Faculty of Geomatics
Sabaragamuwa University of Sri Lanka

Department of Surveying & Geodesy

FC 11218 Basics in Land Surveying

Ranmalee Bandara

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Synopsis

This course introduces students to fundamental aspects of Land Surveying.

The principle of surveying, definitions, introduction to conventional surveying and mapping techniques will be provided.

Ground Rules

Credit Rating	**:** 2 credits (30 lecture hours)
Time	**:** Tuesday – 0800 – 1000 hours
References	**: Additional reference is advised**
Evaluation Policy	**:** Final Examination 50%
	Continuous Assessments 50%
	(Assignments/Quizzes)


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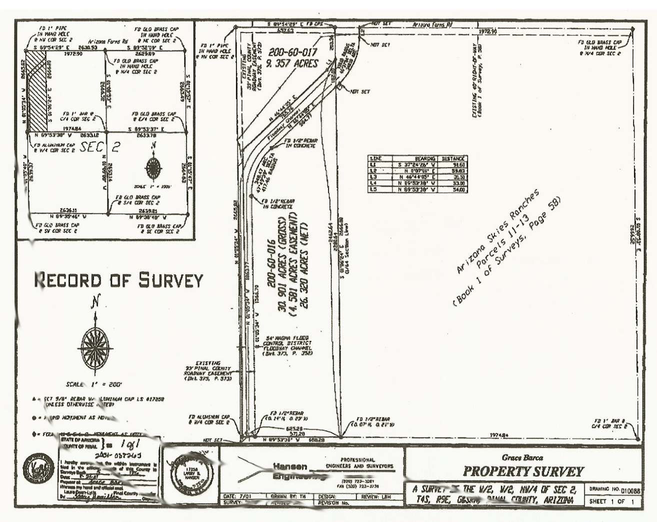
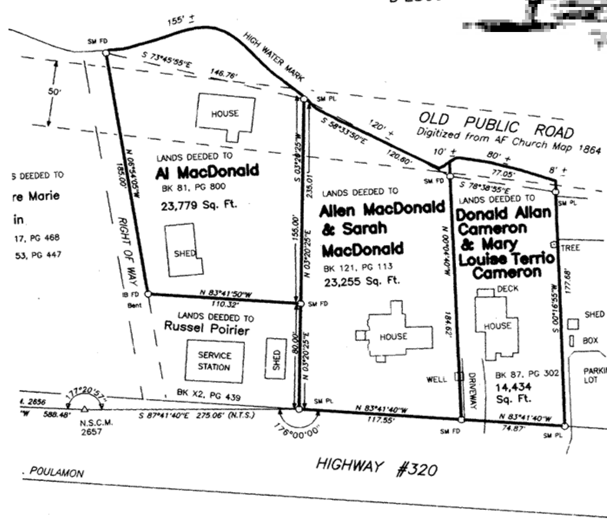
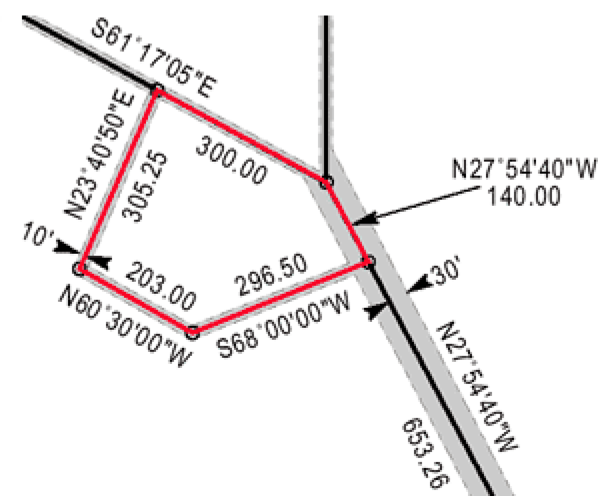
Land Surveying
ROAD
Trimble
GeoXT
Activity 3.Topographic Profile
of a Shield Volcano
West
East
Mauna Loa Volcano, Island of Hawaii
murphy

What IS Surveying?

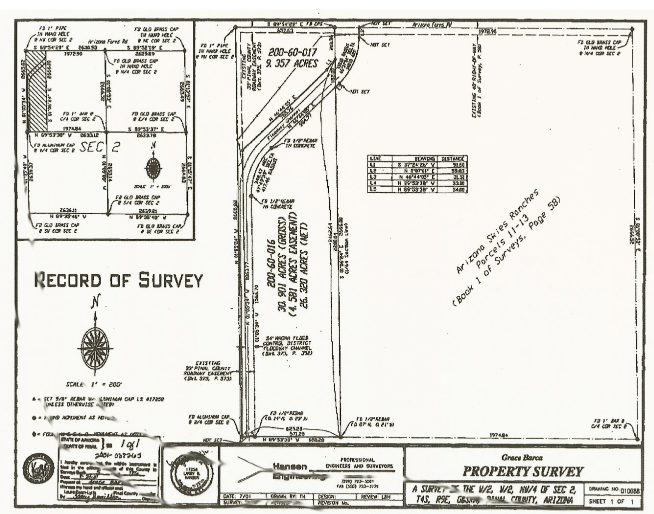


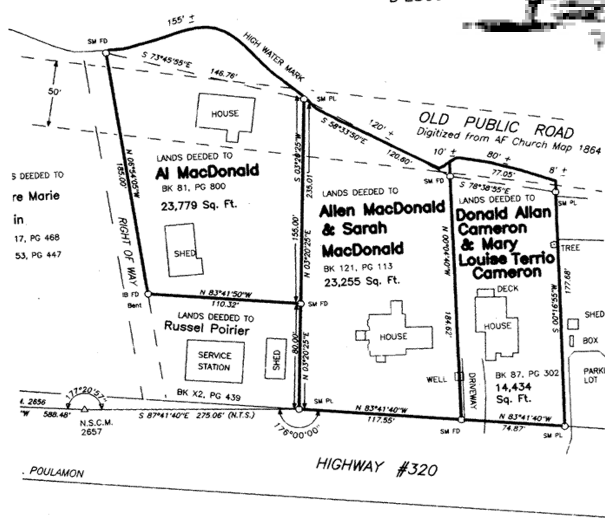




What IS Surveying?

The art of making **measurements** of the **relative positions** of natural and man-made features on the earth’s surface, and the **presentation** of this information either graphically or numerically





Since When?

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- The Egyptians first used it to accurately divide land into plots for the purpose of taxation
- Greeks developed the science of geometry and were using it for precise land division
- Greeks developed the first piece of surveying equipment (Diopter), and standardized procedures for conducting surveys

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- 1600 – triangulation – various changes in land mapping and surveying techniques, and was used for mapping entire countries
- Early 1800 – Industrial Revolution – more advanced surveying instruments were developed – Surveyors assisted in construction of canals, roads, railways, etc.

Today …

To map the earth above and below the sea



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Prepare navigational maps (land, air, sea)

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Establish boundaries of public and private lands

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Develop data bases for natural resource management

Development of engineering data

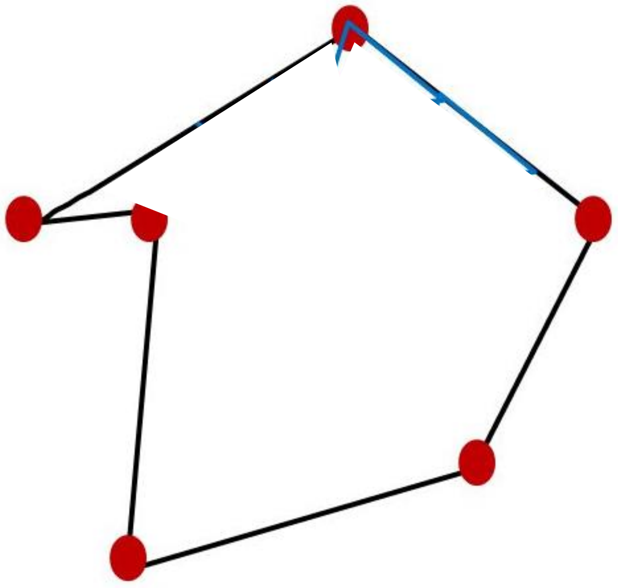
Principal of Surveying

“Working from WHOLE to PART”

Principal of Surveying

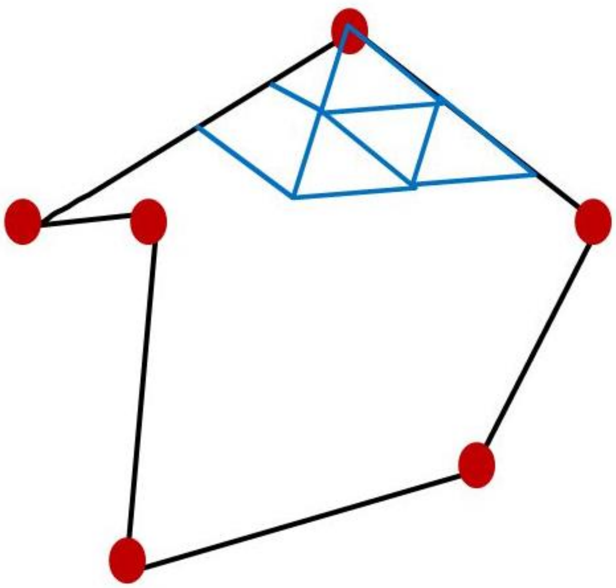
“Working from WHOLE to PART”

Step 1 – establish a system of (major) control points – fixed with a fairly high standard of accuracy



Principal of Surveying

"Working from WHOLE to PART"



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- Idea – **prevent** <u>accumulation</u> of errors

Principal of Surveying

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Step 1 – establish a system of (major) control points – fixed with a fairly high standard of accuracy

Step 2 – between them, minor control points – lesser accuracy – detail collection

- Idea – **prevent** <u>accumulation</u> of errors
- **<u>ALWAYS</u>** from high accuracy – low accuracy

How is this Achieved?

Relative positions (2D case):

Requirement – find two points and measure the distance between them

Hence, a coordinate system can be created

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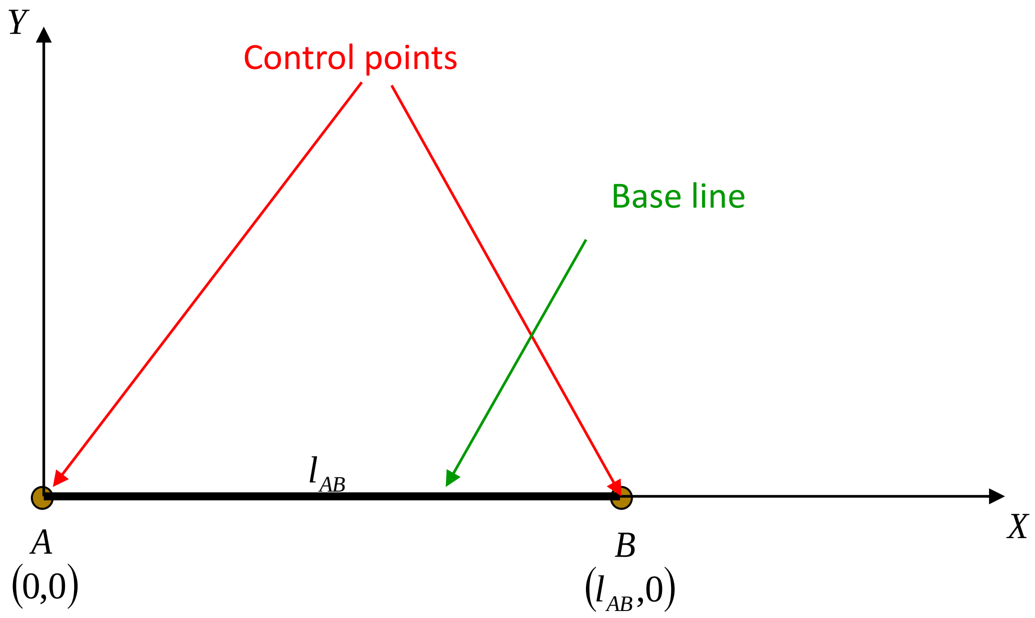

How is this Achieved?

Let’s determine the position of a third, unknown point (C)

Two unknowns –X_C, Y_C

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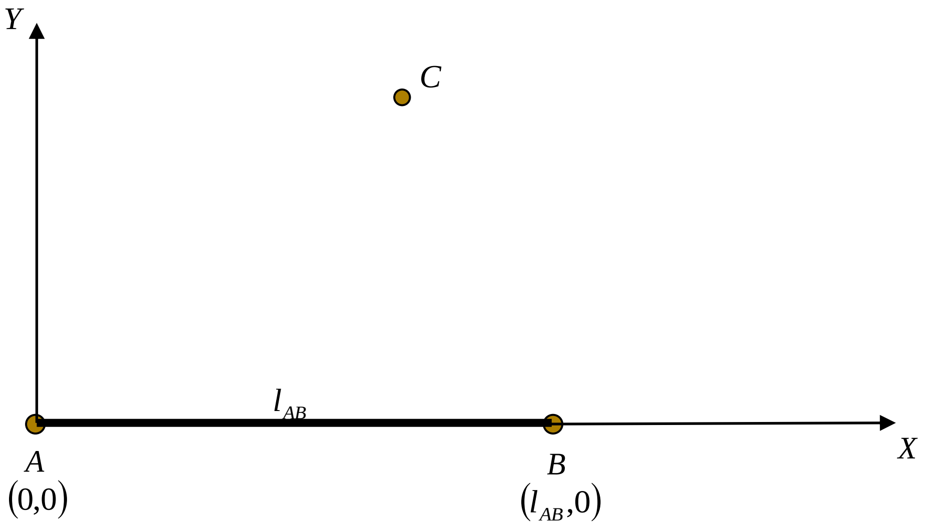

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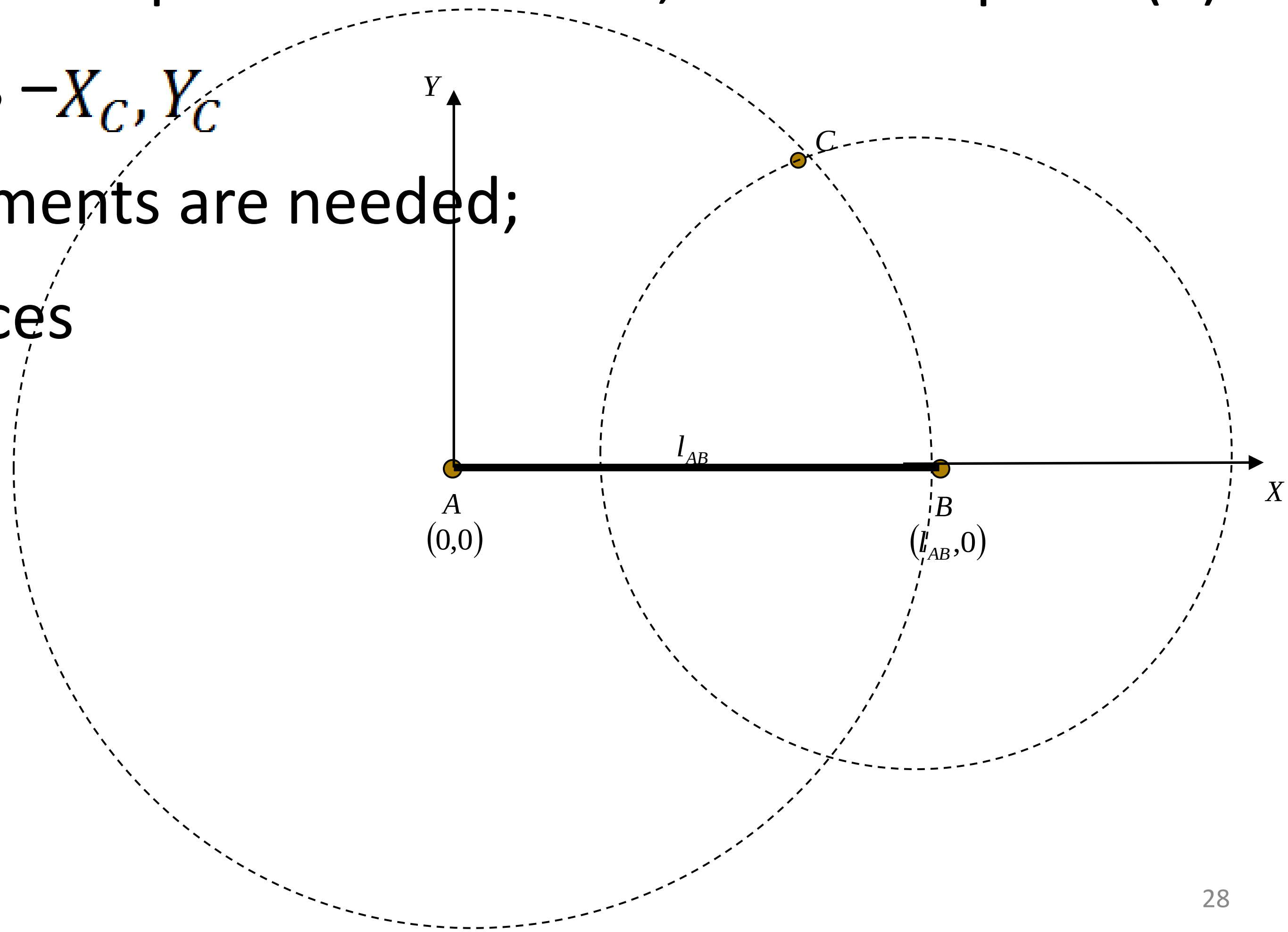

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Let's determine the position of a third, unknown point (C)

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TWO measurements are needed;

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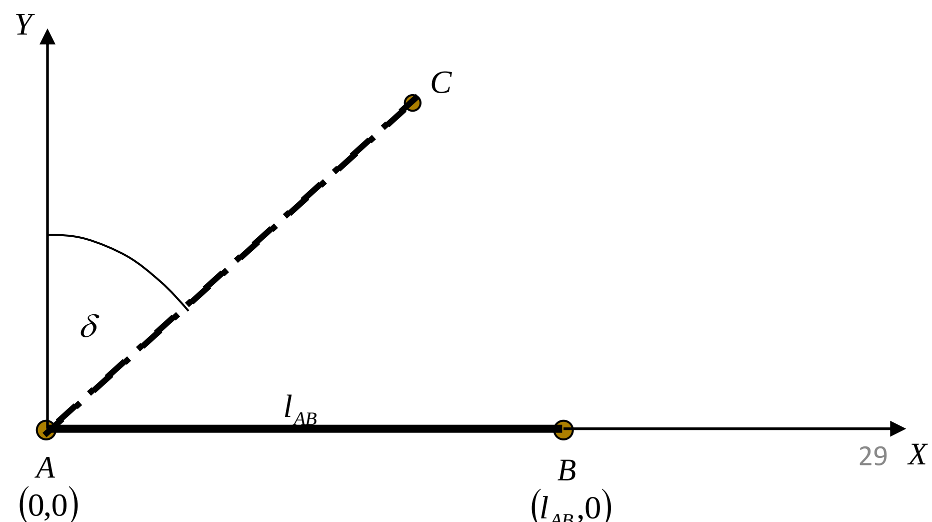
(ii) one distance and one angle



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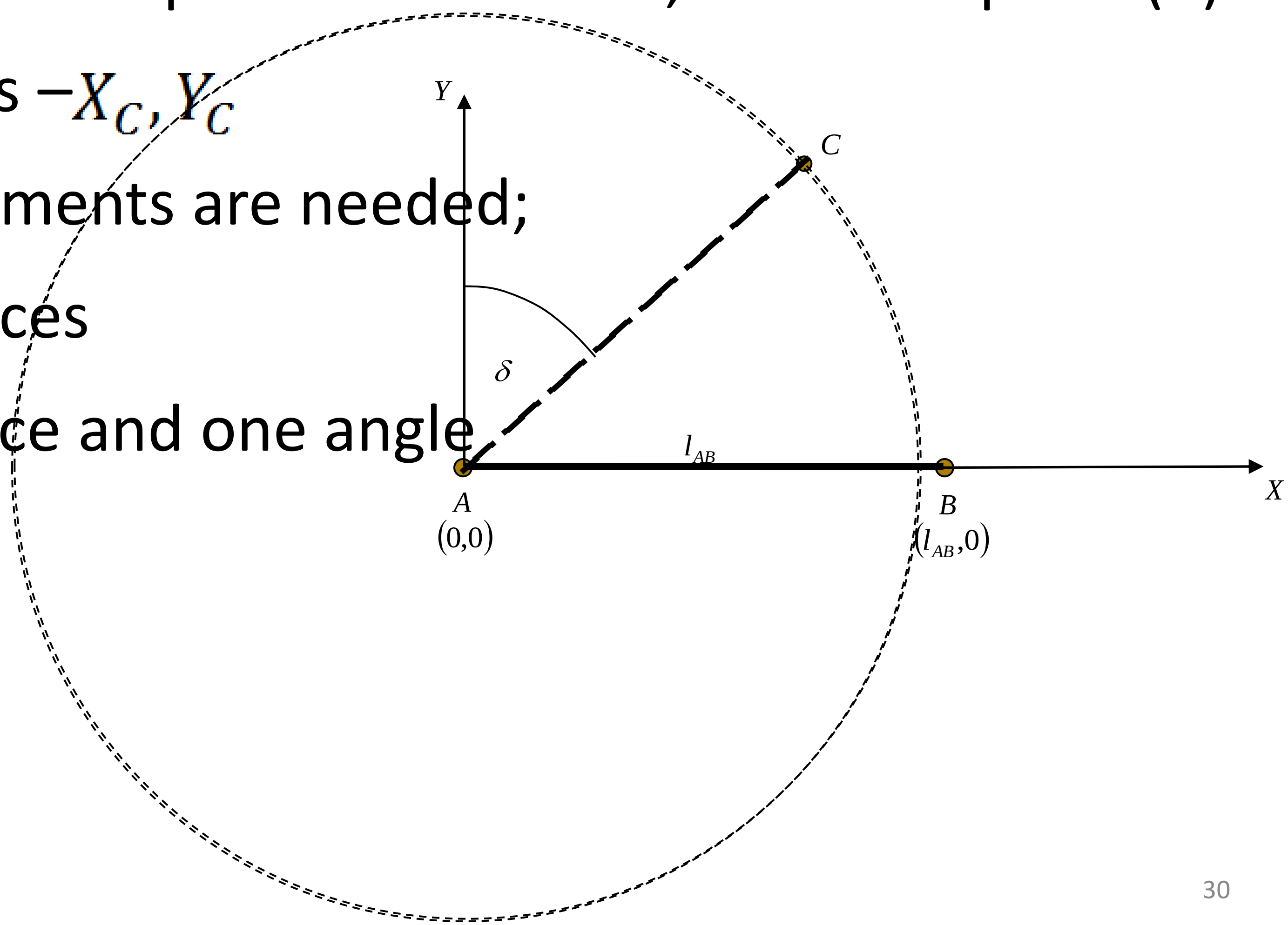

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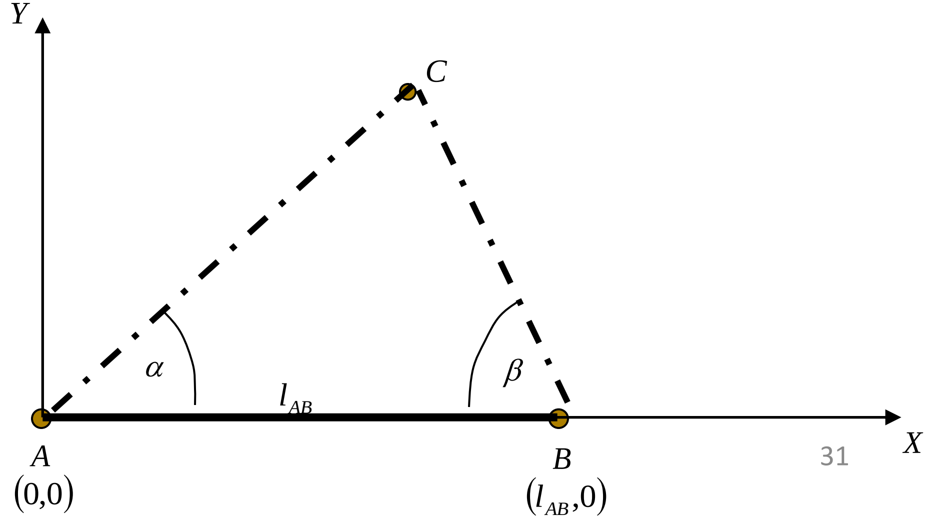
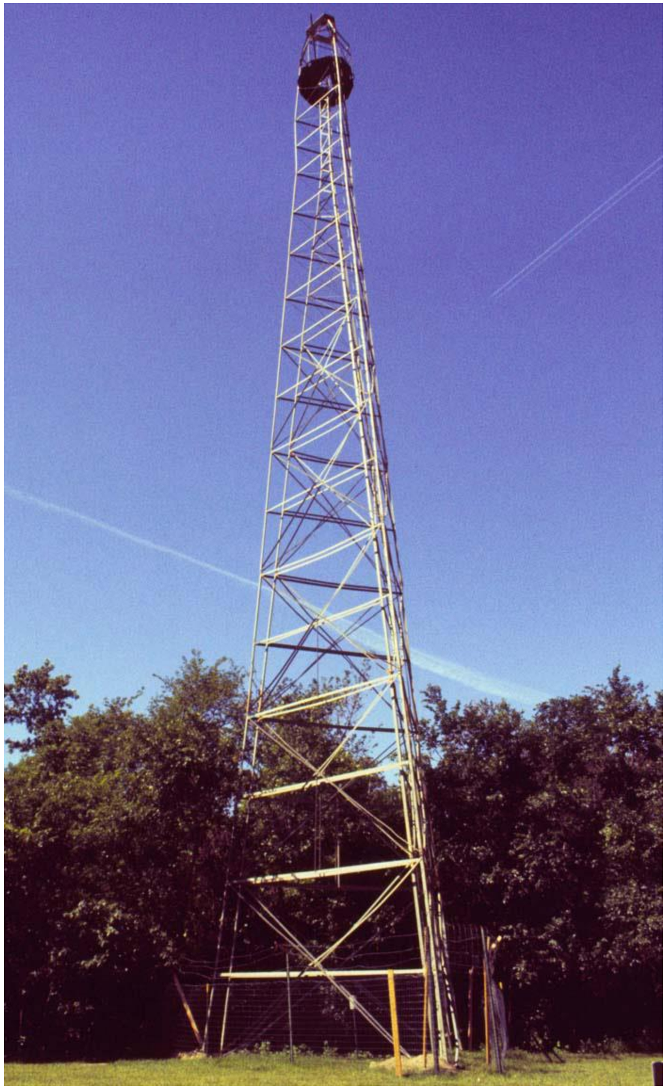


Control Points/Benchmarks



Classification (Division) of Surveying

Plane Surveying

According to the space involved:

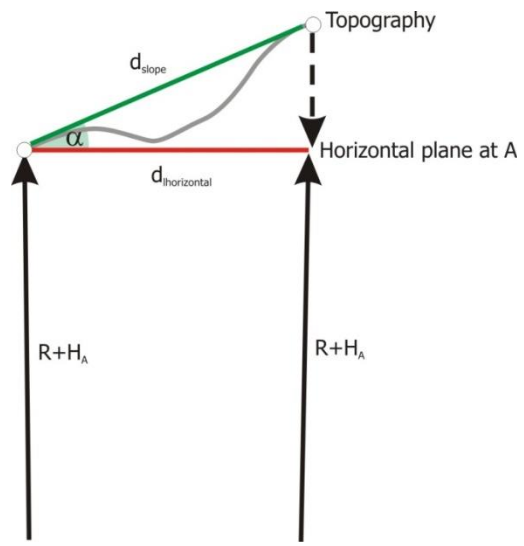
Note: The two radii can be assumed to be parallel, when the (A,B) is small

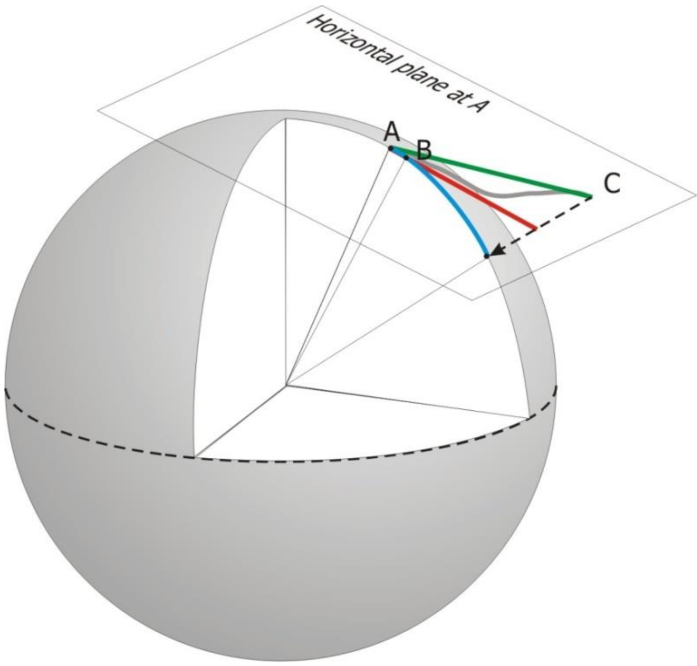
Classification (Division) of Surveying

Plane Surveying

According to the space involved:

- Relatively small areas
- Surface of earth can be assumed to be flat





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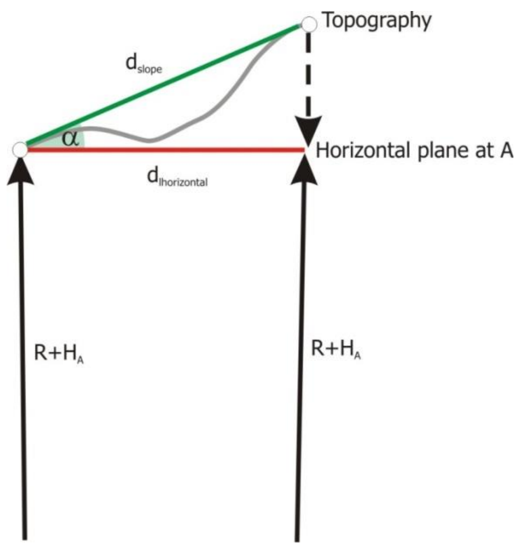

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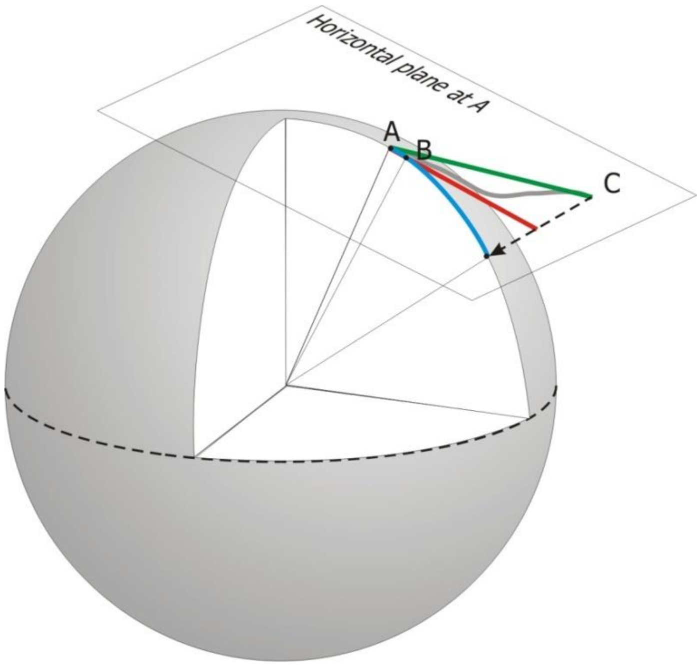

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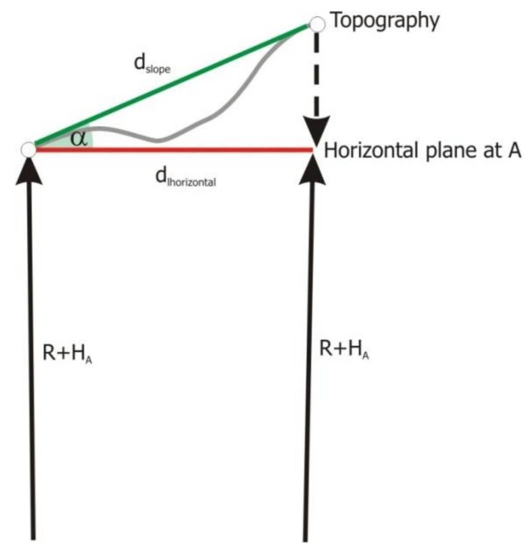
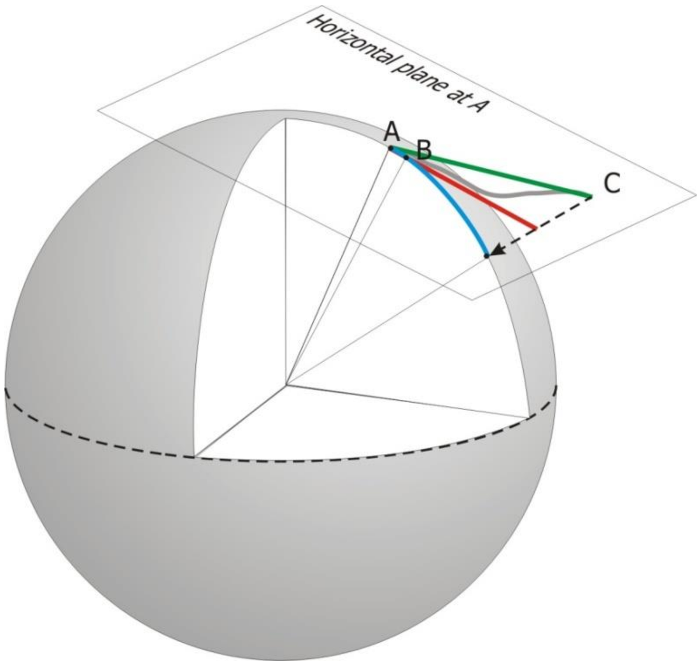
Classification (Division) of Surveying

Plane Surveying

According to the space involved:

- Relatively small areas
- Surface of earth can be assumed to be flat
- Measurements plotted represent a horizontal projection of the actual field measurements

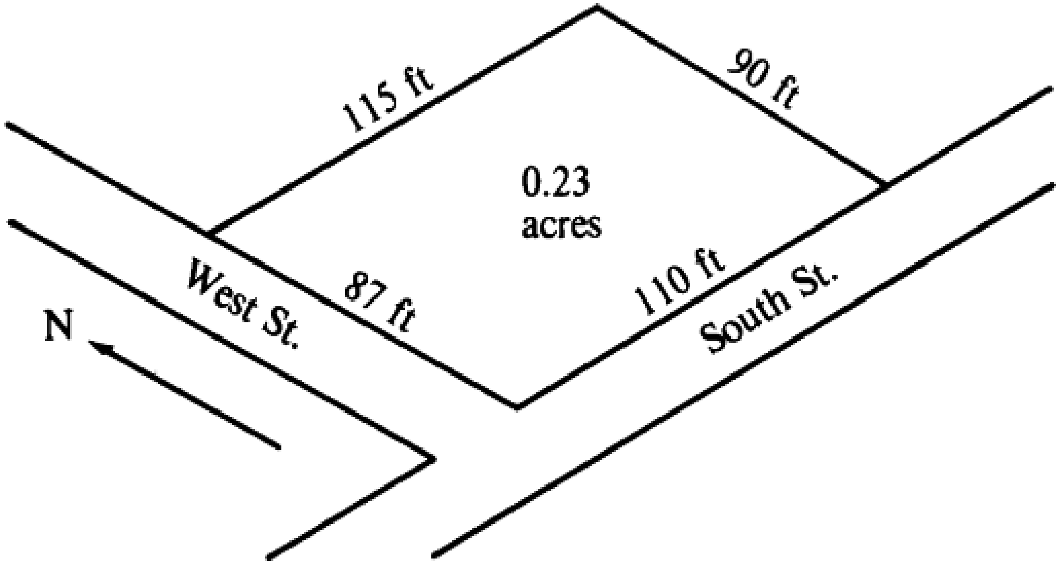




Classification (Division) of Surveying

Plane Surveying

- Surveys up to 256 km^2 (16km by 16km) – error due to earth's curvature is not serious (deviation ~1 cm)



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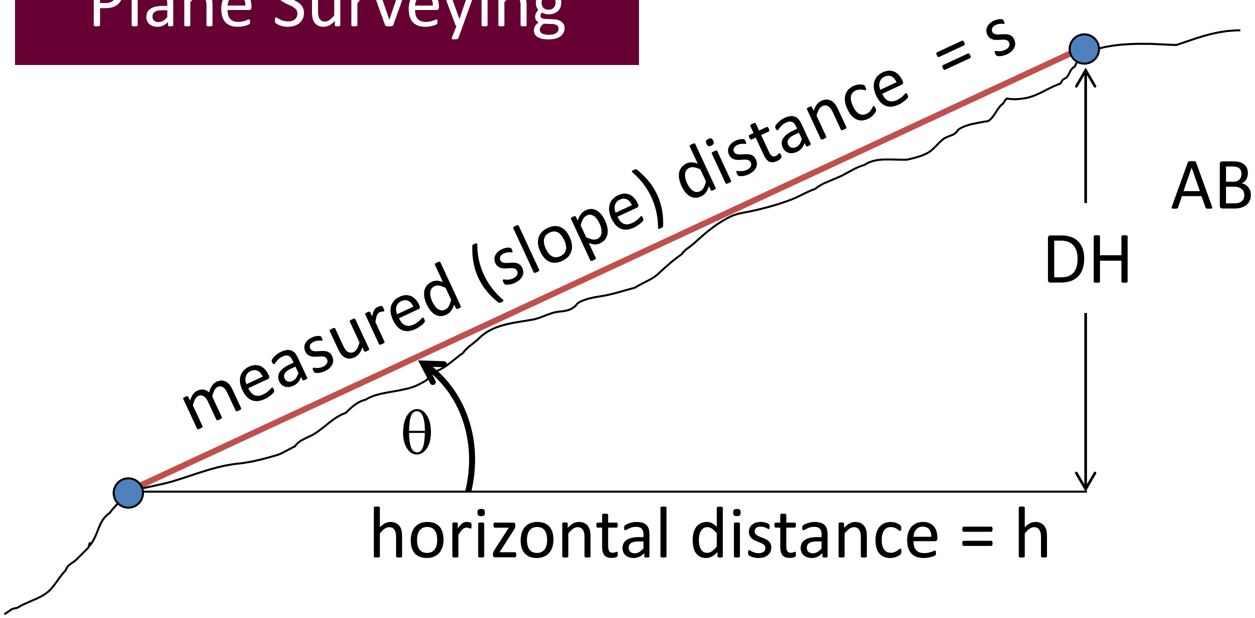

