CHAPTER-2
TAPE MEASUREMENT

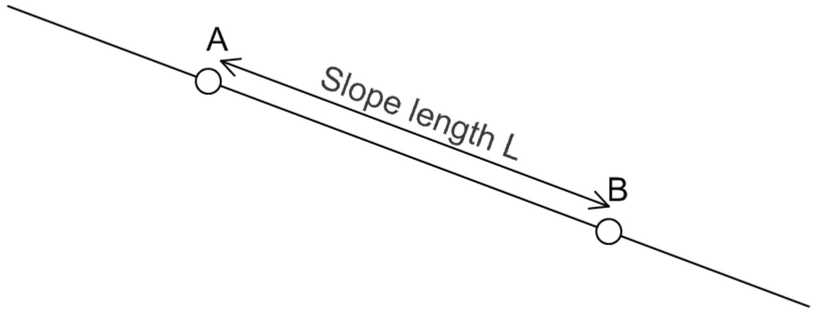
Introduction

- One of the fundamentals of surveying is the need to measure distance. Distances are not necessarily linear, especially if they occur on the spherical earth.
- we will deal with distances in geometric space, which we can consider a straight line from one point or feature to another.

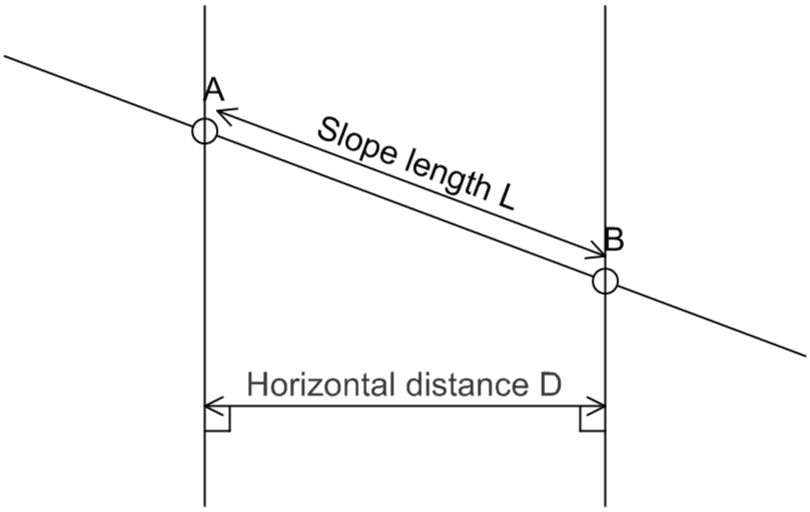
Contents

- Types of Distance Measurement
- Measurement Methods
  - ***Direct*** **(tapes)**
  - ***Indirect*****: (EDM, Stadia, subtense bar)**
- Errors and Corrections for Tape Measurement
- EDM

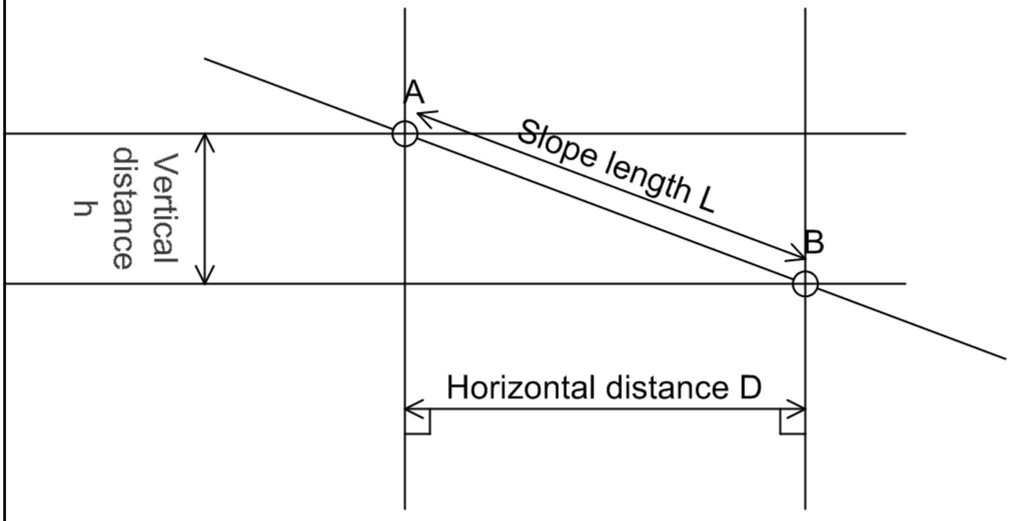
Types of Distance Measurement



Types of Distance Measurement



Types of Distance Measurement



Examples: which one to use

1. If you are intending to draw a map or area, horizontal distance and height difference (vertical distance) should be used to enable plan and height information to be drawn.
2. If you are to locate points such as a corner of a building or centre line of a road, slope distance and vertical distance are required to enable pigs be located at correct points on site (Layinging Out).

