# GEE 4812:
# Principles of Geomatics

# Linear Measurements


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- Taping
- Optical Distance Measurements
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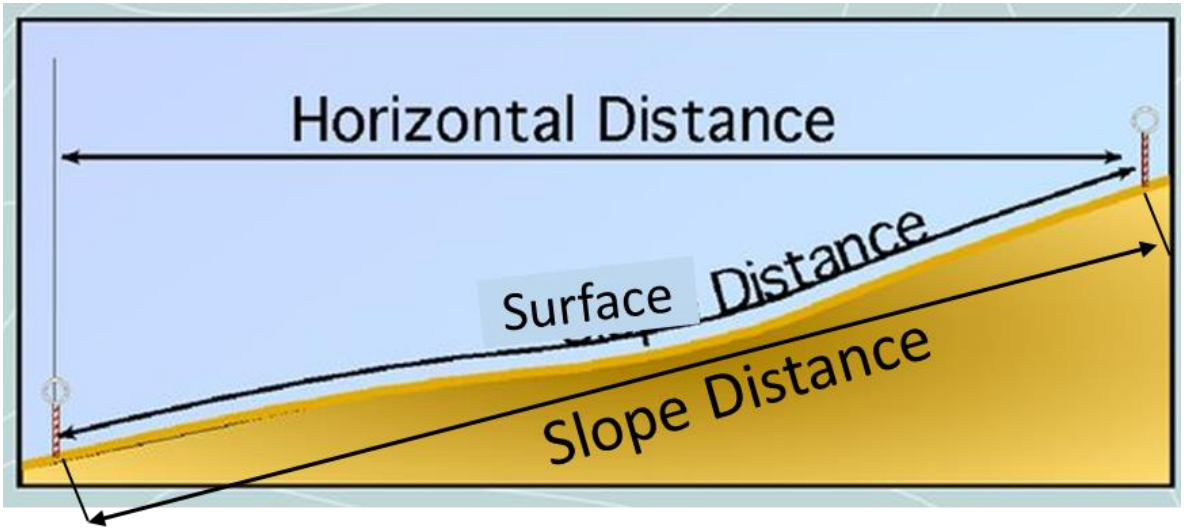
# Linear Measurements

- Linear distance is the straight line distance between 2 points regardless of orientation.
- The measurement of distance is one of the fundamental operations in surveying and is carried out by taping, optical Distance Measurement (ODM) or Electromagnetic Distance Measurement (EDM) techniques.
- Whichever of these is used, the usual requirement in Geomatics is for horizontal distances.

# Surface vs Horizontal Distance

- Surface distance between two points is a distance measured along the surface of the earth.
- Horizontal distance between two points is the distance between those points measured on a horizontal plane.
- Slope distance is the straight line distance along the slope between two points.



# Taping

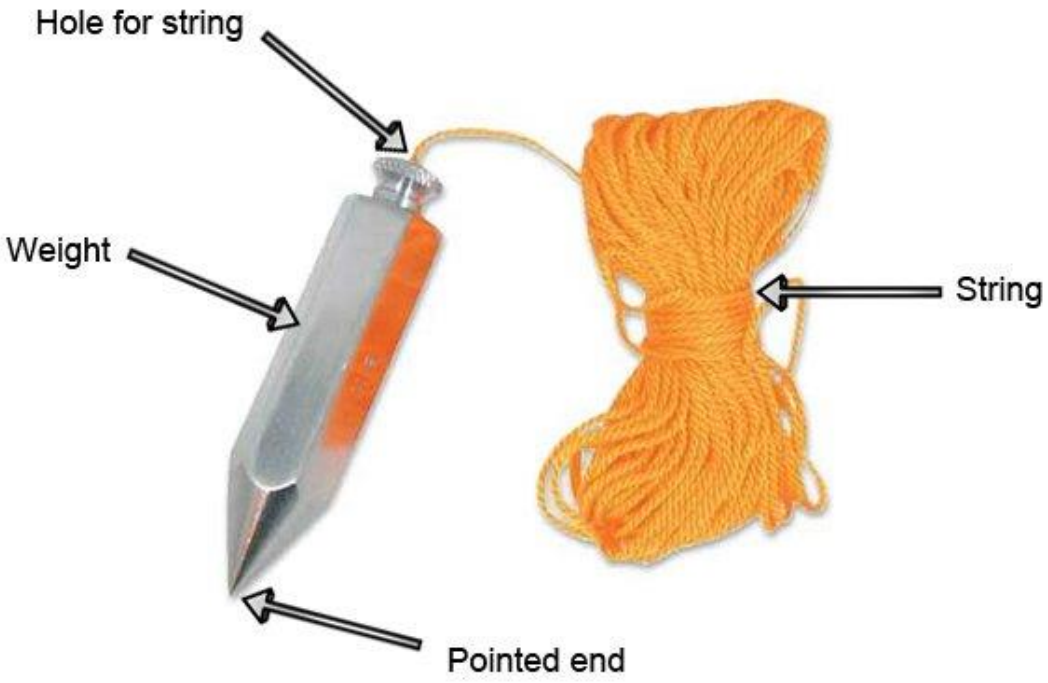

https://theconstructor.org/surveying/types-tapes-used-surveying/34973/

# Taping

- Taping involves measuring distance by use of tapes.
- There are a number of types of tapes in use with different sizes ranging from 20m, 30m, 50m or 100m.
- The most common types of tapes are steel, invar, glass fiber and synthetic material.
- Taping comes with errors that are systematic in nature due to the atmospheric conditions and the conditions under which tape is being used.

