, random errors will tend to accumulate in proportion to the square root of the number of measurements. This is referred to as the Law of Compensation.

2-5.

| Measured Values | Residual v | $v^2$                   |
|-----------------|------------|-------------------------|
| 3.462           | 0.0008     | 0.000001                |
| 3.467           | 0.0058     | 0.000034                |
| 3.465           | 0.0038     | 0.000014                |
| 3.458           | -0.0032    | 0.000010                |
| 3.463           | 0.0018     | 0.000003                |
| 3.457           | -0.0042    | 0.000018                |
| 3.468           | 0.0068     | 0.000046                |
| 3.452           | -0.0092    | 0.000085                |
| 3.464           | 0.0028     | 0.000008                |
| 3.456           | -0.0052    | 0.000027                |
| Avg = 3.4612    |            | $\Sigma v^2 = 0.000246$ |

a. Most probable value of the measured quantity

$$\text{Mean} = 3.461$$

b. Probable error of a single measurement.

$$E_{50} = \pm 0.6745 \cdot (0.000246 / (10-1))^{(1/2)} = \pm 0.0035 \text{ ft}$$

c. 90% error.

$$E_{90} = \pm 1.6449 \cdot (0.000246 / (10-1))^{(1/2)} = \pm 0.0086 \text{ ft}$$

d. 95% error.

$$E_{95} = \pm 1.9599 \cdot (0.000246 / (10-1))^{(1/2)} = \pm 0.0102 \text{ ft}$$

2-6.

| Measured Values      | Residual v | v <sup>2</sup>                  |
|----------------------|------------|---------------------------------|
| 154.70               | 0.052      | 0.002756                        |
| 154.67               | 0.022      | 0.000506                        |
| 154.68               | 0.032      | 0.001056                        |
| 154.69               | 0.042      | 0.001806                        |
| 154.62               | -0.028     | 0.000756                        |
| 154.66               | 0.012      | 0.000156                        |
| 154.60               | -0.048     | 0.002256                        |
| 154.74               | 0.093      | 0.008556                        |
| 154.55               | -0.097     | 0.009506                        |
| 154.58               | -0.067     | 0.004556                        |
| 154.65               | 0.002      | 0.000006                        |
| 154.63               | -0.018     | 0.000306                        |
| <b>Avg = 154.648</b> |            | <b>Σ v<sup>2</sup> = 0.0322</b> |

- Most probable value of the measured quantity  
 Mean = 154.65
- Probable error of a single measurement.  
 $E_{50} = \pm 0.6745 * (0.0322 / (12-1))^{(1/2)} = \pm 0.04 \text{ ft}$
- 90% error.  
 $E_{90} = \pm 1.6449 * (0.0322 / (12-1))^{(1/2)} = \pm 0.09 \text{ ft}$
- 95% error.  
 $E_{95} = \pm 1.9599 * (0.0322 / (12-1))^{(1/2)} = \pm 0.11 \text{ ft}$

2-7.

- Most Probable Error =  $(0.6745)(\pm 0.21) = \pm 0.14 \text{ ft}$
- Error @  $2\sigma = (2.00)(\pm 0.21) = \pm 0.42 \text{ ft}$   
 Estimated Precision =  $0.42 / 916.45 = 1/2182$
- Error @  $3\sigma = (3.00)(\pm 0.21) = \pm 0.63 \text{ ft}$   
 Estimated Precision =  $0.63 / 916.45 = 1/1454$

2-8.

| Measured Values       | Residual v | v <sup>2</sup>                   |
|-----------------------|------------|----------------------------------|
| 736.352               | -0.0072    | 0.000052                         |
| 736.363               | 0.0038     | 0.000014                         |
| 736.375               | 0.0158     | 0.000250                         |
| 736.324               | -0.0352    | 0.001239                         |
| 736.358               | -0.0012    | 0.000001                         |
| 736.383               | 0.0238     | 0.000566                         |
| <b>Avg = 736.3592</b> |            | <b>Σ v<sup>2</sup> = 0.00212</b> |