Methods of Measurement

- Pacing
  - Accuracy 1 : 100
- Taping
  - Accuracy 1 : 10,000
- Electronic Distance Measurement (EDM)
  - Accuracy 1 : 10,000 to 1:100,000

Pacing

- Practical measure of distance.
- Don't try to pace out one meter with every step. Walk casually over 100 m counting the number of steps. Work out the length of a casual step and use this instead.
- Varies with uphill, downhill, and your age.
- Low accuracy
- No equipment needed

Taping (or chaining)

- Chainage is applied to measurement with a steel tape or synthetic tape (plastic or fiberglass).

All standard in lengths

- 100 m, 50m, 30 m, 20 m.
- It is fairly quick, easy and cheap, and hence is the most common form of distance measurement.
- Chainage is prone to errors and mistakes.
- For high accuracy, steel tape should be used which is graduated in mm and calibrated under standard temp (20 degree) and tension (5kg). Be careful, break easily.
- Synthetic tape is more flexible graduated in 10mm

Some Taping Instruments

Measuring wheels

Tapes in lengths up to 100 ft

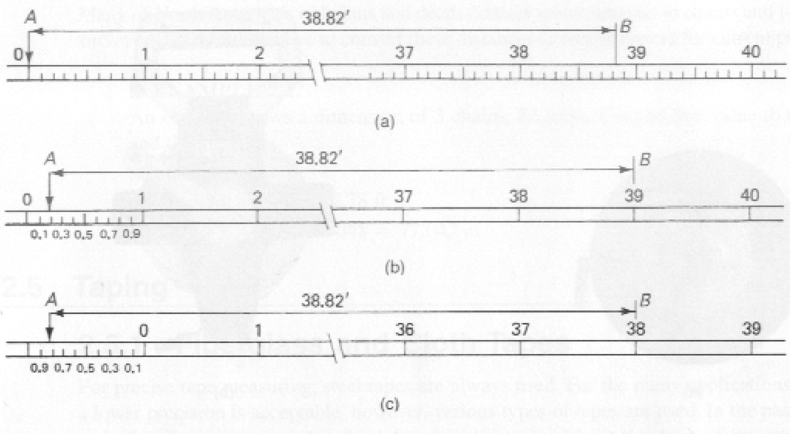
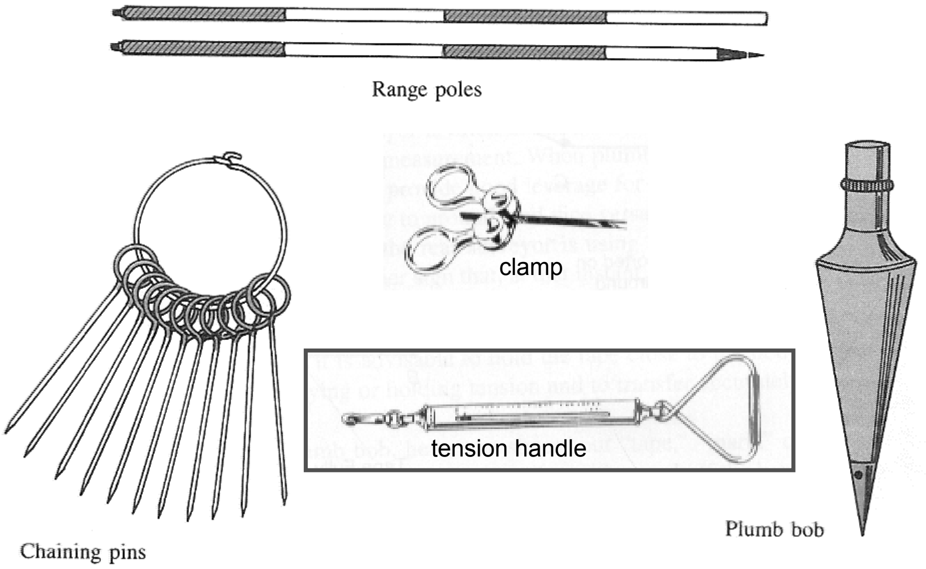