# Taping Accessories: Plum Bob

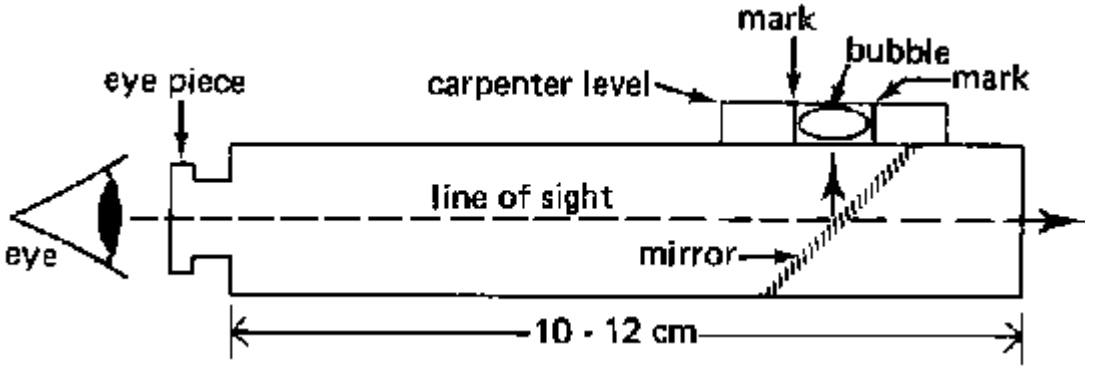
- Made of brass, used in taping to transfer the tape to ground.





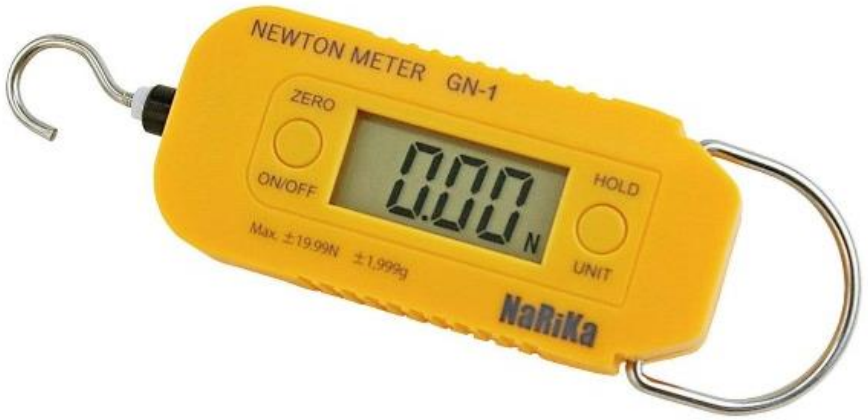
# Taping Accessories: Hand Level

- Used to keep the steel tape horizontal when measuring.

# Taping Accessories: Tension Handle

- Used to hold the tape correctly and with the right tension.
- As tapes have a standard tension.