- Most probable value of the measured quantity  
 Mean = 736.359 ft
- Standard Deviation =  $\pm (0.004 / (6-1))^{1/2} = \pm 0.0206 \text{ ft}$
- Error @  $3.29\sigma = (\pm 0.028 \text{ ft})(3.29) = \pm 0.0678 \text{ ft}$

2-9.

| Measured Values      | Residual v | v <sup>2</sup>                    |
|----------------------|------------|-----------------------------------|
| 201.658              | -0.019     | 0.000342                          |
| 201.642              | -0.035     | 0.001190                          |
| 201.660              | -0.017     | 0.000272                          |
| 201.732              | 0.055      | 0.003080                          |
| 201.649              | -0.028     | 0.000756                          |
| 201.661              | -0.016     | 0.000240                          |
| 201.730              | 0.053      | 0.002862                          |
| 201.680              | 0.004      | 0.000012                          |
| <b>Avg = 201.677</b> |            | <b>Σ v<sup>2</sup> = 0.008756</b> |

a. Most probable value of the measured quantity

$$\text{Mean} = \underline{201.677 \text{ ft}}$$

b. Standard Deviation =  $\pm(0.008756/(8-1))^{1/2} = \underline{\pm 0.035 \text{ ft}}$

c. Error @  $3.29\sigma = (\pm 0.035 \text{ ft})(3.29) = \underline{\pm 0.115 \text{ ft}}$

2-10.

| Measured Values     | Residual v | v <sup>2</sup>                  |
|---------------------|------------|---------------------------------|
| 155.35              | -0.09      | 0.0074                          |
| 155.42              | -0.02      | 0.0003                          |
| 155.30              | -0.14      | 0.0186                          |
| 155.58              | 0.14       | 0.0207                          |
| 155.47              | 0.03       | 0.0011                          |
| 155.32              | -0.12      | 0.0135                          |
| 155.61              | 0.17       | 0.0302                          |
| 155.44              | 0.00       | 0.0000                          |
| <b>Avg = 155.44</b> |            | <b>Σ v<sup>2</sup> = 0.0918</b> |

a. Most probable value of the measured quantity

$$\text{Mean} = \underline{155.44 \text{ ft}}$$

b. Standard Deviation =  $\pm(0.0918/(8-1))^{1/2} = \underline{\pm 0.11 \text{ ft}}$

c. Error @  $3.29\sigma = (\pm 0.11 \text{ ft})(3.29) = \underline{\pm 0.36 \text{ ft}}$

2-11.

| Measured Values     | Residual v | v <sup>2</sup>                  |
|---------------------|------------|---------------------------------|
| 613.27              | -0.04      | 0.0012                          |
| 613.24              | -0.07      | 0.0042                          |
| 613.34              | 0.03       | 0.0012                          |
| 613.29              | -0.02      | 0.0002                          |
| 613.43              | 0.12       | 0.0156                          |
| 613.22              | -0.09      | 0.0072                          |
| 613.39              | 0.08       | 0.0072                          |
| 613.40              | 0.09       | 0.0090                          |
| 613.26              | -0.05      | 0.0020                          |
| 613.21              | -0.10      | 0.0090                          |
| <b>Avg = 613.31</b> |            | <b>Σ v<sup>2</sup> = 0.0570</b> |

a. Most probable value of the measured quantity

$$\text{Mean} = \underline{613.31 \text{ ft}}$$

b. Standard Deviation =  $\pm(0.0570/(12-1))^{1/2} = \underline{\pm 0.07 \text{ ft}}$

c. Error @  $3.29\sigma = (\pm 0.07 \text{ ft})(3.29) = \underline{\pm 0.23 \text{ ft}}$

2-12.  $E_{\text{total}} = \pm 0.008(32)^{1/2} = \underline{\pm 0.045 \text{ ft}}$