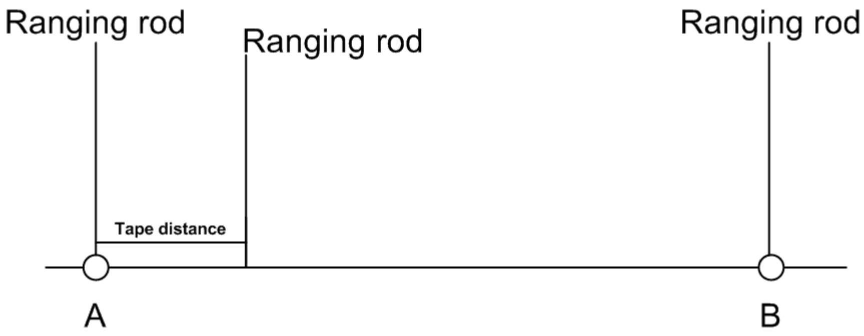
FIGURE 2.4 Various tape markings (hundredth marks not shown). (a) Fully graduated tape. (b) Cut tape. (c) Add tape.

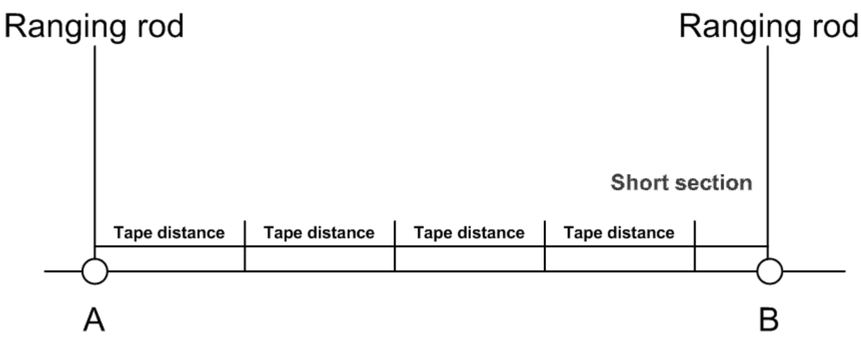
Accessories



Taping Procedures

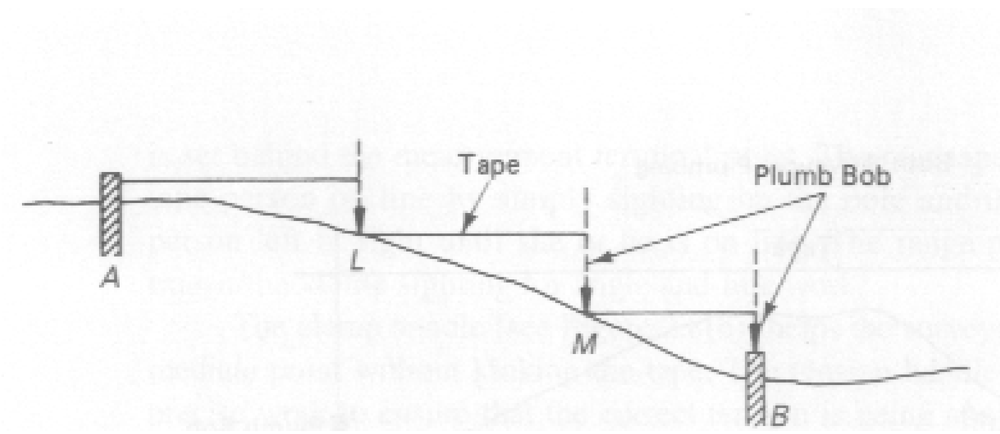
- ranging rods set up between points A and B
- from A to B, set zero of tape at A
- tape unwound towards B
- A third range rod is “ranged” in at C
- Tape straightened, held tight and read at rod C
- C marked with a pin
- for next bay, tape moved from A and zero set at C and so on