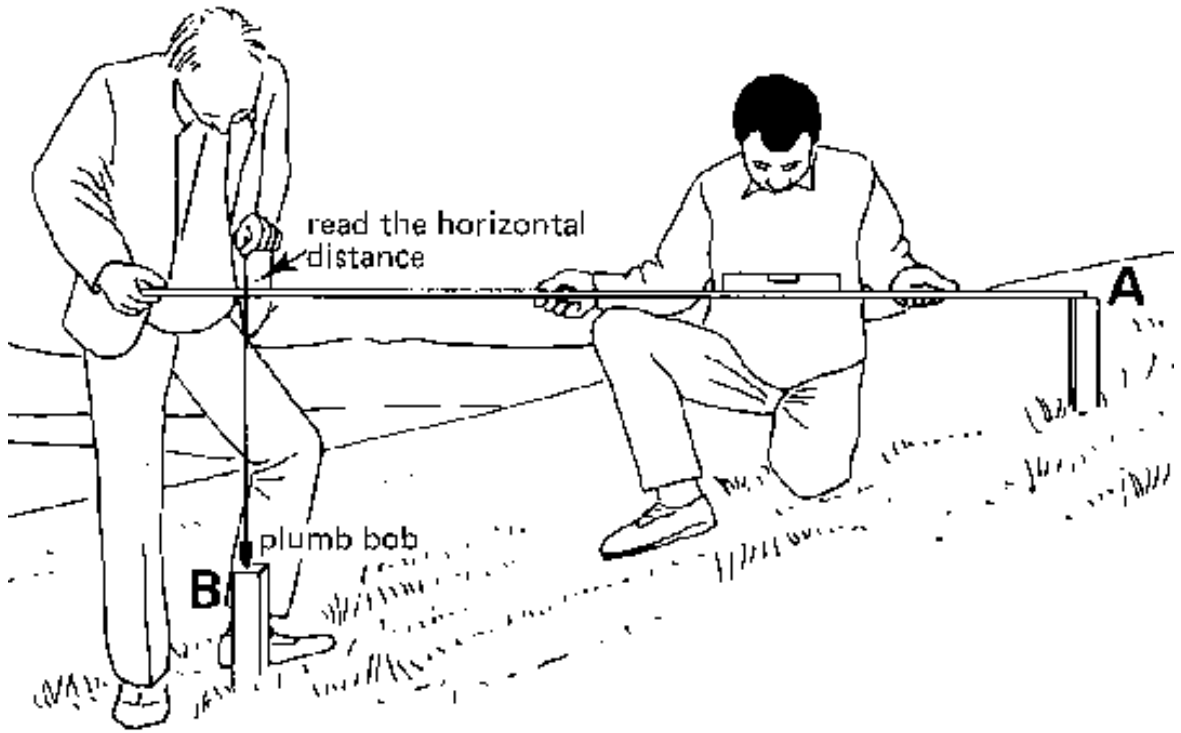


# Taping: Over Level Ground

- If the taping is done over level ground where there is no under-bush, the tape can rest on the ground.
- A taping crew consists of two people: the head tape person and the rear tape person.
- The head tape person takes one end of the tape walks down the line towards the point.

# Taping: Over Sloping/Uneven Ground

- To measure horizontal distance with a tape, a level and plum bob must be used.
- The tape is held level, horizontal, and measurement at the elevated end is transferred using a plum bob.



# Taping: Limitations

- The following errors may arise when using taping method:

  I. Standardization

  II. Temperature

  III. Slope

  IV. Tension

  V. Sag

# Standardization Errors

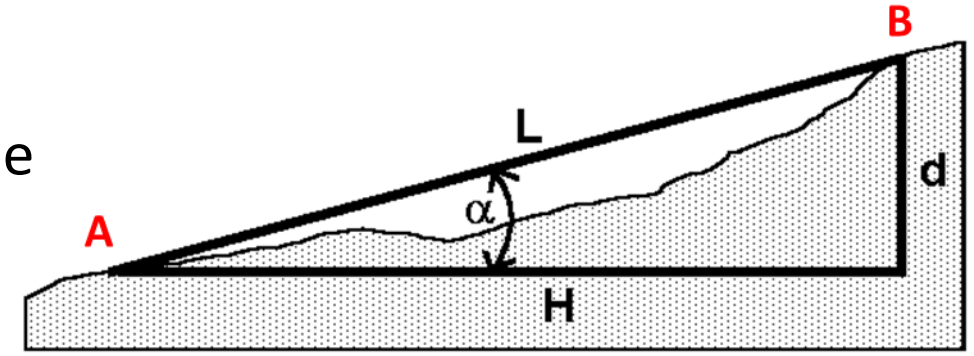
- This error arises from wear and tear of the tape due to stretching.
- This wear and tear is as a result of the repeated use of the tape over a long period of time as pulling tension.
- Measured lengths will either be greater than the correct length.

# Error Due To Temperature

- Materials expand with rise and contract with temperature decrease.
- The expansion/contraction may cause the tape to bend or distort.
- Measured lengths will either be greater or lesser than the actual length.
- Tapes should be stored under room temperature conditions.

# Slope Errors

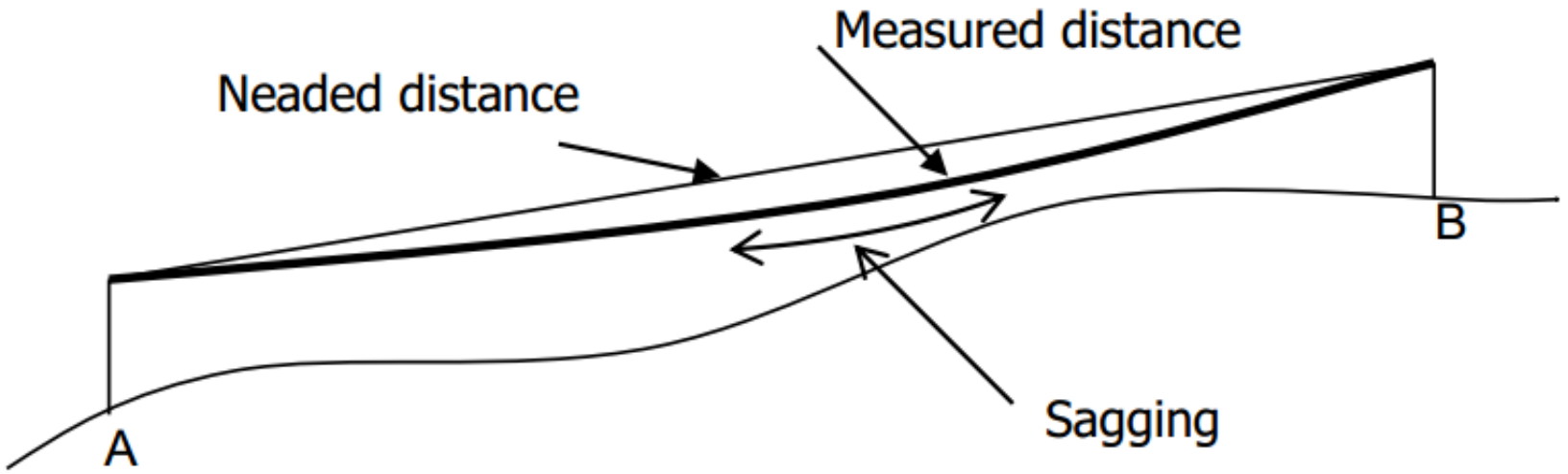
- All plan distances are always quoted as horizontal distances L.
- Due to the unevenness of the ground surface the distances measured by tape are slope distances.
- Slope distance will always be greater than horizontal distance.