2-13. a)  $E_{\text{total}} = \pm 0.007(24)^{1/2} = \underline{\pm 0.034 \text{ ft}}$

b)  $E_{\text{total}} = \pm 0.004(24)^{1/2} = \underline{\pm 0.020 \text{ ft}}$

2-14.  $E_{\text{total}} = \pm 0.020(15.2744)^{1/2} = \underline{\pm 0.0781 \text{ ft}}$

$$E_{\text{total}} = \pm 0.020(18.1237)^{1/2} = \underline{\pm 0.0851 \text{ ft}}$$

$$E \text{ for both sides} = [(0.0781)^2 + (0.0851)^2]^{1/2} = \underline{0.116 \text{ ft}}$$

2-15.  $E_{\text{total}} = \pm 0.004(25)^{1/2} = \underline{\pm 0.020 \text{ ft}}$

2-16.  $n = \# \text{ of tape lengths} = 1500/30 = 50$

$$E_{\text{total}} = \pm 0.003(50)^{1/2} = \underline{\pm 0.0212 \text{ m}}$$

2-17.  $\text{Area} = (158.46)(212.71) = 33,706.03 \text{ sq ft}$

$$E_{\text{product}} = \pm [(158.46)^2(0.04)^2 + (212.71)^2(0.03)^2]^{1/2} = 8.99 \text{ sq ft}$$

Say 9 sq ft

2-18. a)  $n=22$  tape lengths

$$\pm E (22)^{1/2} = \pm 0.20$$

$$E = \underline{\pm 0.04 \text{ ft / tape length}}$$

b)  $n=40$  tape lengths

$$\pm E_{95} (40)^{1/2} = \pm 0.24$$

$$E = \pm 0.0379 = 1.9599 \cdot \sigma = 1.9599 \cdot E_{\text{standard}}$$

$$E_{\text{standard}} = \underline{\pm 0.0194 \text{ ft}} \quad \text{Say } \underline{\pm 0.02 \text{ ft}}$$

2-19.  $E_{\text{series}} = \pm E \cdot n^{1/2}$

$$\pm 1' = \pm E \cdot 9^{1/2}$$

$$E = \underline{\pm (1/3)' = 20''}$$

## Chapter 3 Solutions

3-1.

- Pacing (convenient for estimating distances and for checking distances measured by other methods—very inaccurate.)
- Odometers (convenient for measuring on smooth surfaces such as pavements and for initial route location surveys—quite inaccurate.)
- Stadia (convenient for locating details for maps and for estimating other distances—poor accuracy.)
- Subtense bar (convenient for measuring across rough terrain and for relatively short distances under about 500 ft. Has been made obsolete by the far more accurate and quickly used EDMs.)
- Taping (convenient and quite accurate for short distances up to a few hundred feet but tedious and slow compared to EDMs. May have to make quite a few corrections as for temperature, slope sag, pull, etc.)
- Electronic distance measuring instruments (EDMs) (quick and accurate for short and long distances. May have to make corrections for humidity and slopes.)

3-2.

- Pacing (estimating distances as for lots and checking distances made by more precise means.)
- Odometer (measurements of amounts of paving for roads and parking lots. Initial location surveys and quick checks on other measurements.)
- Stadia (locating details for maps, making rough surveys and for checking more precise surveys.)
- Taping (short distances, accurate work.)
- EDMs (quick, accurate, long or short distances, difficult terrain.)

3-3. Avg. # of paces =  $(95+93+97+98+92) / 5 = \underline{95 \text{ paces}}$

Avg. pace =  $250 / 95 = \underline{2.632 \text{ ft}}$

Avg. # of paces for unknown dist. =  $(115+118+116+117) / 4 = \underline{116.5 \text{ paces}}$

Dist. Paced =  $(116.5 \text{ paces})(2.632 \text{ ft / pace}) = 306.63 \text{ say } \underline{307 \text{ ft}}$

3-4. Avg. # of paces =  $(140+143+141+142) / 4 = \underline{141.5 \text{ paces}}$