AB in Plan = **s Cos θ**

To calculate the *horizontal* distance :

$$\boxed{h = s \cos\theta \quad \text{or} \quad h = (s^2 - DH^2)^{1/2}}$$

Classification (Division) of Surveying

Geodetic Surveying

According to the space involved

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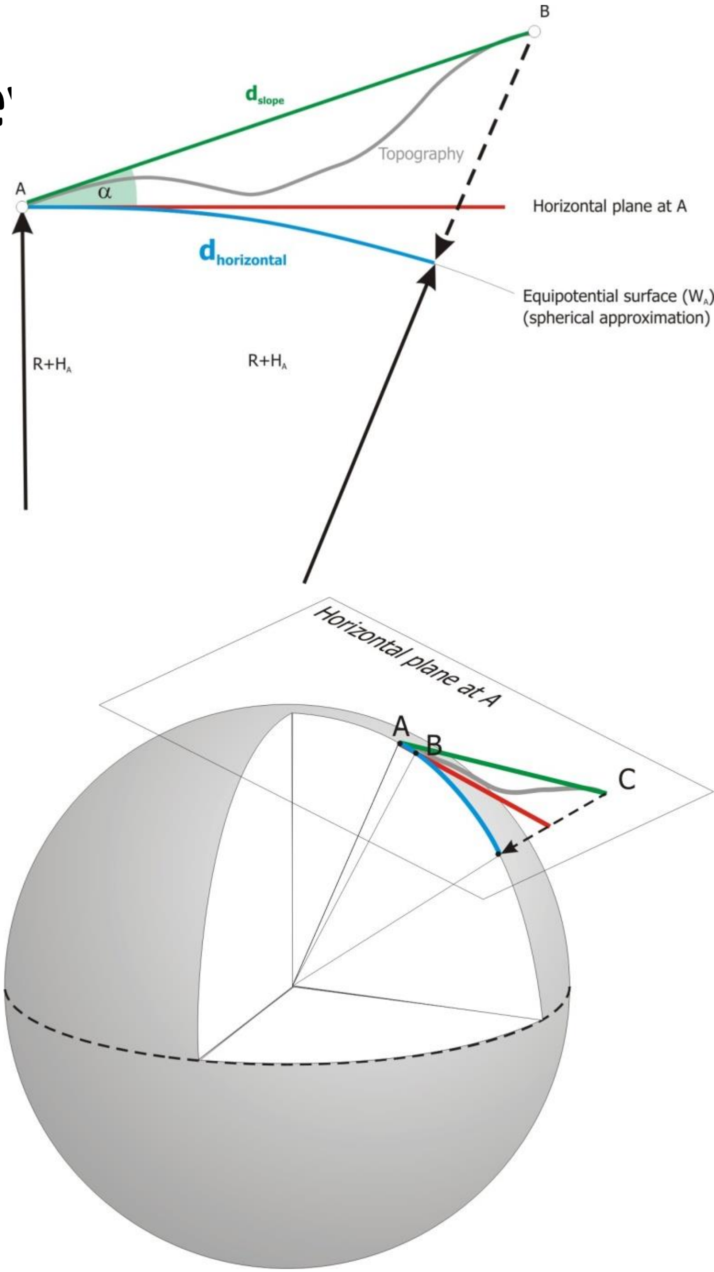
Geodetic Surveying

According to the space involved:

- Large areas



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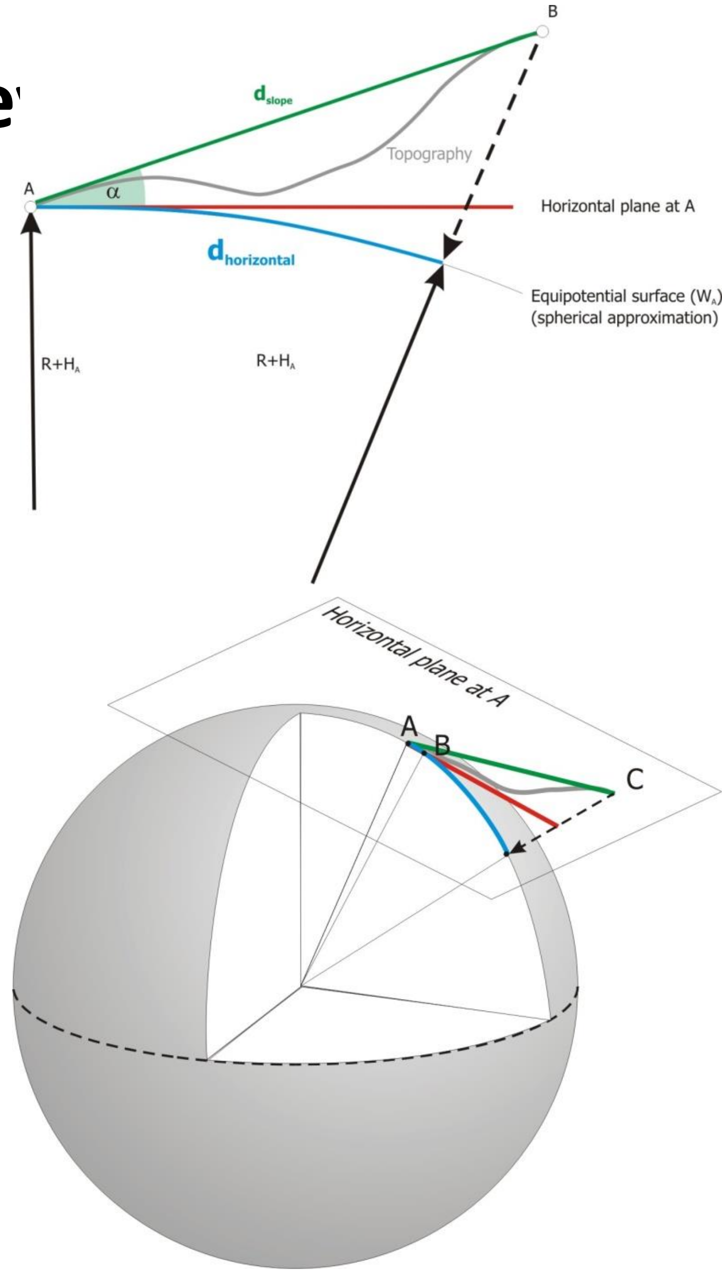
Geodetic Surveying

According to the space involved:

- Large areas
- Surface of the Earth <u>can not</u> be assumed to be flat

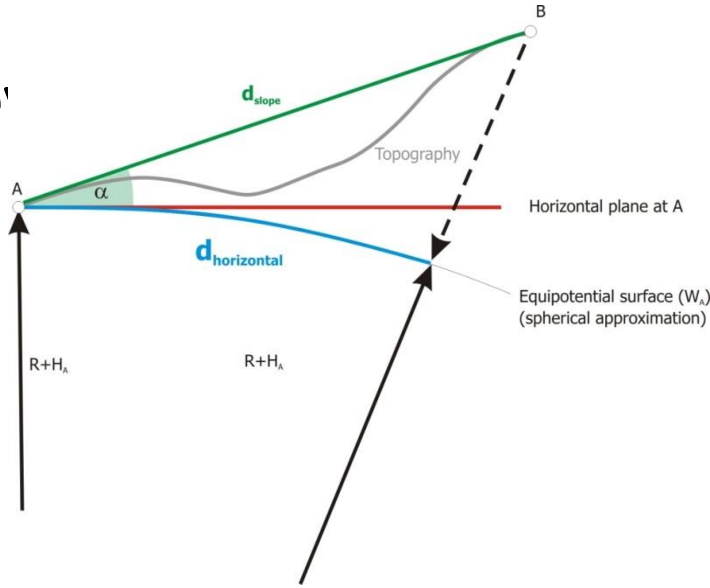


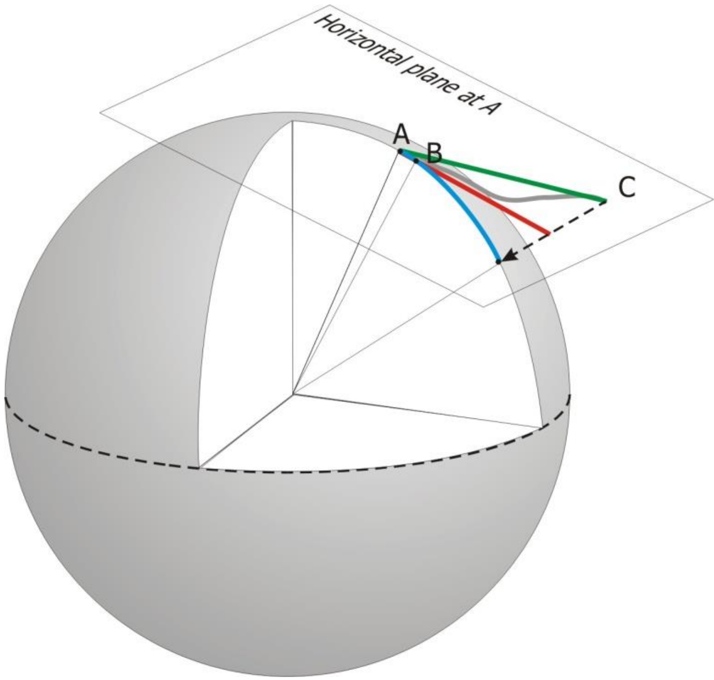
Classification (Division) of Surve

Geodetic Surveying

According to the space involved:

- Large areas
- Surface of the Earth <u>can not</u> be assumed to be flat
- The curvature of the Earth is taken into account

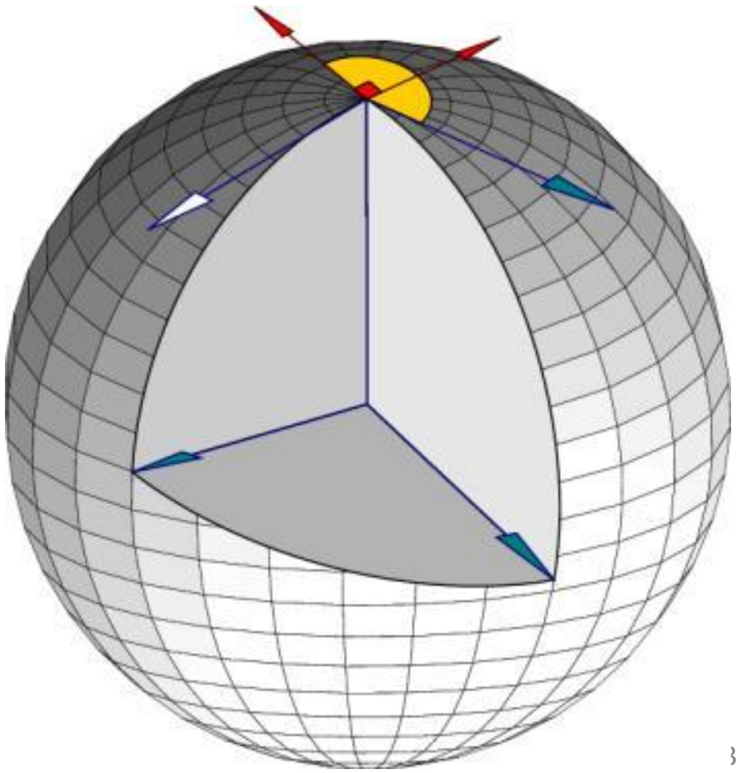




Classification (Division) of Surveying

Geodetic Surveying

- Higher degree of accuracy in linear as well as angular observation is necessary



Classification (Division) of Surveying

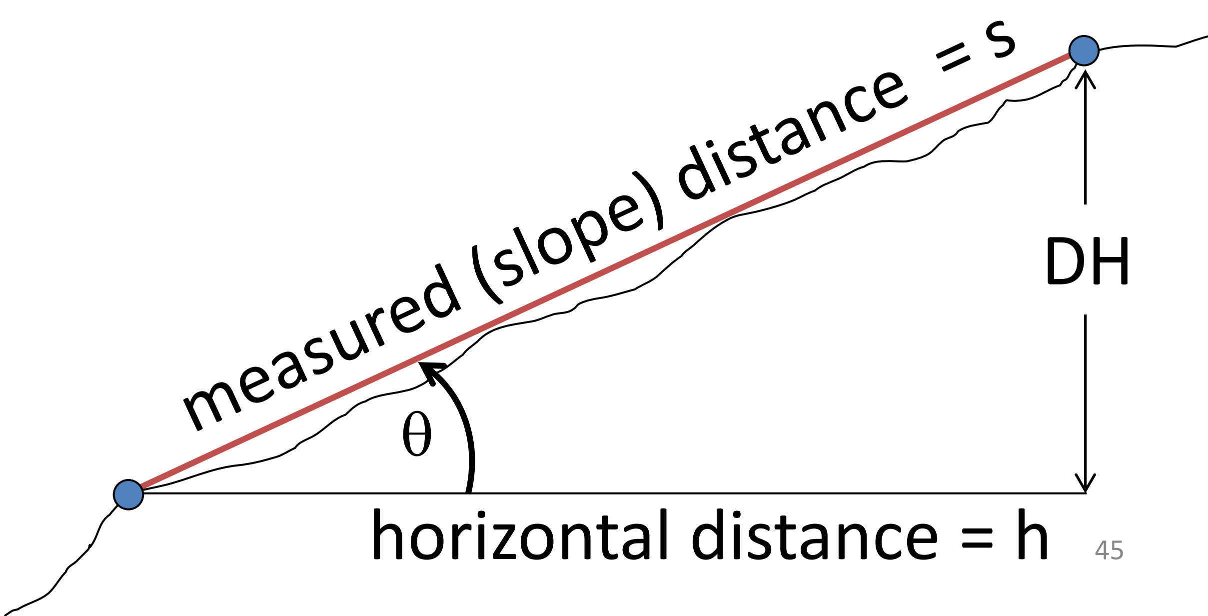
Geodetic Surveying

- Higher degree of accuracy in linear as well as angular observation is necessary
- Mostly used for
  - Establishing control networks
  - Determining the size and shape of the Earth
  - Determining the gravity field of the Earth

Classification (Division) of Surveying

Geodetic Surveying

- Calculation of the projected plane distances – curvature correction is applied to the measured distances



Classification (Division) of Surveying

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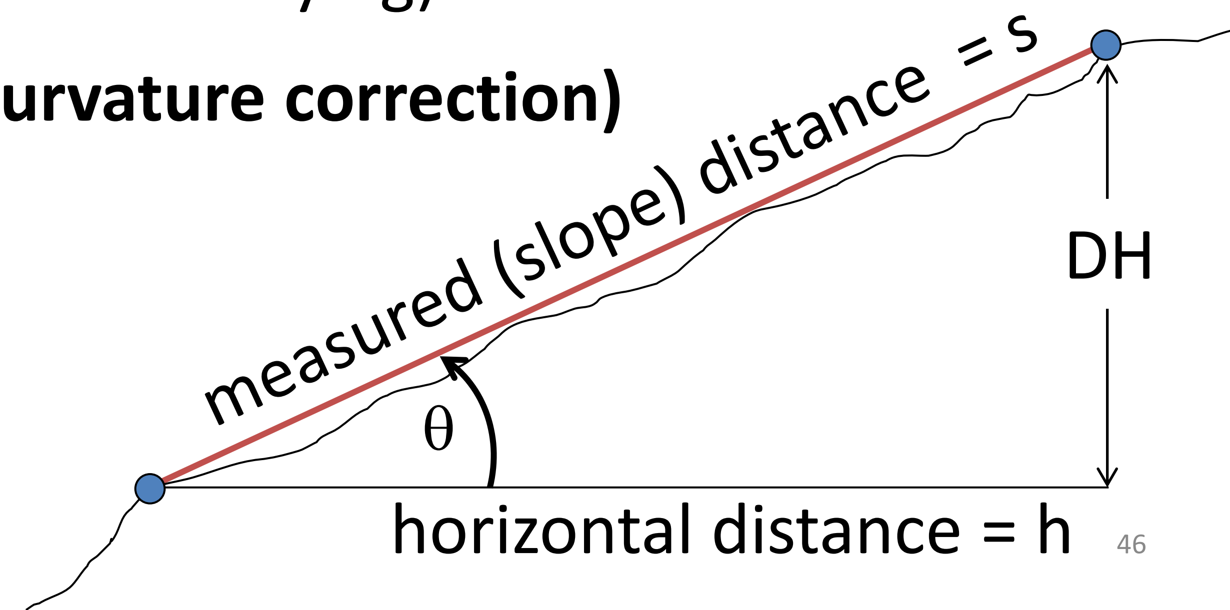
If AB is an arc (in geodetic surveying)

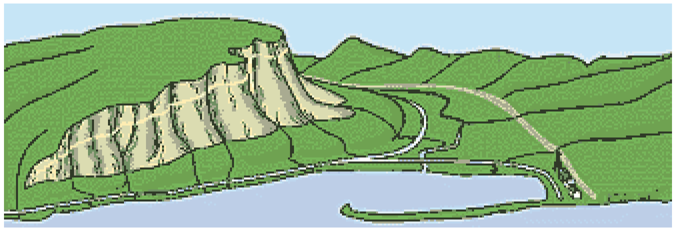
h = s cos q + (earth's curvature correction)

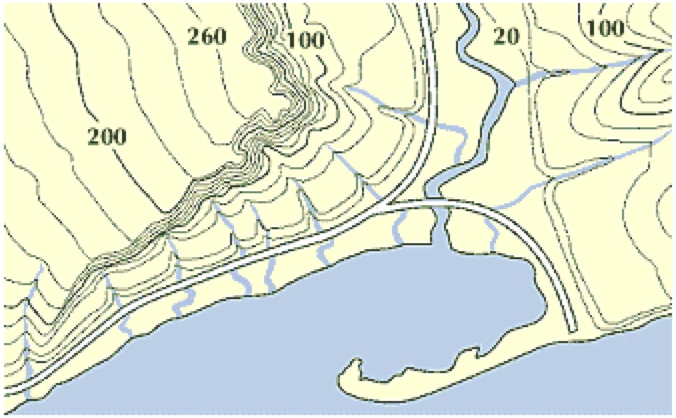


Classification – According to Applications

- Topographic Surveys

  e.g. configuration of terrain (hills, rivers, forests, valleys), location of objects (natural, man-made)

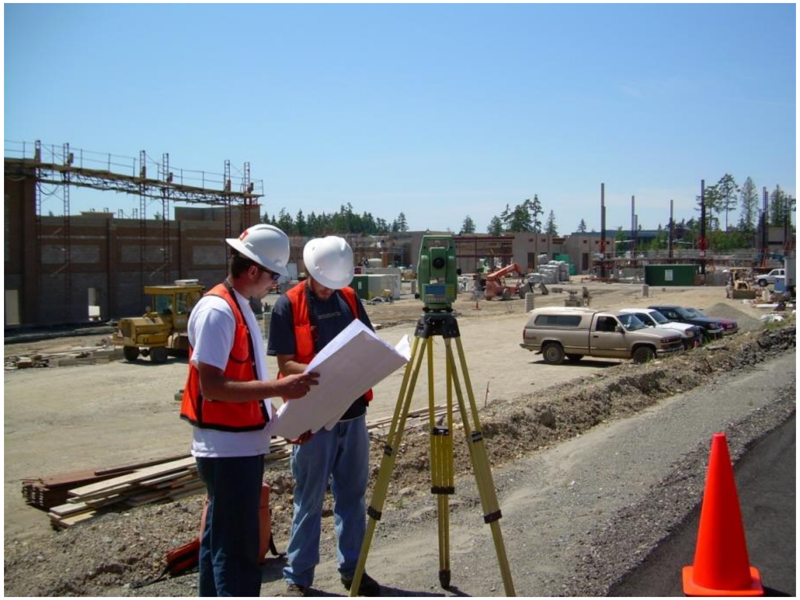


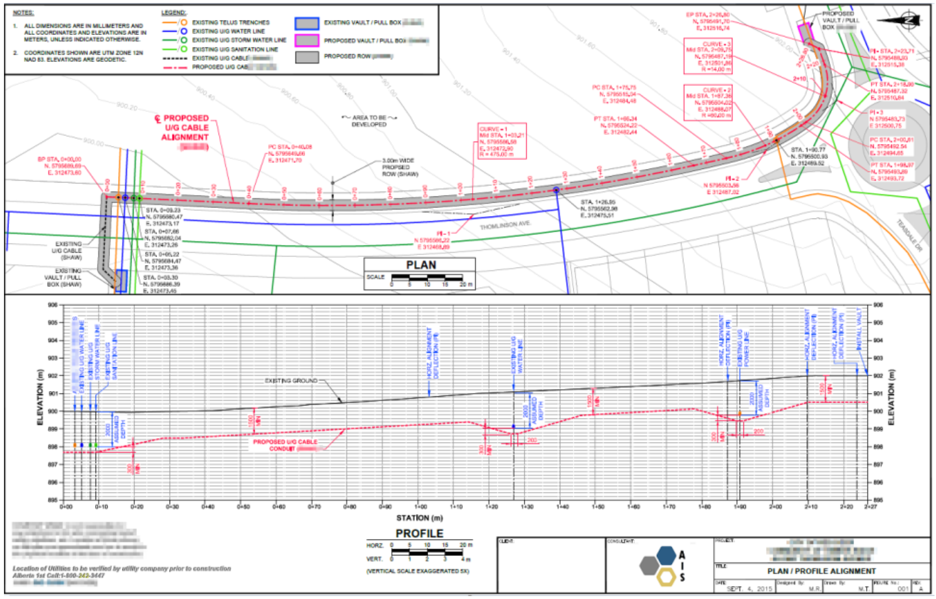


Classification – According to Applications

- Engineering Surveys

  To collect detailed data for the design for of projects involving roads, railways, etc.

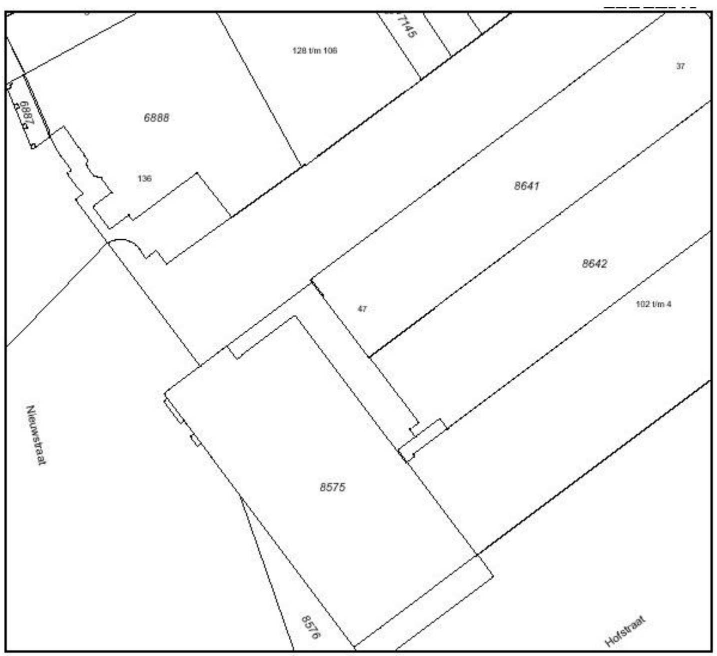


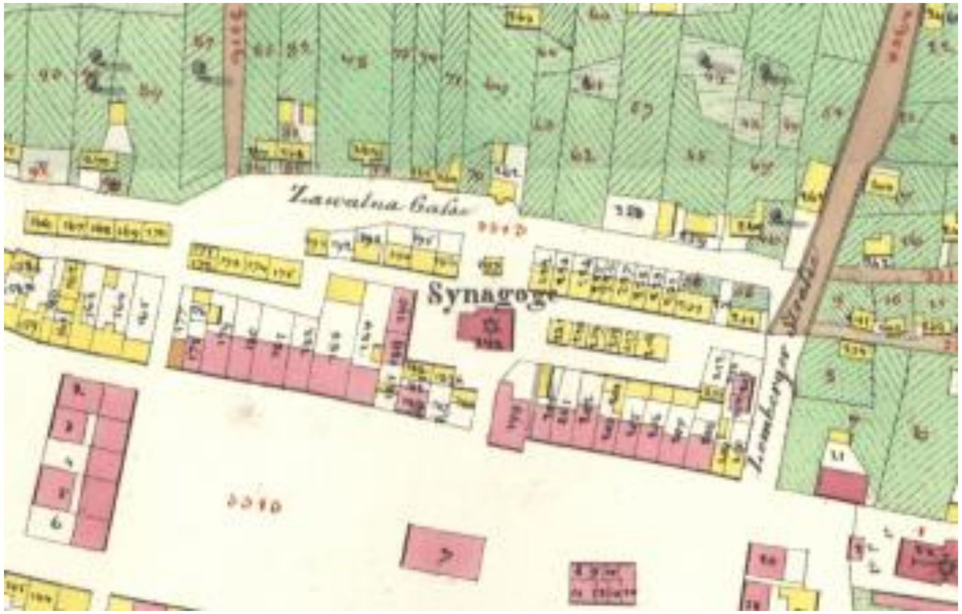


Classification – According to Applications

- Cadastral Surveys

  Showing boundaries of properties like houses, buildings, fields, colonies





Classification – According to Applications

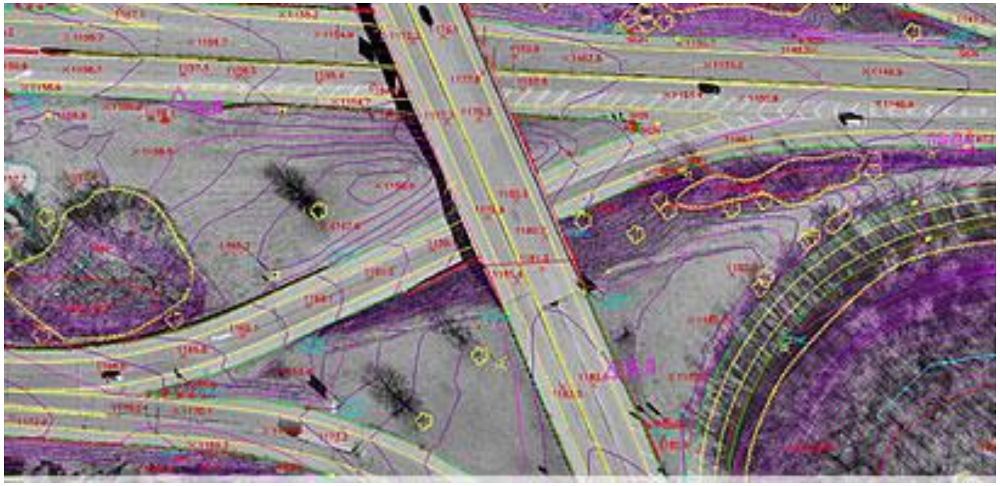
- Mine Surveys

  Control, locate, and map underground and surface works related to mining operations

Classification – According to Applications

- Photogrammetric Surveys

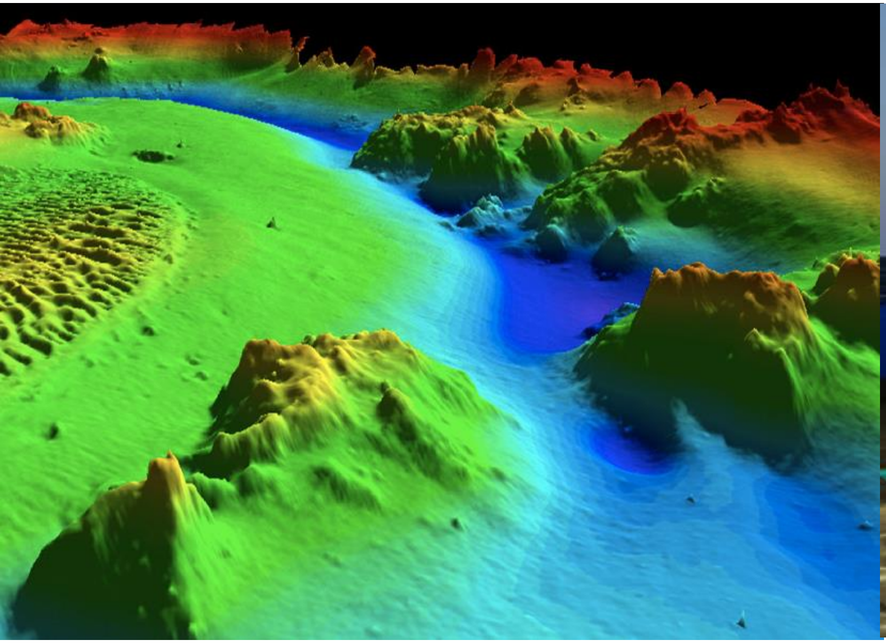
  Utilizes the principles of aerial Photogrammetry, in which measurements made on photographs are used to determine the positions of photographed objects

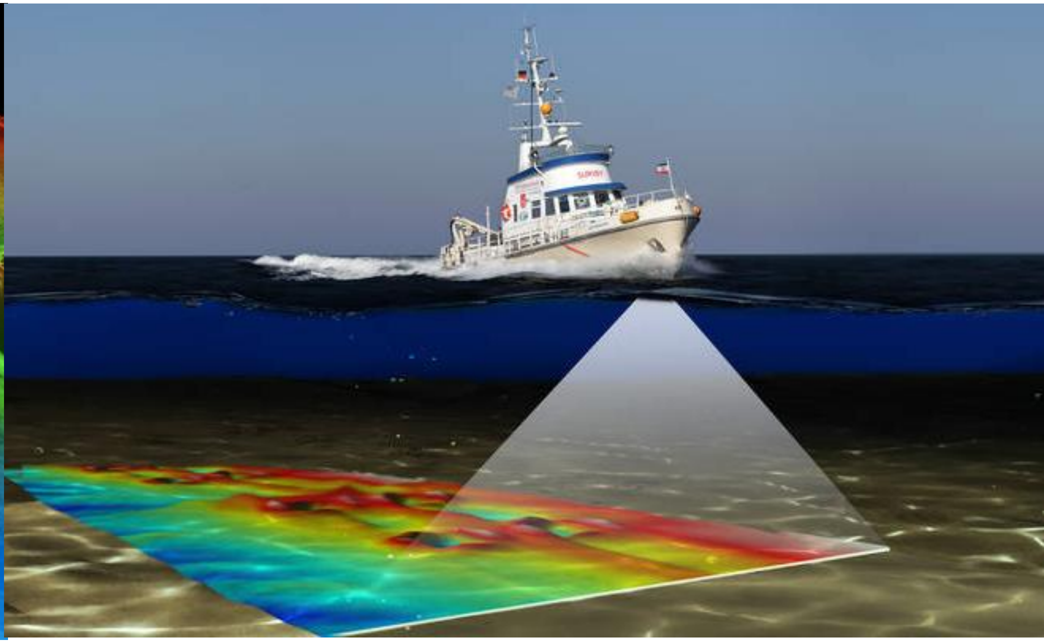


Classification – According to Applications

- Hydrographic Surveys

  Survey of bodies of water made for the purpose of navigation, water supply, or sub-aqueous construction





Evolution of Surveying Instruments

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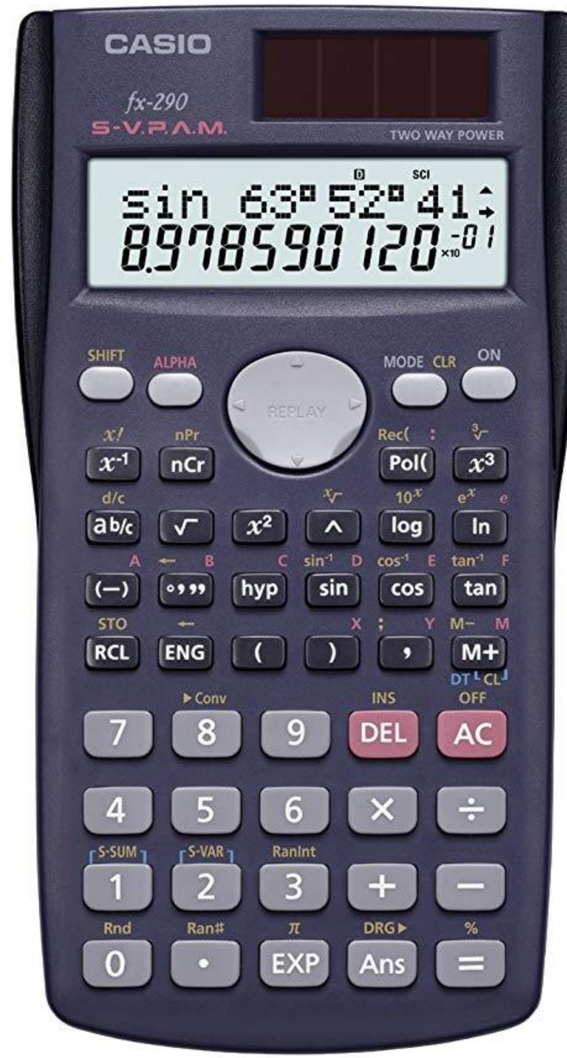

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https://infrastructure.eng.unimelb.edu.au/collection/

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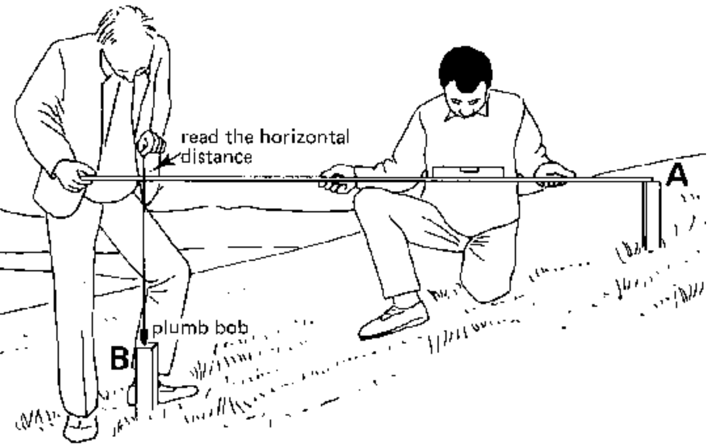
Types of Measurements in Surveying

1. Distance – Horizontal, Vertical



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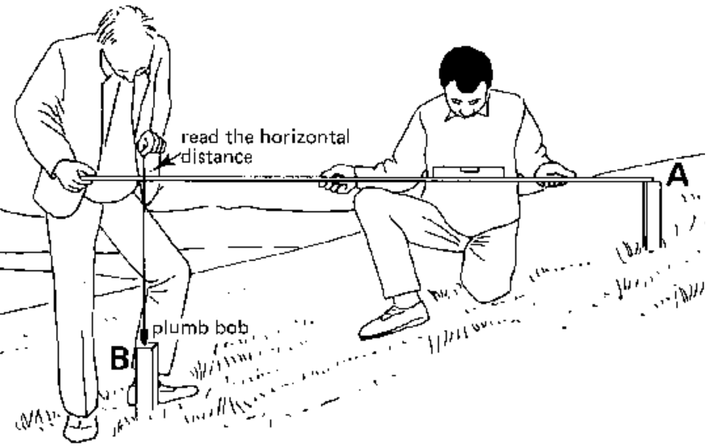

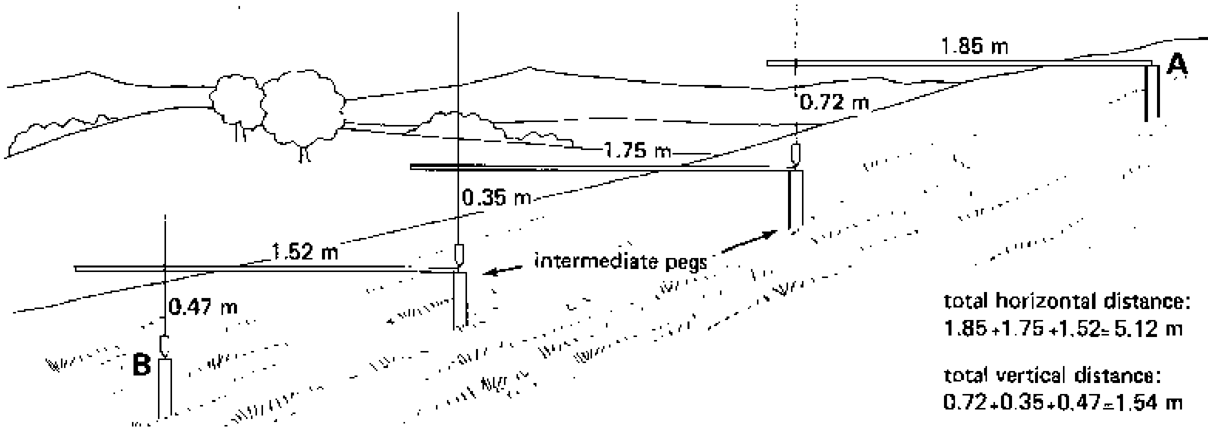

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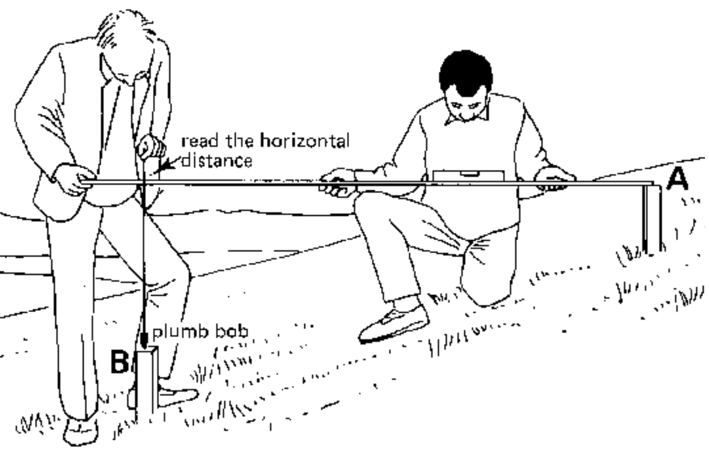