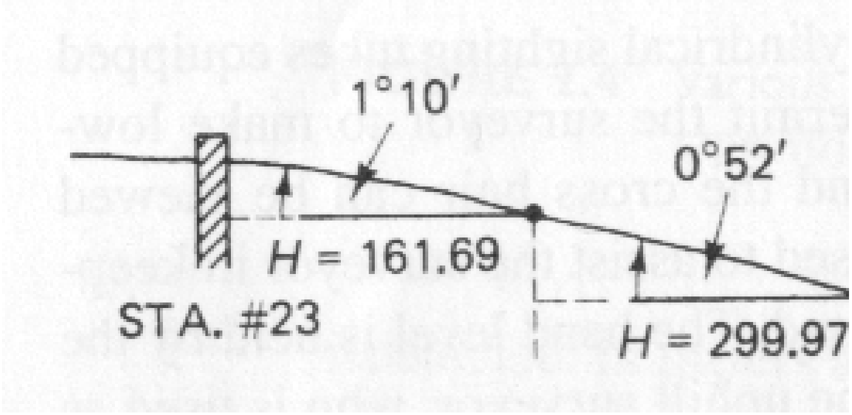


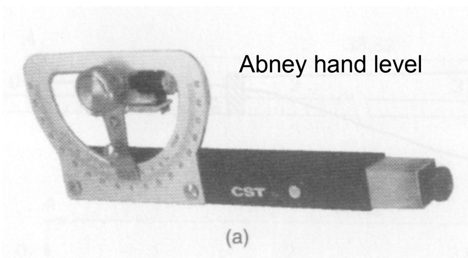


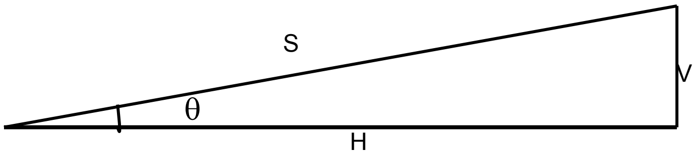
Length AB = 4 x Full tape distance + 1 Short section

REMEMBER ! It works only on smooth ground or uniform slope surfaces


Tape
Plumb Bob
A
L
M
B


1°10′
0°52′
H = 161.69
STA. #23
H = 299.97


Abney hand level
CST
(a)



Slope

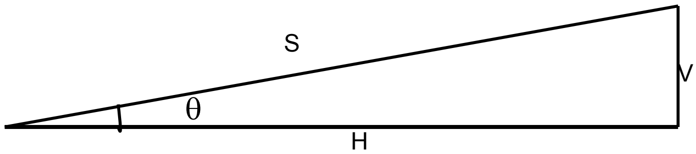
-Hor. Dist. (H) / Slope dist. (S) = Cos θ

$H = S \cos\theta$

-Also $H^2 + V^2 = S^2$ $H = (S^2-V^2)^{1/2}$

-Slope = gradient (rate of grade) Ratios = V/H * 100 %

= (tan θ) * 100 %



-Given: Slope distance. S and slope angle θ

H/S = Cos θ; then H = S . Cos θ

-Given: Slope distance. S and gradient (slope)

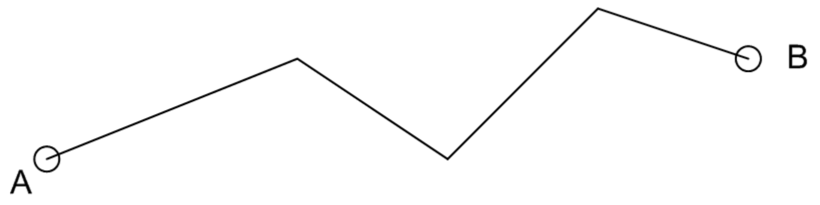
Grad./100 = tan θ ; .... Find θ

Then; H/S = Cos θ ; Find H

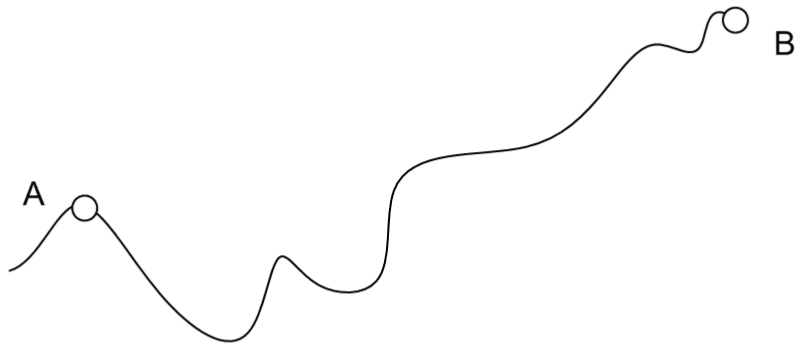
-Given: Slope distance S. And vertical. distance V.