# Error Due To Tension

- In this case, errors arise when the tape is pulled at a tension which differs from the standard tension used at standardization.
- The tape will stretch less than its standard length when a tension less than the standard tension is applied, making the tape too short.
- A tape stretches in an elastic manner until it reaches its elastic limit, when it will deform permanently and ruin the tape.

# Sag Errors




- If the tape cannot be supported for its length then it will hang freely and attain the form of catenary (sag) under the influence of gravity.
- When used in catenary, the distance so obtained is longer than expected due to the sagging of the tape due to its weight.

# Optical Distance Measurements (ODM)

- ODM also known as tacheometry, is a branch of angular surveying in which the horizontal and vertical distances of points are obtained by optical means.
- In this method distances and heights are determined from the instrument readings alone.
- Quicker than the use of ordinary measurement methods i.e tape or chain.

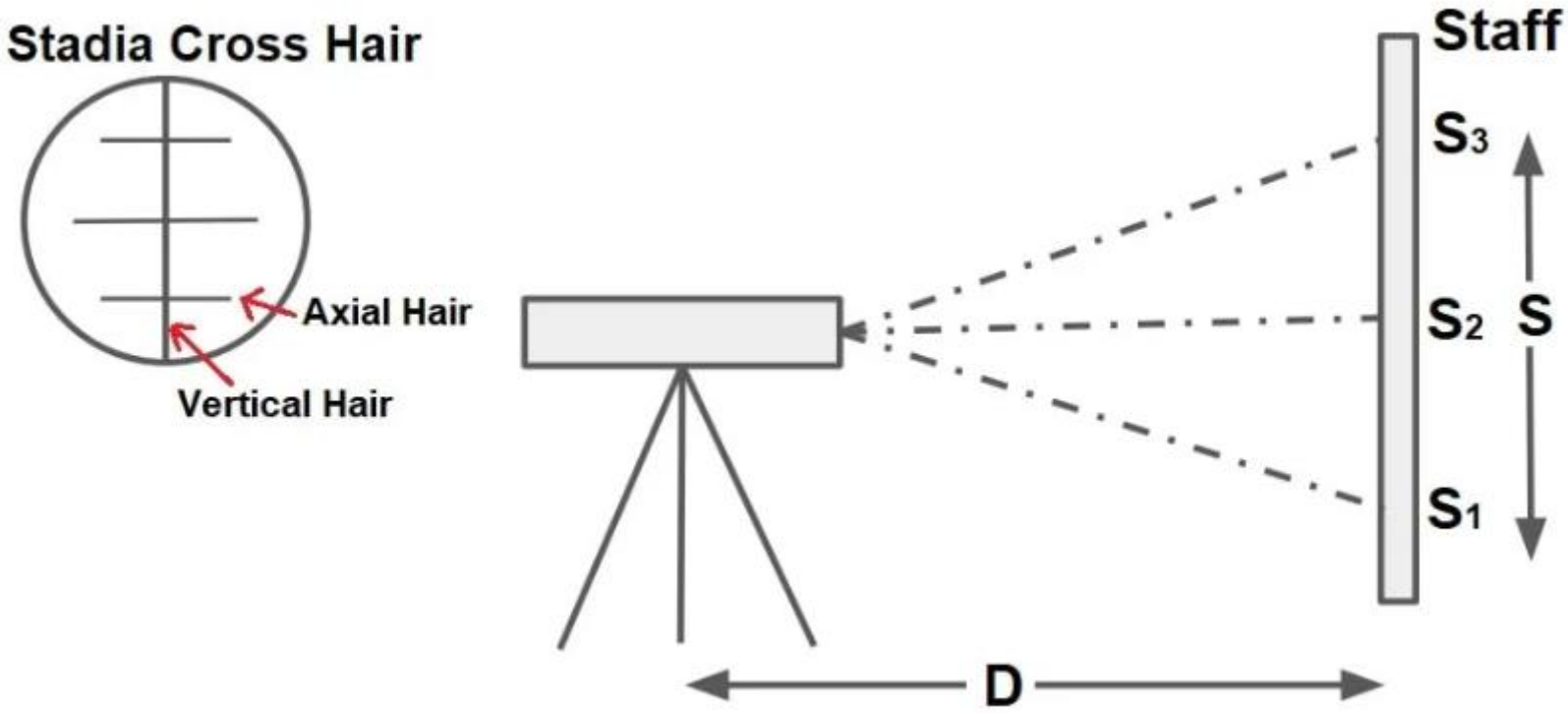
# Optical Distance Measurements (ODM)