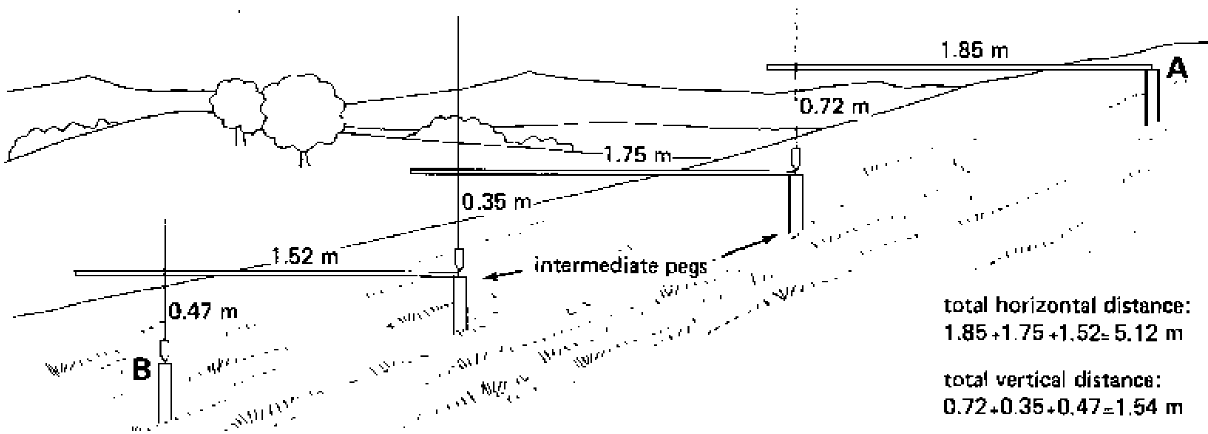

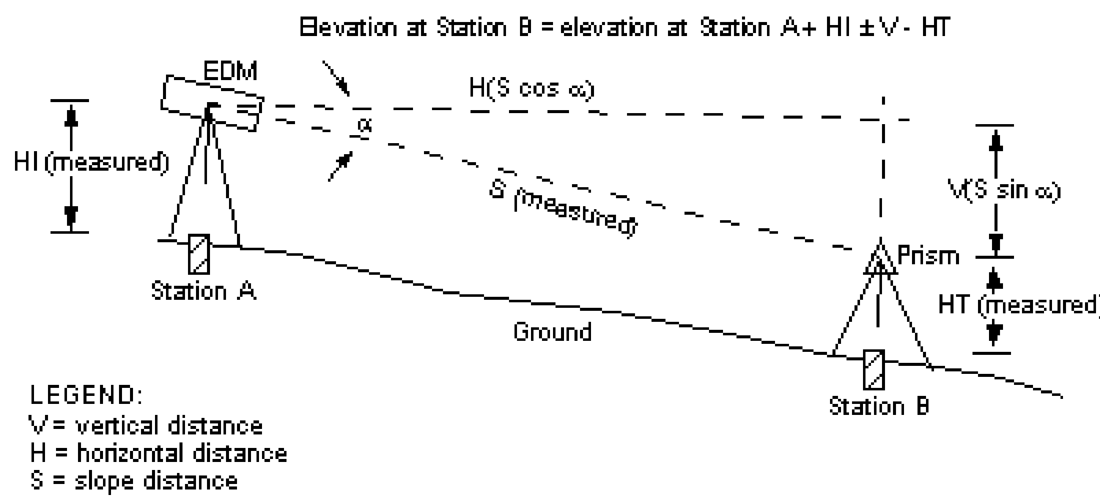

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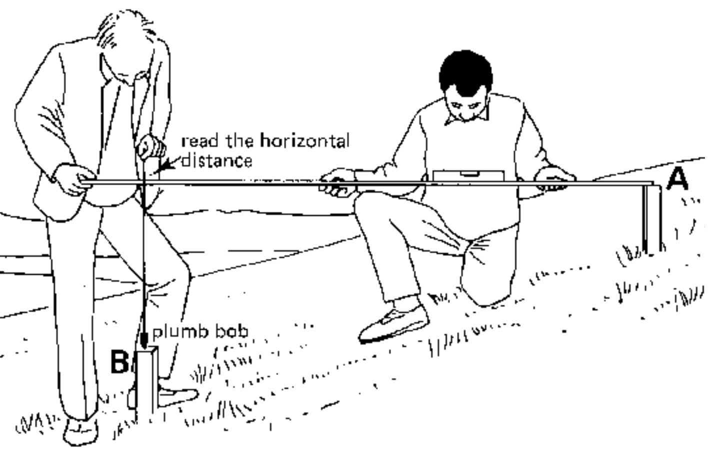

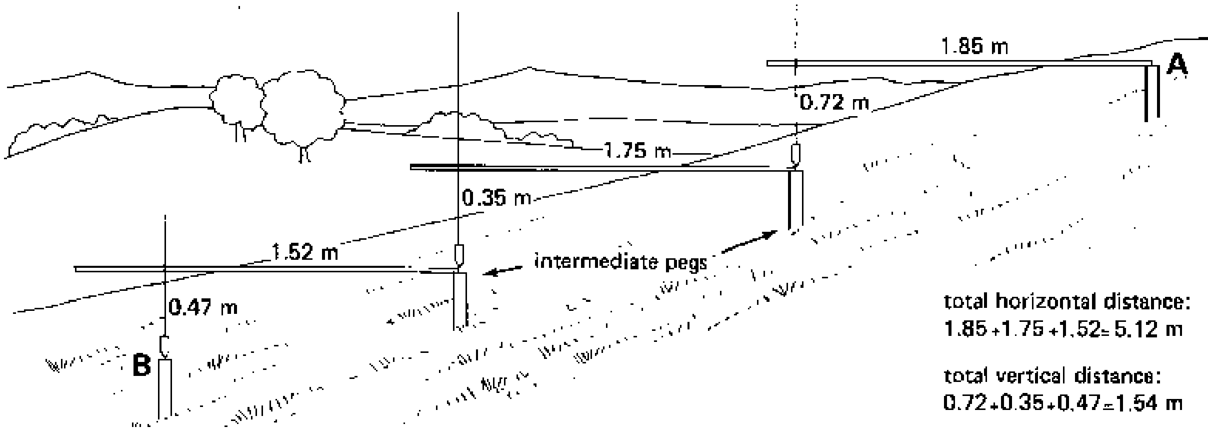

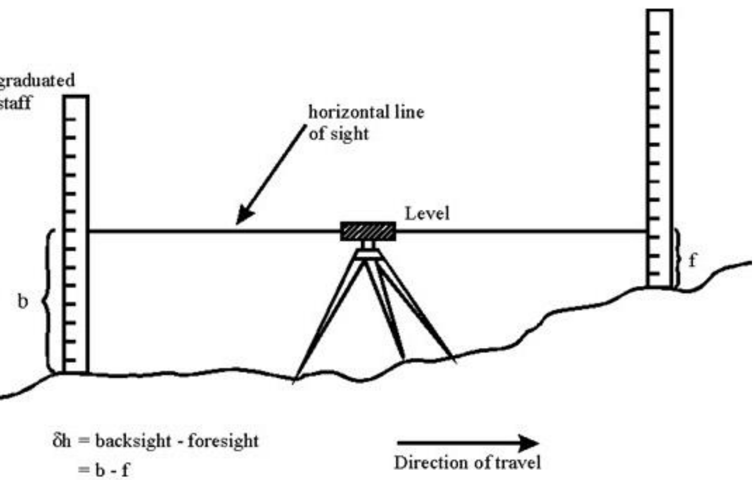

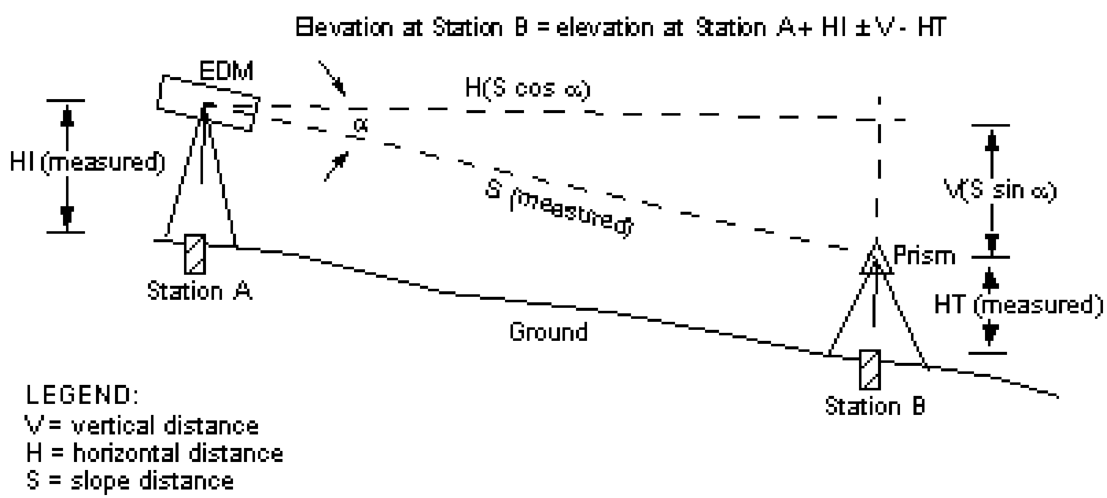

Types of Measurements in Surveying

2. Direction (Angle) – Horizontal, Vertical

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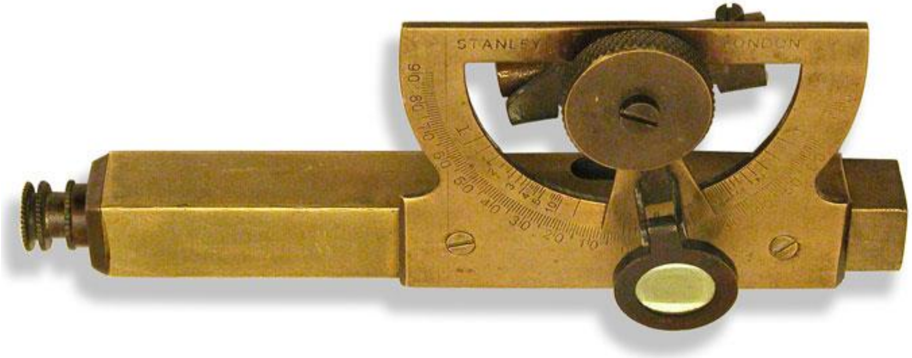

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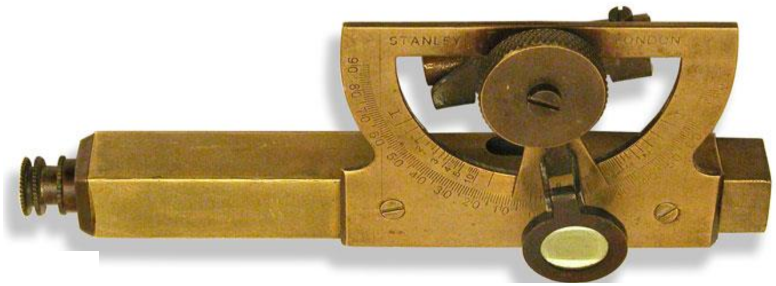
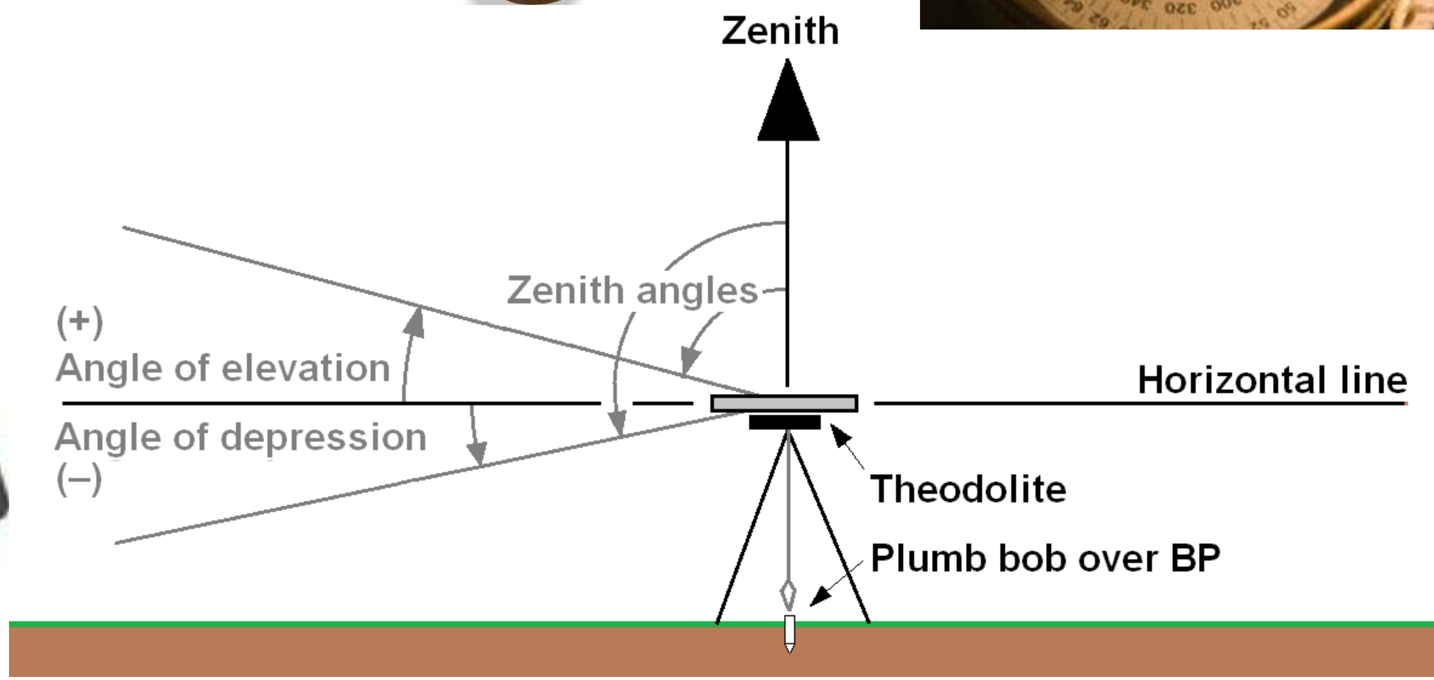




Types of Measurements in Surveying

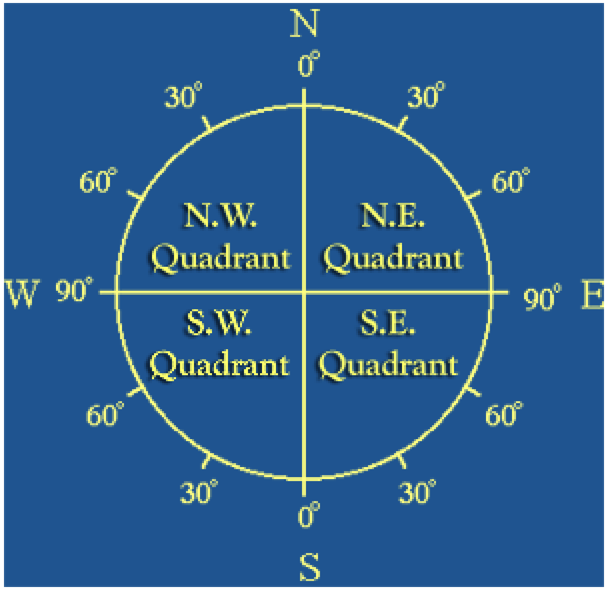
Direction (Angle)

Bearing

Whole Circle Bearing

Quadrantal Bearing

Reduced Bearing

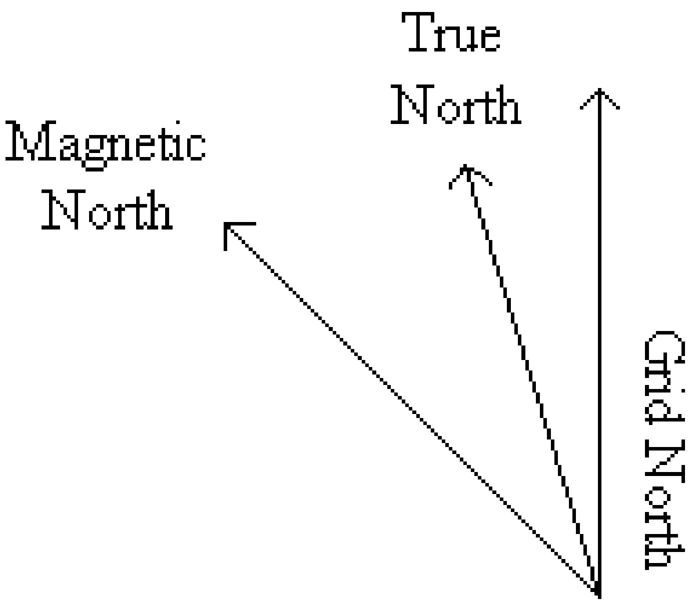


Types of Measurements in Surveying

Direction (Angle)

Bearing

- Whole Circle Bearing
- Quadrantal Bearing
- Reduced Bearing
- Magnetic Bearing
- True Bearing



Units of Measurements

- Angular
- Linear
- Area
- Volume

- Unit conversions???

English Units to Metric and vice versa

Units of Measurements

Quantity	Unit	Symbol
Length	kilometre metre millimetre	km m mm
Area	square metre hectare	m^2 ha
Volume	cubic metre	m^3
Angle	degrees minutes seconds	° ' "
Mass (Weight)	Kilogram	kg
Temperature	Degrees Celsius	°C

Units of Measurements

- Unit conversions???

English Units to Metric and vice versa

$$1\ meter = 39.37\ inches$$

$$1\ meter * \frac{39.37}{12} \cong 3.2808\ feet$$

$$1\ foot * \frac{12}{39.37} \cong 0.3048\ meters$$

$$1\ mile \cong 1609.4\ meters \cong 1.6094\ kilometers$$

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$$1\ square\ meter \cong 1.1960\ square\ yards$$

$$1\ square\ meter \cong 10.7639\ square\ feet$$

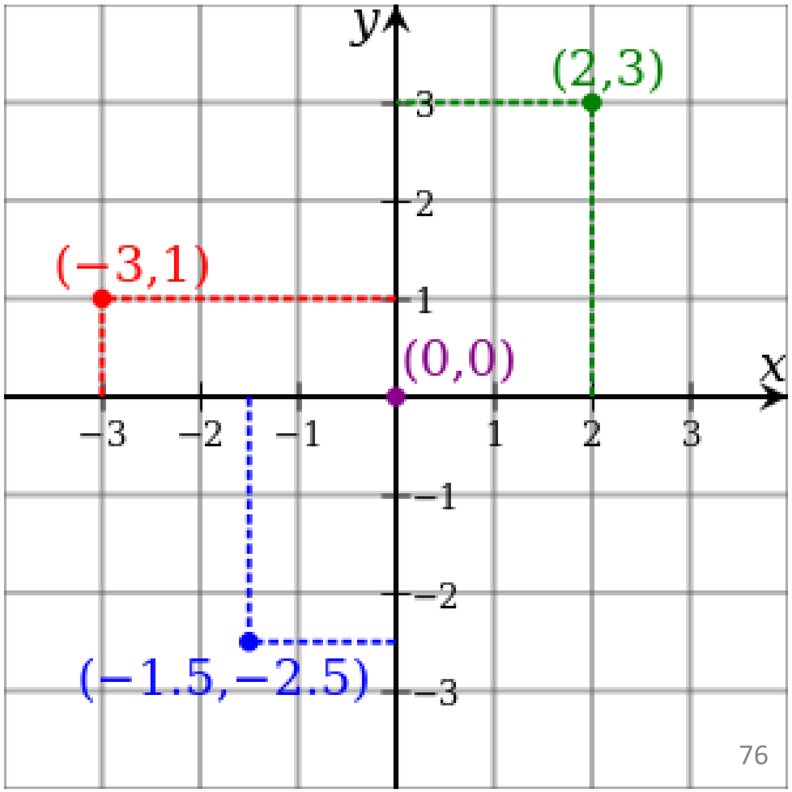
$$1\ hectare \cong 2.4710\ acres$$

$$1\ square\ kilometer \cong 247.1044\ acres$$

$$1\ square\ mile \cong 2.5900\ square\ kilometers \cong 258.9998\ hectares$$

What is a Coordinate System?

A system that uses one or more numbers, or **coordinates**, to uniquely determine the position of a point or other geometric element



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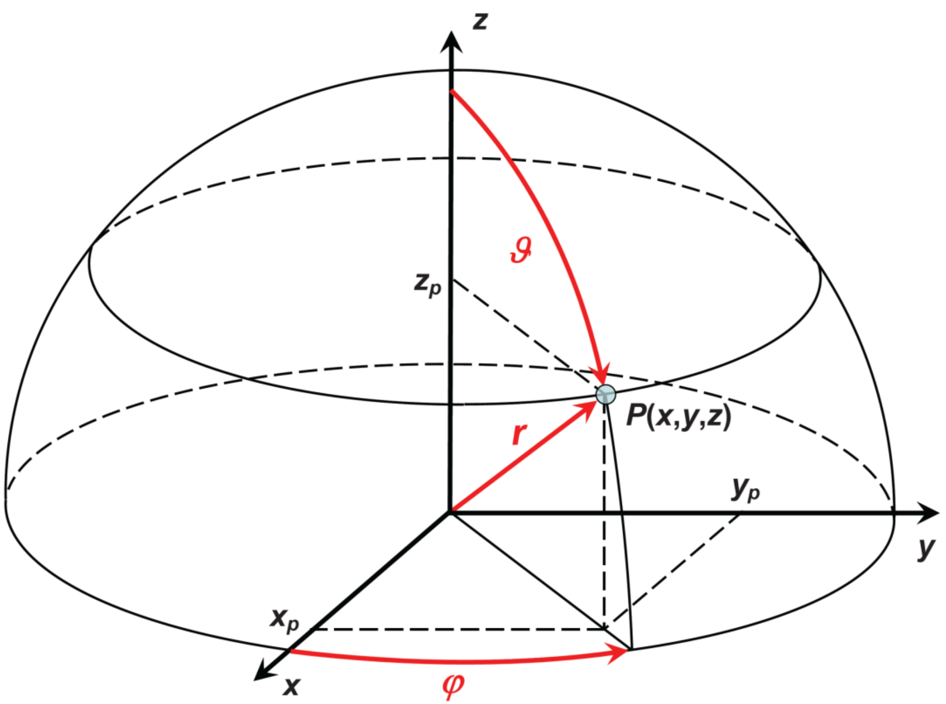
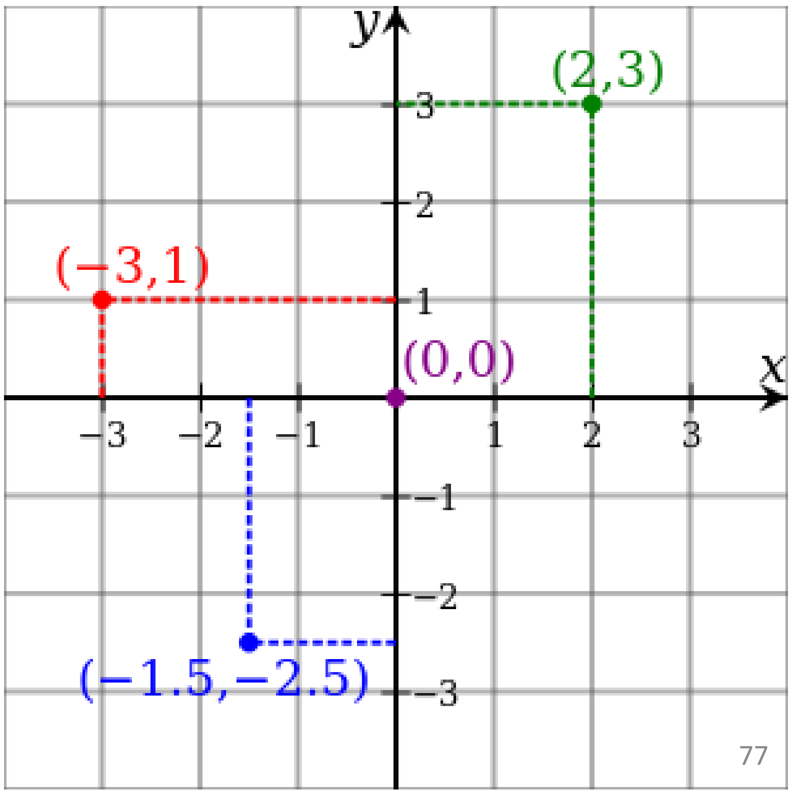
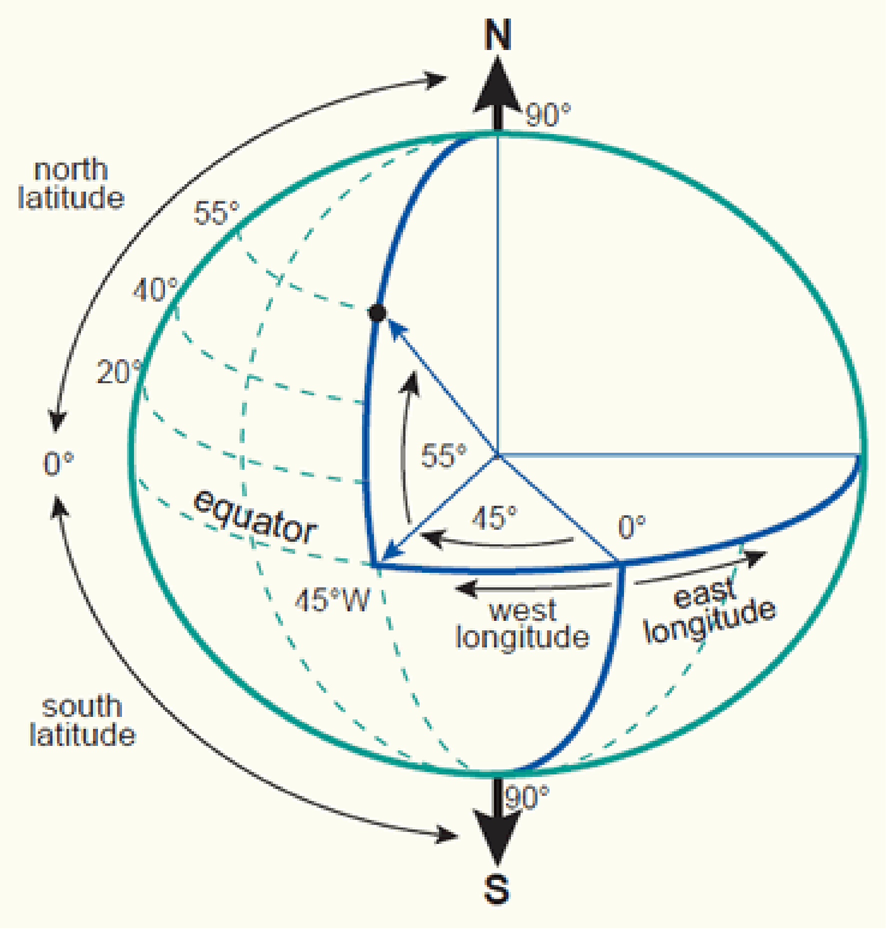




Geographic Coordinate System



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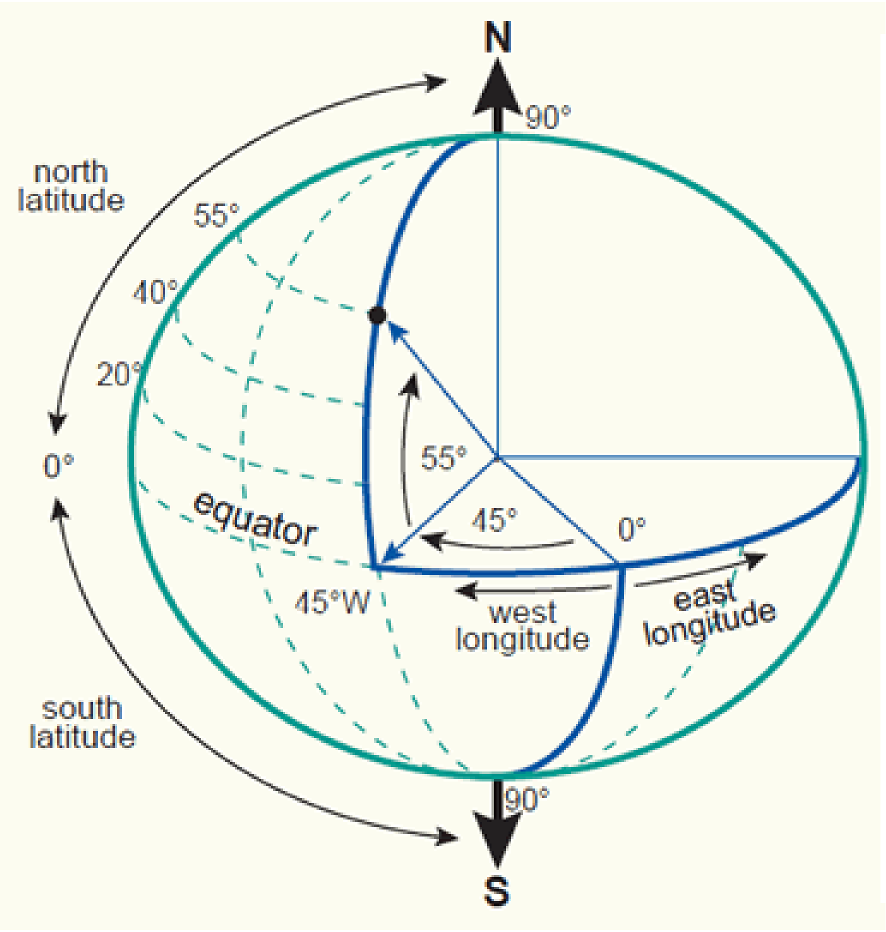
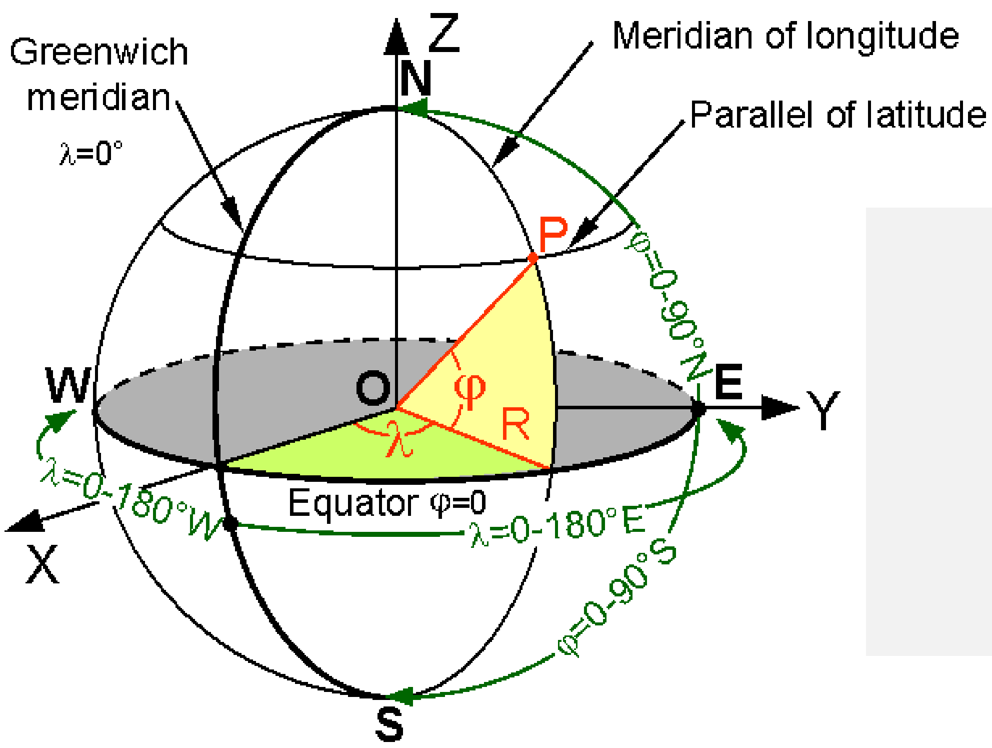
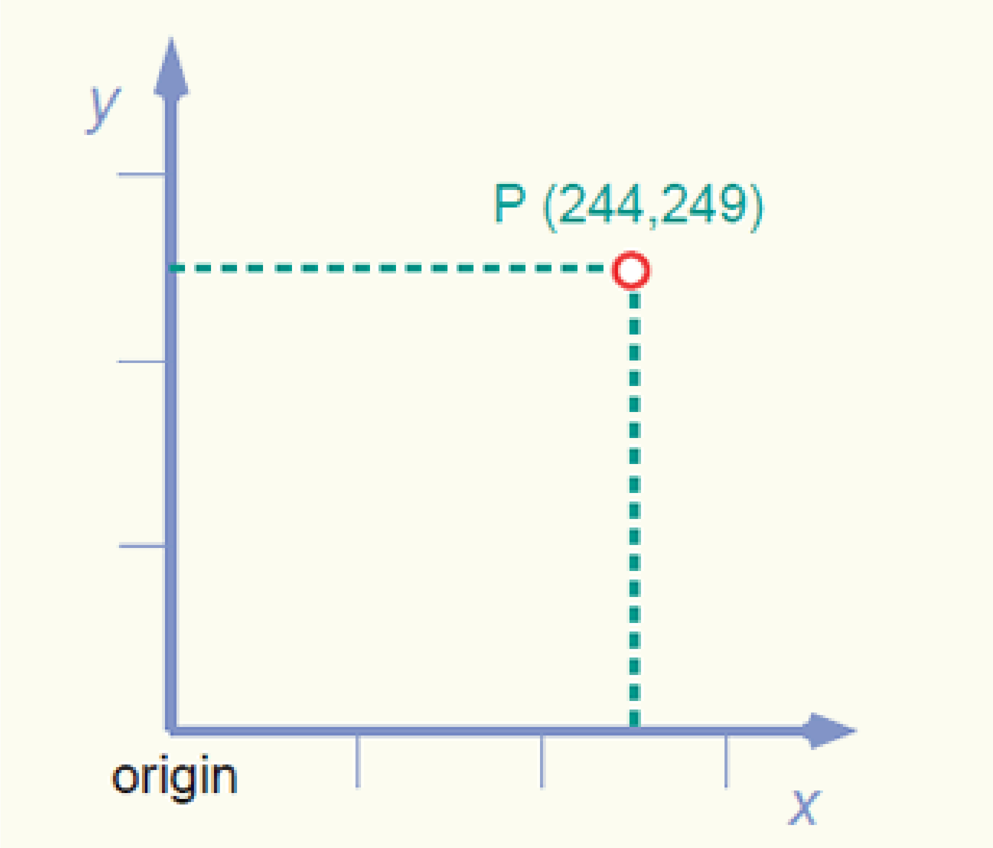




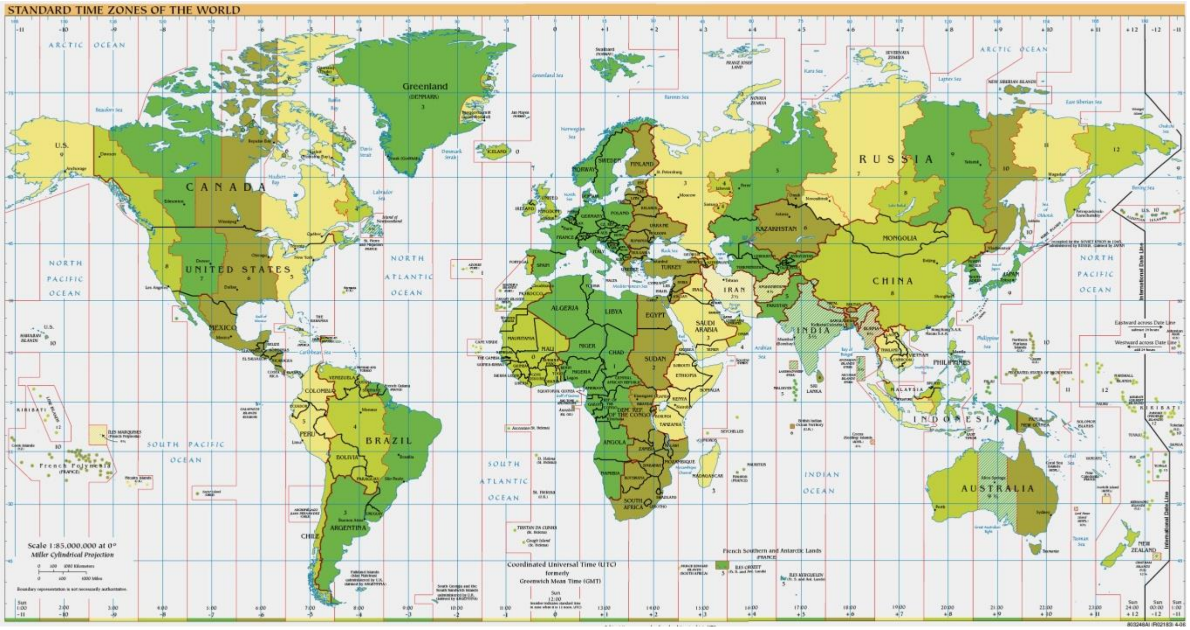
Cartesian Coordinate System

Horizontal axis – *X*-axis – **Easting**
Vertical axis – *Y*-axis – **Northing**



What is a Map?

