# STRUCTURE OF SURVEYING INSTRUMENTS

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# LEVELLING

- **What is Levelling?**
  - Use of Levelling
  - Levelling Terminology
- **Types of Levelling**
  - Geometric Levelling
  - Trigonometric Levellig
  - Precise Levelling

# LEVELLING

- **Errors in Levelling**
  - Collimation Error
  - Earth Curvature Error
  - Refraction Error
- **Testing and Adjustment of a Level**
  - Determining Collimation Error

# What is Levelling?

**Levelling**, is the process of measuring, by direct or indirect methods, vertical distances in order to determine elevations.

**Figure 1 :** Levelling Rod and Instrument

**Figure 2 :** Levelling Process

# Uses of Levelling

In the context of measurements, levelling is used for the following purposes:

- **Referencing of Points:** To determine and check the vertical stability of the points with respect to reference points (benchmarks) in its immediate vicinity.
- **Connection to GPS Reference Points:** To determine its regional stability and to separate sea level rise from vertical crustal motion, the point should be connected via GPS to reference stations fixed in a global co-ordinate system.
- **Connection to National Levelling Network:** Mean sea level is used to define vertical datums for national surveying and mapping , hence the point must be connected to the national levelling network. Connection to the network will also allow all points to be connected to each other, providing information on spatial variations in mean sea level.

# Levelling Terminology

**Geoid;** is a surface coinciding with mean sea level in the oceans, and lying under the land.

**Level surface;** is a curved surface that at every point is perpendicular to the plumb line.

**Level line;** is a line in a level surface, therefore a curved line.

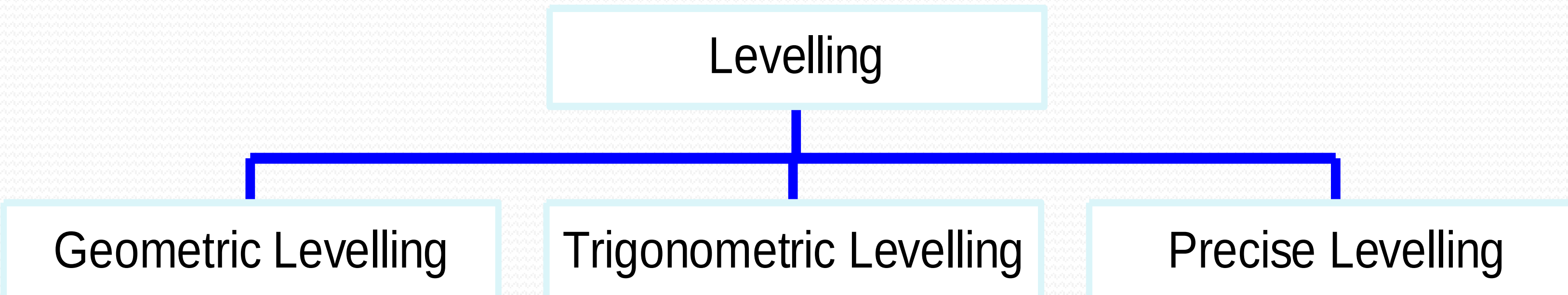
**Mean Sea Level (MSL):** is the average height of the sea's surface for all stages of the tide over a 19 year period.

**Datum:** is a level surface to which elevations are referred (for instance mean sea level).

**Elevation** is the vertical distance from a datum (usually mean sealevel) to a point or object.

**Bench Mark (BM)** is a relatively permanent object, natural or artificial, having a marked point whose elevations above or below an adopted datum is known or assumed (metal disks set in concrete, large rocks, non movable parts of fire hydrants, and curbs.

# Types of Levelling



# Types of Levelling

- Geometric Levelling : In geometric levelling the difference of height between two points is determined by differences of readings to the levelling rod placed on those points. The readings are made with a levelling instrument.