$H = (S^2-V^2)^{1/2}$

Example



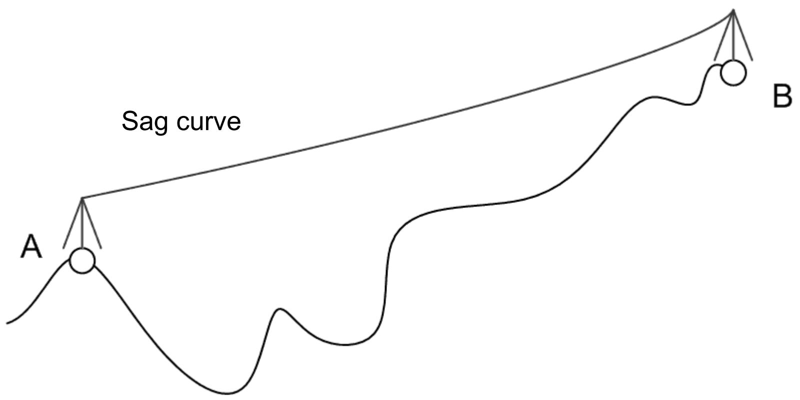
Example



How about this very uneven case

or if high accuracy is required?

Example



Sag curve measurement is not common nowadays and is restricted to steel tape only.

Taping: Corrections

Once a line is being measured, it is necessary to convert the measured length into a horizontal length. Series corrections have to be applied. Five possible corrections have to be considered. These are

- Erroneous Tape Length
- Slope
- Tension
- Temperature
- Sag

Taping: Corrections

- For synthetic tapes, only Erroneous Tape Length and slope corrections will be applied
- The best accuracy that can be achieved is in the order of 1:1000
- When using steel tapes, if only Erroneous Tape Length and slope corrections are considered, the best possible accuracy that can be obtained in the range 1:5000 If tension and temperature are added into consideration, accuracy can be increased to better than 1:10000 ~ 1: 20000
- Sag only applies if tape is supported only at ends

1. Erroneous Tape Length

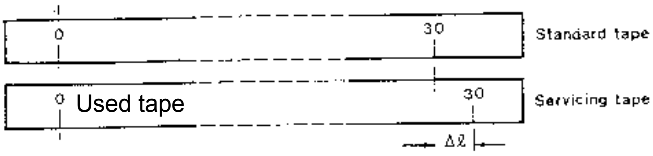
- tape has a nominal length under certain conditions, a tape stretches with time.
- standardisation needs to be carried out frequently by using reference tape or baseline.

standardization length (actual tape length)

$$e_{st} = L_m \times \left(\frac{L_s - L_n}{L_n} \right)$$

nominal length (assumed tape length)

For a 30m Nominal Length Tape



When comparing to a standard tape, the used tape has a length

30 m + Δl

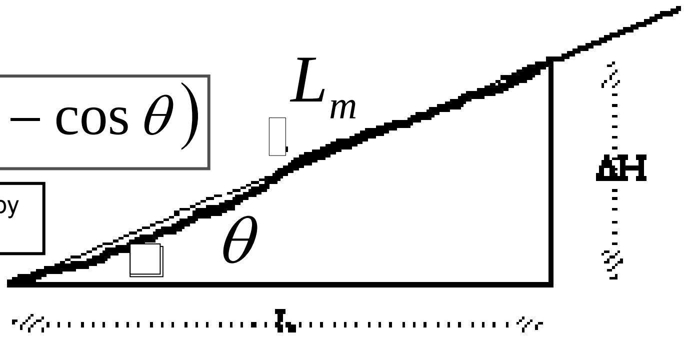
For every 30m measurement, the small elongated amount should be added for correction.

2. Slope Correction

- All plan distances are always quoted as horizontal distances L, therefore any distance not measured on the horizontal will need to be corrected for slope. Slope correction must ALWAYS be considered, and either eliminated in the field or mathematically compensated.

$$e_{slope} = L_m(1 - \cos\theta)$$

Angle may be measured by Theodolites



3. Tension Correction

- A tape has a given length when pulled with a certain tension. If the tension changes then so does the tape length.