- All that is required necessary is that the assistant, who carries a staff on which the instrument is sighted, shall be able to reach the various points to be surveyed and levelled, and a clear line of sight exists between the instrument and the staff.
- Thus, ODM is very useful in broken terrain and where obstacles such as rivers, roads and crops occur.

# ODM: Stadia System

- With the combination of a standard theodolite or level with stadia lines on the telescope diaphragms and the leveling staff the distance is determined by way of reading the stadia intercepts.
- The stadia lines define a parallactic angle Θ and the measurement process involves observing the staff intercepts subtended by this fixed angle over the required distance.

# ODM: Stadia System




$$S = S_3 - S_1$$

$S_1 - lower\ staff\ reading$

$S_2 - middle\ staff\ reading$

$S_3 - upper\ staff\ reading$

# ODM: Stadia System

- The stadia system uses standard theodolites and levels with lines engraved on their diaphragms to view a standard levelling staff.
- With the combination of a standard theodolite or level with stadia lines on the telescope diaphragms and the leveling staff the distance is determined by way of reading the stadia intercepts (Fig 1.)

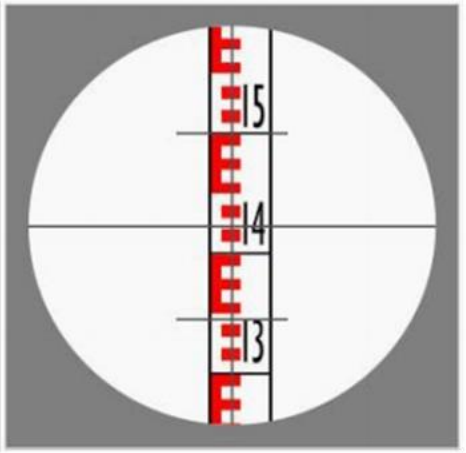



Fig 1 - View of staff through a modern telescope

# ODM: Stadia System

- A transit theodolite fitted with special stadia diaphragm is known as tacheometer.

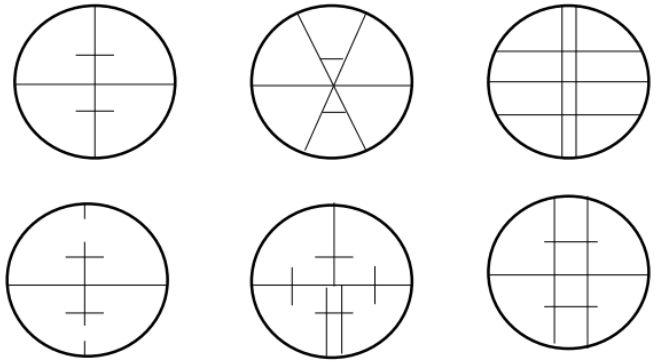


Fig 2 – Common Types of stadia diaphragms.

- Its telescope contains two horizontal hairs called stadia hairs in addition to the regular crosshairs.
- The stadia hairs are equidistant from the central cross-hairs and they are specially termed as stadia lines or stadia webs.

# ODM: Stadia System

- In effect, the lines define a fixed angle and the measurement process involves observing the staff intercept subtended by this fixed angle over a required distance.
- The basic principles are shown in Fig.3. in which it is assumed that the telescope is level and the staff is vertical.

# ODM: Stadia System

- Considering the rays passing through the optical Centre of the objective to form an image in the plane of the diaphragm, then by similar triangles:

  - f = focal length of the object glass.
  - i = stadia hair interval = ab.
  - s = staff intercept = AB.
  - c = distance from O to the vertical axis of the instrument.
  - d = distance from O to the staff.
  - d’ = distance from O to the plane of the diaphragm.
  - D = horizontal distance from the vertical axis to the staff.