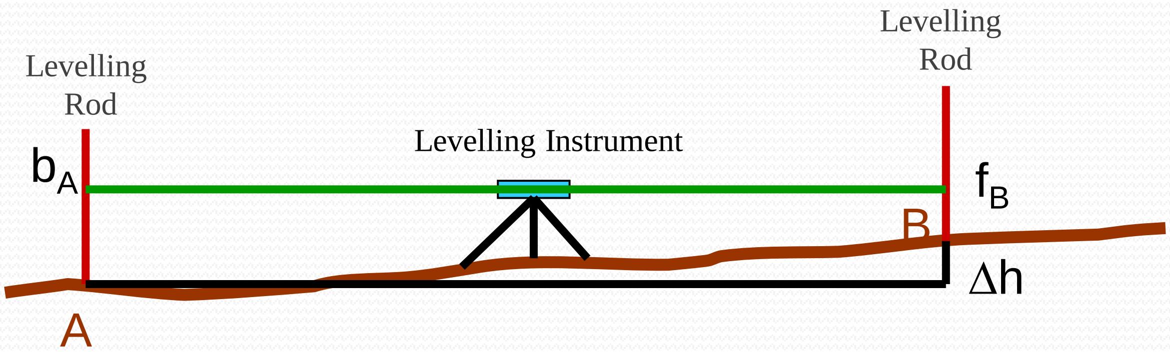



**Figure 3 :** Geometric Levelling

$$\Delta h_{AB} = b_A - f_B$$
$$\Delta H_B = H_A + \Delta h_{AB}$$

# Types of Levelling

- Trigonometric Levelling : The difference in elevation between two points is determined by measuring distance (slope or horizontal) and vertical angle.

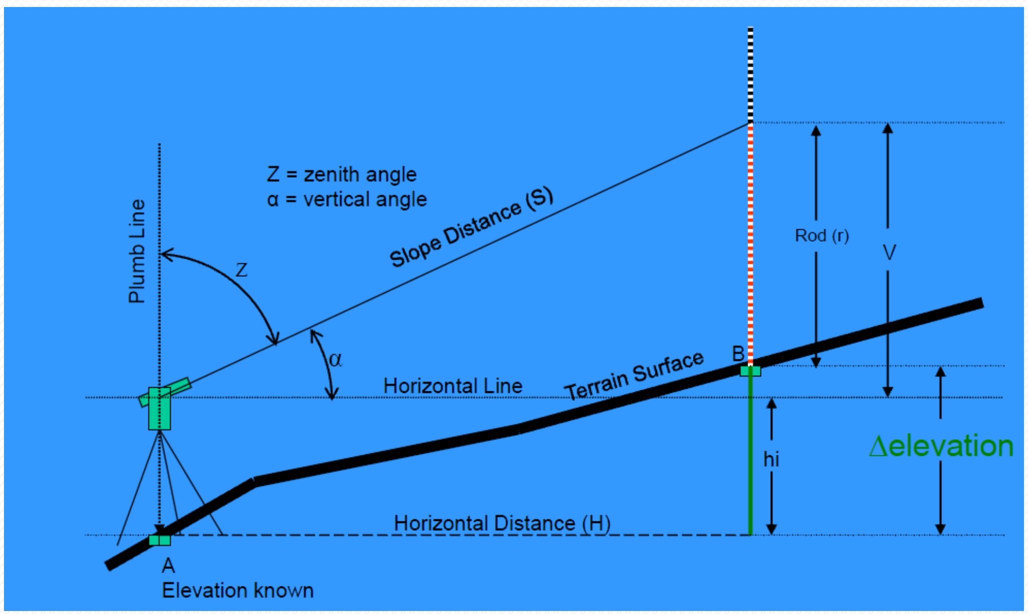



**Figure 4 :** Trigonometric Levelling

$V = S \times \sin \alpha$ or $V = H \times \cot z$

$\Delta elevation + r = hi + V$

$\Delta elevation = hi + V - r$

$H_B = H_A + hi + V - r$

# Types of Levelling

- Precise Levelling : is a particularly accurate method of geometric levelling which uses highly accurate levels and with a more rigorous observing procedure than general engineering levelling.