Representation of a portion of the Earth surface on a Plane



Scale

Relationship between a given **distance** on the **ground** and the **corresponding** distance on the **map**

$$\textit{scale} = \frac{\textit{distance on the map}}{\textit{corresponding distance on the ground}}$$

Working With Maps …

Surveying Techniques

- Chain Surveying/Linear Measurements

Surveying Techniques

- Plane Table Surveying

Surveying Techniques

- Compass Surveying

Surveying Techniques

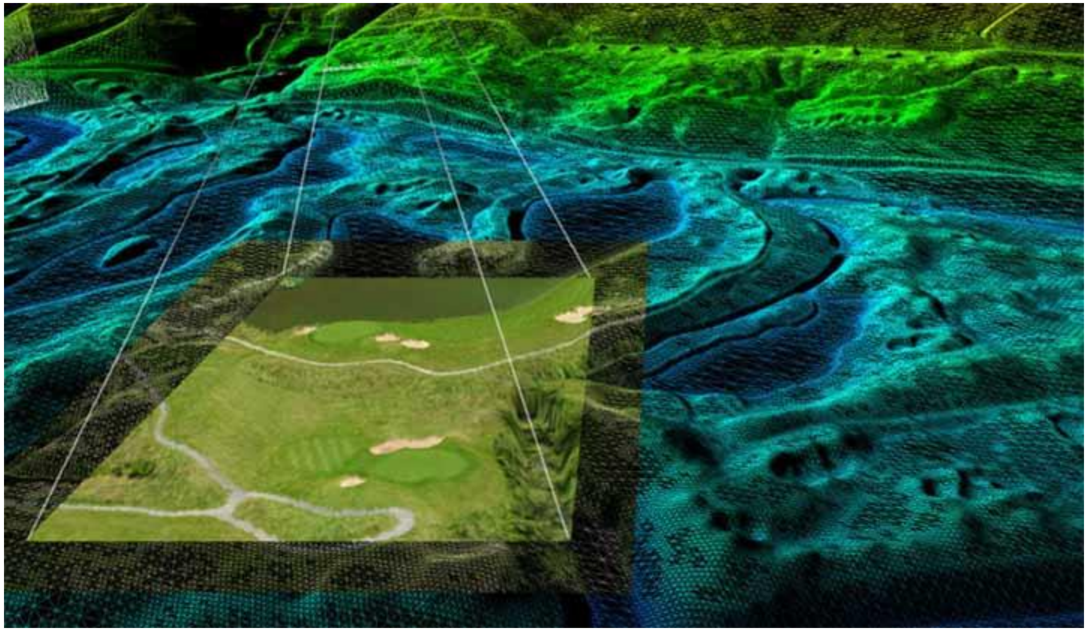
- Theodolite Surveying

Surveying Techniques

- Tacheometric Surveying

Surveying Techniques

- Aerial Surveying



Sources of Errors

Instrumental imperfections

Due to imperfections or faulty adjustment of the instrument being used

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Personal limitations

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Natural causes

e.g. variation in speed of wind, temperature, humidity, refraction, gravity and magnetic declination

Types of Errors

Blunders

Mistakes and gross errors

Types of Errors

Blunders

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Systematic or Cumulative errors

Repeated size and sign

Affects accuracy

Types of Errors

Blunders

Mistakes and gross errors

Systematic or Cumulative errors

Repeated size and sign

Affects accuracy

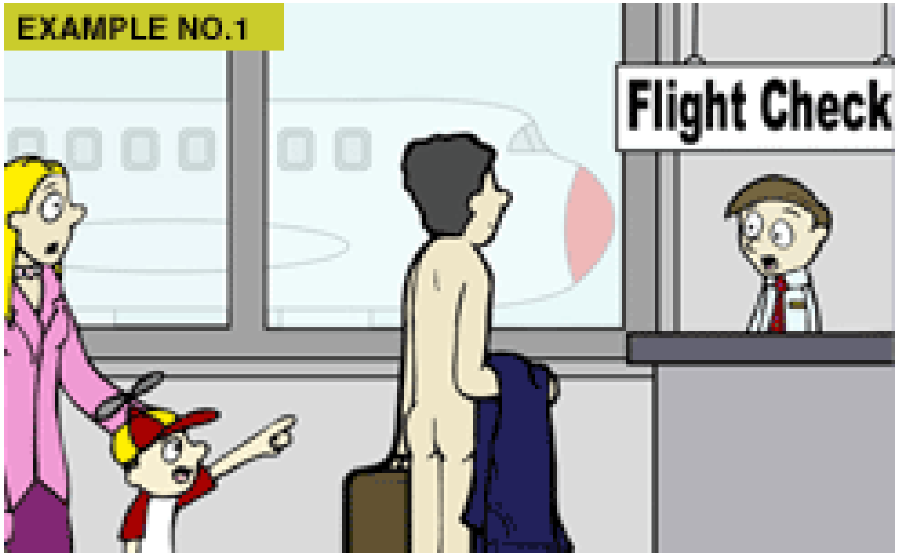
Random or Accidental errors

Small and usually undetectable (noise)

Affects precision

Types of Errors – Blunders

- Can occur at any stage of survey (observing, booking, computing or plotting)
- Very damaging effects on results



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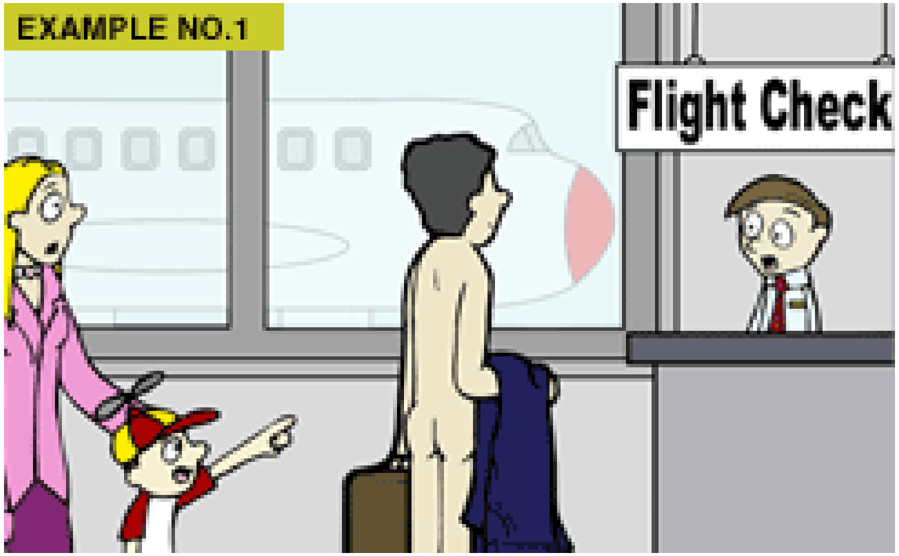

<u>Examples:</u>

Miscounting the number of tape lengths, recording the wrong value , striking the wrong key, transposing digits (68 as 86)

Types of Errors – Blunders

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- Errors arises from sources that act in a similar manner on observations
- Method of measurement, instrument used, and physical conditions at the time of measurement must all be considered
- Errors not revealed by taking the same measurement with the same instruments
- To check for systematic error is to re-measure the quantity by an <u>entirely different method</u> using different instruments

Types of Errors – Systematic Errors

- As it has a constant sign, their effect on the final result is cumulative

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- Examples :
  - Erroneous length of chain
  - Variation of temperature
  - Erroneous graduation of a instrument

Types of Errors – Random Errors

- Errors those which remain after mistakes and systematic errors have been eliminated

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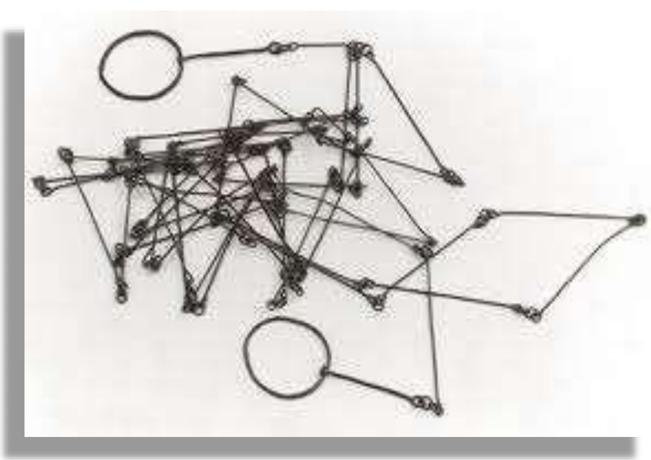
- Errors those which remain after mistakes and systematic errors have been eliminated
- Some random errors, by their nature, tend to cancel themselves
- Errors have the following characteristics;

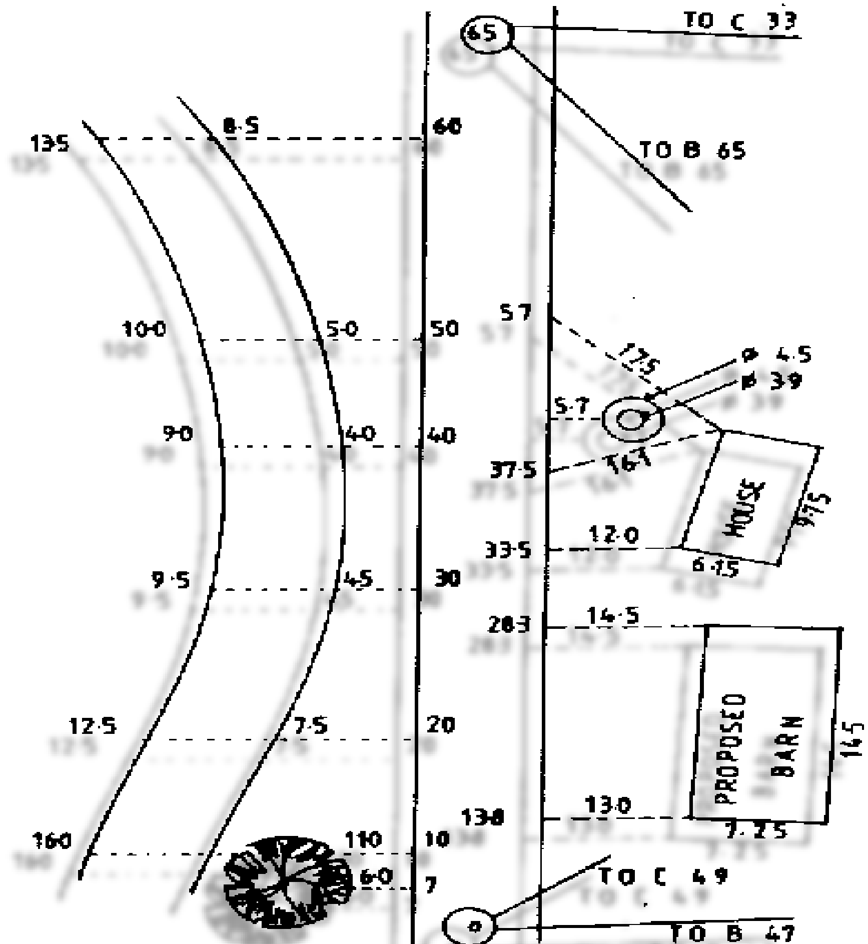
  Small errors occur more frequently than large ones

  Positive and negative errors are more likely to occur

  Very large errors seldom occur

Chain Surveying/Linear Measurements





Chain Surveying

- This is the **simplest type of surveying** in which **only linear measurements** are made with a chain or a tape

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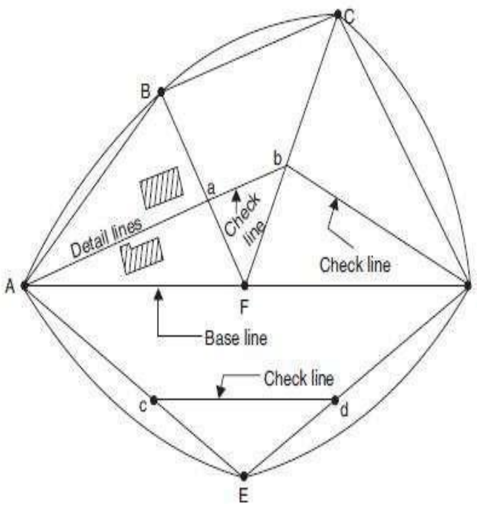
- Measurements are taken in the field and other **supplementary work** like plotting calculations are carried out in **office**

- **Basic principle** of Chain Surveying is **Triangulation**:
  The entire area is divided into a network of triangles

Chain Surveying

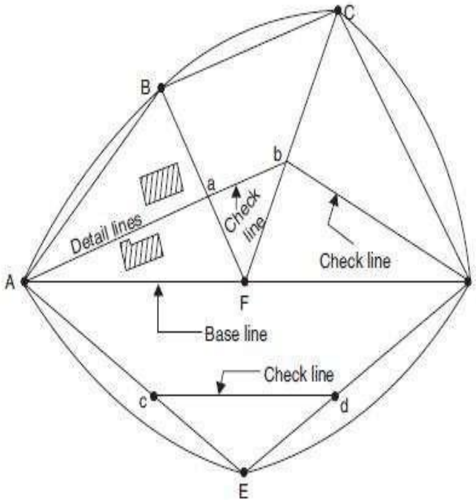
- The **primary triangle** (basic triangle/1st triangle) is **surveyed very precisely** so that errors are not transformed to the secondary triangles



Chain Surveying

- The **primary triangle** (basic triangle/1st triangle) is **surveyed very precisely** so that errors are not transformed to the secondary triangles

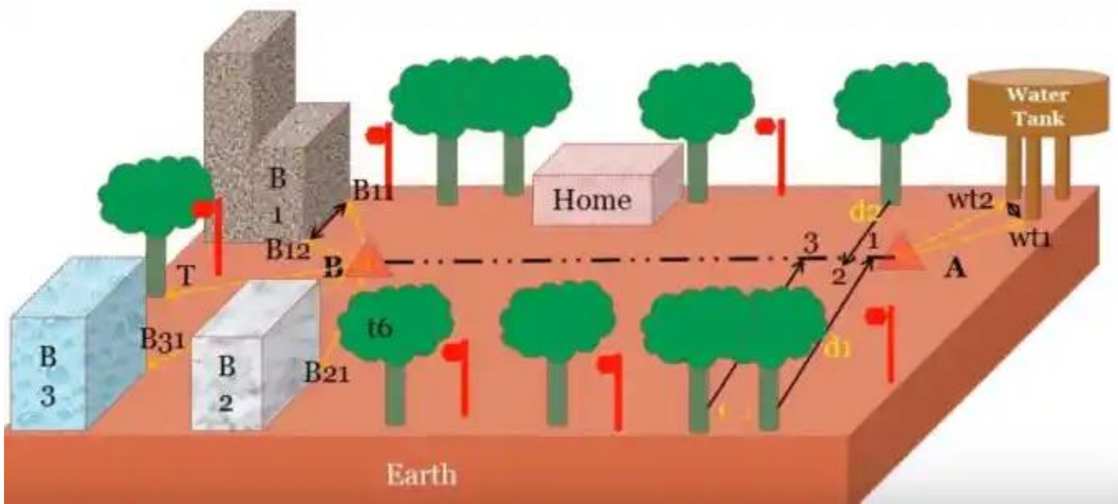
- For <u>minimum transfer of error</u>, **triangles** are supposed to be **well-proportioned** i.e. angle should be between 30 degrees to 120 degrees



Applicability of Chain Surveying

- Can be used if the area under consideration meets the following conditions:

    i. The area is fairly small
    ii. The ground is moderately levelled
    iii. The area is open
    iv. The ground has few and simple details



Chain Surveying – Equipment

- Chain

Chain Surveying – Equipment

-
- Tape

Chain Surveying – Equipment

-
-
- Ranging-Rod

Chain Surveying – Equipment

-
-
-
- Arrows

Chain Surveying – Equipment

- Wooden pegs/pickets

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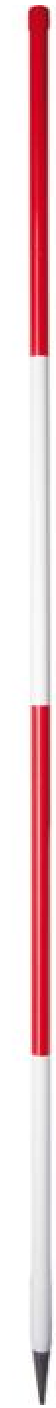


Chain Surveying – Stations

- **Main stations:**

  The end of lines that determine the boundary of the surveying

- **Tie (Subsidiary) Stations:**

  Points which are specified on the chain line (main survey lines) where it is required to identify interior details like buildings and fences

Chain Surveying – Station Selection

i. **Stations** should be **visible** from at least two or more stations

ii. As far as possible, **main lines** should run on **level ground**

iii. All angles shall be **well-defined** (Angles between 30 degrees and 120 degrees)

iv. Each triangle should have at least one check line

Chain Surveying – Station Selection

v. Survey **lines** should be as **few** as possible

vi. Obstacles to ranging and chaining should be avoided

vii. Sides of the **larger triangles** should **pass** as **close** to the **boundary lines** as possible

viii. Trespassing and frequent crossing of the roads should be avoided

Chain Surveying – Types of Lines

- **Base Line:**

  It is the **main** and **longest line** from which all measurements to demonstrate details of the work are taken

  Passes through the **center** of the field

Chain Surveying – Types of Lines

- **Chain (Main Survey) Lines:**

  The **lines** that **join main stations** are termed as chain lines or main survey lines

Chain Surveying – Types of Lines

- **Tie (Subsidiary) Lines:**

  It **joins two fixed points** on the chain line

  The advantage of tie line appears while checking surveying accuracy in locating interior details such as buildings and paths

  The position of each tie line should be close to some features (eg: paths, buildings)

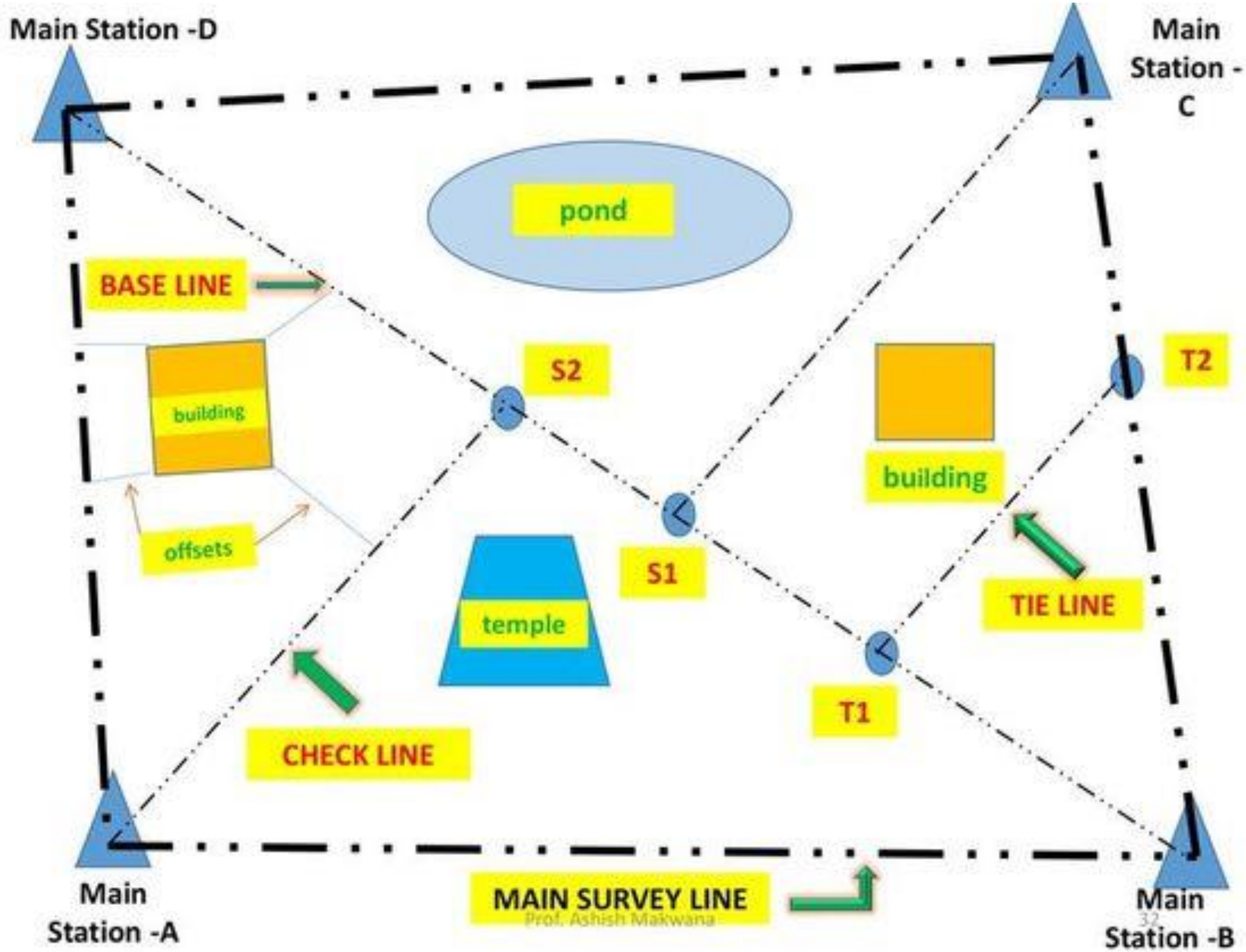
Chain Surveying – Types of Lines

- **Check (Proof) Lines:**

  It **joins triangle apex** to some **fixed points** on any two sides of a triangle

  It is used to examine the accuracy of the framework. The length of check line measured on ground shall be consistent with its length on the plan.

Chain Surveying

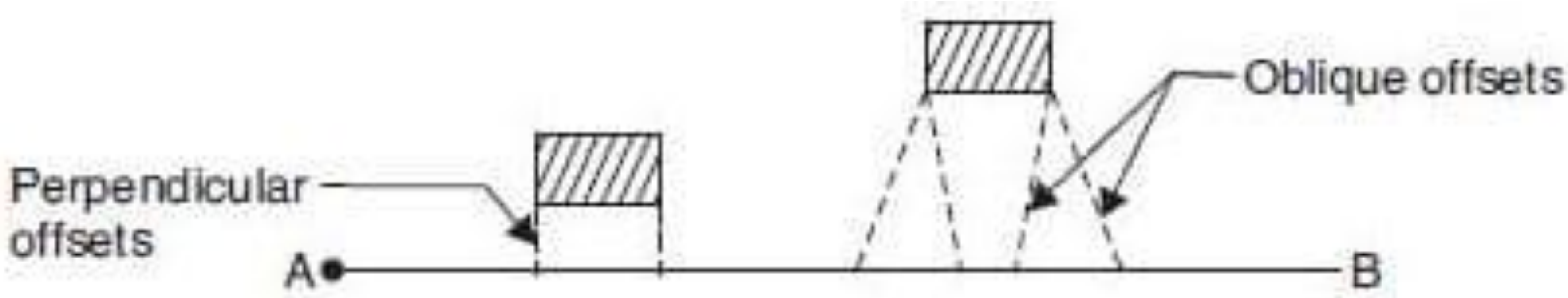


Chain Surveying – Offsets

- **Lateral measurements** from the baseline
- Used to **fix locations of various objects** with respect to the baseline
- Normally **established at right angles**
- There are **two major type** of offsets:

  perpendicular offsets

  oblique offsets



Chain Surveying – Perpendicular Offsets

- Measurements taken at a **right angle** to the **survey line** called **perpendicular** or right-angled **offsets**

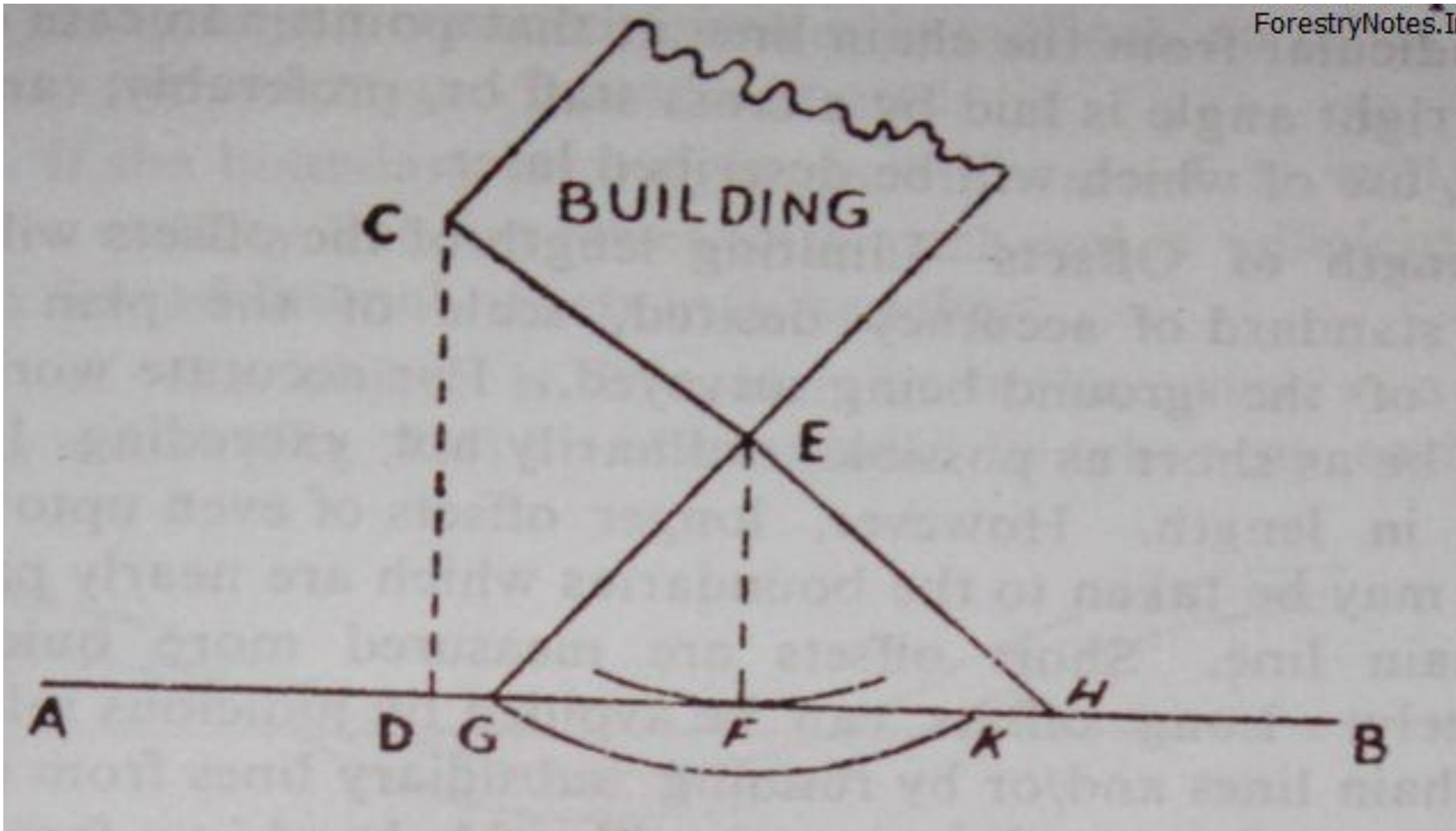
- Setting perpendicular offsets:

  Swinging

  Using cross staffs

  Using optical or prism square

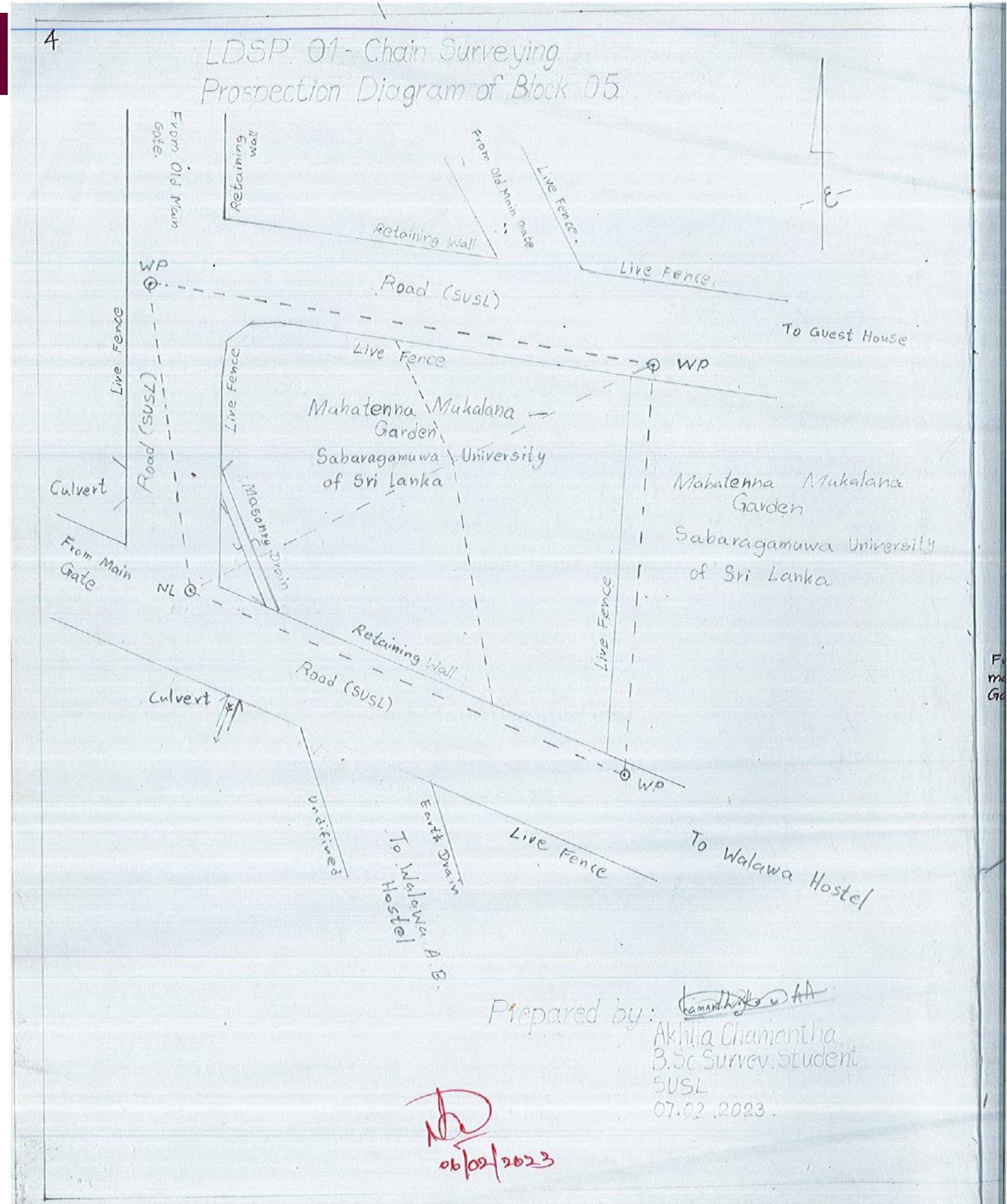
Chain Surveying – Perpendicular Offsets – Swinging



Chain Surveying – Procedure

i. **Reconnaissance** – inspect the area to be surveyed and prepare Prospection Diagram
ii. Decide and design the **base line** which should go through the center of the field
iii. Design the all stations, tie/check lines, and mark them on the prospection diagram
iv. Mark all **stations** on the ground by driving **pegs**, and/or digging and fixing a stone
v. Keep ranging rods on stations
vi. Chaining can begin
vii. Measure the chainage and offsets, and record them

Chain Surveying – Prospection Diagram



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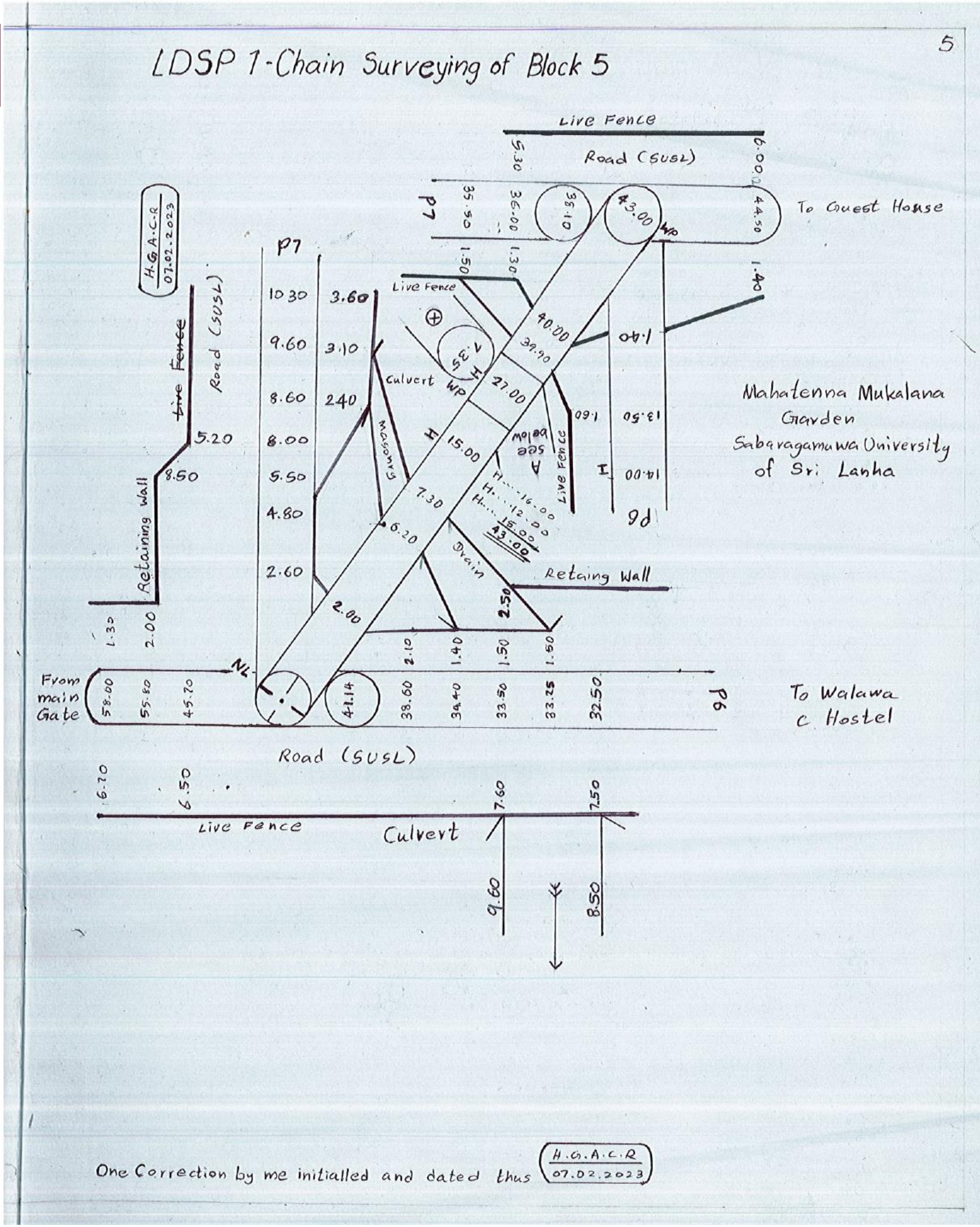

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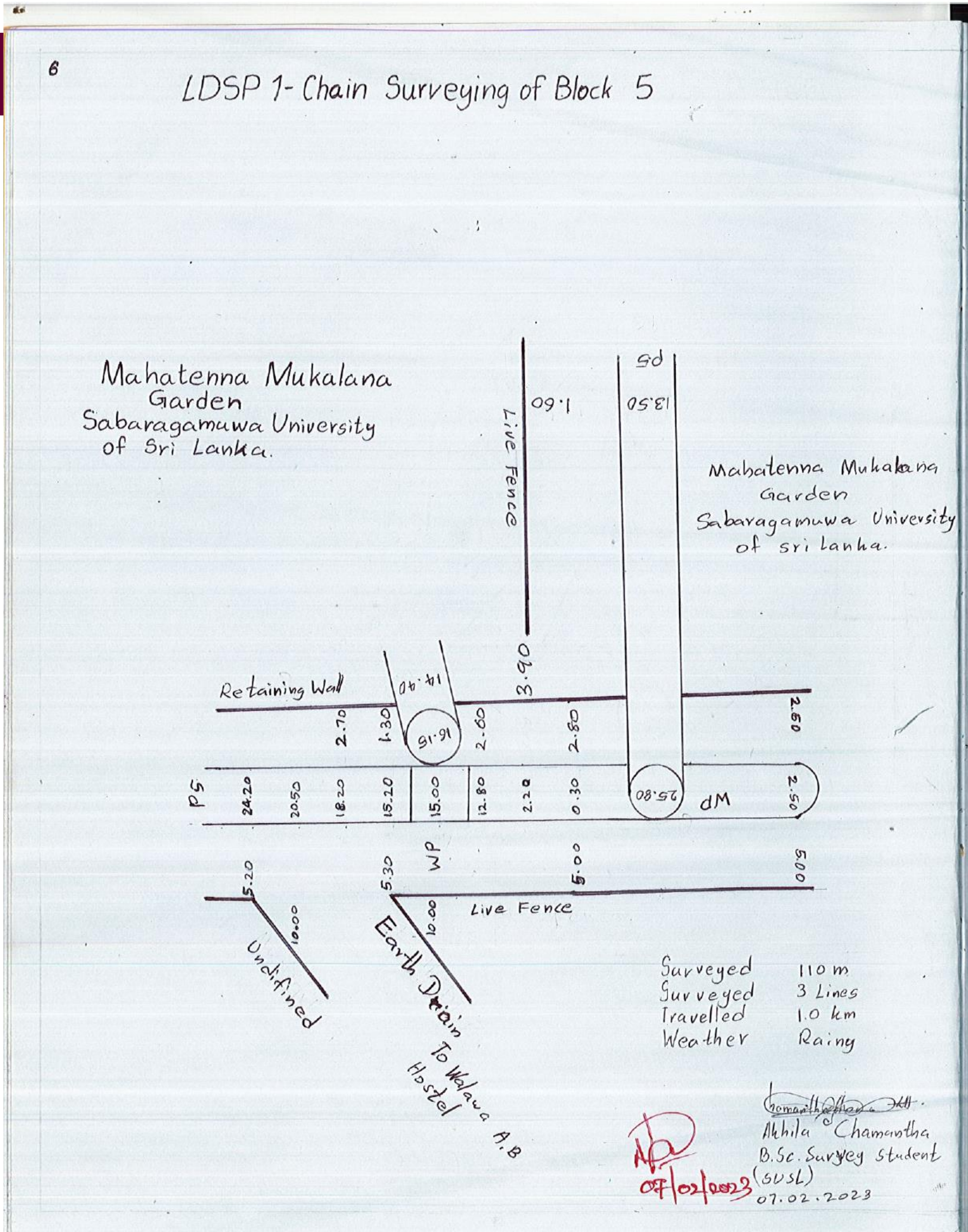

