CONSTRUCTION SURVEYING AND PROJECT LAYOUT

Trigonometry Functions
This section is concerned with the ability to establish distances and elevations from established points, setup an instrument, layout the project, and interpret site information. Jack Roberts surveying book (1995) provides numerous examples on project layout, math and trigonometry. The three basic relationships in trigonometry, the sine, cosine, and tangent arise from the right triangle. The angles of the right triangle are related by trigonometry, and the sides of the right triangle are related by the Pythagorean theorem. For a right triangle the sides are related by:

\[ a^2 + b^2 = c^2 \]

Also, a right triangle has a standard relationship of 3 (a): 4 (b) : 5 (c). This allows you to determine the length of the third of a right triangle if you are given two side lengths. The trigonometry relationships are given by:

\[ \text{SIN angle A} = \frac{\text{opposite side} = a}{\text{hypotenuse} = c} \]

\[ \text{COS angle A} = \frac{\text{adjacent side} = b}{\text{hypotenuse} = c} \]

\[ \text{TAN angle A} = \frac{\text{opposite side} = a}{\text{adjacent side} = b} \]

How to Find the Length of One Side of a Right Triangle Given Other Side & One Angle
A sidewalk 4 feet wide and 58 feet long must be laid out. The 58 foot long side (hypotenuse c) of the sidewalk intersects a street at an angle of 26 degrees (A). Find the length of side (b) street.

Select the formula which will give the length of side b, given the angle A and the length of the hypotenuse. The formula is \( c \times \text{COS A} \) will work. This means that you should multiple the length of c (58 feet) by the cosine \( \text{COS (26 degrees)} \) of angle A. The value for the \( \text{COS 26 degrees} \) from a Trigonometric Function Table is \( .89879 \). Now multiply 58 feet by \( .89879 \) which results in the length of side \( b \) of the right triangle being 52.13 feet.

Using the information for the sidewalk given above. You want to calculate the length of side a which is perpendicular to the street. The formula is \( c \times \text{SIN A} \). This means that you should multiple the length of c (58 feet) by the sine \( \text{SIN (26 degrees)} \) of angle A. The value for the \( \text{SIN 26 degrees} \) from a Trigonometric Function Table is \( .43837 \). Now Multiply 58 feet by \( .43837 \) which results in the length of side \( a \) of the right triangle being 25.43 feet.
Elevations and Surveying Calculations
Surveys are usually done in the horizontal plane and they are keyed to a reference elevation. This reference elevation is referred to as the “datum elevation. These points on the survey are noted as being either at or a certain distance above or below the datum plane. The most common datum plane used is “mean sea level” or “MSL”. The mean is given the elevation of 0'- 0". The federal and state government have determined the elevations of various inland points throughout the country in relationship to the elevation of 0'- 0". These points are called Benchmarks.

Job Benchmark Elevation = 100.00 feet.
Top of Footing (TOF) = 98.0 feet

<table>
<thead>
<tr>
<th>BM</th>
<th>Benchmark.</th>
<th>HI</th>
<th>Height of the Instrument.</th>
</tr>
</thead>
<tbody>
<tr>
<td>IP</td>
<td>Intermediate Point.</td>
<td>TP</td>
<td>Turning Point.</td>
</tr>
<tr>
<td>BS</td>
<td>Back sight.</td>
<td>FS</td>
<td>Foresight.</td>
</tr>
<tr>
<td>BOF</td>
<td>Bottom of Footing.</td>
<td>FF</td>
<td>Finish Floor.</td>
</tr>
</tbody>
</table>

Below are the Field Notes from a leveling operation.

<table>
<thead>
<tr>
<th>IP</th>
<th>BM El.</th>
<th>BS Rod Reading</th>
<th>HI</th>
<th>FS Rod Reading</th>
<th>TP EL</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>843.29'</td>
<td>4.68'</td>
<td>847.97'</td>
<td>5.91'</td>
<td>842.06</td>
</tr>
<tr>
<td>#2</td>
<td>842.06'</td>
<td>3.17'</td>
<td>845.23'</td>
<td>3.94'</td>
<td>841.29</td>
</tr>
<tr>
<td>#3</td>
<td>841.29'</td>
<td>5.05'</td>
<td>846.34'</td>
<td>4.72'</td>
<td>841.62</td>
</tr>
<tr>
<td>Math Check = -1.67'</td>
<td>12.90'</td>
<td>minus</td>
<td>14.57'</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TP El. =</td>
<td>841.62</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BM El. =</td>
<td>843.29'</td>
<td></td>
<td></td>
<td></td>
<td>-1.67'</td>
</tr>
</tbody>
</table>

Jack Roberts (1995) states that the primary “principle to remember is to add the back sight and subtract the foresight”(p 85). This is expressed as

benchmark elevation + back sight - foresight = TP elevation
and also as benchmark + back sight = HI elevation.
Surveying and Layout Exercise