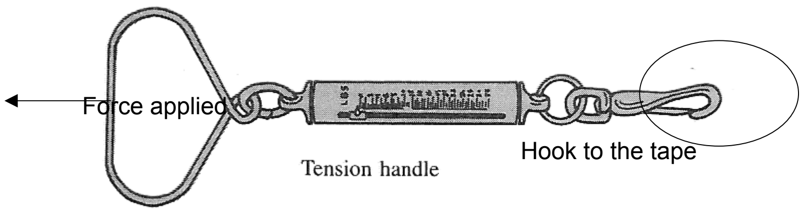
Standardisation tension

Tension applied

$$e_{tension} = \frac{(T - T_s)L_m}{E \times A}$$

Modulus of Elasticity of tape material
For steel, E = 200,000 N/mm^2

Cross section Area



4. Temperature Correction

- Most materials expand and contract with temperature change, and this effects taped distances. If a tape has stretched due to heat it will read shorter than it would at its normal (or standard) temperature.

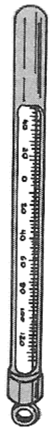
$$e_{temp} = L_m \times (c \times \Delta t)$$

Length error due to Temperature change

Measured length

Coefficient of linear expansion

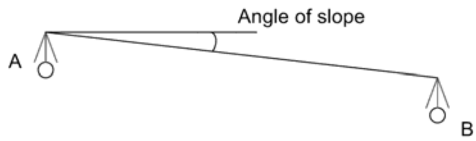
Temperature change



Thermometer

5. Sag Correction

- If the tape cannot be supported for its length then it will hang freely under the influence of gravity. The shape of the tape will take is known as (**sag**) and can be determined mathematically.



Weight of tape per unit length

Angle of slope

$$e_{catenary} = \frac{w^2 L_m^3 \cos^2 \theta}{24 \times T^2}$$

Tension applied to the ends

Combined Errors

Actual length is:

$$L_a = L_m \pm e_{temp} \pm e_{st} - e_{sag} - e_{slope} \pm e_{tension}$$

Steel Taping: Examples

A steel tape of nominal length 30 m was used to measure a line AB by suspending it between supports. The following measurements were recorded

Line	Length Measured	Slope Angle	Mean Temp.	Tension
AB	29.872 m	$3^o\ 40'$	5^oC	120 N

The standardisation length of the tape against a reference tape was known to be 30.014 m at 20^oC and 50 N.

If the tape weighs 0.17 N/m and has a cross sectional area of 2 mm^2, calculate the horizontal length of AB.

Temp. correction factor = 0.0000112 $m/^oC$

$$\text{temperature correction} = L_m(c \times \Delta t) = 29.872 \times 0.0000112 \times (5-20) = -0.0050\,m$$

$$\text{standardisation correction} = L_m \times \frac{L_s - L_n}{L_n} = \frac{29.872 \times (30.014 - 30.000)}{30.000} = +0.0139\,m$$

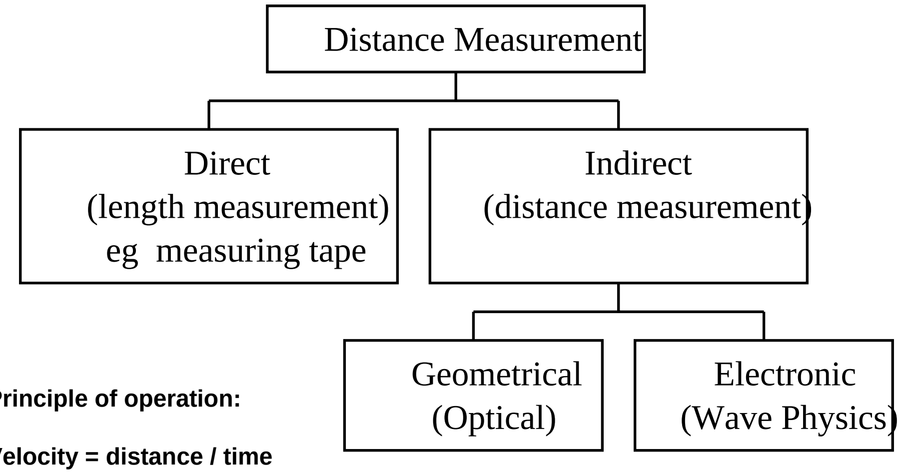
$$\text{sag correction} = -\frac{w^2 L_m^3 \cos^2\theta}{24T^2} = -\frac{(0.17)^2 (29.872)^3 \cos^2 3^o40'}{24(120)^2} = -0.0022\,m$$

$$\text{slope correction} = -L_m(1-\cos\theta) = -29.872(1-\cos 3^o40') = -0.0611\,m$$

$$\text{tension correction} = \frac{(T - T_s)L_m}{EA} = \frac{(120-50)\times 29.872}{200 \times 10^3 \times 2} = +0.0052\,m$$