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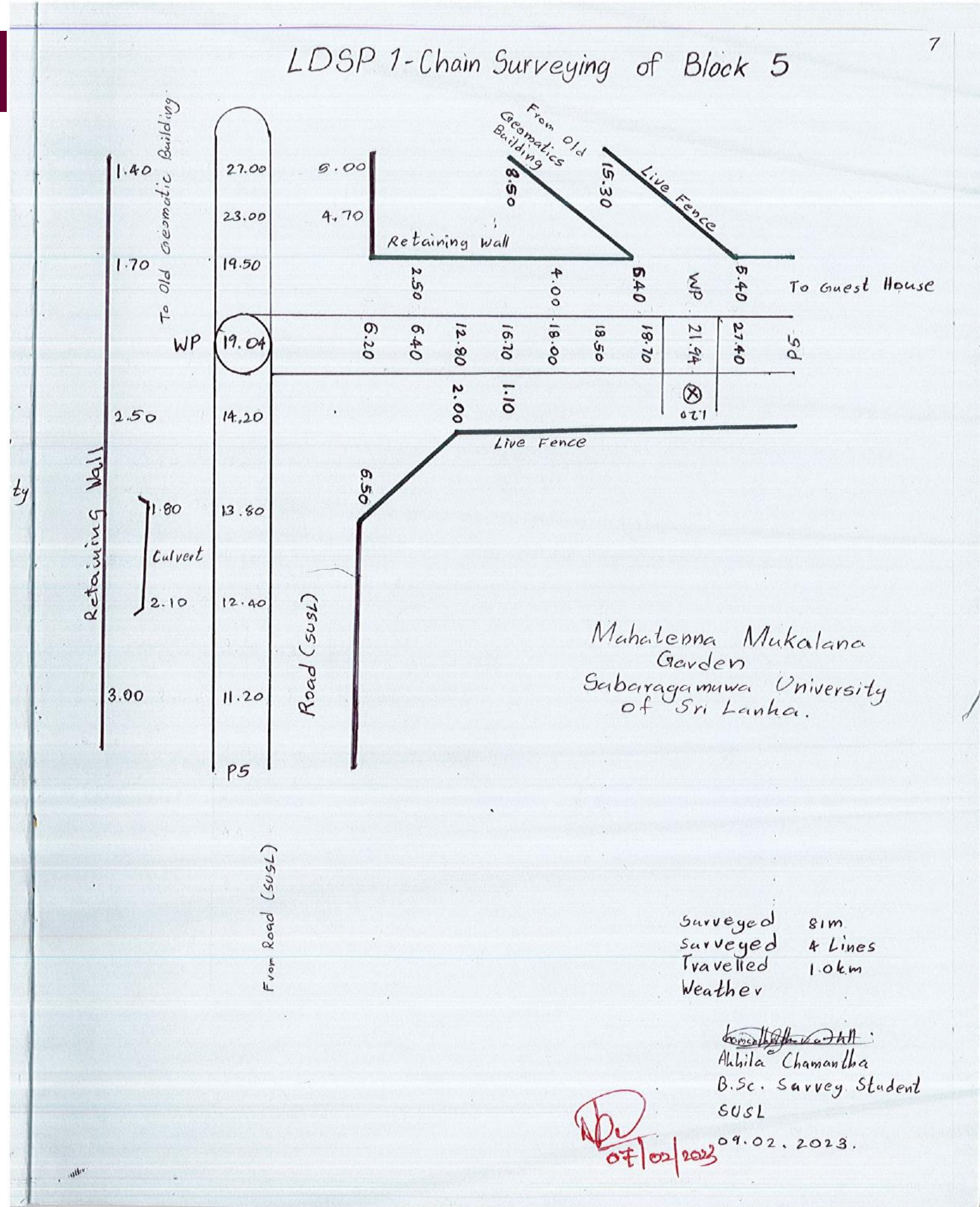


Obstacles In Chaining

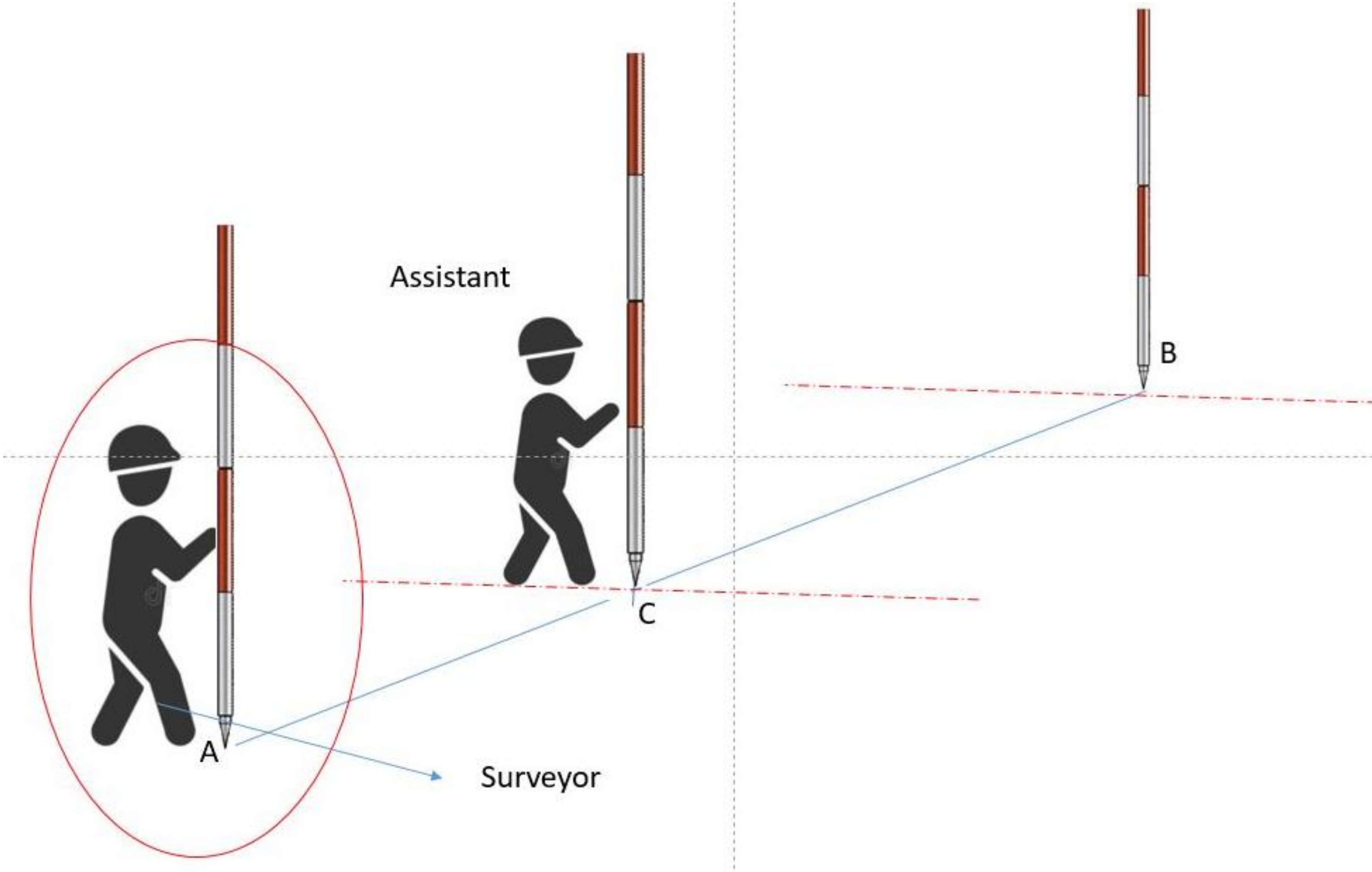
- Various obstacles/obstructions such as woods, hills, ponds, rivers etc. are met
- Chaining **should be** continued in a **straight line**
- The various obstacles may be classed as:
  A. Chaining Free, Vision Obstructed
  B. Chaining Obstructed, Vision Free
  C. Both Chaining and Vision Obstructed

Ranging??

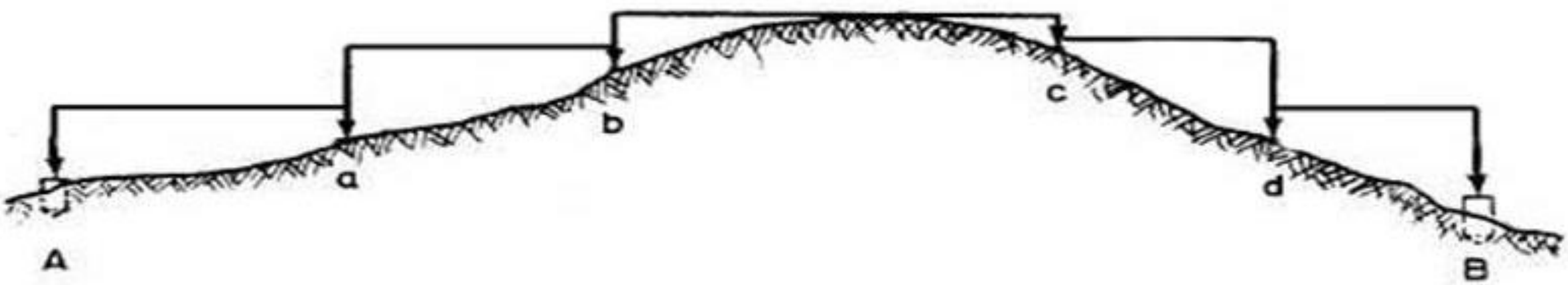
- When a **survey line is longer** than a chain length, it is necessary to **align intermediate points** on chain line so that the **measurements** are along the **line**

- The **process** of **locating intermediate points** on survey line is known as **ranging**

Ranging??



Stepping??



Obstacles In Chaining: Chaining Free, Vision Obstructed

- **Case 1:**
  Both ends are visible from **intermediate point** on the line (Reciprocal ranging/Indirect ranging)

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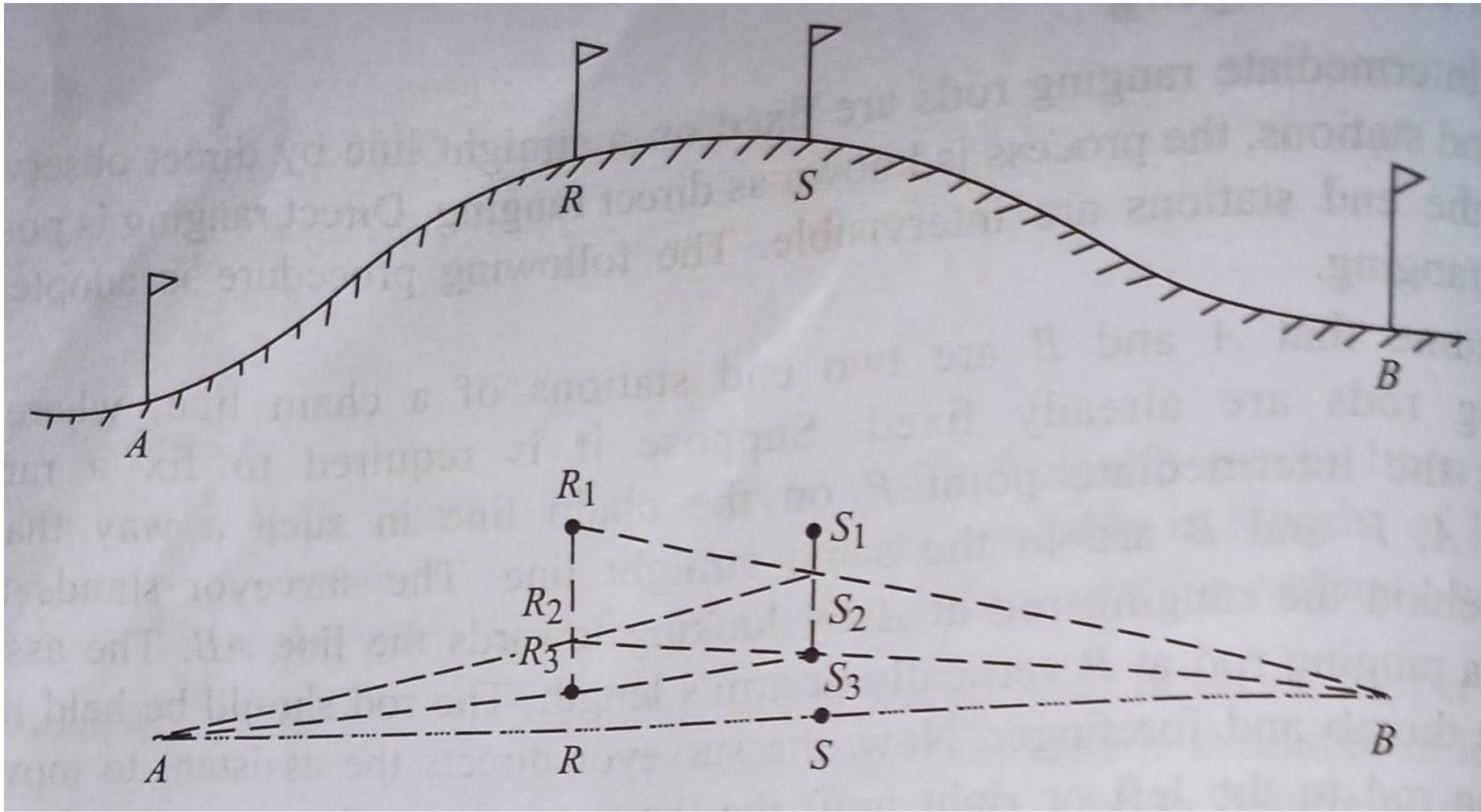

Obstacles In Chaining: Chaining Free, Vision Obstructed

- **Case 2:**

  Both **ends** are **not visible** from some **intermediate point**

  Random line method is suitable

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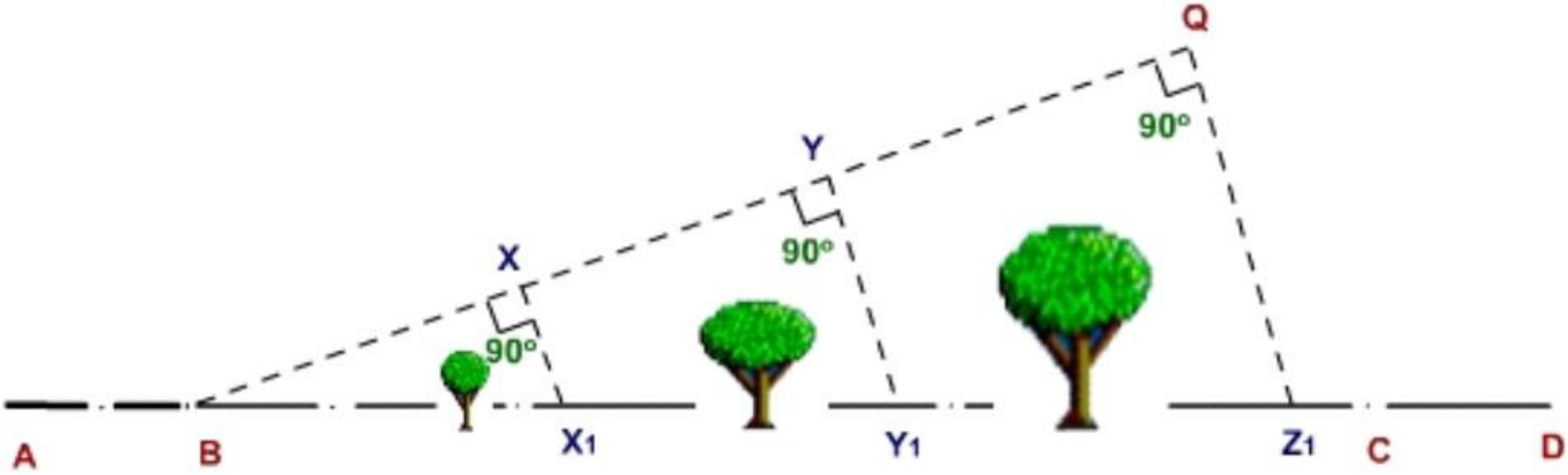

Obstacles In Chaining: Chaining Obstructed, Vision Free

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  When it is **possible** to **chain round** the obstacle e.g pond

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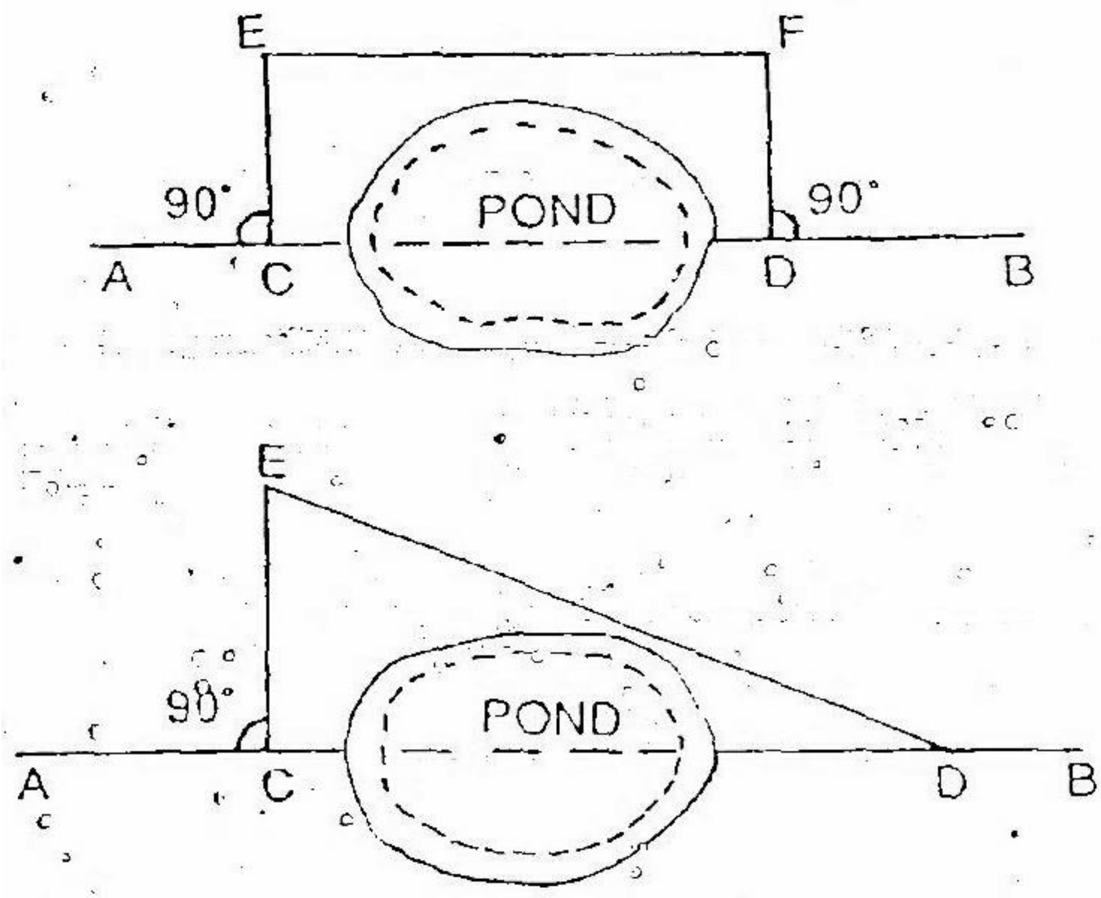

Obstacles In Chaining: Chaining Obstructed, Vision Free

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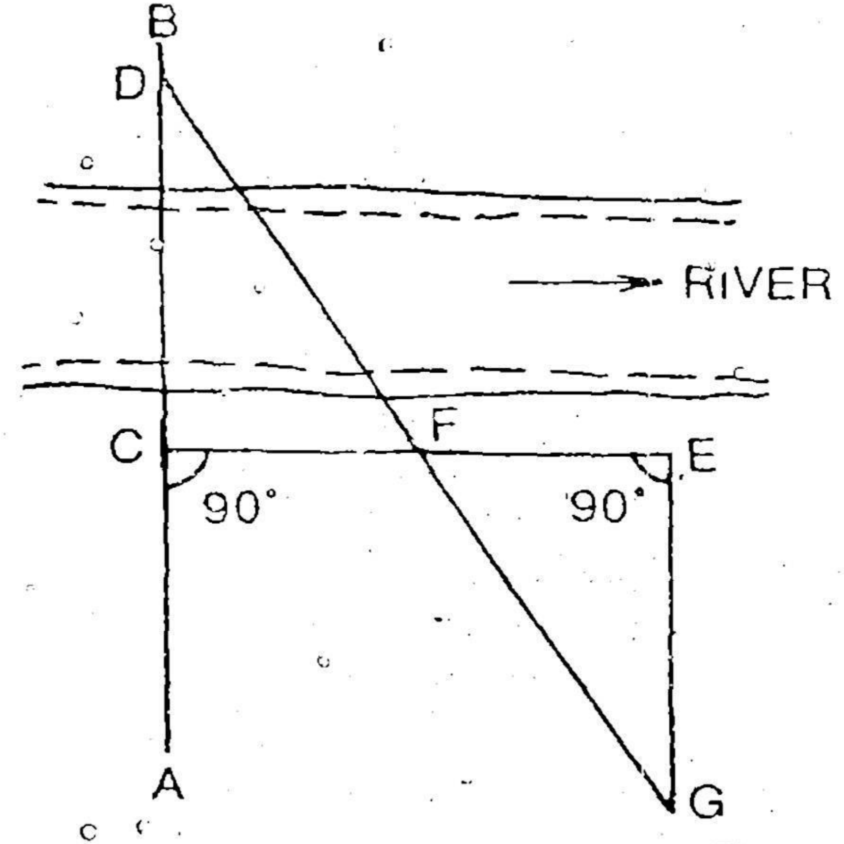
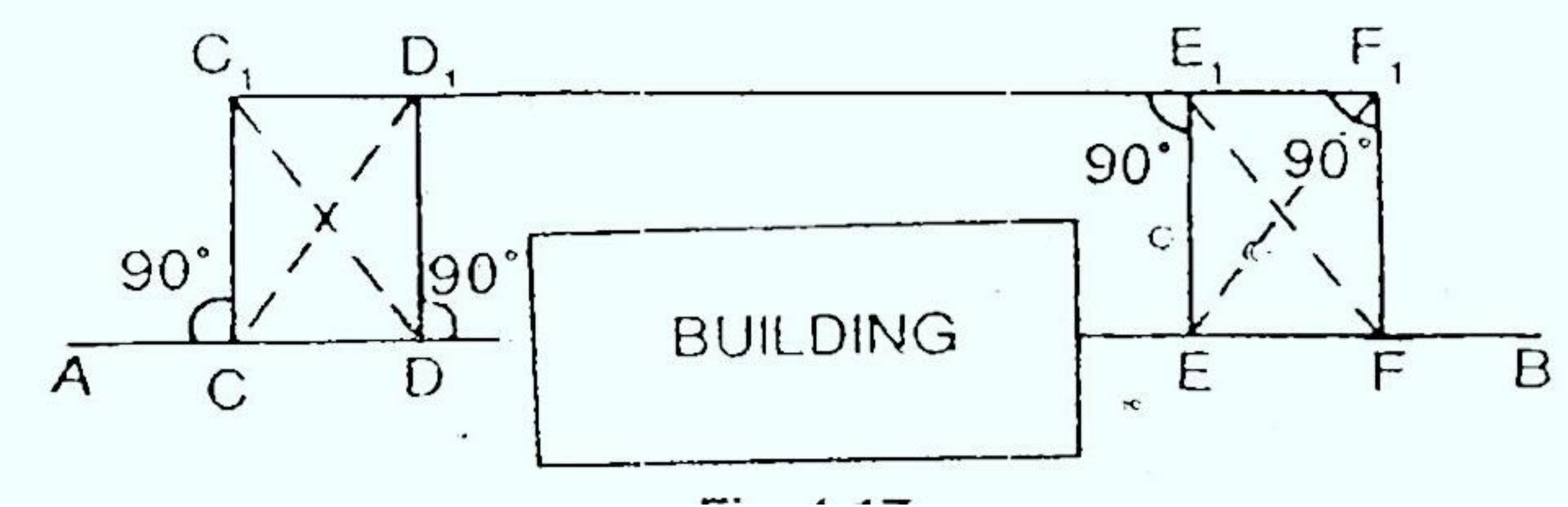


Obstacles In Chaining: Both Chaining and Vision Obstructed



Advantages (Pros) of Chain Surveying

- Is simplest and commonest method used in surveying
- Simple to use equipment are used
- Does not involve complicated mathematical calculations
- ….

Disadvantages (Cons) of Chain Surveying

- Can not be conducted in built up and/or large areas
- Is subject to several chances of errors of accumulation
- It is time consuming
- Can not be/difficult conducted in areas with steep slopes or water logged areas
- Chain survey becomes more complicated when there are obstacles

Sources of Errors in Chain Surveying

- Instrument?
- Personal?
- Natural/Environmental?

Types of Errors in Chain Surveying?

- Blunders/Gross?
- Systematic?
- Random?

Accuracy? Precision?

- **Accuracy**
  Closeness of a measured value to a standard or known value

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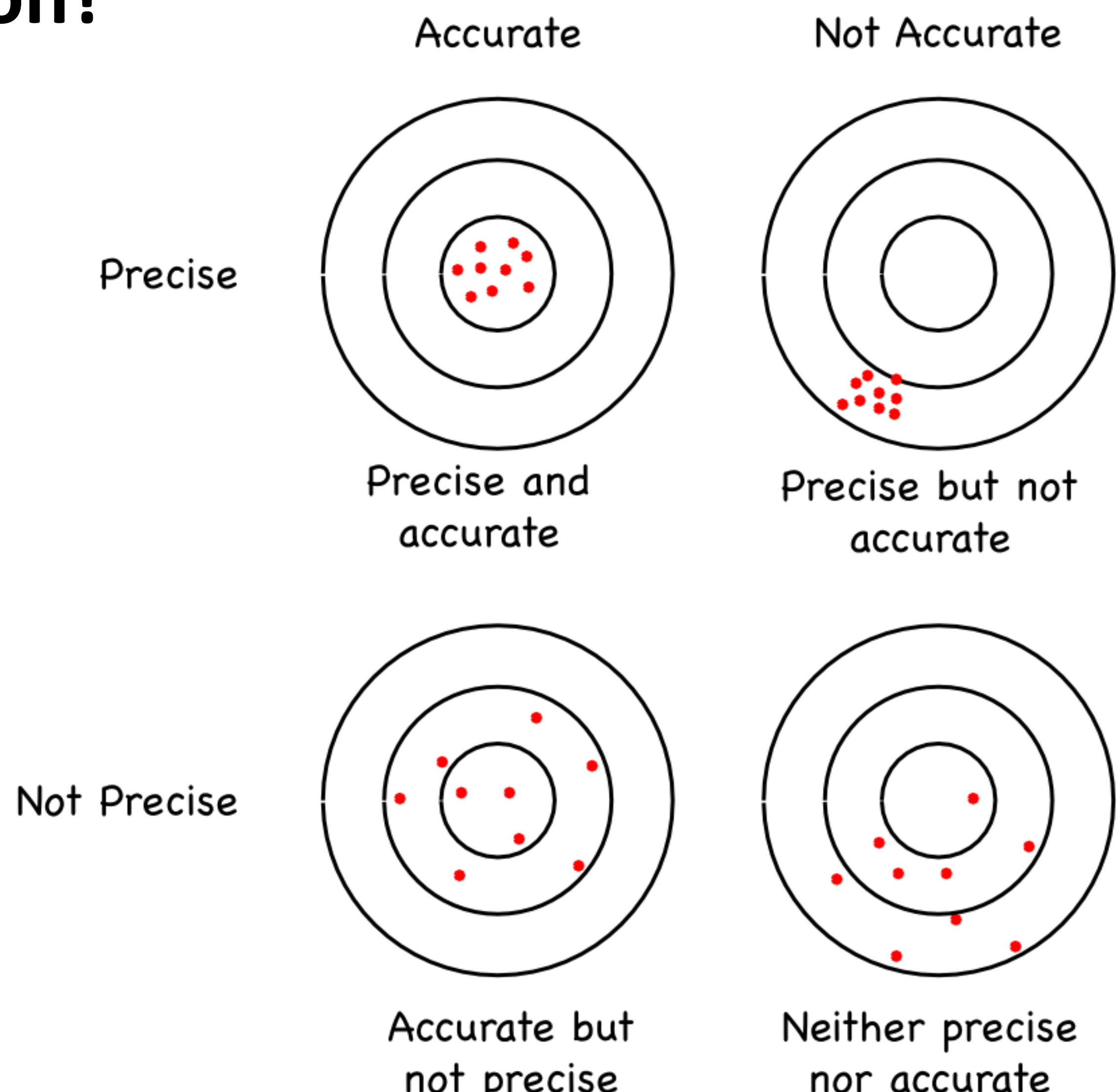

Q1

Example 1:

A survey line CD intersects a building. To overcome the obstacle a perpendicular DE, 87 m long; is set out at D. From E, two lines EF and EG are set out at angles 50° and 65° respectively with ED. Find the lengths EF and EG such that points F and G fall on the prolongation of CD. Also find the obstructed distance DF.

Q1

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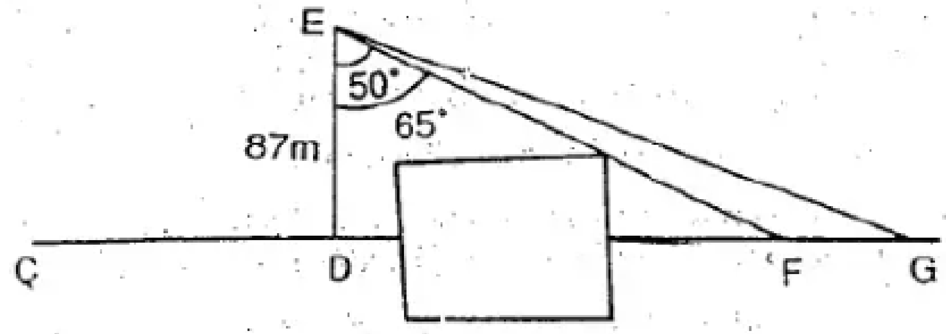

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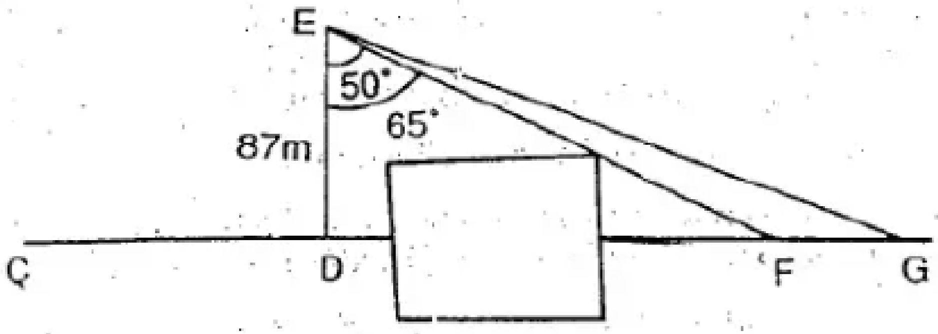
Example 1:

A survey line CD intersects a building. To overcome the obstacle a perpendicular DE, 87 m long; is set out at D. From E, two lines EF and EG are set out at angles 50° and 65° respectively with ED. Find the lengths EF and EG such that points F and G fall on the prolongation of CD. Also find the obstructed distance DF.



Solution:

From Δ DEF,

$$\frac{DE}{EF} = cos50^o$$

87

Q2

Example 2:
A survey line BAC crosses a river, A and C being on the near and opposite banks respectively. A perpendicular AD, 40 m long, is set out at A. If the bearings of AD and DC are 48°30' and 288°30' respectively, draw the sketch and find the bearing of the chain line BAC and also the chainage of C when that of A is 207.8 m.

Q2

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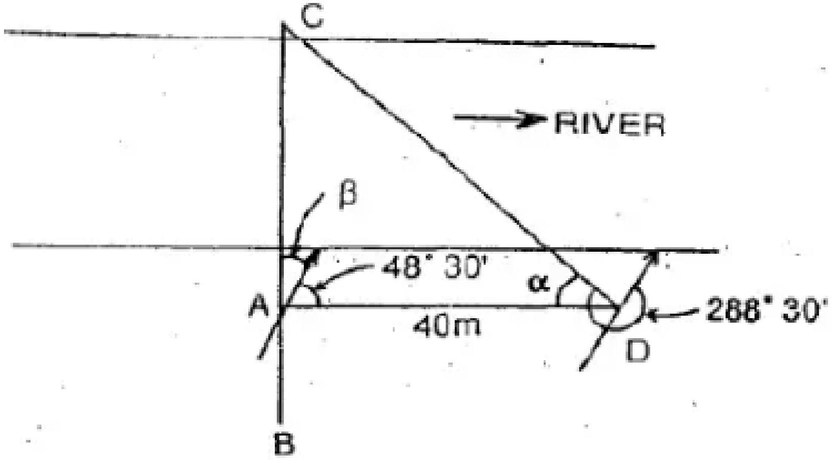

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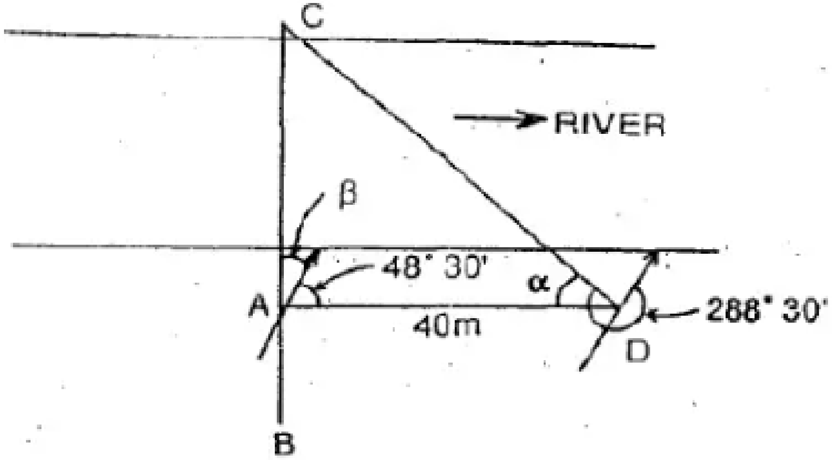
Solution:



$\angle ADC = \alpha = \text{FB of DC} - \text{BB of AD}$

$\alpha = 288°30' - (48°30' + 180°0')$

$\alpha = 60°0'$

$\beta = 90°0' - 48°30' = 41°30'$

Bearing of the chain line $= 360°0' - 41°30' = 318°30'$

Q3

Example 3:
A chain line PQ intersects a pond. Two points A and B are taken on the chain line on opposite sides of the pond. A line AC, 250 m long, is set out on the left of AB and another line AD, 300 m long, is set out on the right of AB. Points C, B and D are in the same straight line CB and BD are 100 and 150 m long respectively. Calculate the length of AB.

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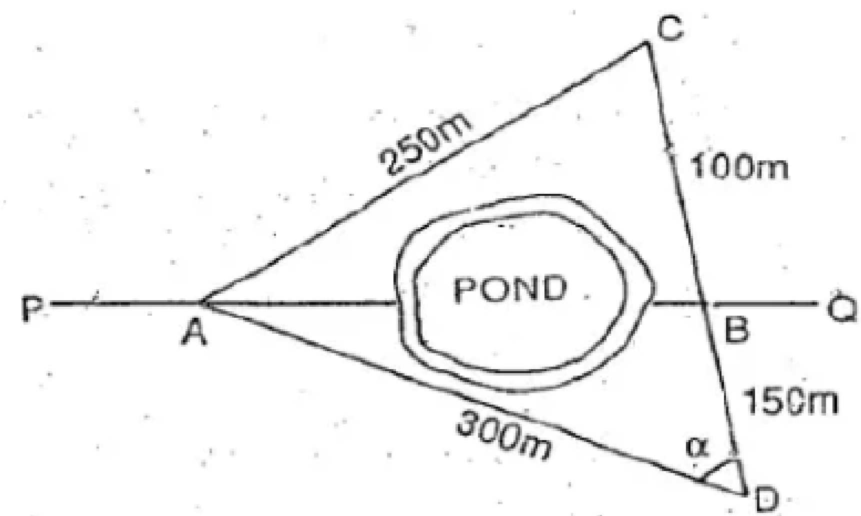

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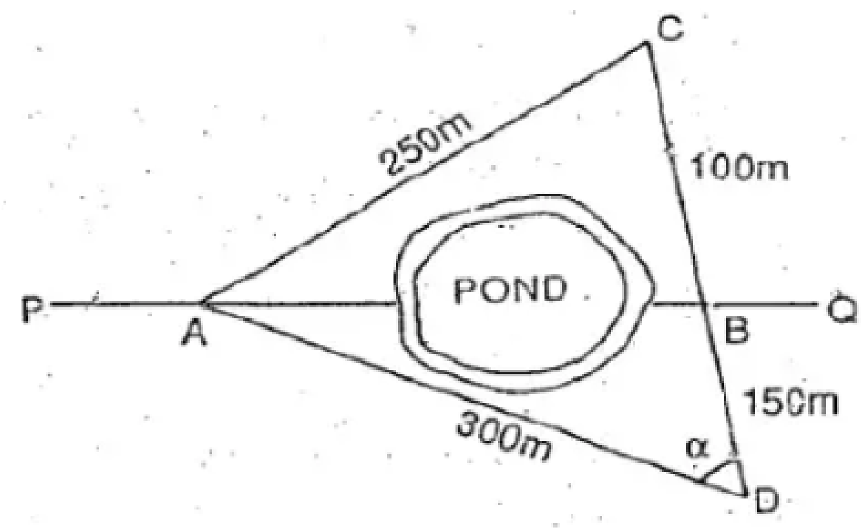

Solution:

$CD = CB + BD = 100 + 150 = 250$ m

In Δ ADC, let $\angle ADC = \alpha$

$AC^2 = AD^2 + DC^2 - 2(AD)(DC)\cos\alpha$

$$\cos\alpha = \frac{(AD)^2 + (DC)^2 - (AC)^2}{2(AD)(DC)}$$

Plane Table Surveying

- A **graphical method** of survey in which the **field observations and plotting** are done **simultaneously**.

