Measuring Elevation

- Elevation refers to the height above or below a fixed geographic reference point.
- In most cases, we measure elevation from the Earth’s sea level as our reference point, but in some cases the ground level is used as the reference point.

Measuring Elevation

- Elevation plays a crucial part in everyday life.
- In engineering, elevation is used to determine the center of gravity and the type of materials to be used.
- The elevation of a particular place can also help predict and prevent disasters such as flooding.

Mississippi River at flood stage ~ 217 ft. above sea level

Mississippi River at flood stage ~ 227 ft. above sea level

Mississippi River at flood stage ~ 237 ft. above sea level

- Humans adapt to their environment, as some are adapted to higher elevations while others are adapted to lower elevations.
- A majority of the world’s population lives in coastal regions with elevations of 500 feet or less.
- The people of Tibet in Central Asia are adapted to living at 17,500 ft. where crops cannot grow and the oxygen is extremely thin.
Measuring Elevation

- Elevation refers to the height above or below a fixed geographic reference point.
- In most cases, we use the Earth’s sea level as our reference point, but in some cases the ground level is used as the reference point.
- One method for measuring elevation is to use differential leveling.

Differential Leveling

Importance of Vertical Positions

- A vertical position is the height of a point relative to some reference surface, such as mean sea level, a geoid, or an ellipsoid.
- The roughly 600,000 vertical control points in the U.S. National Spatial Reference System (NSRS) are referenced to the North American Vertical Datum of 1988 (NAVD 88).

Differential Leveling

Importance of Leveling

- The determination of elevations is called leveling.
- Measuring relative elevations changes is a comparatively simply process.
- Precise and accurate control of relative elevations are critical to most construction projects.

Differential Leveling

The Level

- A level consists of a high-powered telescope.
- The level is attached to a spirit or bubble level that keeps the line of sight of the telescope horizontal.

Differential Leveling

Level Instrument
Differential Leveling

Level Instrument

Red numbers indicate foot intervals

Differential Leveling

Definitions

Bench mark (BM) - relatively permanent point of known elevation

Backsight (BS) - a sight taken to the level rod held at a point of known elevation (either a BM or TP)

Differential Leveling

Definitions

Point A

Starting point (elevation 100.00 ft)

Point B

BS = 6.32 ft
HI = 106.32 ft
FS = 3.10 ft

Elevation = 103.22 ft

Delta E = BS - FS

Differential Leveling

Definitions

Point A

Starting point (elevation 100.00 ft)

Point B

BS = 6.32 ft
HI = 106.32 ft
FS = 3.10 ft

Elevation = 103.22 ft

Delta E = BS - FS

Differential Leveling

Definitions

Point A

Starting point (elevation 100.00 ft)

Point B

BS = 6.32 ft
HI = 106.32 ft
FS = 3.10 ft

Elevation = 103.22 ft

Delta E = BS - FS
Differential Leveling

Definitions

*Height of instrument (HI)* - the elevation of the line of sight of the telescope

**Starting point (elevation 100.00 ft)**

**Point A**

**Point B**

**BS = 6.32 ft**

**HI = 106.32 ft**

**FS = 3.10 ft**

**Elevation = 103.22 ft**

---

Differential Leveling

Definitions

*Foresight (FS)* - a sight taken on any point to determine its elevation

**Starting point (elevation 100.00 ft)**

**Point A**

**Point B**

**BS = 6.32 ft**

**HI = 106.32 ft**

**FS = 3.10 ft**

**Elevation = 103.22 ft**

---

Differential Leveling

**Computation of Elevations – Find Elevation of BM₂**

<table>
<thead>
<tr>
<th>Point</th>
<th>BS</th>
<th>HI</th>
<th>FS</th>
<th>Elevation</th>
</tr>
</thead>
<tbody>
<tr>
<td>BM₁</td>
<td>12.64</td>
<td>112.64</td>
<td>100.00</td>
<td></td>
</tr>
</tbody>
</table>

**BM₂**

**TP₁**

**BM₁**

**TP₁**

**BS**

**10.88**

**112.64**

**120.41**

**109.53**

---

Differential Leveling

**Computation of Elevations – Find Elevation of BM₂**

<table>
<thead>
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<tbody>
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<td>12.64</td>
<td>112.64</td>
<td>100.00</td>
<td></td>
</tr>
</tbody>
</table>

**TP₁**

**BS**

**2.56**

**109.53**

**117.65**
Differential Leveling

### Computation of Elevations – Find Elevation of BM₂

<table>
<thead>
<tr>
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<th>Elevation</th>
</tr>
</thead>
<tbody>
<tr>
<td>BM₁</td>
<td>12.64</td>
<td>112.64</td>
<td>100.00</td>
<td></td>
</tr>
<tr>
<td>TP₁</td>
<td>10.88</td>
<td>120.41</td>
<td>3.11</td>
<td>109.53</td>
</tr>
<tr>
<td>TP₂</td>
<td>9.72</td>
<td>127.57</td>
<td>2.56</td>
<td>117.85</td>
</tr>
<tr>
<td>BM₂</td>
<td></td>
<td></td>
<td>3.10</td>
<td>124.47</td>
</tr>
</tbody>
</table>

### Differential Leveling

Check the summation of the backsight and the foresight with the change in elevation

\[ \text{Change in elevation} = +33.24 - 8.77 = 24.47 \]

### Differential Leveling

The initial **backsight (BS)** is taken to a point of known elevation

The backsight reading is added to the elevation of the known point to compute the **height of the instrument (HI)**

The level may be moved to a temporary point called a **turning point (TP)**

The elevation of a point is the **height of the instrument (HI)** minus the **foresight (FS)**

### TopHat Problems

[Diagram of TopHat Problem]
Computation of Elevations - Group Problem 1

Prepare a set of level notes for the survey illustrated below. What are the elevations of points TP_1 and TP_2?

<table>
<thead>
<tr>
<th>Point</th>
<th>BS</th>
<th>HI</th>
<th>FS</th>
<th>Elevation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.27</td>
<td></td>
<td>4.91</td>
<td>356.68</td>
</tr>
<tr>
<td></td>
<td>2.33</td>
<td></td>
<td>6.17</td>
<td></td>
</tr>
</tbody>
</table>

Computation of Elevations - Group Problem 2

Prepare a set of level notes for the survey illustrated below. What are the elevations of points TP_1 and TP_2?

<table>
<thead>
<tr>
<th>Point</th>
<th>BS</th>
<th>HI</th>
<th>FS</th>
<th>Elevation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6.46</td>
<td></td>
<td>3.11</td>
<td>110.42</td>
</tr>
<tr>
<td></td>
<td>8.78</td>
<td></td>
<td>3.06</td>
<td></td>
</tr>
</tbody>
</table>

Common Mistakes

- Misreading the rod - reading 3.54 instead of 3.45
- Moving the turning point - use a well-defined TP
- Field note mistakes - work within your group to check your records
- Mistakes with extended rod - make sure the leveling rod is fully extended
Differential Leveling

Suggestions for Good Leveling

- Anchor tripod legs firmly
- Check the bubble level before and after each reading
- Take as little time as possible between BS and FS
- Try to keep the distance to the BS and the FS equal
- Provide the rodperson with a level for the rod

Any Questions?