Avg. pace =  $400 / 141.5 = \underline{2.827 \text{ ft}}$

# of paces req'd. for 525 ft =  $525 / 2.827 = 185.7 \text{ say } \underline{186 \text{ paces}}$

3-5. a)  $(632.18 \text{ m})(3.280840 \text{ ft / m}) = 2074.08 \text{ ft}$

b)  $(895.49 \text{ m})(3.280840 \text{ ft / m}) = 2937.96 \text{ ft}$

c)  $(1254.3 \text{ m})(3.280840 \text{ ft / m}) = 4115.16 \text{ ft}$

3-6. a)  $24^\circ 19' 12'' = 24^\circ 19' + 12''/60 = 24^\circ 19.2' = 24^\circ + 19.2'/60 = \underline{24.32^\circ}$

b)  $59^\circ 44' 37'' = 59^\circ 44' + 37''/60 = 59^\circ 44.616666' = 59^\circ + 44.616666'/60 = \underline{59.7436^\circ}$

c)  $123^\circ 10' 09'' = 123^\circ 10' + 9''/60 = 123^\circ 10.15' = 123^\circ + 10.15'/60 = \underline{123.1692^\circ}$

3-7. a)  $99.4871^\circ = 99^\circ + (0.4871)(60') = 99^\circ 29.226' = 99^\circ 29' + (0.226)(60'') = \underline{99^\circ 29' 13.6''}$

b)  $51.9534^\circ = 51^\circ + (0.9534)(60') = 51^\circ 57.204' = 51^\circ 57' + (0.204)(60'') = \underline{51^\circ 57' 12.2''}$

c)  $148.6736^\circ = 148^\circ + (0.6736)(60') = 148^\circ 40.416' = 148^\circ 40' + (0.416)(60'') = \underline{148^\circ 40' 25''}$

3-8. Avg. angle reading on the subtense bar =  

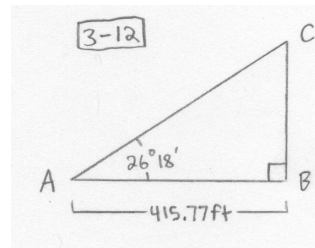
$$\frac{0^{\circ}44'20'' + 0^{\circ}44'18'' + 0^{\circ}44'21'' + 0^{\circ}44'19''}{4}$$
 Avg. =  $0^{\circ}44'20''$   
 Horizontal length of line =  $\cot \alpha / 2 = \cot(0^{\circ}44'20'' / 2) = \cot(0^{\circ}44.333333' / 2)$   
 $= \cot(0.73888888^{\circ} / 2) = \underline{155.08 \text{ m}}$

3-9. Distance =  $83.00 - 0.48 = \underline{82.52 \text{ ft}}$

3-10. Cross-sectional area of tape  
 $= (1/40)(5/16) = 0.0078125 \text{ sq. in.}$   
 Volume of tape in cubic ft.  
 $= (0.0078125 / 144)(100) = 0.0054253472222 \text{ ft}^3$   
 Wt. of tape =  $(0.0054253472222)(490) = \underline{2.66 \text{ lb}}$

3-11. Cross-sectional area of tape  
 $= (0.030)(3/8) = 0.01125 \text{ sq. in.}$   
 Volume of tape in cubic ft.  
 $= (0.01125 / 144)(100) = 0.0078125 \text{ ft}^3$   
 Wt. of tape =  $(0.0078125)(490) = \underline{3.83 \text{ lb}}$

3-12. Changing angle A to decimal form  
 $= 26^{\circ} + (18/60)^{\circ} = 26.3^{\circ}$   
 $\cos(26.3^{\circ}) = 415.77 \text{ ft} / L_{AC}$   
 $L_{AC} = 415.77 / 0.896486430 = \underline{463.78 \text{ ft}}$   
 $L_{BC} = [(463.78)^2 - (415.77)^2]^{1/2} = \underline{205.49 \text{ ft}}$



3-13.  $\sin A = 126.42 / 82.83 = 0.655196963$   
 Angle A =  $\underline{40^{\circ}56.075'}$