Plane Table Surveying

- In this method of surveying, a table top - similar to a drawing board fitted on to a tripod - is the main instrument.
- A drawing sheet is fixed on to the table top, the observations are made to the objects, distances are scaled down and the objects are plotted in the field itself.

Plane Table Surveying

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- It is also ideally suited to filling detail on a map already prepare and available on the drawing sheets.

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- It is **most suitable** for **small scale maps**.

Plane Table Surveying

- A **graphical method** of survey in which the **field observations and plotting** are done **simultaneously**.
- It is also ideally suited to filling detail on a map already prepare and available on the drawing sheets.
- It is **most suitable** for **small scale maps**.
- The plan is drawn by the surveyor in the field, while the area to be surveyed is before his eyes. Therefore, there is **no possibility of omitting** the necessary **measurements**

Plane Table Surveying: Principle

- The **principle** of plane tabling is **parallelism.**

Plane Table Surveying: Principle

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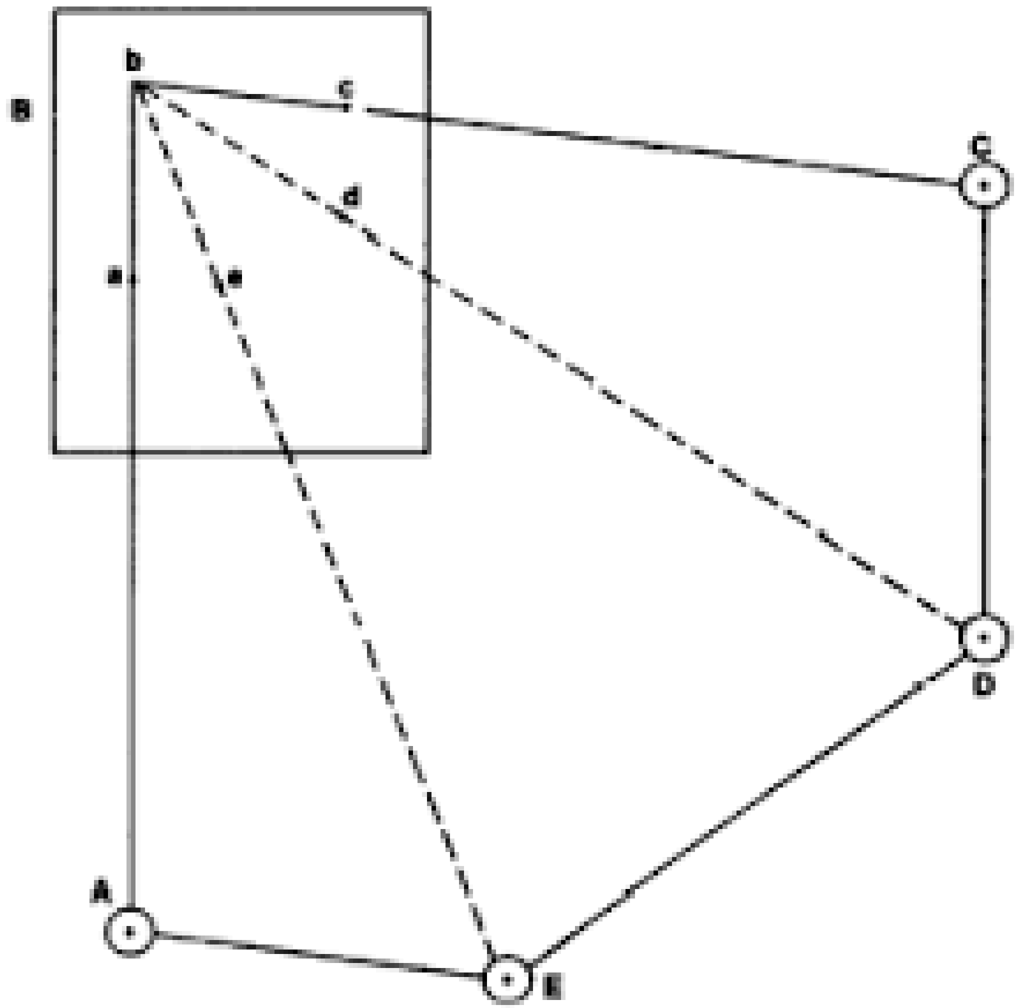
- **Principle:** "All the rays drawn through various details should pass through the survey station."

Plane Table Surveying: Principle



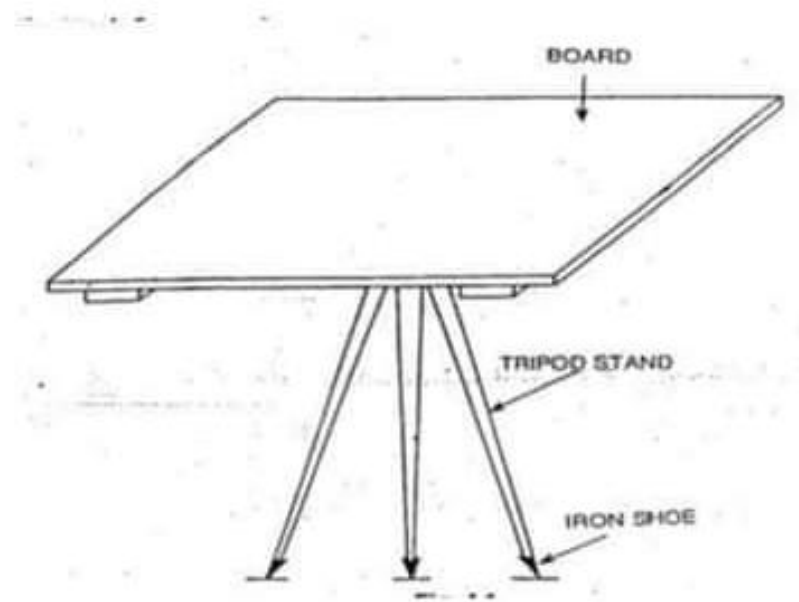
Plane Table Surveying: Principle

- The **principle** of plane tabling is **parallelism.**
- **Principle:** “All the rays drawn through various details should pass through the survey station.”
- The position of plane table at each station must be identical, i.e. at each survey station the table must be oriented in the direction of the magnetic north.

Plane Table Surveying: Equipment and Accessories

- Plane Table with Tripod

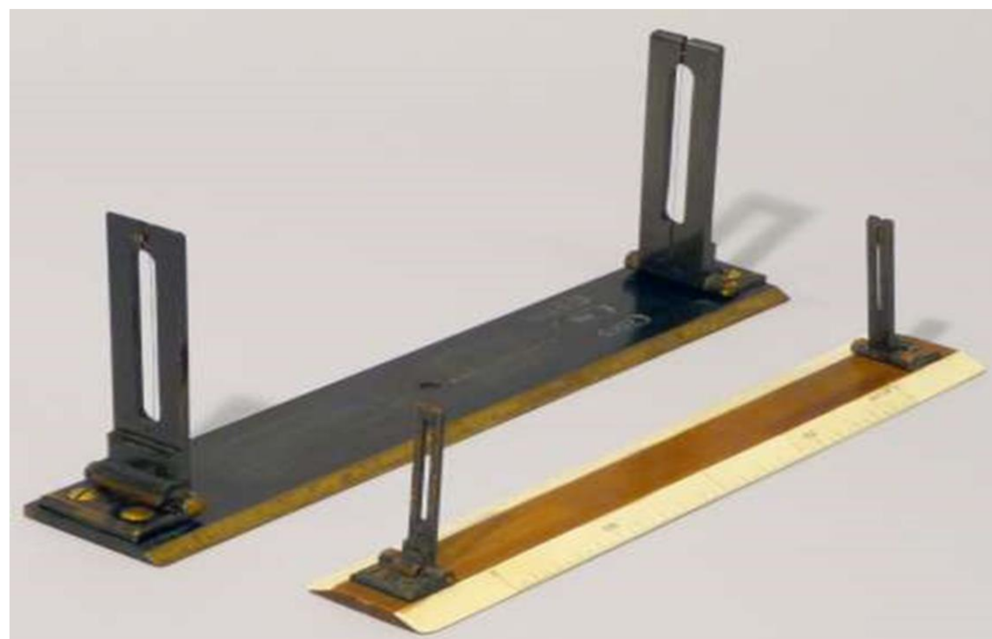
A simple plane table is a drawing board provided with a ball and socket arrangement for leveling the table, with an arrangement to fix the table to a tripod



Plane Table Surveying: Equipment and Accessories

- Alidade:

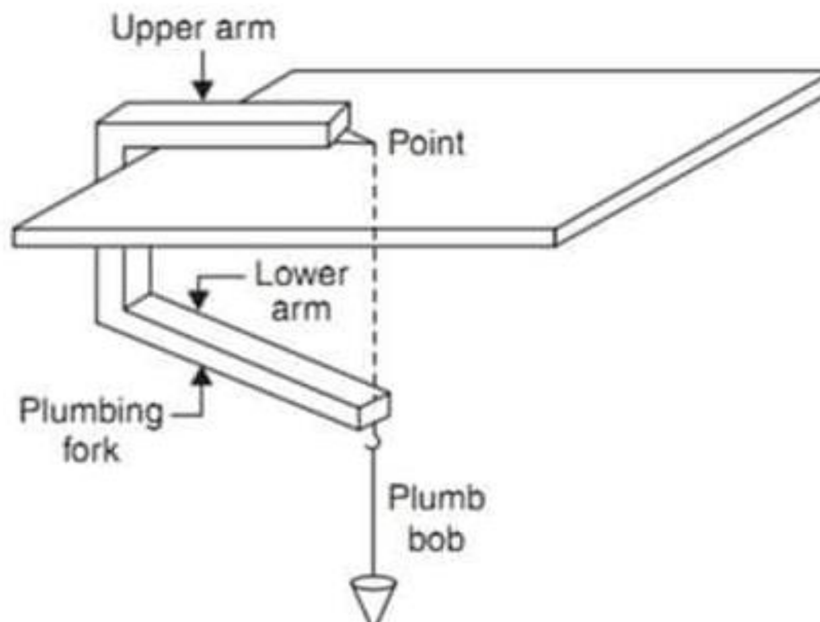
An alidade or a turning board is a device that allows one to sight a distant object and use the line of sight to perform a task.



Plane Table Surveying: Equipment and Accessories

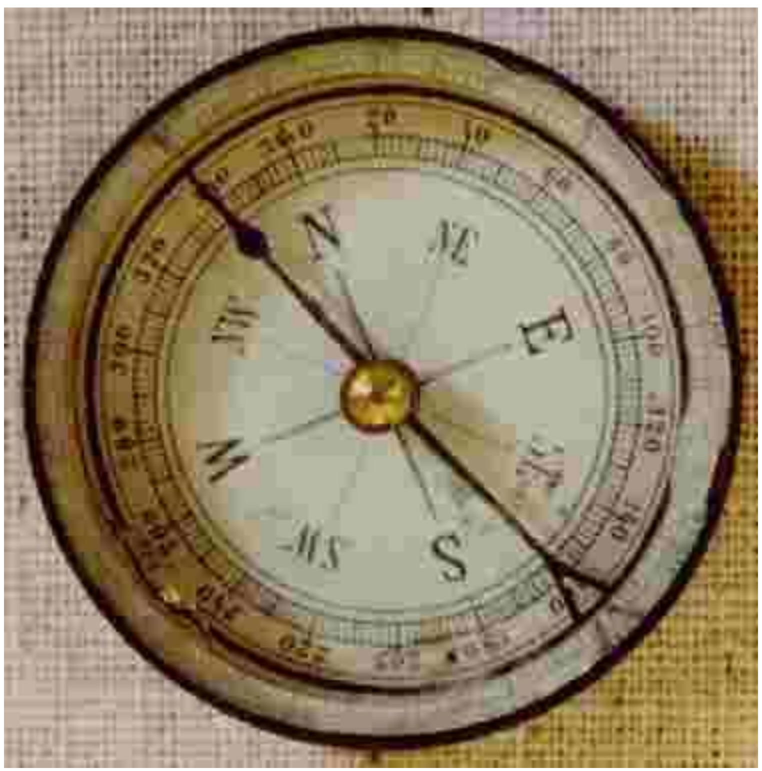
- Plumbing Fork

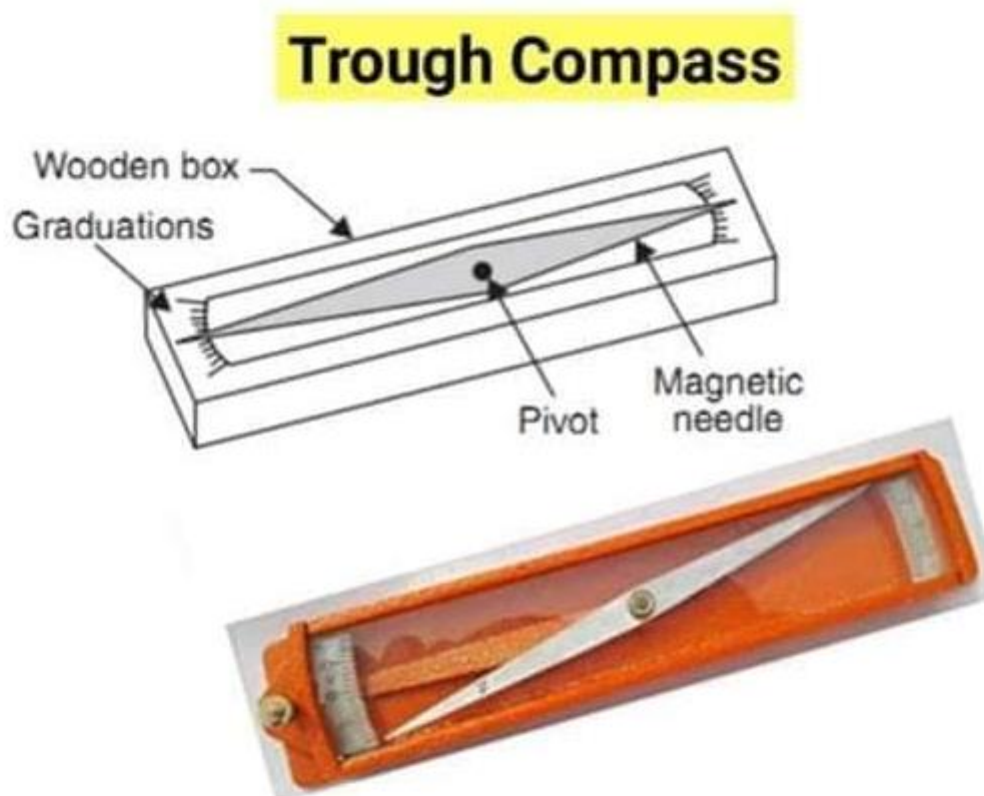
A U-shaped piece of metal or wooded frame. The end of one of its arm is pointed and the other arm is having an arrangement for hanging a plumb bob.



Plane Table Surveying: Equipment and Accessories

- Compass/Trough Compass



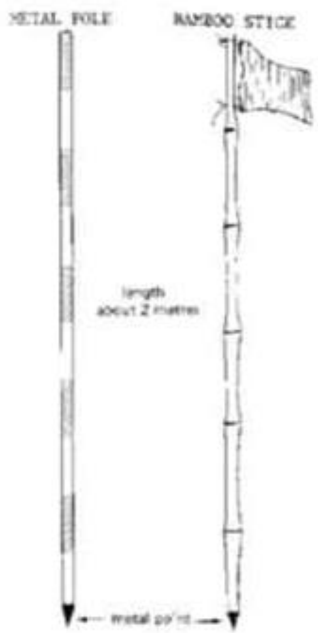


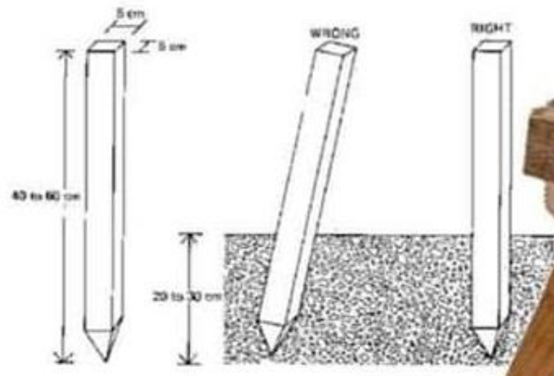
Plane Table Surveying: Equipment and Accessories

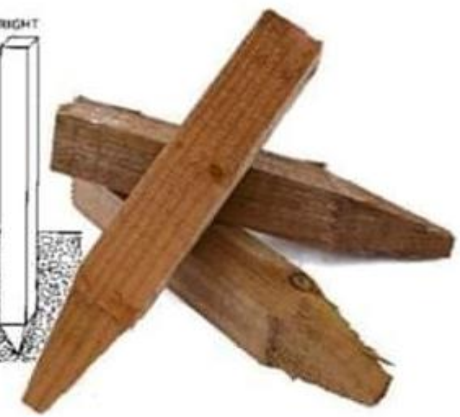
- Spirit Level

Plane Table Surveying: Equipment and Accessories

- Ranging Rods, Pegs and Tape (Chain)

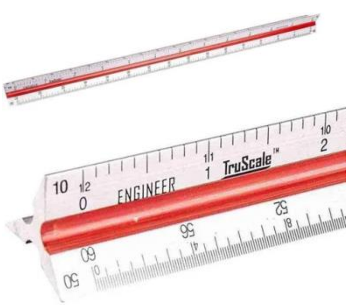






Plane Table Surveying: Equipment and Accessories

- Drawing paper (and other accessories for drawing)



Plane Table Surveying: Setting Up the Plane Table

- Fixing the plane table on the tripod stand
- Leveling the table
- Centering the table
- Marking the North-line
- Orientation
    - Orientation by magnetic needle
    - Orientation by back-sighting
- Sighting the points using the alidade

Plane Table Surveying: Methods of Plane Tabling

I. Radiation
II. Intersection
III. Traversing
IV. Resection

Plane Table Surveying: Methods of Plane Tabling

I. Radiation
II. Intersection
III. Traversing
IV. Resection
    - Special Methods of Resection
        a. Compass method
        b. Back-ray method
        c. Two-point problem
        d. Three-point problem

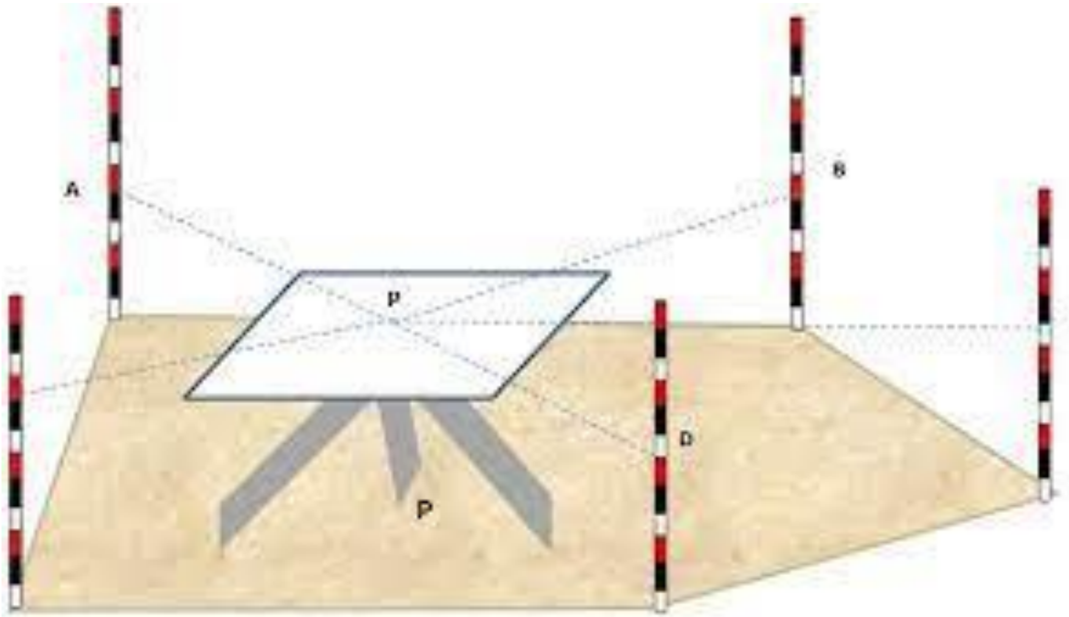
Plane Table Surveying: For Locating Details

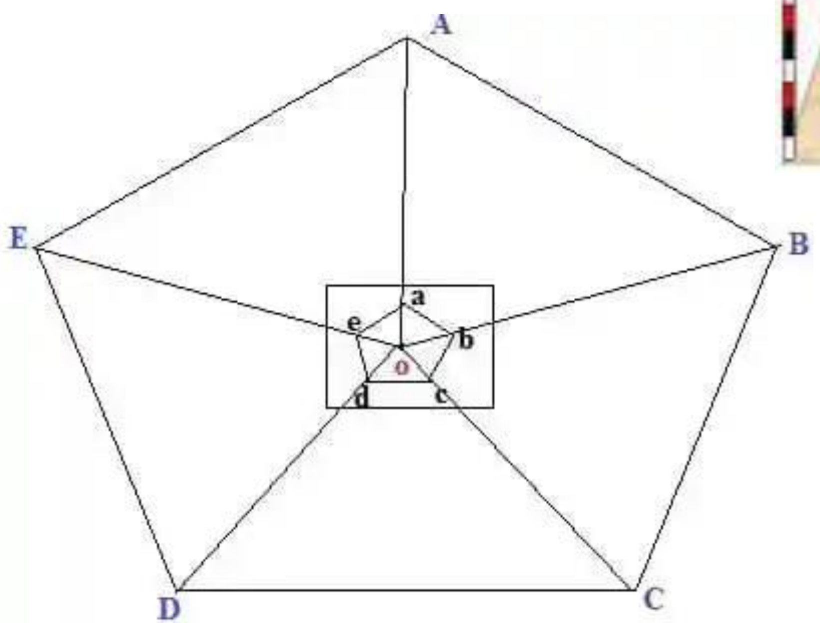
(I) Radiation Method:

i. With the help of the Alidade, a ray is drawn towards the point.
ii. Using the chain/tape, the horizontal distance is measured from the Plane Table to the point.
iii. Using the scale of plotting, this point is located on the sheet.

Plane Table Surveying: For Locating Details

(I) Radiation Method:





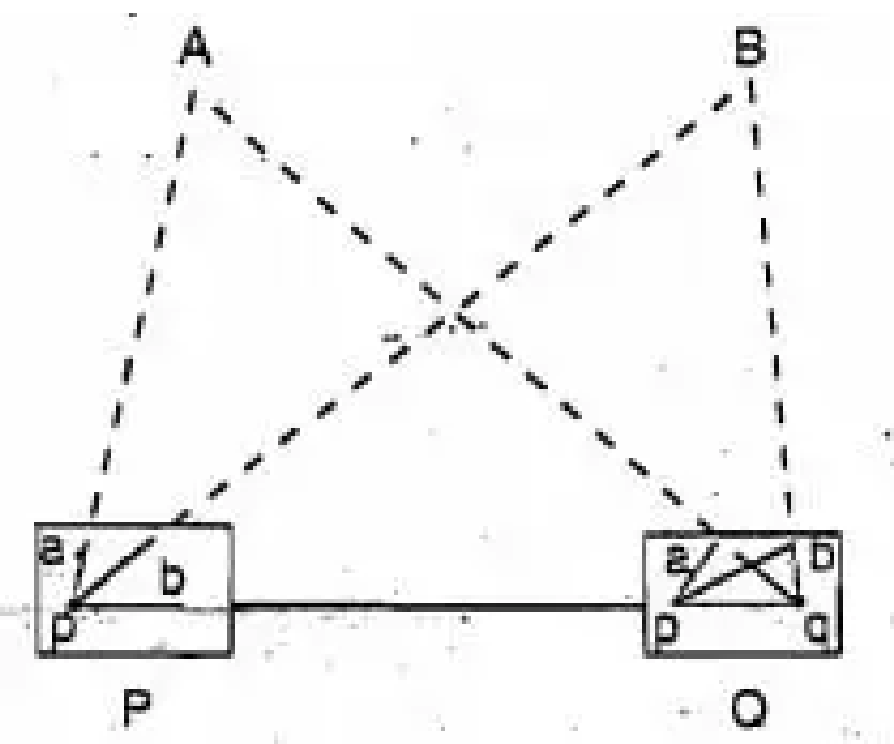
Plane Table Surveying: For Locating Details

(II) Intersection Method:

- In this method no chain or tape is needed, just two instrument stations are needed.
- Intersecting rays are drawn from these two stations whose location is already plotted on sheet (by measuring the distance between them).
- The point of intersection of the two rays is the location of the point of interest
- This method is commonly used for locating:
  - (i) details
  - (ii) the distant and inaccessible points

Plane Table Surveying: For Locating Details

(II) Intersection Method:



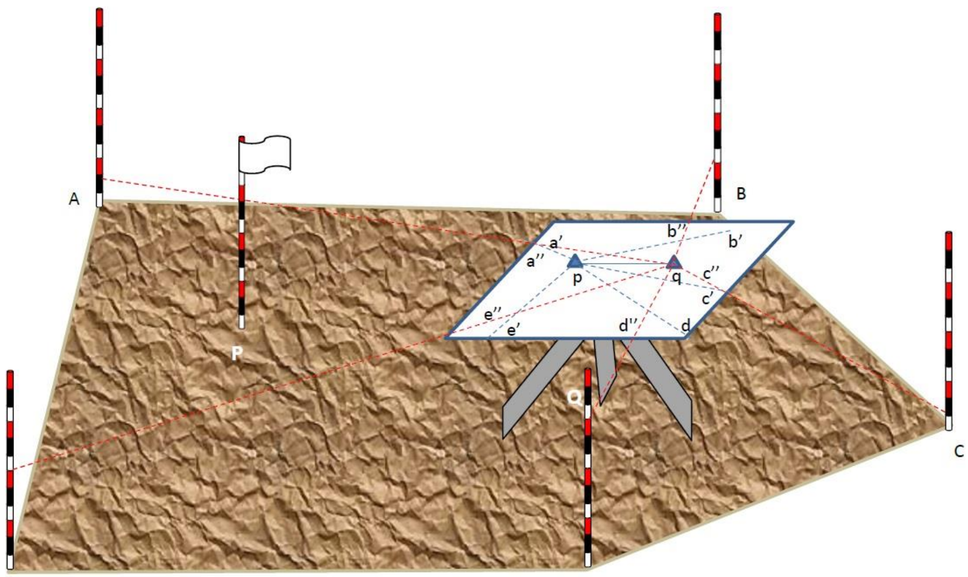


Figure 0-2

Plane Table Surveying: For Locating Plane Table Stations

(III) Traversing:

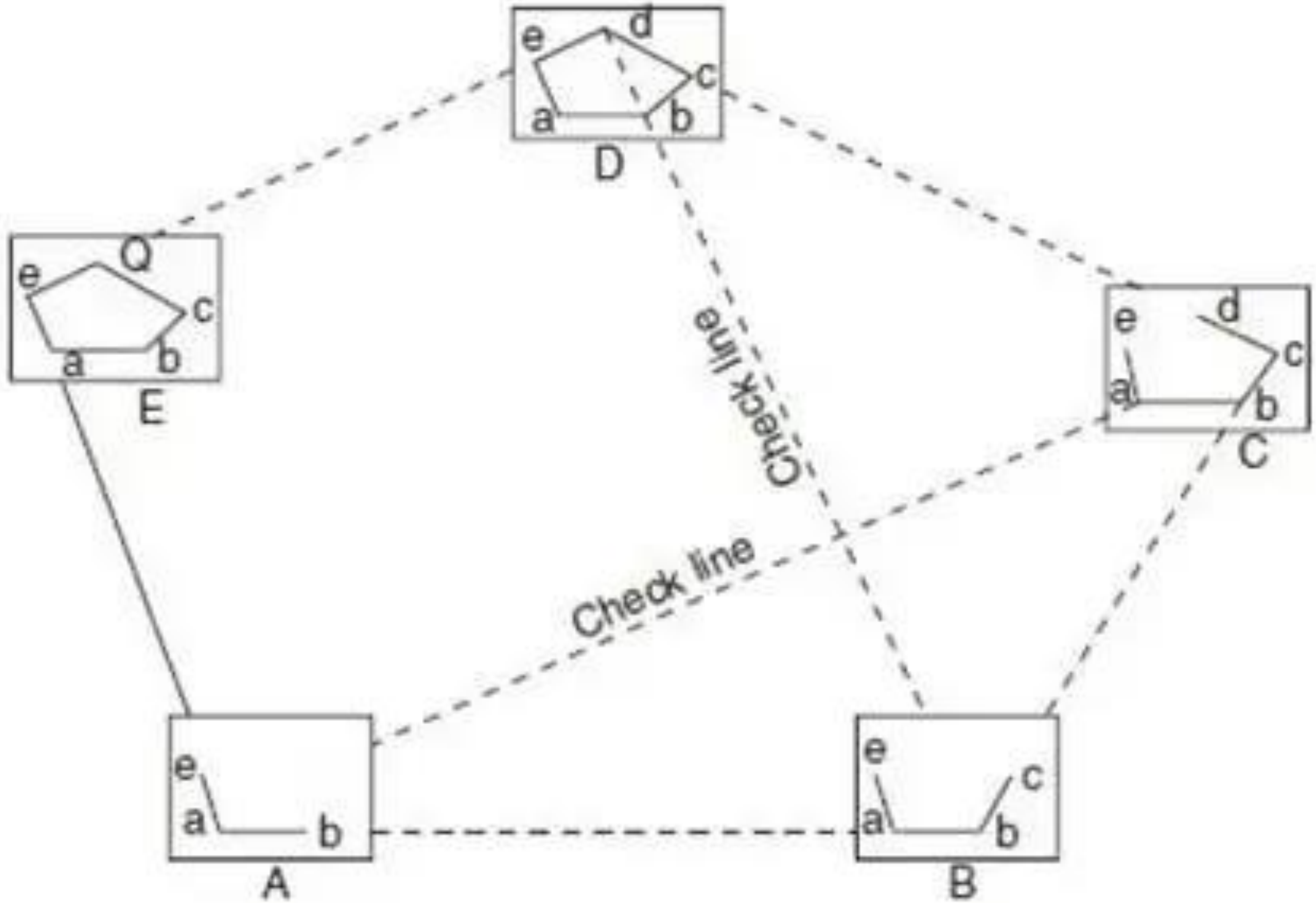
- The location of the Plane Table station is located in the following manner:

    i. At the previous station, a ray is drawn in the forward direction (towards the next station) and the point is plotted by measuring the horizontal distance and plotting it to scale.

    ii. The instrument is shifted to the next station (which is just located in the first step) and the previous station is back-sighted to orient the plane table.

Plane Table Surveying: For Locating Plane Table Stations

(III) Traversing:



Plane Table Surveying: For Locating Plane Table Stations

(IV) Resection

- Is the process/method of finding the position of a station where plane table is placed.
- Sights are taken towards the known and visible points and rays are plotted.

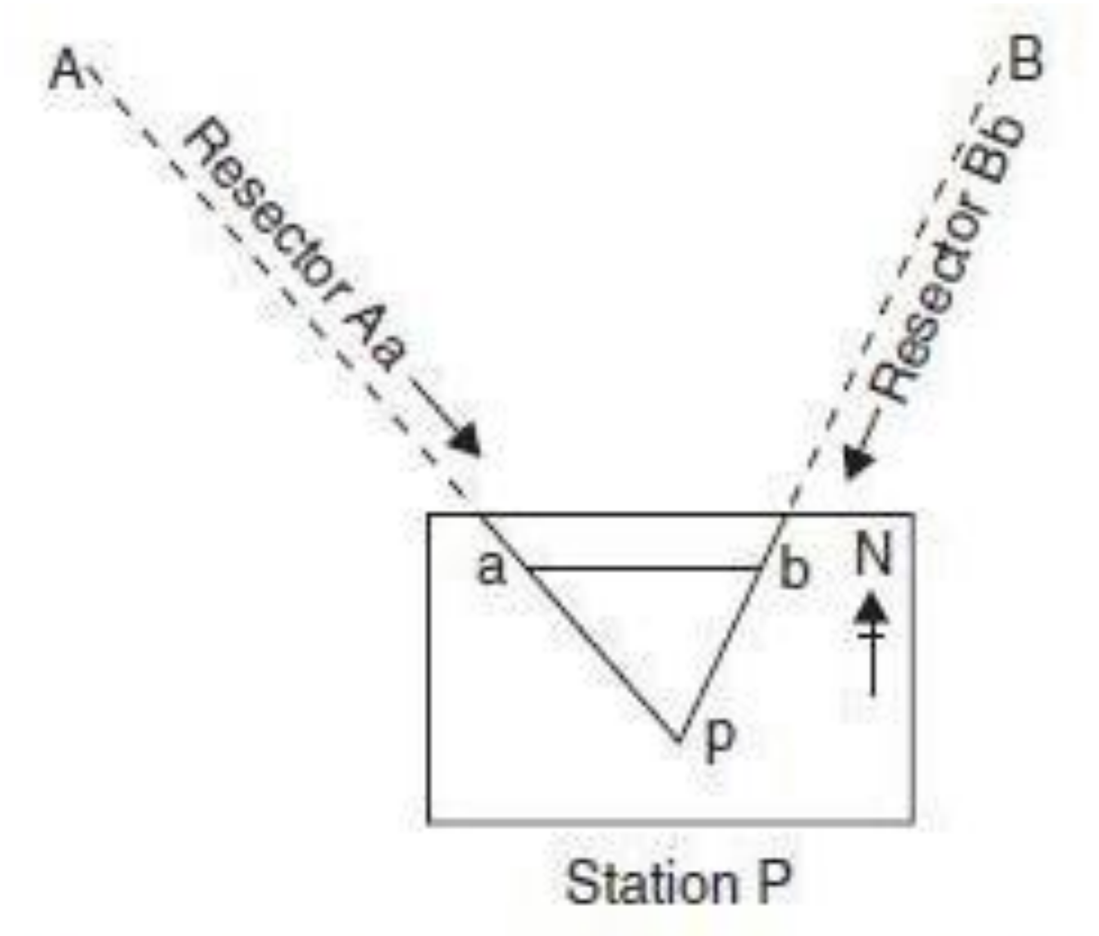
Plane Table Surveying: For Locating Plane Table Stations

(IV) Resection by the (a) Compass Method:

- Let *a* and *b* be the plotted positions of A and B of two well defined points in the field.
- Keeping the compass along the north direction marked on the drawing sheet, the table is oriented on station P, the position of which is to be found on paper.
- The resectors Aa and Bb are drawn to locate p, the plotted position of station point P.
- This method gives satisfactory results <u>if the area is not influenced by local attractions</u>.
- It is used for small scale mapping only.

Plane Table Surveying: For Locating Plane Table Stations

(IV) Resection by the (a) Compass Method:



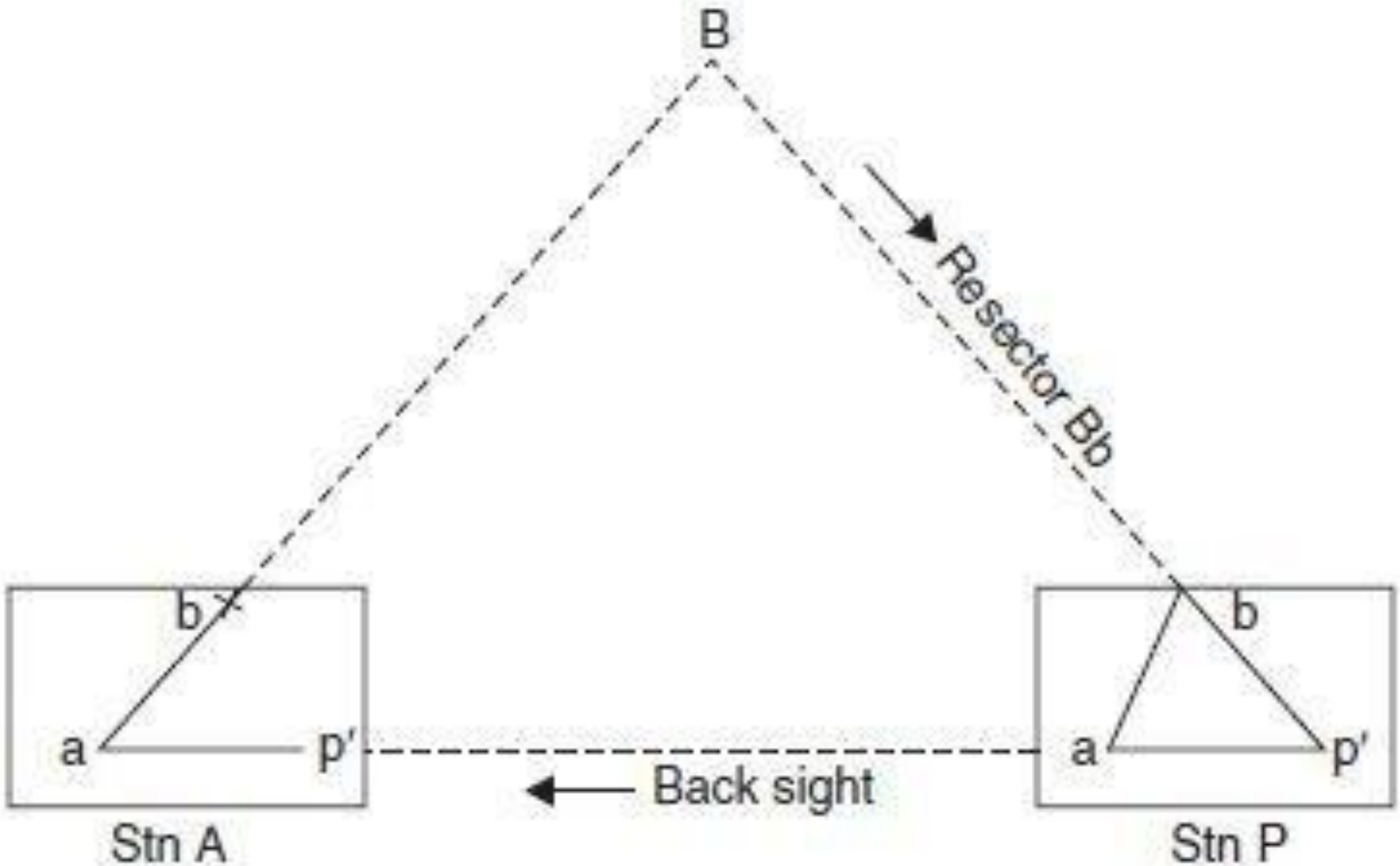
Plane Table Surveying: For Locating Plane Table Stations

(IV) Resection by the (b) Back-ray Method:

- From station A, the position of B is plotted as *b* and ray has been taken to station P as *ap*.
- Then plane table is set at P and oriented by back sighting A, line AP is not measured.
- Instead, the position of P is obtained on the paper by taking resection Bb.