horizontal length AB = 29.872 +(-0.0050+0.0139-0.0022-0.0611+0.0052)
= 29.823m

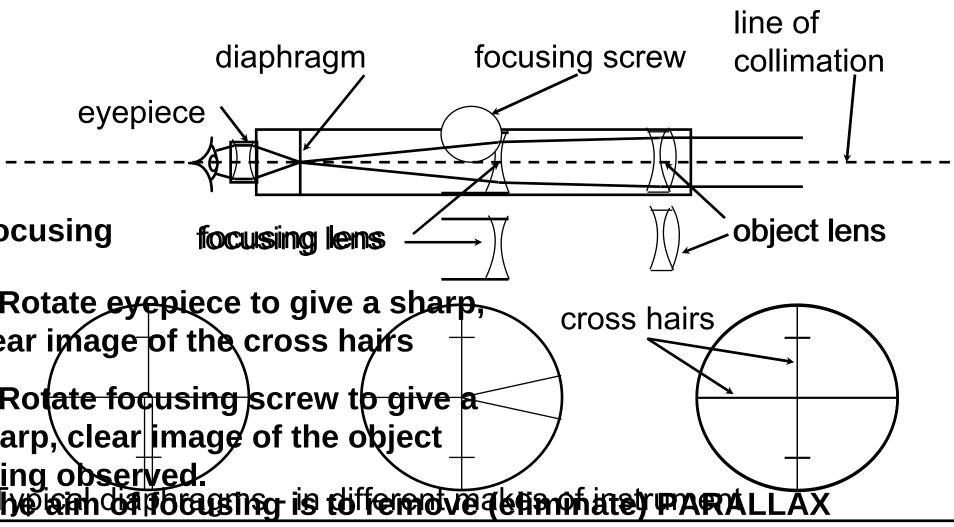
EDM Electro-Optical Distance Measurement



Principle of operation:

Velocity = distance / time

A surveying optical telescope



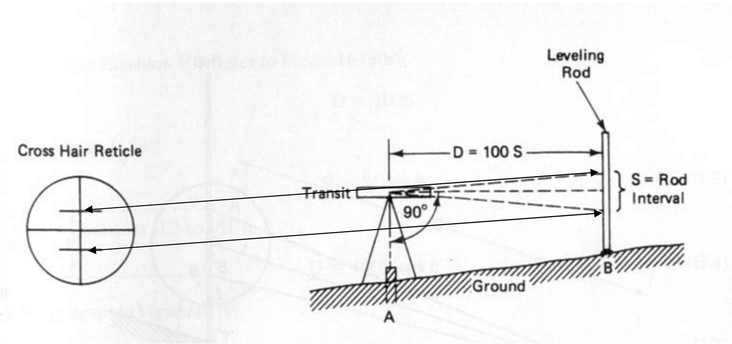
Focusing

1. Rotate eyepiece to give a sharp, clear image of the cross hairs

2. Rotate focusing screw to give a sharp, clear image of the object being observed.

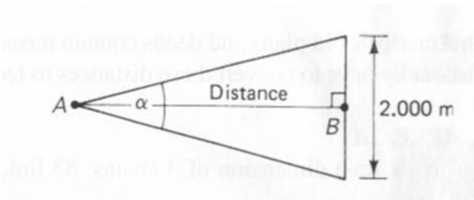
The aim of focusing is to remove (eliminate) PARALLAX