  In precise levelling we aim to achieve high orders of accuracy such as 1 mm per 1 km traverse.

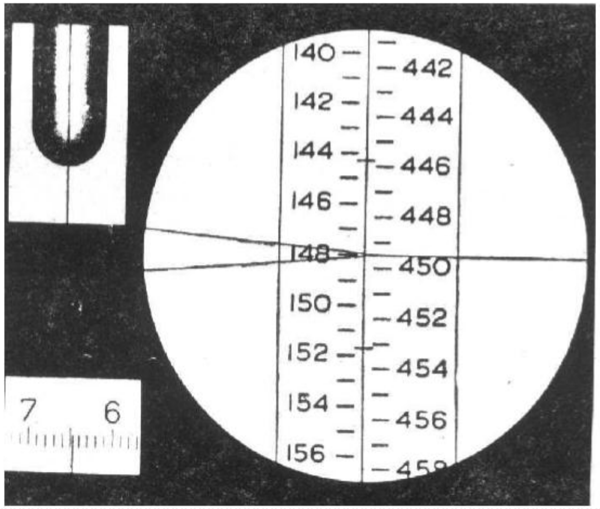



**Figure 5:** Invar rod reading (1.48647)

# Errors in Levelling

- Collimation Error: Collimation error occurs when the collimation axis is not truly horizontal when the instrument is level.

  The effect is illustrated in the sketch below, where the collimation axis is tilted with respect to the horizontal by an angle α:

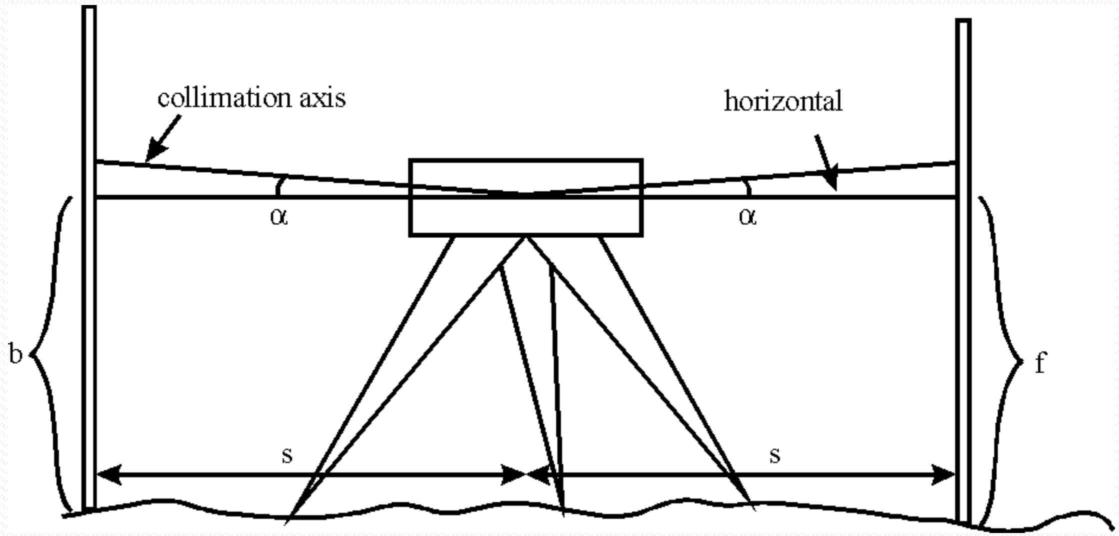
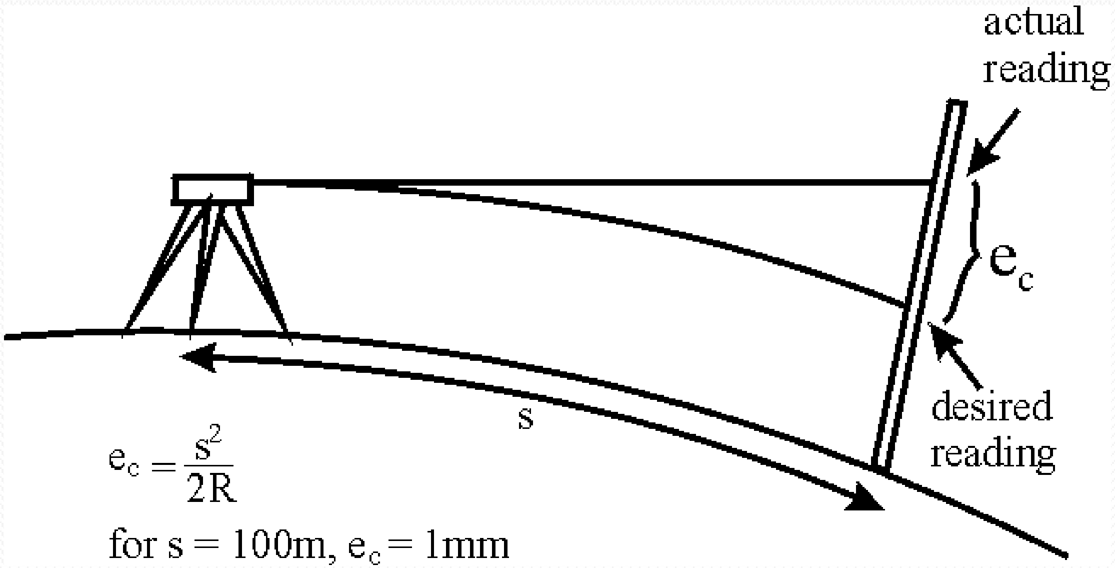