Plane Table Surveying: For Locating Plane Table Stations

(IV) Resection by the (b) Back-ray Method:



Plane Table Surveying: For Locating Plane Table Stations

(IV) Resection by the (c) Two-point problem:

- Let A and B be two well defined points like lightening conductor or spire, for which the plotted positions *a* and *b* are already known.
- Now the problem is to orient the table at P so that by resection its plotted position *p* can be obtained.
- The following steps may be followed to solve this problems:
  i. Select a suitable point Q near P such that the angles PAQ and PBQ are not acute.
  ii. Roughly orient the table at Q and draw the resectors Aa and Bb to get the point *q*.

Plane Table Surveying: For Locating Plane Table Stations

(IV) Resection by the (c) Two-point problem:

iii. Draw the ray *qp* and locate *p1* with estimated distance QP.
iv. Shift the plane table to P and orient the table by back sighting to Q.
v. Draw the resector Aa to get *p*.
vi. Draw the ray pB. Let it intersect line *bq* at *b1*.
vii. The points *b* and *b1* are not coinciding due to the angular error in the orientation of table. The angle *bab* is the angular error in orientation.

Plane Table Surveying: For Locating Plane Table Stations

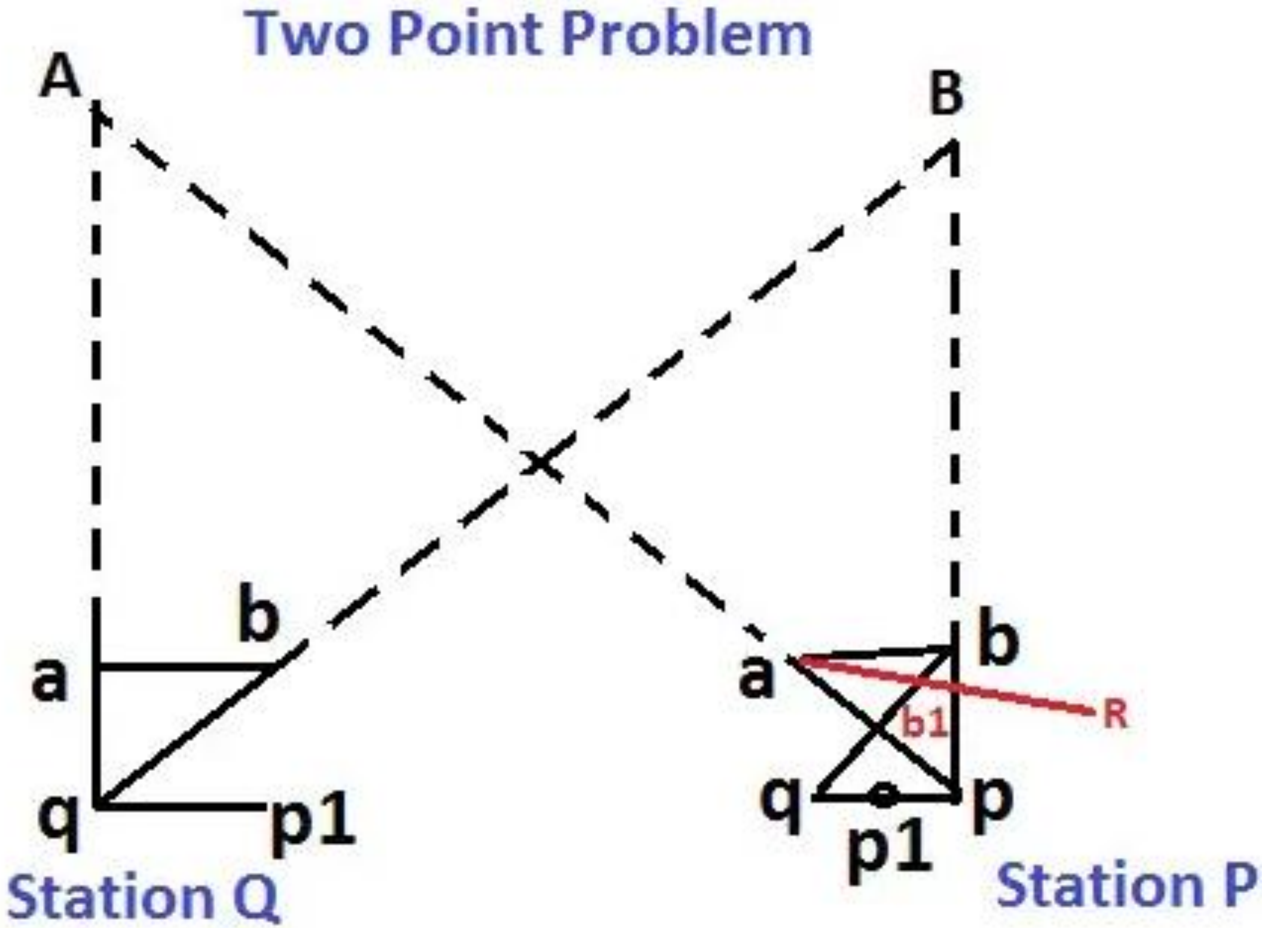
(IV) Resection by the (c) Two-point problem:

viii. To correct it, fix a ranging rod at R along *ab*. Unclamp the table and rotate it till line *ab* sights ranging rod at R. Then clamp the table. This gives the correct orientation of the table which was used in plotting the points A and B.

ix. The resectors Aa and Bb are drawn to get the correct plotted position *p* of the station P.

Plane Table Surveying: For Locating Plane Table Stations

(IV) Resection by the (c) Two-point problem:



Plane Table Surveying: For Locating Plane Table Stations

(IV) Resection by the (d) Three-point problem:

- Let A, B, C be three well defined objects on the field whose plotted positions *a*, *b* and *c* are known. Now the problem is to locate the plotted position of the station point P.

???

Plane Table Surveying – Advantages (Pros)

- It is suitable for location of details as well as contouring for large scale maps directly in the field.
- As surveying and plotting are done simultaneously in the field, chances of omitting details are less.
- The plotting details can immediately get compared with the actual objects present in the field. Thus errors as well as accuracy of the plot can be ascertained as the work progresses in the field.
- Contours and specific features can be represented and checked conveniently as the whole area is in view at the time of plotting.

Plane Table Surveying – Advantages (Pros)

- Only relevant details are located because the map is drawn as the survey progresses. Irrelevant details get omitted in the field itself.
- Plane table survey is generally more rapid and less costly than most other types of surveys.
- As the instruments used are simple, not much skill for operation of instruments is required. This method of survey requires no field book

Plane Table Surveying – Disadvantages (Cons)

- Plane table survey is not possible in unfavourable climates such as rain, fog and so on.
- This method of survey is not very accurate and thus unsuitable for large scale or precise work.
- As no field book is maintained, plotting at different scales require full exercise.
- The method requires large amount of time to be spent in the field.
- Quality of the final map depends largely on the drafting capability of the surveyor.
- This method is effective in relatively open country where stations can be sighted easily

Plane Table Surveying – Sources of Errors

- Instrumental errors?
- Personal errors?
- Natural errors?

Plane Table Surveying – Types of Errors

- Blunders/Gross errors/Mistakes?
- Random errors?
- Systematic errors?

Plane Table Surveying: For Locating Plane Table Stations

(IV) Resection by the (d) Three-point problem:

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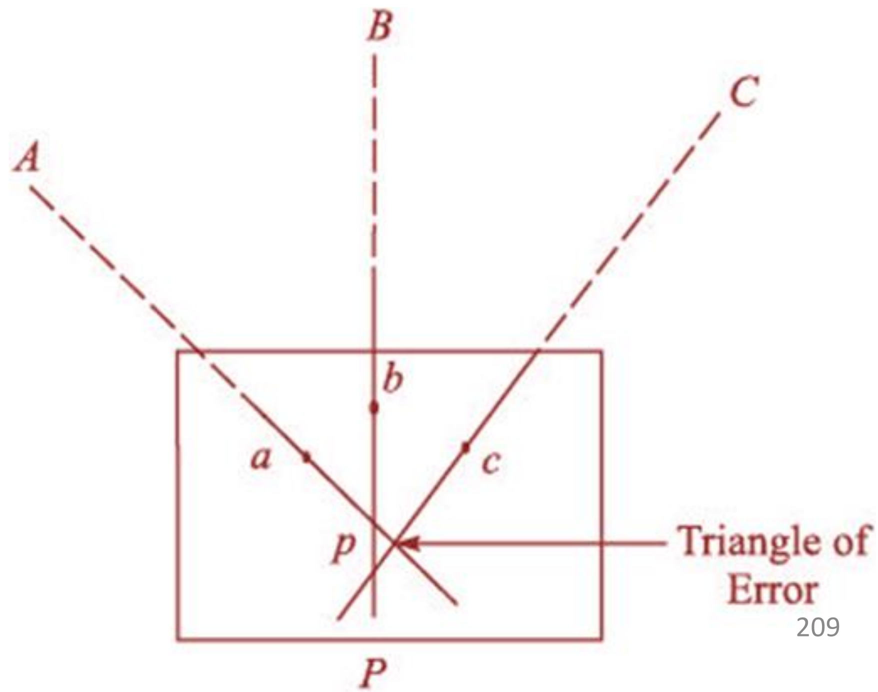
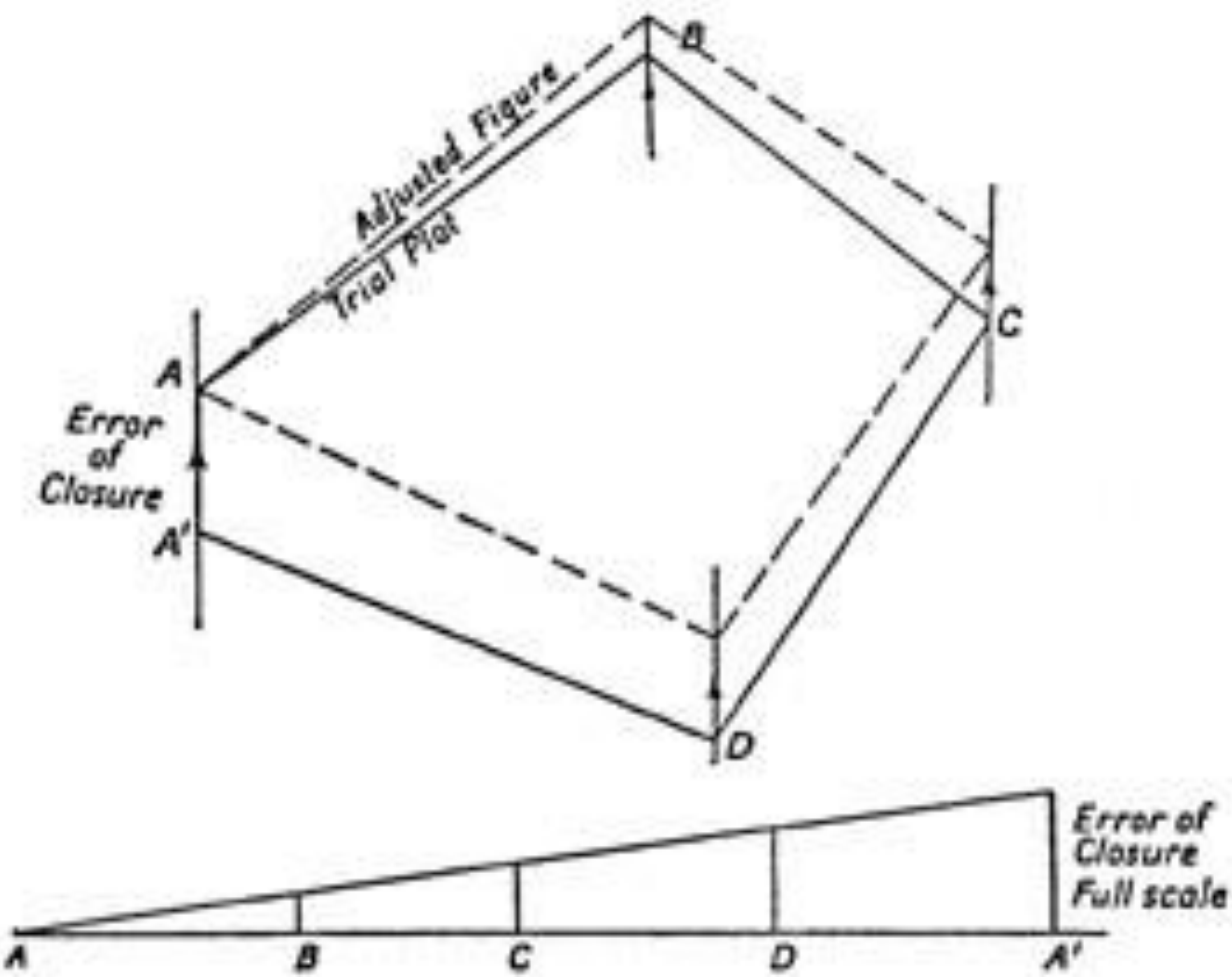


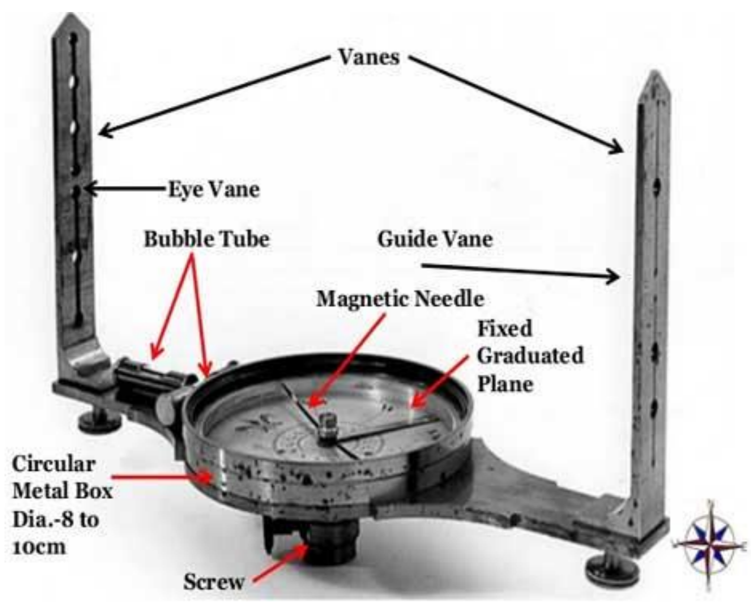
Bessel's graphical method

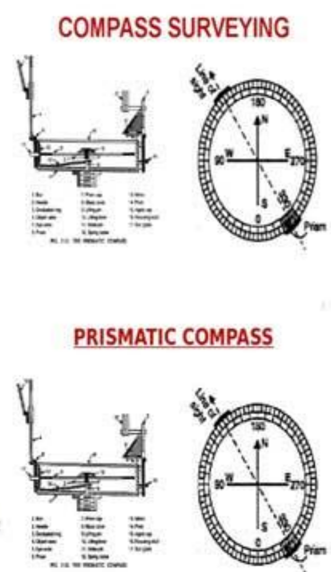
Plane Table Surveying – Adjusting the Traverse



Compass Surveying

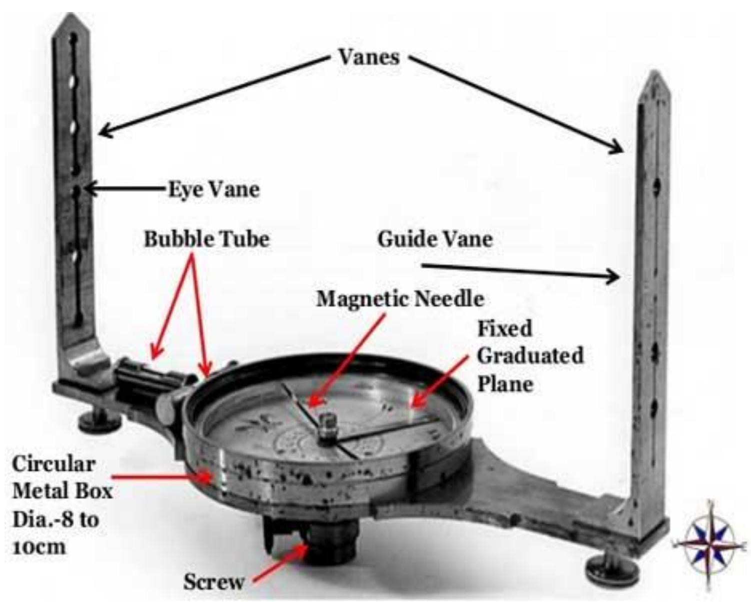
- Is used to **locate** an item using **both angular and linear** measurements.

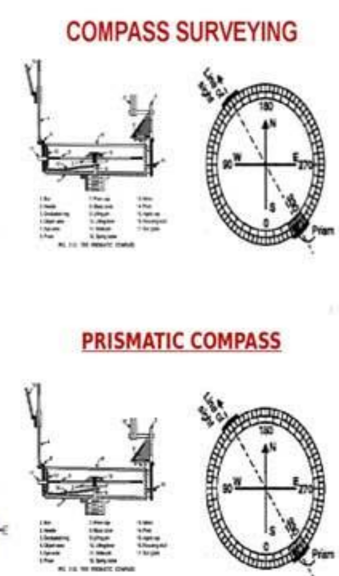




Compass Surveying

- Is used to **locate** an item using **both angular and linear** measurements.
- In this case, a **compass** is used to measure **angles**, while a **chain or tape** is used to measure **lengths**.





Compass Surveying

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- It is commonly used in land surveys.
- The simplicity of the prismatic compass makes it applicable in preliminary surveying, road surveying, rough traversing, and so on, <u>where high accuracy is not required</u>.
- It is used to find out <u>angles between the bearings of a line</u>

Compass Surveying

- Compass surveying is recommended when the area is large, undulating and crowded with many details.

- Compass surveying is **not recommended** for areas where <u>local attraction</u> is suspected due to the presence of magnetic substances like steel structures, iron ore deposits, electric cables conveying currents, and so on.

Compass Surveying – Principle:

- The Principle of Compass Survey is **Traversing**
- This involves a series of connected lines.
- Such survey does not require the formulation of a network of triangles

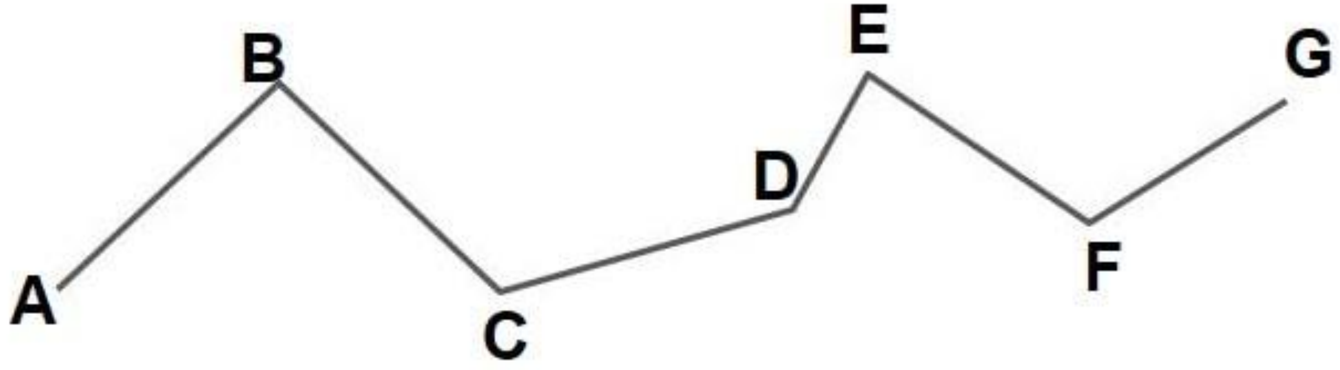
Compass Surveying – Principle:

- The Principle of Compass Survey is **Traversing**
- This involves a series of connected lines.
- Such survey does not require the formulation of a network of triangles
- Prismatic Compass survey is carried out in two ways:

  1. Open Traverse Survey
  2. Closed Traverse Survey

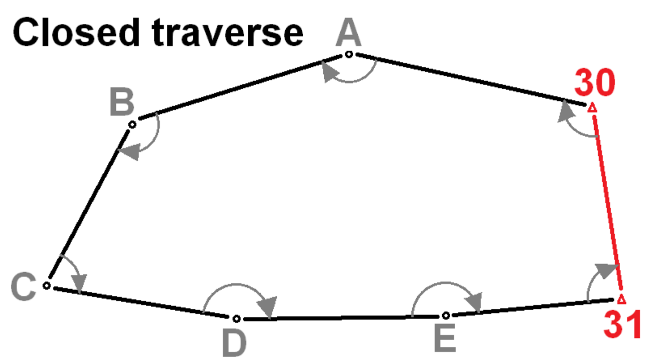
Compass Surveying – (1) Open Traverse

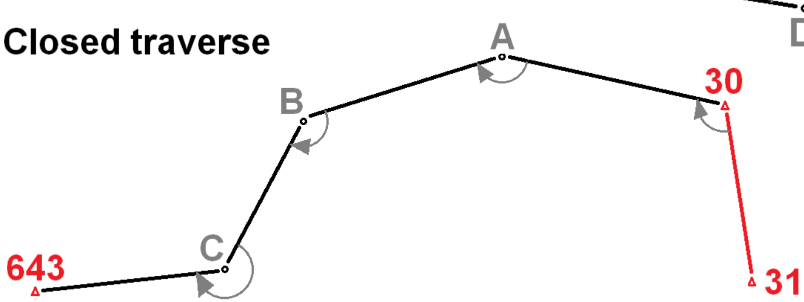
- A traverse is said to be **open traverse** when the traverse **starts at one point and terminates at another point**.
- Open traverse is also called as **unclosed traverse**.
- It is suitable for surveying of roads, coastal lines, etc.

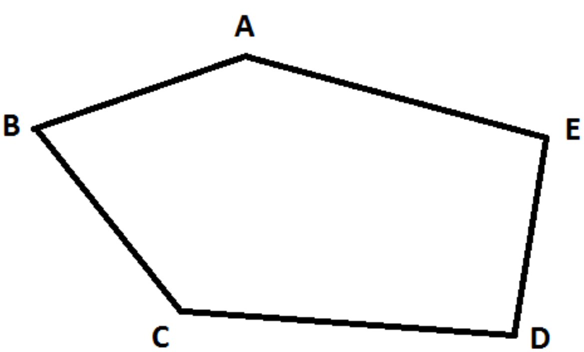


Compass Surveying – (2) Closed Traverse

- A traverse is said to be **closed traverse** when the **traverse forms a closed circuit**.
- It is suitable for the survey of boundaries of ponds, sports grounds, forests, etc.

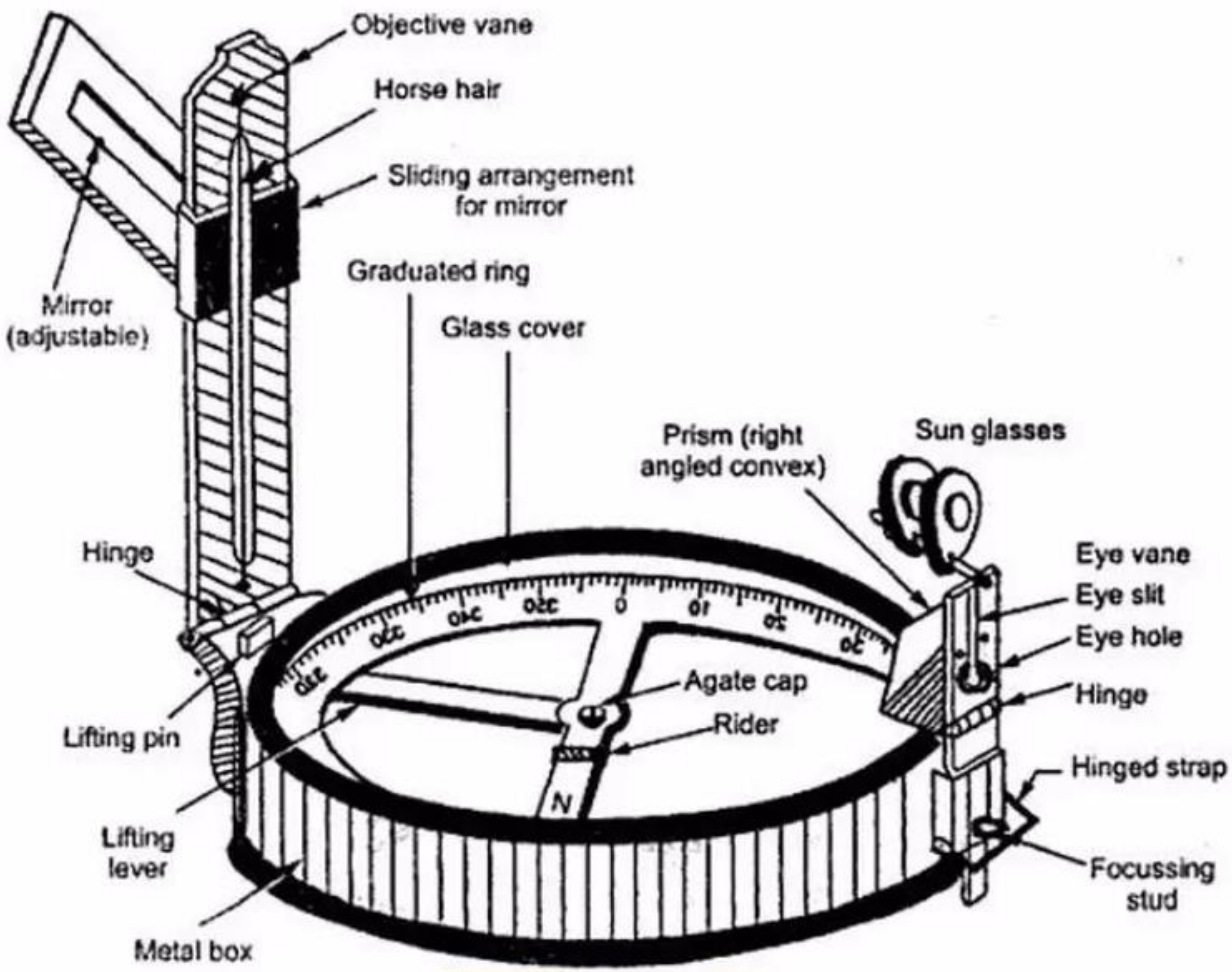






Closed Traverse

Prismatic Compass



Prismatic compass parts

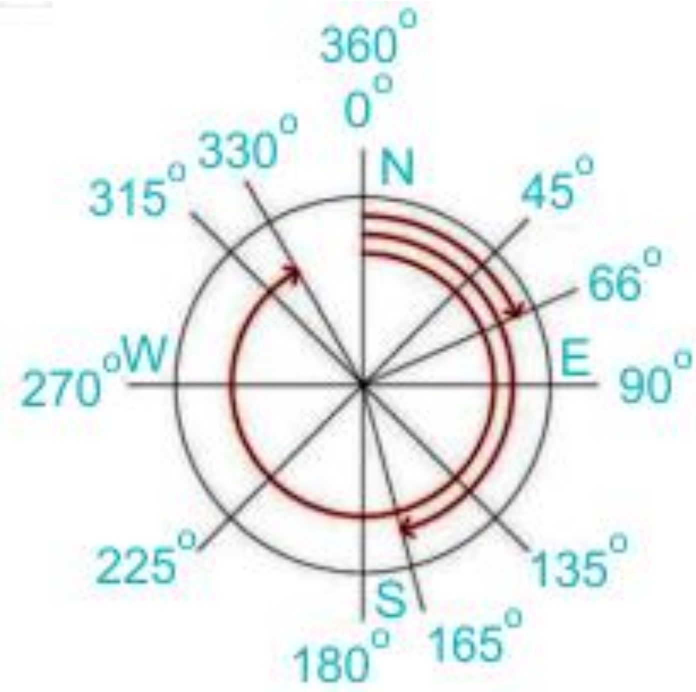
Compass Surveying

- When the needle of the compass is suspended freely, it always points towards the north.

Compass Surveying

- When the needle of the compass is suspended freely, it always points towards the north.
- All angles measured with prismatic compass are with respect to the magnetic north (magnetic meridian).

Compass Surveying



Whole Circle Bearing

- **Horizontal angle** made by a survey line with reference to the magnetic meridian in the clockwise direction – the **bearing** (WCB) of a line.

Compass Surveying

- When the needle of the compass is suspended freely, it always points towards the north.

- All angles measured with prismatic compass are with respect to the magnetic north (magnetic meridian).

- **Horizontal angle** made by a survey line with reference to the magnetic meridian in the clockwise direction – the **bearing** (WCB) of a line.

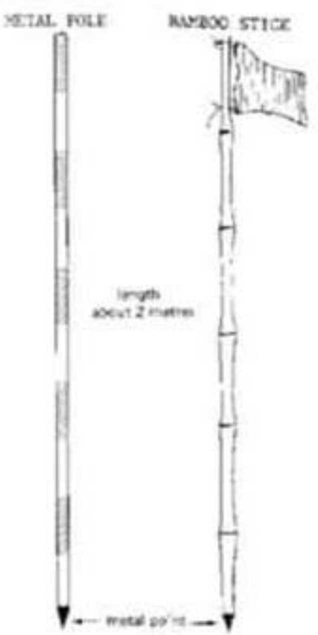
- Least count – 30’ (30 minutes)

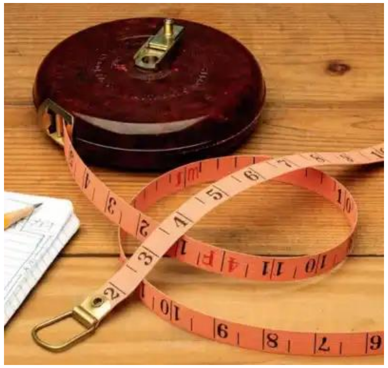
Compass Surveying: Equipment and Accessories

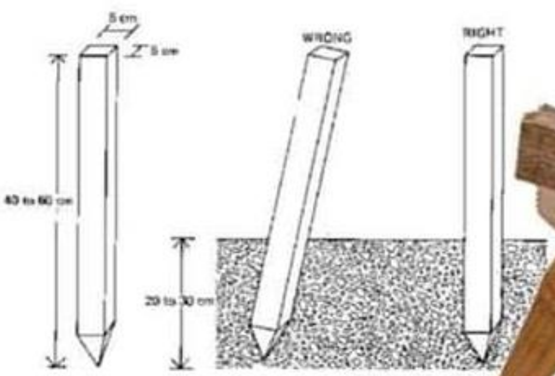
- Prismatic Compass with Tripod Stand
- Plumb bob

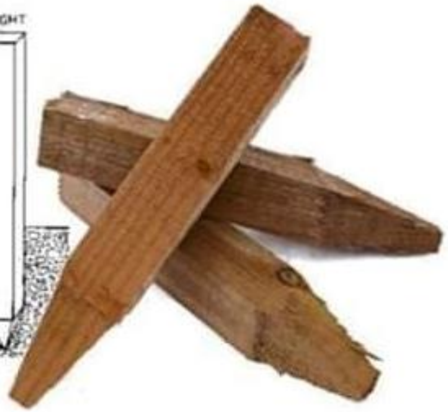
Compass Surveying: Equipment and Accessories

- Ranging Rods, Pegs and Tape (Chain)









Compass Surveying: Adjustment of Compass

(1) Temporary Adjustments:

(i) **Centering**: the process of bringing the vertical axis of the prismatic compass over the station mark.

Compass Surveying: Adjustment of Compass

(1) Temporary Adjustments:

(i) Centering: the process of bringing the vertical axis of the prismatic compass over the station mark.

- The instrument is kept exactly over the station point.
- This can be done either by adjusting the tripod stands or by using a plumb-bob. Sometimes, a pebble can be freely dropped from this center to the bottom of the instrument to check the centering.

Compass Surveying: Adjustment of Compass

(1) Temporary Adjustments:

(ii) **Levelling**: is done by ball and socket arrangement by eye judgment

- The instrument must be held such that the graduated disc swings freely and when viewed from the top edge, it must appear level.
- Generally a tripod is used to support the instrument for leveling

Compass Surveying: Adjustment of Compass

(1) Temporary Adjustments:

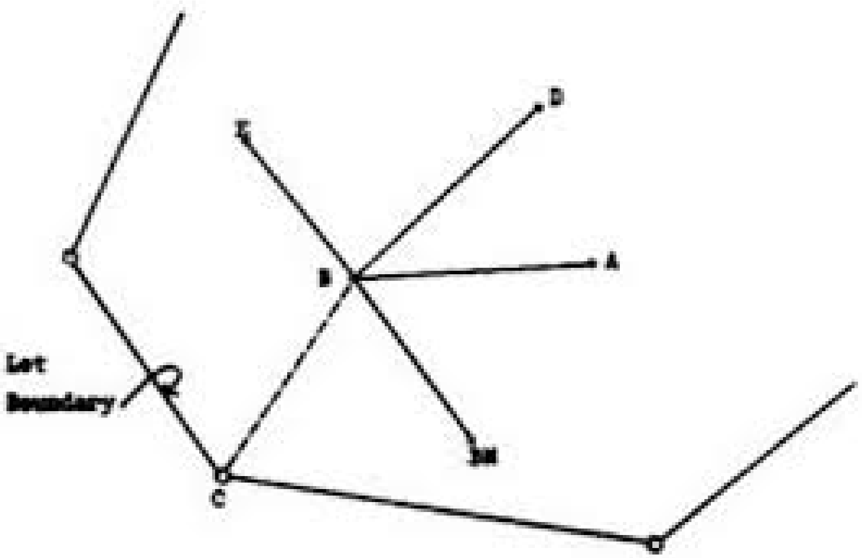
(iii) Focusing the Prism: Till the readings are observed sharp and clear, the prism attachment is slid up and down for proper focusing

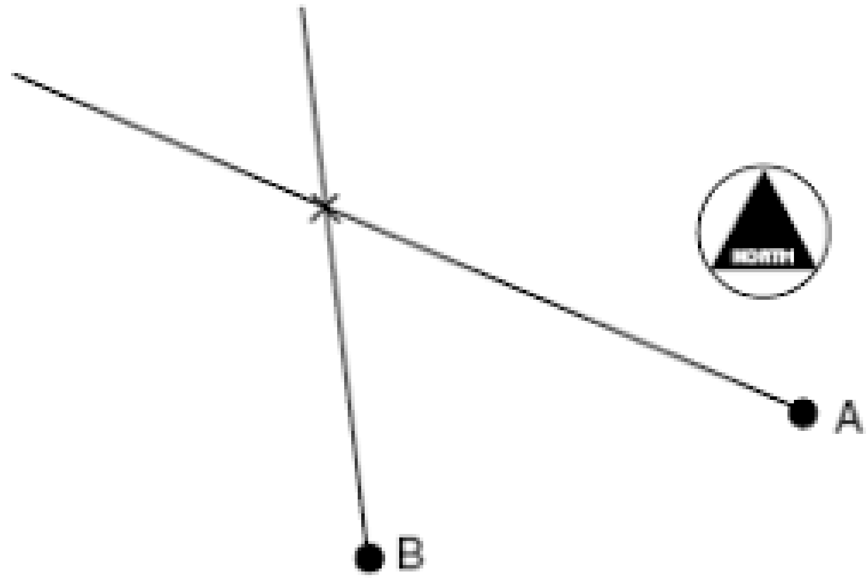
Compass Surveying: Adjustment of Compass

(2) Permanent Adjustments:

There can be damages to the internal parts of the compass due to various reasons, and these need to be checked and corrected.

Compass Surveying: Methods





Compass Surveying: Sources of Errors

- Instrumental errors?

- Personal errors?

- Natural errors?

Compass Surveying: Advantages

- They are portable and lightweight.
- They have fewer settings to fix it on a station
- The error in direction produced in a single survey line does not affect other lines
- It is suitable to retrace old surveys
- No electric power is required for the operation of compass surveying
- …………….

Compass Surveying: Disadvantages

- It is less precise compared to other advanced methods of surveying
- It is easily subjected to various errors such as errors adjoining to magnetic meridian, local attraction etc.
- Imperfect sighting of the ranging rods and inaccurate levelling also cause an error
- ………….

Compass Surveying: Terminology

Back Bearing and Fore Bearing

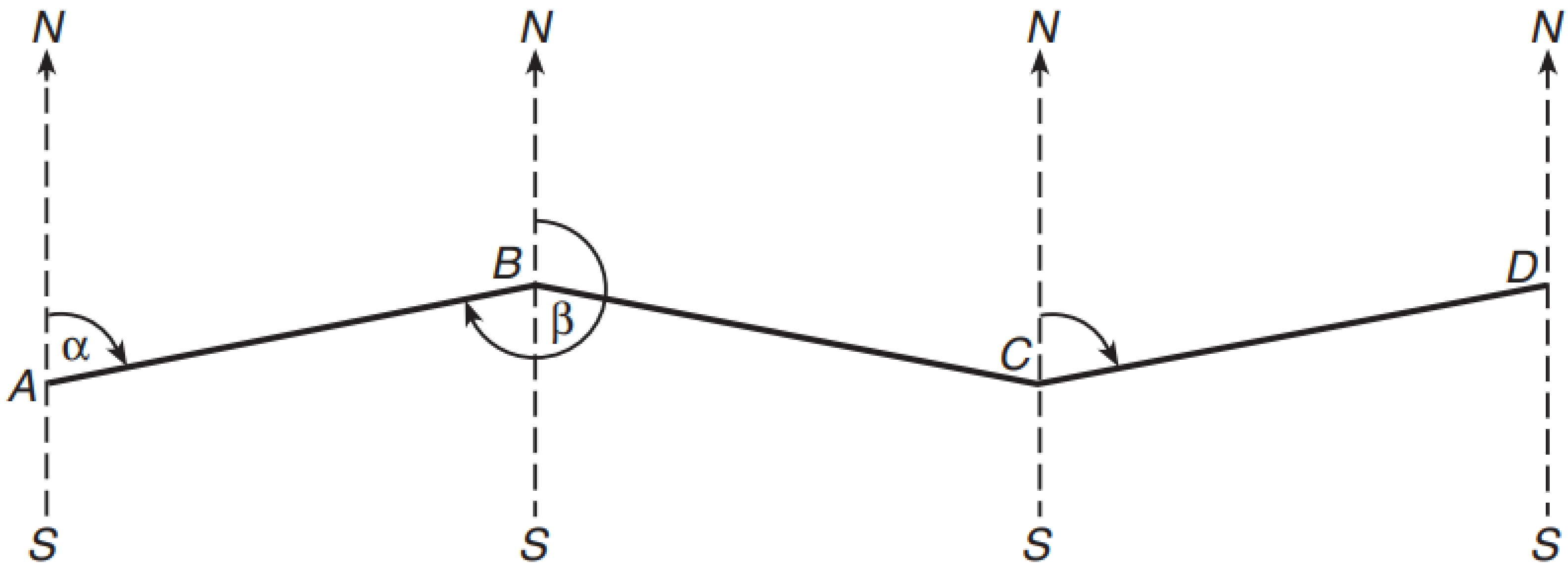


Fig. 4.21. Direction of survey is West to East.