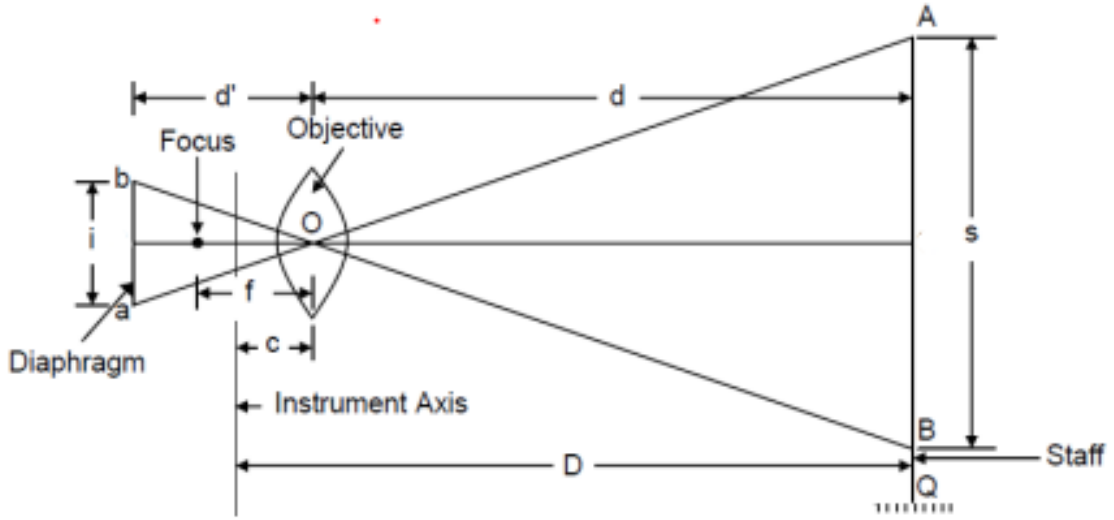
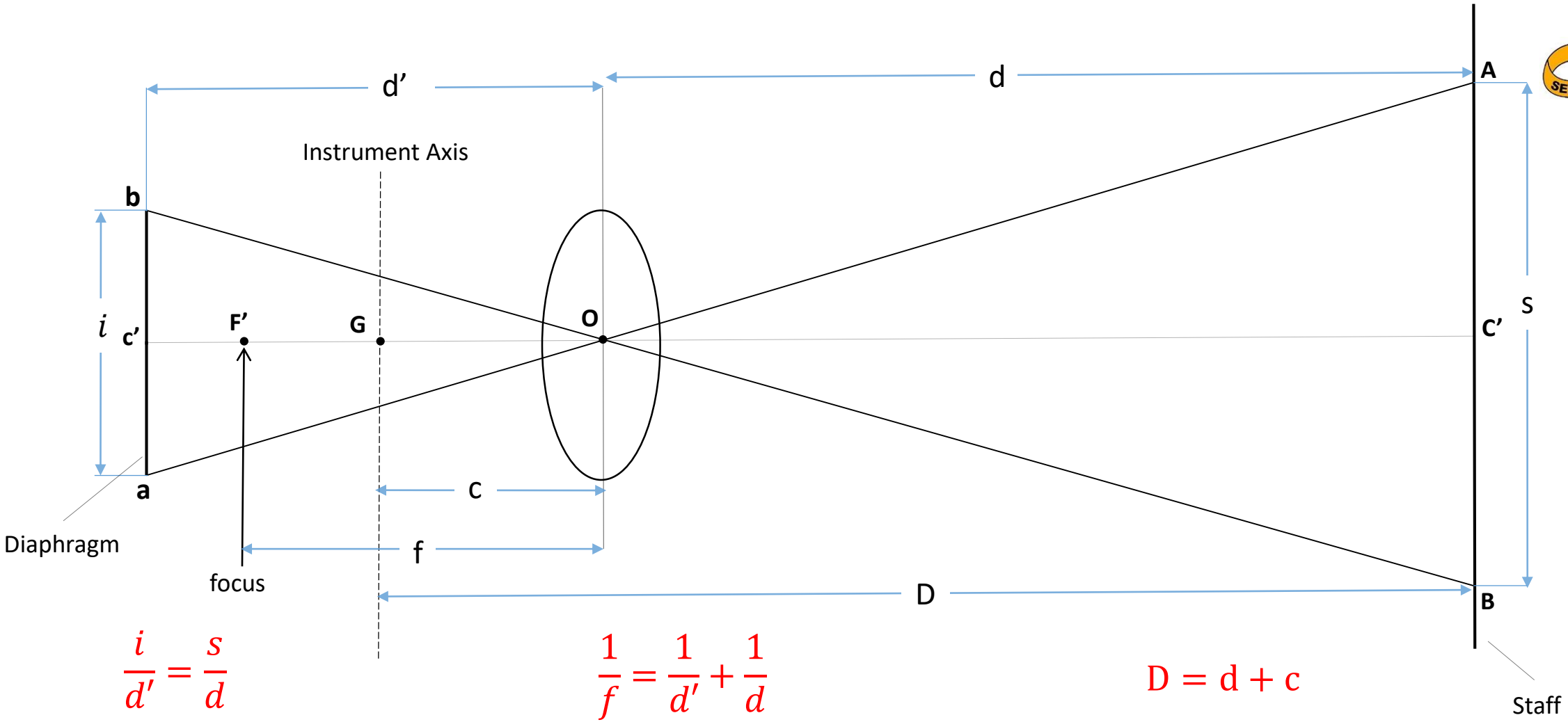