**Figure6:** Collimation Error

# Errors in Levelling

Earth Curvature: Due to the curvature of the Earth, the line of sight at the instrument will deviate from a horizontal line as one moves away from the level.




$$e_c = \frac{s^2}{2R}$$

**Figure 7:** Earth Curvature

# Errors in Levelling

Refraction: The variable density of the Earth's atmosphere causes a bending of the ray from the staff to the level.

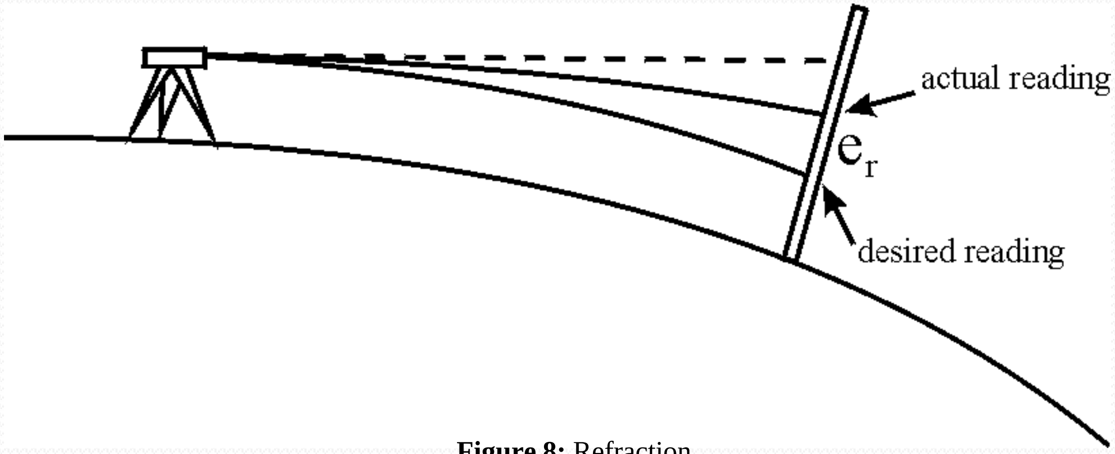



Figure 8: Refraction

$$e_r = \frac{1-k}{2R}.s^2$$

# Testing and Adjustment of a Level

- Determining Collimation Error:

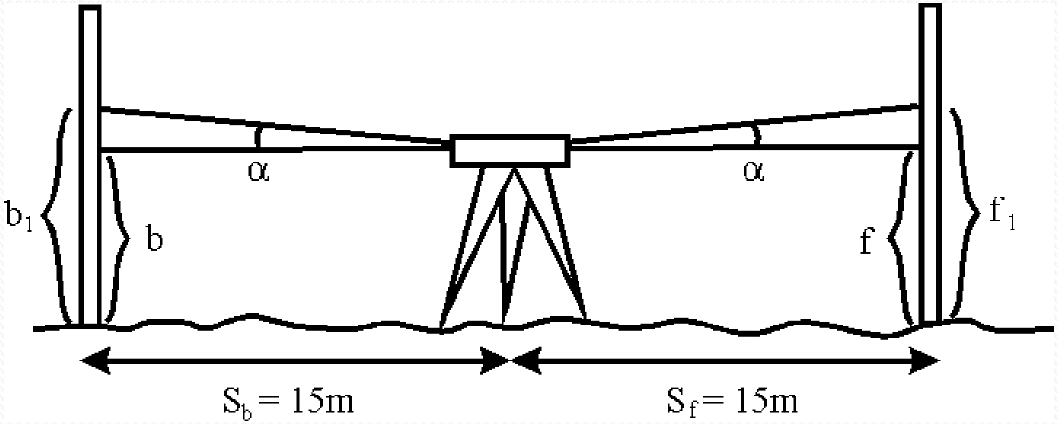
Collimation error is much more significant than the other errors. It should be kept as small as possible so that one need not be too precise in ensuring that fore and back sights are of equal length.

It is possible to determine the collimation error and reduce its size using *Two-peg test.*

There are three steps involved in this procedure:

# Testing and Adjustment of a Level

**1.** Set out and mark on the ground two point some 30m apart. Set up the the level exactly mid-way between them:




$$dh_1 = b_1 - f_1 = (b + s_b.\alpha) - (f + s_f.\alpha)$$
$$= b - f + \alpha.(s_b - s_f)$$
$$= b - f$$

**(because $s_b = s_f$ )**

**Figure 9 :** Determining Collimation Error – Step 1

# Testing and Adjustment of a Level

**2.** Next, move the level to a position just beyond the fore staff position (about 5m):

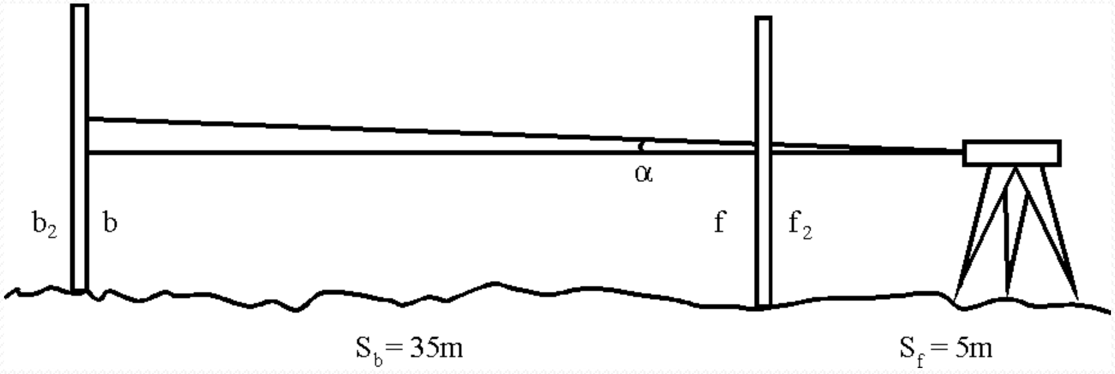



**Figure 10 :** Determining Collimation Error – Step 2

Then repeat the readings. In this case, $s_b$ = 35m and $s_f$ = 5m. Then:

$$dh_2 = b_2 - f_2 = (b + s_b.\alpha) - (f + s_f.\alpha)$$
$$= b - f + \alpha.(s_b - s_f)$$
$$\neq b - f \quad \textbf{(because } s_b \neq s_f\textbf{)}$$