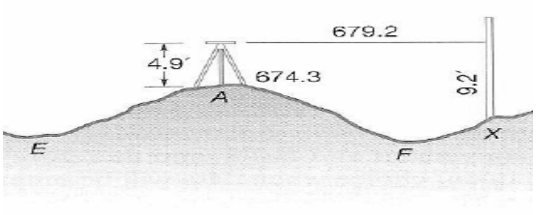
1. Stadia



D = 100 S

2. Subtense bar

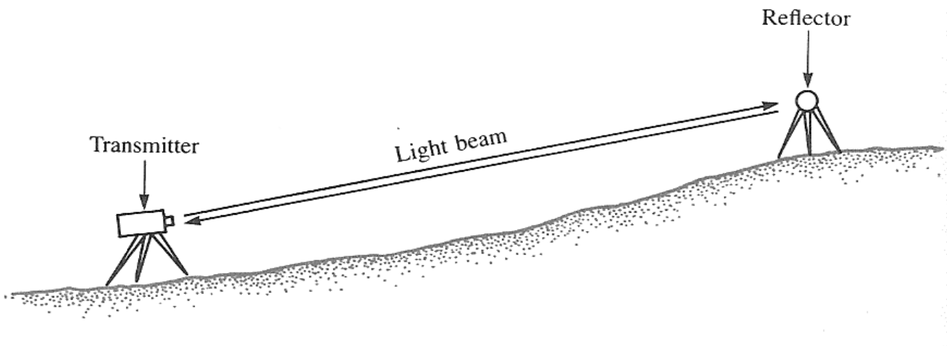


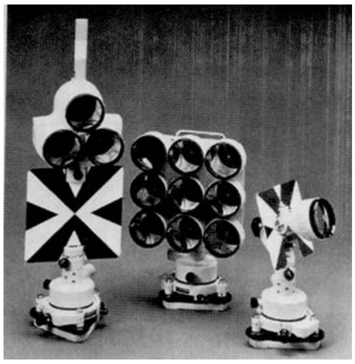


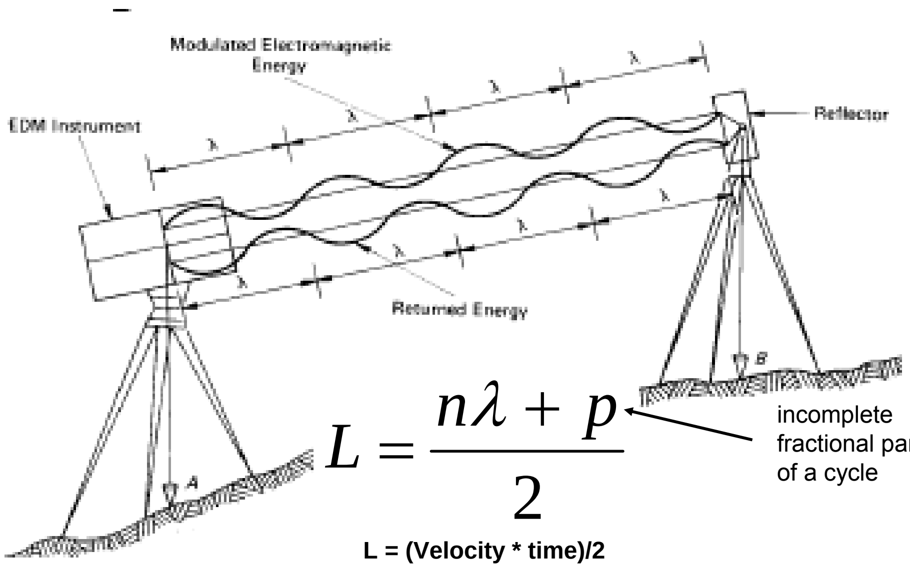
1/Distance= Tan (α/2)
Distance= 1/ Tan (α/2)

3. EDM

- EDM is very useful in measuring distances that are difficult to access or long distances.
- It measures the time required for a wave to be sent to a target and reflect back.







$$L = \frac{n\lambda + p}{2}$$

L = (Velocity * time)/2

EDM Classifications

- Described by form of electromagnetic energy.
  - First instruments were primarily microwave (1947)
  - Present instruments are some form of light, i.e. laser or near-infrared lights.
- Described by range of operation.
  - Generally microwave are 30 - 50 km range. (med)
    - Developed in the early 70’s, and were used for control surveys.
  - Light EDM’s generally 3 - 5 km range. (short)
    - Used in engineering and construction

Systematic Errors

- Microwave
  - Atmospheric conditions
    - Temperature
    - Pressure
    - Humidity - must have wet bulb and dry bulb temperature.
  - Multi-path
    - Reflected signals can give longer distances
- Light
  - Atmospheric conditions
    - Temperature
    - Pressure
  - Prism offset
    - Point of measurement is generally behind the plumb line.
    - Today usually standardized as 30mm.

Accuracy

- Distance is computed by (no. of wavelengths generated + partial wavelength)/2.
- Standard or Random errors are described in the form of $\pm$(Constant + parts per million).
  - Constant is the accuracy of converting partial wavelength to a distance. (1- 5mm) regardless of measured dist.
  - ppm is a function of the accuracy of the length of each wavelength, and the number of wavelengths. (3-5mm/km)

For EDM, constant error = 2mm and ppm = 3mm/km then;

Error of measurement in distance of 0.5 km = 2 + 3 (0.5) = 3.5 mm
and Error of measurement in distance of 4.0 km = 2 + 3 (4) = 15 mm

The End

Example