Fig 3

# ODM: Stadia System




$$\frac{i}{d'} = \frac{s}{d}$$

**Similar Triangles rule**

$$\frac{1}{f} = \frac{1}{d'} + \frac{1}{d}$$

**Lens formula**

$$D = d + c$$

**Distance formula**

Fig 4

# ODM: Stadia System

$$\frac{i}{d'} = \frac{s}{d} \qquad \text{(i)} \qquad \text{Similar Triangles Formula}$$

$$\frac{1}{f} = \frac{1}{d'} + \frac{1}{d} \qquad \text{(ii)} \qquad \text{Lens Formula}$$

$$\mathrm{D} = \mathrm{d} + \mathrm{c} \qquad \text{(iii)} \qquad \text{Distance between instrument and staff}$$

# ODM: Stadia System

from equation (i):

$$d' = \frac{id}{s}$$

substituting d′ into equation (ii) we get:

$$\frac{1}{f} = \frac{1}{id/s} + \frac{1}{d}$$

Making d the subject of the formula we have:

$$d = f\left(\frac{s}{i} + 1\right)$$

Recall equation (iii):

$$\mathrm{D} = \mathrm{d} + \mathrm{c}$$

substituting d into equation (iii) we get:

$$\mathrm{D} = f\left(\frac{s}{i} + 1\right) + \mathrm{c}$$

Expanding the above equation we get:

$$\mathbf{D} = \left(\frac{\boldsymbol{f}}{\boldsymbol{i}}\right)\boldsymbol{s} + (\boldsymbol{f} + \boldsymbol{c})$$

# ODM: Stadia System

- The reduction of this formula would be simplified considerably if:

a) The term $\left(\frac{f}{i}\right)$, the multiplying constant (C), is made some convenient figure (usually 100).

b) The term ($f + c$ ), the additive constant (K) can be made to vanish i.e additive constant is made zero .

- In resolving (a) and (b) above, constants have been established in modern internal-focusing telescope set horizontally; horizontal distance *D* can be established using the straight-line formula.

$$D = \frac{f}{i}.s + (f + c) \equiv D = Cs + K \quad \text{..... (iv)}$$

# ODM: Advantages

- This technique has advantages over taping. These are:

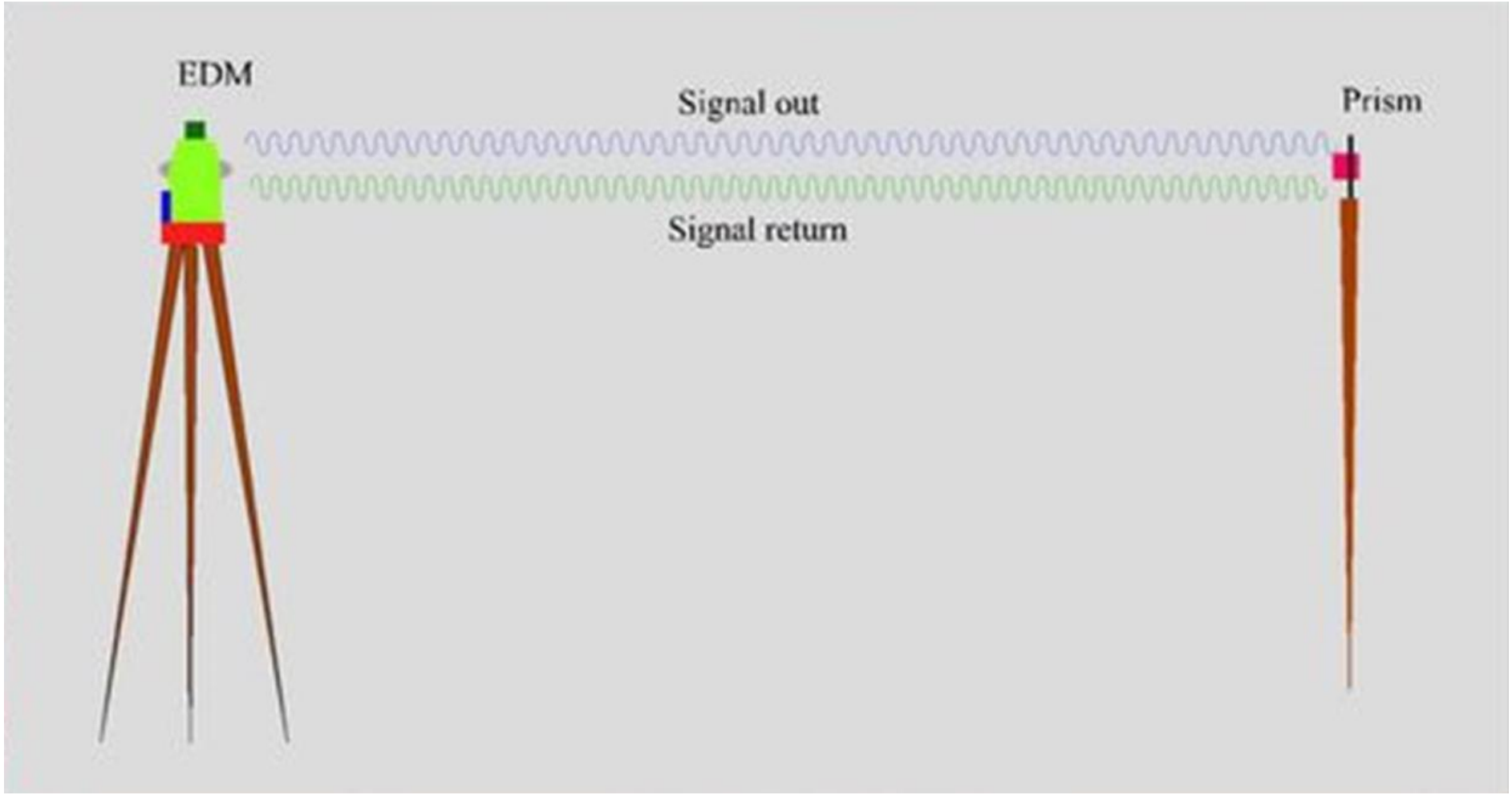
i. Less time taken to measure long distances.