# Testing and Adjustment of a Level

**3.** The difference $dh_2$ - $dh_1$ can be used to calculate what the true back sight reading would be for the second setup, if collimation error were not present:

$$b = b_2 - \frac{s_b - s_f}{s_b}.(dh_2 - dh_1) = b_2 - \frac{30}{35}.(dh_2 - dh_1)$$

The purpose of the adjustment is to reduce the size of this error. If the discrepancy $dh_2$ - $dh_1$ can be reduced to around 2mm this is perfectly adequate, provided sight lengths are there after kept reasonably similar.

# Testing and Adjustment of a Level

**1.** Set out and mark on the ground two point some 30m apart. Set up the the level to a position just beyond the fore staff position (about 5m):

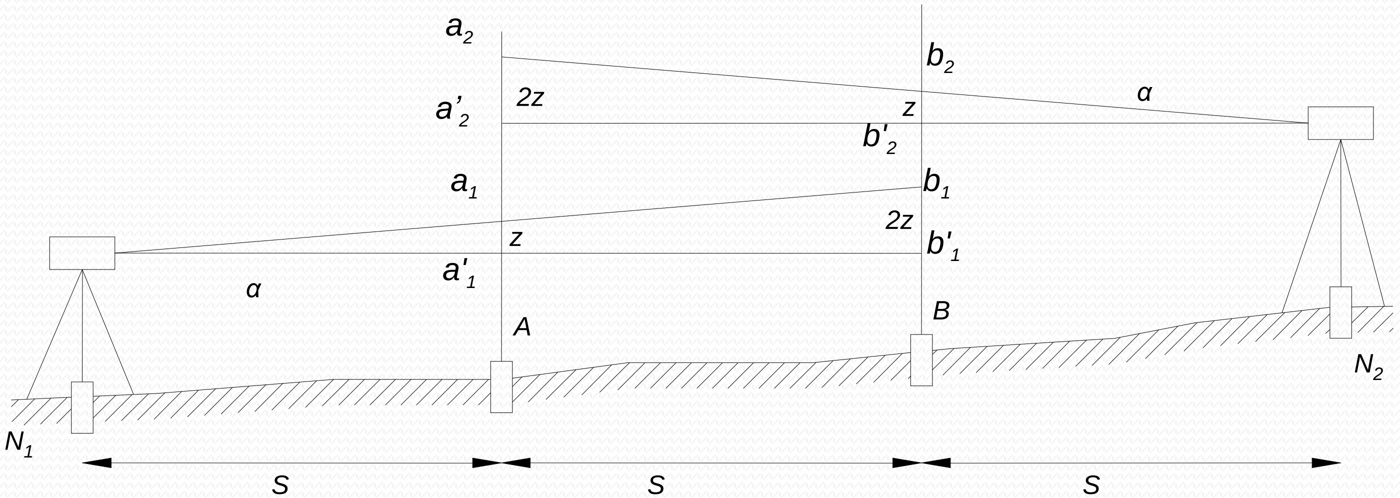



**Figure11:** Determining Collimation Error

Observe and read values ($a_2$, $a'_2$,$a_1$, $a'_1$ and ,$b_2$, $b'_2$,$b_1$, $b'_1$).

# Testing and Adjustment of a Level

**2.** The difference between A and B:

$$\Lambda h_{A,B} = a'_1 - b'_1 = (a_1 - z) - (b_1 - 2z)$$

$$\Lambda h_{A,B} = a'_2 - b'_2 = a_2 - (b'_2 - 2z)$$

$$a'_2 = (a_1 - b_1) + b_2$$