1. You are required to establish grade to the bottom of a footing (BOF) that is 1 foot thick. The elevation at the top of the footing (TOF) is 102.33'. The elevation of the existing grade 106.14'. The backsight (BS) of the instrument on the benchmark (BM) of 100.00' is 6.78'. What is the correct reading of the rod at the bottom of the footing?
   - A. 0.64
   - B. 3.81
   - C. 4.45
   - D. 5.45

2. Given a rectangular structure that is 60' - 9" long by 42' - 6" wide. What is the diagonal measurement in feet and inches for squaring up the structure during layout?
   - A. 51' - 71/2"
   - B. 74' - 13/4"
   - C. 74' - 37/8"
   - D. 103' - 3"

3. Using a right triangle, at the intersection point the slope distance or the hypotenuse is 310 feet long at a slope angle of 20 degrees 00' 00". What is the actual horizontal distance in feet?
   - A. 106.02
   - B. 112.84
   - C. 291.09
   - D. 851.73

4. What is the percentage grade for a slope ratio of 1:13 (rise:run)?
   - A. 0.077
   - B. 1.000
   - C. 7.690
   - D. 13.000
Surveying and Layout Exercise

5. A rod reading of 4.72' is taken on a BM whose elevation is 813.30. The finish floor (FF) is 809.00. The top of the batter board is set one foot above the Finish Floor. What rod reading is required to set the line for the top of the batter board?

- A. 4.30
- B. 5.30
- C. 8.02
- D. 9.02

6. We want to mark the grade points at elevation 668.00 for a ceiling grid systems using a rotating Lazer. When the inverted rod reading is placed on a BM with an elevation of 655.50 the receiver indicates a reading of 5.05 feet. At what reading on the inverted rod will the receiver be placed so that the ceiling grid will be at the correct elevation?

- A. 5.50
- B. 7.45
- C. 12.50
- D. 17.55

7. Using a right triangle, at the intersection point the slope distance or the hypotenuse is 240 feet long at a slope angle of 33 degrees 00' 00". What is the actual height distance?

- A. 130.70'
- B. 155.81'
- C. 201.29'
- D. 369.58'

8. What are the length ratios for a right triangle?

- A. 3:3:3
- B. 3:3:5
- C. 3:4:5
- D. 3:6:9
Surveying and Layout Exercise

9. Assume you have a right triangle which is 36 feet high and perpendicular from the baseline. What are the baseline distance and the diagonal distance?

   ○ A. The baseline is 24 feet, the diagonal is 48 feet.
   ○ B. The baseline is 27 feet, the diagonal is 45 feet.
   ○ C. The baseline is 36 feet, the diagonal is 72 feet.
   ○ D. The baseline is 48 feet, the diagonal is 60 feet.

10. The jobsite has a primary vertical control point with a reference (BM) of 100 feet. An instrument is set up with an HI of 5.42 above the BM. A grade stake is set at an elevation of 96.00'. What is the height reading on the rod for setting the receiver at?

   ○ A. 1.42'
   ○ B. 4.00'
   ○ C. 5.42'
   ○ D. 9.42'

11. Assume that you are looking at the cross section of a concrete lined dike which is 20 feet wide at the bottom and the sides are set at a 70 degree angle from the bottom (horizontal) of the dike, the depth of the water flow is 12 feet and the length of the dike is 166 feet. Using the cross sectional view, how many lineal feet of wetted cross section is there?

   ○ A. 32.97
   ○ B. 45.54
   ○ C. 85.94
   ○ D. 104.64

12. Assume that you have a concrete lined dike which is 20 feet wide at the bottom and the sides are sloped at a 70 degree angle from the bottom (horizontal) of the dike. Also, the depth of the water flow is 12 feet. Using the cross sectional view, how many square feet are in the wetted cross-sectional flow?

   ○ A. 52.32
   ○ B. 104.64
   ○ C. 292.32
   ○ D. 344.64
Surveying and Layout Exercise

13. What does the surveying abbreviation of TP mean?
   - A. Tangent Point.
   - B. Turning Point.
   - C. Traverse Point.
   - D. Terminal Point.

14. Which of the following situations would be most advantageous for using an inverted rod?
   - A. Verifying a highway grid layout.
   - B. Verifying a building footing layout.
   - C. Verifying the elevation of a piece of equipment.
   - D. Verifying the elevation of ceiling mounted duct work.

15. The federal and state governments have established elevations of various inland points throughout the country. What elevation are these points in relationship to?
   - A. 0' - 0"
   - B. 10' - 0"
   - C. 100' - 0"
   - D. 200' - 0"

Given the Back Sight and Fore Sight readings as follows.

<table>
<thead>
<tr>
<th>IP</th>
<th>BM EL</th>
<th>BS Rod Reading</th>
<th>HI</th>
<th>FS Rod Reading</th>
<th>TP EL</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>877.26</td>
<td>7.45</td>
<td>3.10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>#2</td>
<td>7.12</td>
<td>1.10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>#3</td>
<td>4.44</td>
<td>2.17</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

16. What is the Benchmark elevation at IP #4?
   - A. 864.62
   - B. 889.90
   - C. 896.27
   - D. 902.64