ii. Since distance measurement is not done on the ground, it is a little bit easier to measure on undulating grounds.

# ODM: Limitations

- Limited to distances less than 120 meters.
- Affected by Curvature and Refraction.

# Electromagnetic Distance Measurement systems (EDM)



# Electromagnetic Distance Measurement systems (EDM)

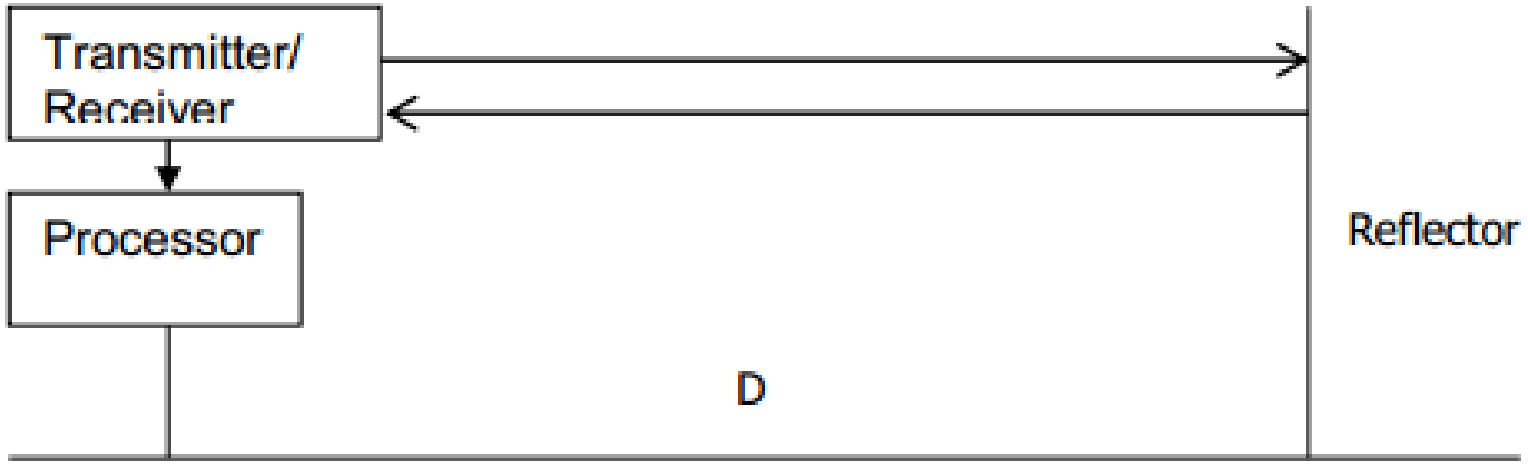
- An EDM instrument use electromagnetic waves, which may be classified according to the type of electromagnetic radiation that carries the measuring signal.
- These are microwave EDM instruments that generally employ radio waves and the electro-optical EDM instruments which utilize visible or near-infrared radiation.
- The system has three major components: the propagation timer; the transmitter/receiver and the microprocessor

# Electromagnetic Distance Measurement systems (EDM)

- The propagation timer is to determine the travel time of the wave to and from the reflector
- The transmitter transmits the wave and the same time the receives it.
- The microprocessor does the computations of the distance.
- Now for the system to work, there has to be a reflecting surface on the other end of the line.

  In this respect reflecting prisms are used.
- Further more there has to be a clear line of sight (no blockages in the signal) between the transmitter and the reflector.

# Electromagnetic Distance Measurement systems (EDM)




The principle

Therefore

$$D = V^* t$$

Where

D = distance between transmitter and reflector

V = velocity of of electromagnetic wave in air

t = half the time taken for the transmitted and the reflected wave.

# EDM: Limitations

I. Human Errors

II. Atmospheric Effects

III. Instrument Errors

# EDM Limitations: Human Errors

- The operator must be careful when setting up and operating the instrument in order to eliminate or minimise errors which are human.
- Due care has to paid to centring the instrument, pointing to the targets (reflectors) and setting the atmospheric correction values.

# EDM Limitations: Atmospheric Effects

- The measuring wave is affected by the atmospheric conditions such as temperature, pressure and humidity.
- Correction of such errors is done by measuring the temperature and pressure at the time measuring the distance are entered in the instrument.


# END