Compass Surveying: Terminology

Relationship Between Back Bearing and Fore Bearing

Let the fore bearing of a line $AB = \alpha°$

Back bearing of $BA = \beta°$

or $$\beta = 180° + \angle SBA = 180° + \angle BAN' = \alpha + 180°$$

$\therefore$ Back bearing

$$= \text{Fore bearing} + 180° \qquad \ldots(i)$$

Now, consider the bearing of BA as a fore bearing $= \beta$

Then, $$\alpha = 180° - \angle S'AB = 180° - \angle ABN = 180° - (360° - \beta)$$

$$= \beta - 180°$$

or Back bearing = Fore bearing – 180° $\qquad \ldots(ii)$

Compass Surveying: Terminology

Relationship Between Back Bearing and Fore Bearing

Equations (*i*) and (*ii*) may be combined into one equation *i.e.*

Back bearing = Fore bearing ± 180°, using +ve sign if the fore bearing is less than 180° and – ve sign if it is more than 180°.

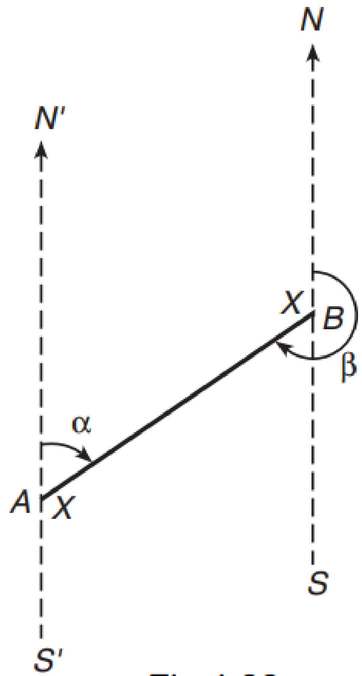


Fig.4.22.

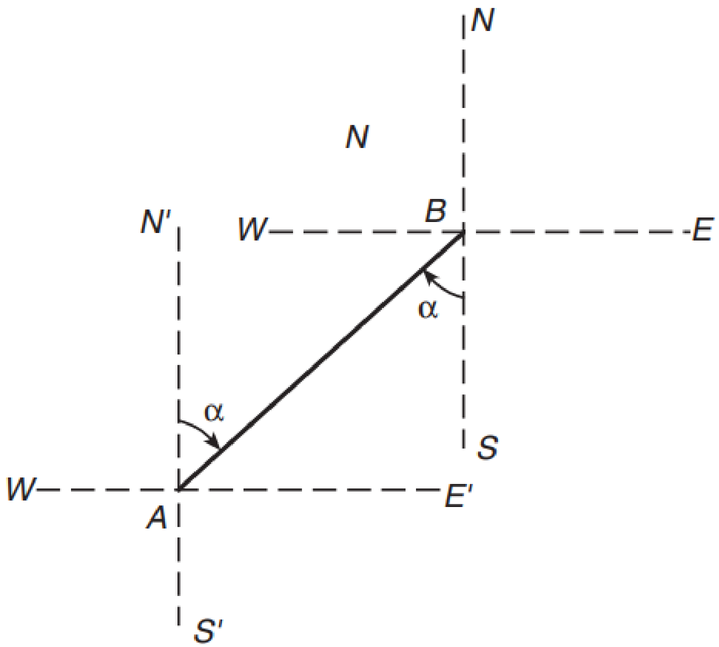


Fig.4.23.

Compass Surveying: Terminology

Calculation of Bearing from Included Angles

Let the observed bearing of the line AB be θ_1 (given)

α, β, γ, δ, φ...etc., the included angles measured clockwise between adjacent lines.

θ_2, θ_3 θ_4, θ_5, etc., the bearings of successive lines.

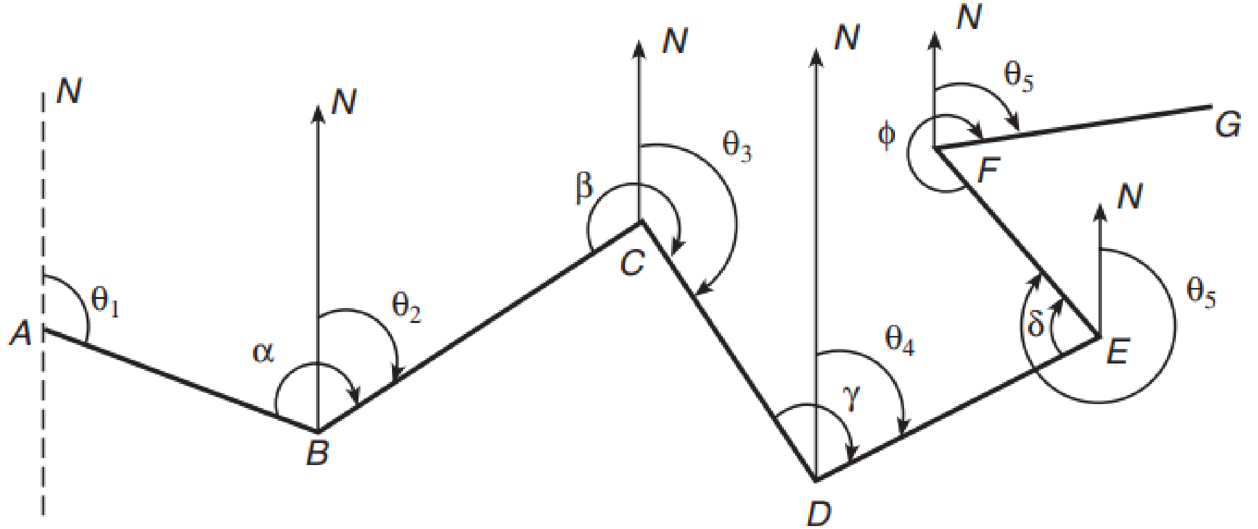


Fig. 4.26.

Compass Surveying: Terminology

$$\text{The bearing of } BC = \theta_2 = \theta_1 + \alpha - 180°$$

$$\text{The bearing of} CD = \theta_3 = \theta_2 + \beta - 180°$$

$$\text{The bearing of} DE = \theta_4 = \theta_3 + \lambda - 180°$$

$$\text{The bearing of } EF = \theta_5 = \theta_4 + \delta - 180°$$

$$\text{The bearing of} FG = \theta_6 = \theta_5 + \varphi - 180°$$

Compass Surveying: Question

Example 4.6. *The fore bearings of traverse sides are as follow: AB* $85° \ 10'$; *BC* $155° \ 30'$; *CD* $265° \ 5'$ and *DE* $355° \ 30'$. *Find their back bearings.*

Compass Surveying: Question

Example 4.6. *The fore bearings of traverse sides are as follow: AB 85° 10′; BC 155° 30′; CD 265° 5′* and *DE 355° 30′. Find their back bearings.*

Solution. We know that

Back bearing of a line = fore bearing of the line ± 180°.

$\therefore$ Back bearing of $AB = 85° \, 10' + 180° = 265° \, 10'$. **Ans.**

Back bearing of $BC = 155° \, 30' + 180°$

$= 335° \, 30'$. **Ans.**

Back bearing of $CD = 265° \, 05' - 180°$

$= 85° \, 05'$ **Ans.**

Back bearing of $DE = 355° \, 30' - 180°$

$= 175° \, 30'$. **Ans.**

Compass Surveying: Question

Example 4.8. *Find the included angles between lines AB and AC if their whole circle bearings are :*

(i)	AB 75° 30′	AC 108° 50′
(ii)	AB 185° 50′	AC 269° 25′
(iii)	AB 60° 10′	AC 245° 10′
(iv)	AB 70° 20′	AC 285° 40′.

Compass Surveying: Question

Solution.

(*i*) Bearing of $AB = 75° 30'$

Bearing of $AC = 108° 50'$

$\because$ Included angle BAC = Bearing of AC – Bearing of AB

$= 108° 50' - 75° 30' = 33° 20'$. **Ans.**

(*ii*) Bearing of $AB = 185° 50'$

Bearing of $AC = 269° 25'$

$\therefore$ Included angle $BAC = 269° 25' - 185° 50' = 83° 35'$. **Ans.**

(*iii*) Bearing of $AB = 60° 10'$

Bearing of $AC = 245° 10'$

Difference in bearings $= 245° 10' - 60° 10' = 185° 0'$

As it is more than 180°, deduct it from 360°

$\therefore$ Included angle $BAC = 360° - 185° 0' = 175° 0'$. **Ans.**

(*iv*) Bearing of $AB = 70° 20'$

Bearing of $AC = 285° 40'$

$\therefore$ Difference in bearings $= 285° 40' - 70° 20'. = 215° 20'$

As it is more than 180°, deduct it from 360°

$\therefore$ Included angle $BAC = 360° - 215° 20' = 144° 40'$. **Ans.**

Compass Surveying: Question

Example 4.10. *The bearings of the sides of a closed transverse ABCDEA are as follow :*

Side	*F.B.*	*B.B.*
AB	$107° 15'$	$287° 15'$
BC	$22° 00'$	$202° 00'$
CD	$281° 30'$	$101° 30'$
DE	$181° 15'$	$1° 15'$
EA	$124° 45'$	$304° 45'$

Compute the interior angles of the traverse and exercise necessary checks.

Compass Surveying: Local Attraction

- North end of a freely suspended magnetic needle always points to the magnetic north, if it is not influenced by any other external forces except the earth's magnetic field.

- It is a common experience that the magnetic needle gets **deflected** from its normal position, **if placed near magnetic rocks, iron ores, cables carrying current or iron electric poles**.

Compass Surveying: Detection of Local Attraction

- The presence of local attraction at any station may be detected by observing the fore and back bearings of the line.
- If the difference between fore and back bearings is 180°, both end stations are free from local attraction.
- If not, the discrepancy may be due to:
    i. An error in observation of either fore or back bearings or both.
    ii. Presence of local attraction at either station.
    iii. Presence of local attraction at both the stations.

Compass Surveying: Detection of Local Attraction

- It may be noted that local attraction at any station affects all the magnetic bearings by an equal amount and hence, the included angles deduced from the affected bearings are always correct.
- In case, the fore and back bearings of neither line of a traverse differ by the permissible error of reading, **the mean value of the bearings of the line least affected**, may be accepted.

Compass Surveying: Detection of Local Attraction

- The correction to other stations, may be made according to the following methods.
  i. By calculating the included angles at the affected stations.
  ii. By calculating the local attraction of each station and then applying the required corrections, starting from the unaffected bearing.

Compass Surveying: Method of elimination of local attraction by applying Corrections to Bearings

i. Calculate the magnitude and direction of the error due to local attraction at each affected station.

ii. Run down the bearings, starting from the bearing unaffected by local attraction.

Compass Surveying: Method of elimination of local attraction by applying Corrections to Bearings

Example 4.13. *A closed compass traverse ABCD was conducted round a lake and the following bearings were obtained. Determine which of the stations are suffering from local attraction and give the values of the corrected bearings :*

AB	74° 20′	256° 0′
BC	107° 20′	286° 20′
CD	224° 50′	44° 50′
DA	306° 40′	126° 00′

Compass Surveying: Method of elimination of local attraction by applying Corrections to Bearings

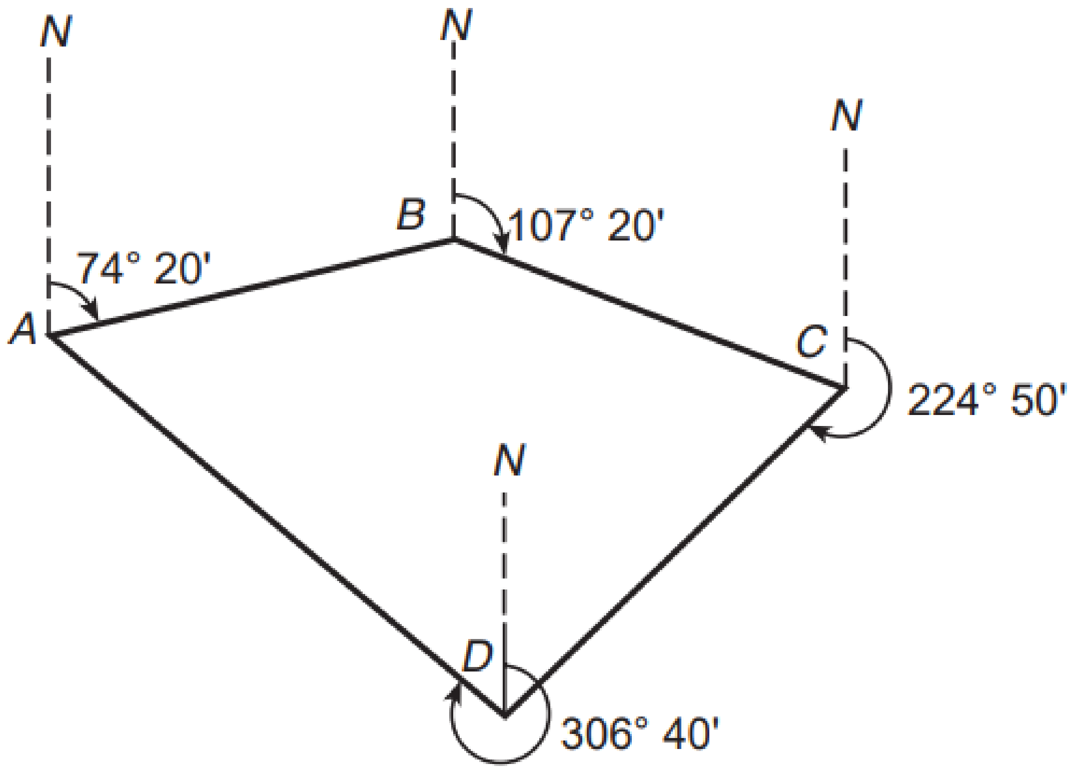


Fig. 4.35.

Compass Surveying: Method of elimination of local attraction by applying Corrections to Bearings

Station ID	Line	Observed Bearing	Local Attraction	Correction	Corrected Bearing
B	AB	74° 20′	2° 20′	+ 0° 40′	75° 00′
	BA	256° 00′		- 1° 00′	255° 00′
C	BC	107° 20′	1° 0′	- 1° 00′	106° 20′
	CB	286° 20′		0	286° 20′
D	CD	224° 50′	0° 0′	0	224° 50′
	DC	44° 50′		0	44° 50′
A	DA	306° 40′	0° 40′	0	306° 40′
	AD	126° 00′		+ 0° 40′	126° 40′

Compass Surveying: Method of elimination of local attraction by applying Corrections to Bearings

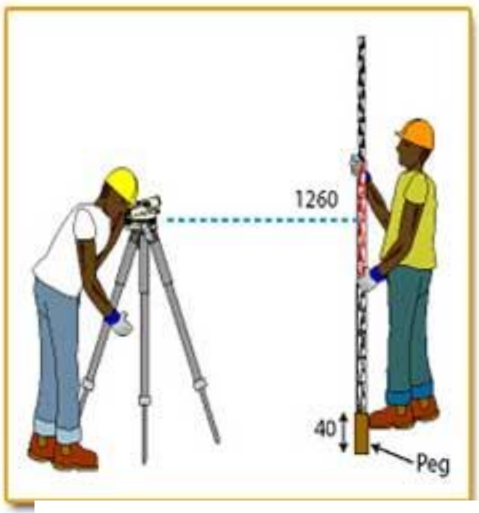
Example 4.15. *The following fore and back bearings were observed in traversing with a compass. Correct for local attraction :*

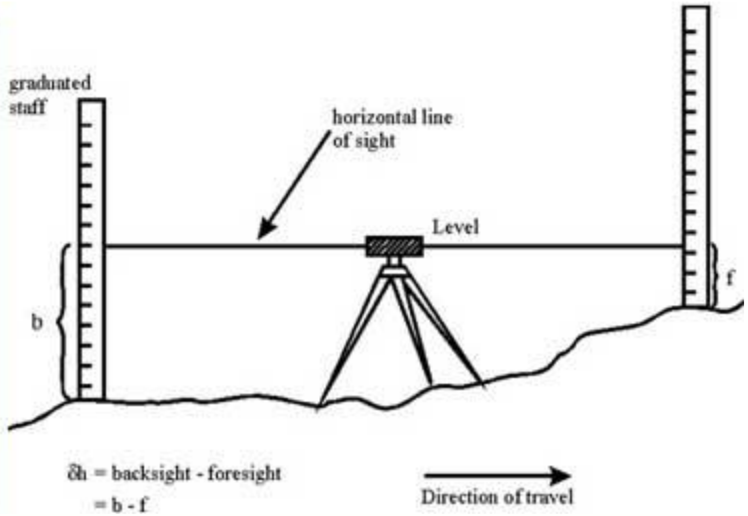
Line	*Fore bearing*	*Back bearing*
AB	44° 30′	226° 30′
BC	124° 30′	303° 15′
CD	181° 0′	1° 0′
DA	289° 30′	108° 45′

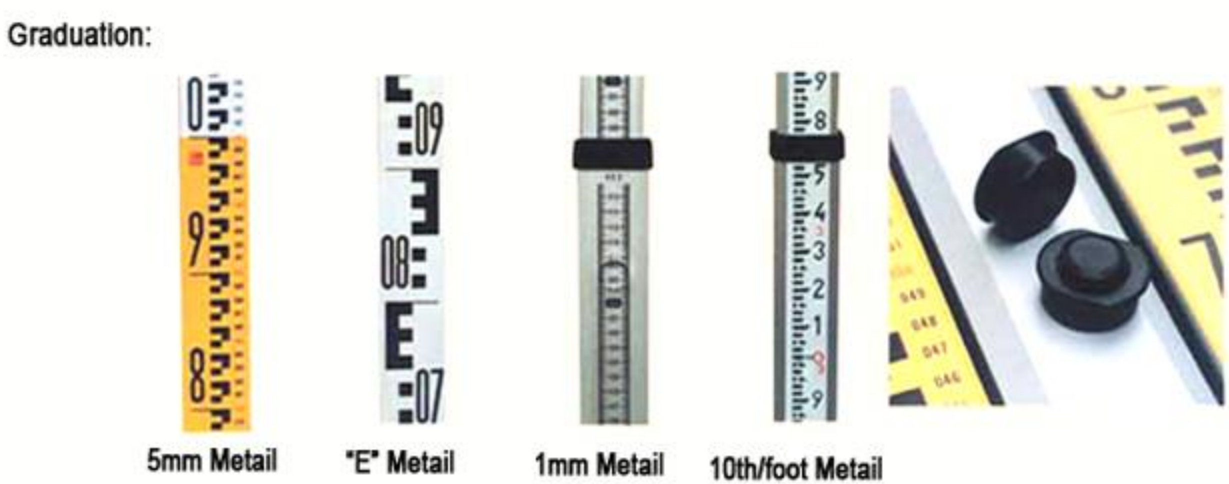
Compass Surveying: Method of elimination of local attraction by applying Corrections to Bearings

Station ID	Line	Observed Bearing	Local Attraction	Correction	Corrected Bearing
B	AB	44° 30′	2° 00′	+ 0° 45′	45° 15′
	BA	226° 30′		- 1° 15′	225° 15′
C	BC	124° 30′	1° 15′	- 1° 15′	123° 15′
	CB	303° 15′		0	303° 15′
D	CD	181° 00′	0	0	181° 00′
	DC	1° 00′		0	1° 00′
A	DA	289° 30′	45′	0	289° 30′
	AD	108° 45′		+ 0° 45′	109° 30′

Levelling


1260
40
Peg


graduated
staff
horizontal line
of sight
Level
b
f
δh = backsight - foresight
= b - f
Direction of travel


Graduation:
5mm Metail
"E" Metail
1mm Metail
10th/foot Metail


BOSCH

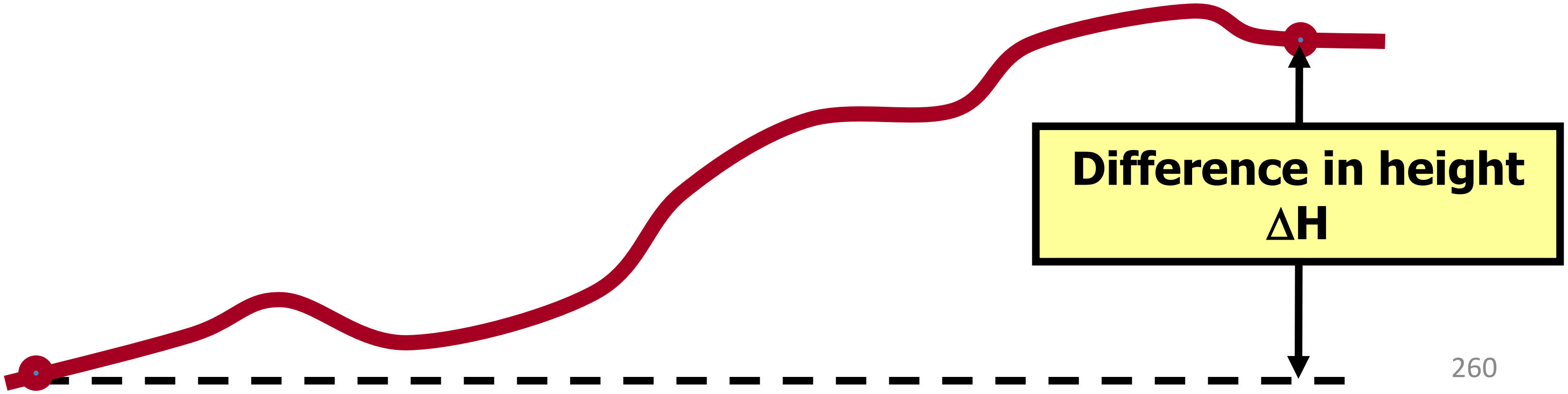
Levelling

Levelling – Purpose

- **There are 2 main objectives**

  1. Find the elevations of given points with respect to a given or assumed reference surface (datum)

  2. Establish points at a given elevation or at different elevations with respect to a given or assumed datum.



Levelling – Objectives

Objective 1 – Enable engineering works to be designed

- Establish new vertical control
- Determine the heights of discrete points
- Provide spot heights or contours on a plan
- Provide data for road cross-sections or volumes of earthworks

Levelling – Objectives

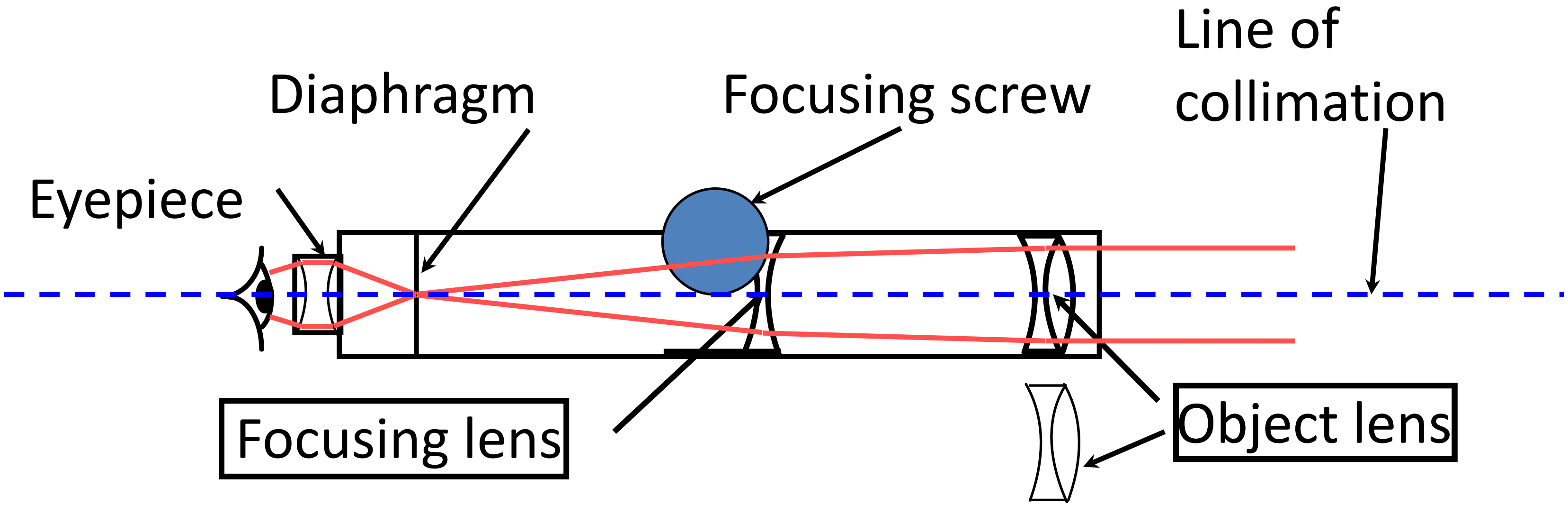
Objective 2 - Required in the setting out of all kinds of engineering works

- Provide a level or inclined plane to set out of construction work

Levelling – Equipment

- **Level:** The purpose of a level is to provide a horizontal line of sight
- A telescope which can be extremely accurately set so it is horizontal, has a set of cross-hairs, and can be turned through 360° horizontally.
- Provides line of sight
- A level tube to make a line of sight horizontal
- A levelling head to bring the bubble in its centre of run

Levelling – Equipment

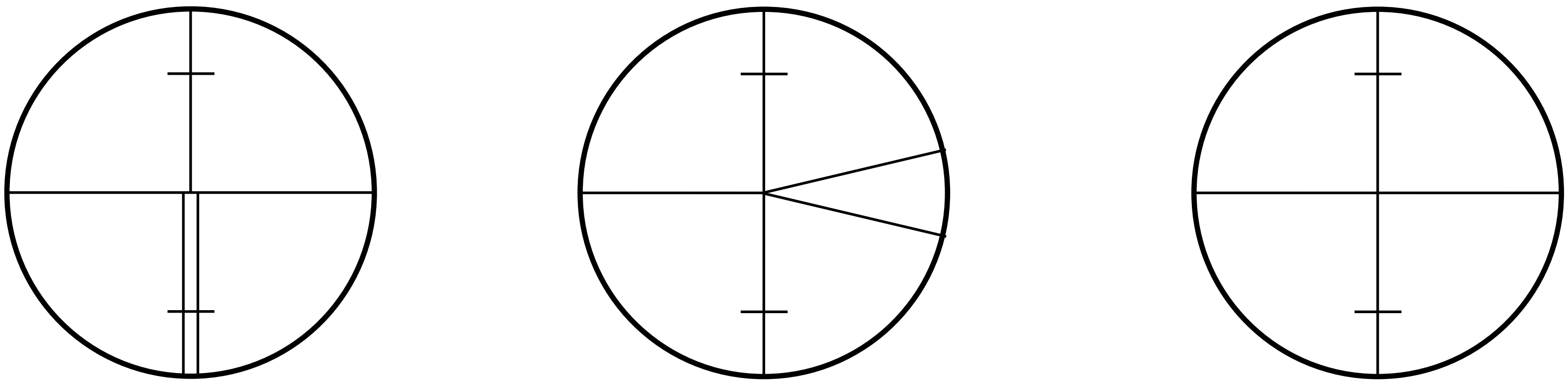


Focusing:

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

Levelling – Equipment – Diaphragms



Typical diaphragms - in different makes of instrument

Levelling – Equipment – Categories of Levels

- Dumpy levels
- Tilting levels
- Automatic levels
- Digital levels
- Hand levels
- Electronic laser levels

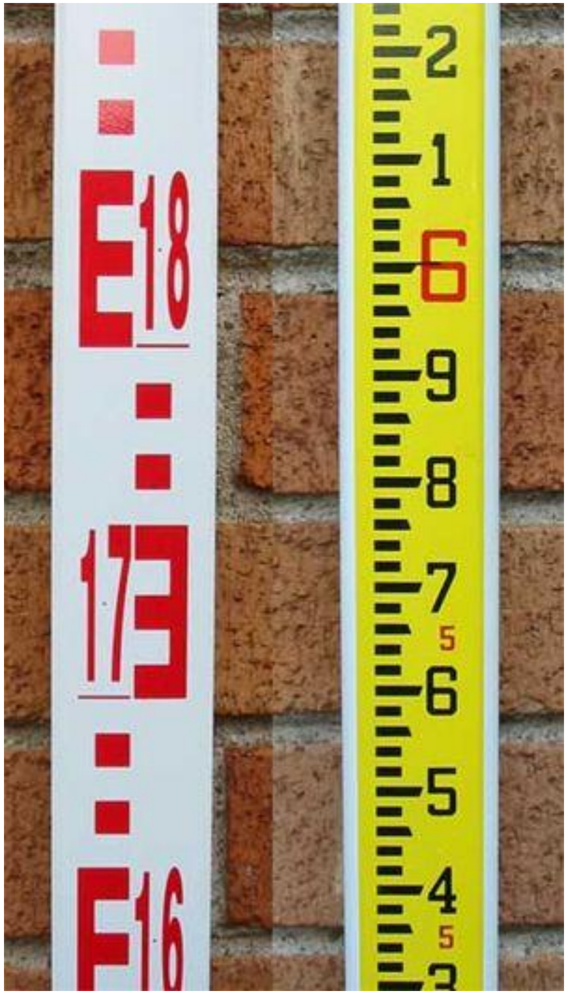
Levelling – Equipment – Tripod

A fully adjustable 3-legged stand on which the level sits, so that the level:

- is roughly horizontal, prior to fine adjustment
- is at a height at which the user can see through it easily

Levelling – Equipment – Staff, Tape, Umbrella

- Staff
  - A measuring stick, usually 4m tall, and clearly marked in divisions of 10 mm (allowing readings to be taken to 1mm by interpolation), which is held vertically



Levelling – Equipment – Staff, Tape, Umbrella

- Staff
    - A measuring stick, usually 4m tall, and clearly marked in divisions of 10 mm (allowing readings to be taken to 1mm by interpolation), which is held vertically
- Tape measure

Levelling – Equipment – Staff, Tape, Umbrella

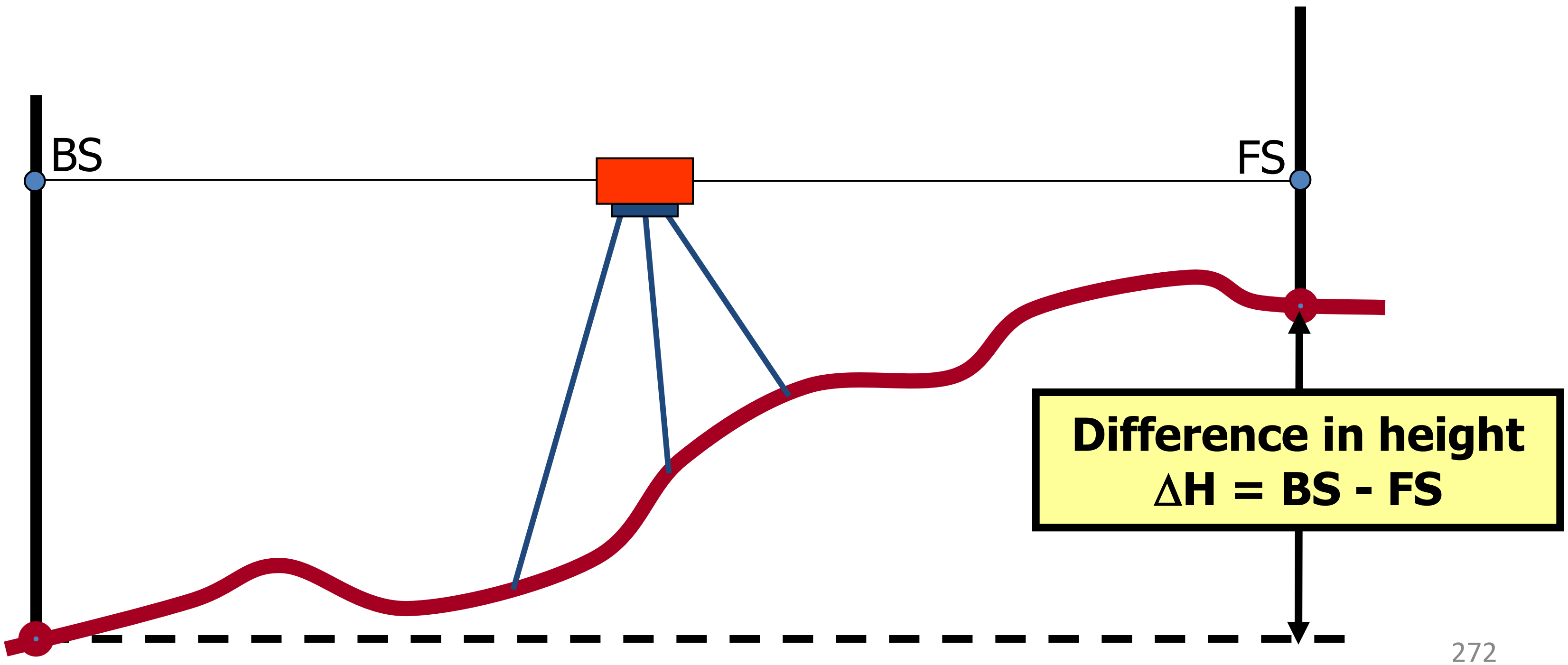
- Staff
  - A measuring stick, usually 4m tall, and clearly marked in divisions of 10 mm (allowing readings to be taken to 1mm by interpolation), which is held vertically
- Tape measure
- Gig Umbrella

Levelling – Definition

- A measurement process whereby the ***difference in height*** between two or more points can be determined

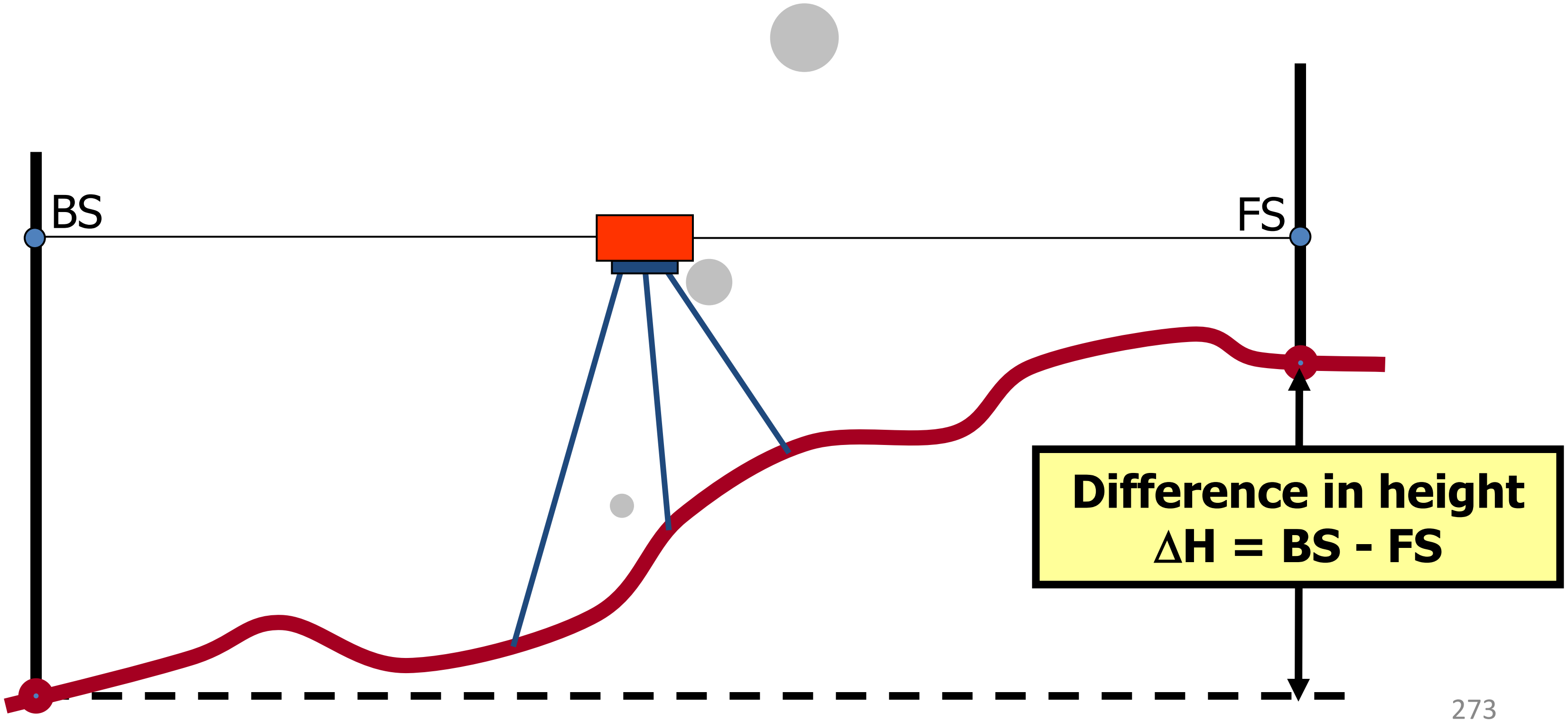
Levelling – Definition

- A measurement process whereby the ***difference in height*** between two or more points can be determined



Levelling – Defi

Note that it is not necessary set up the LEVEL on the line of BS & FS



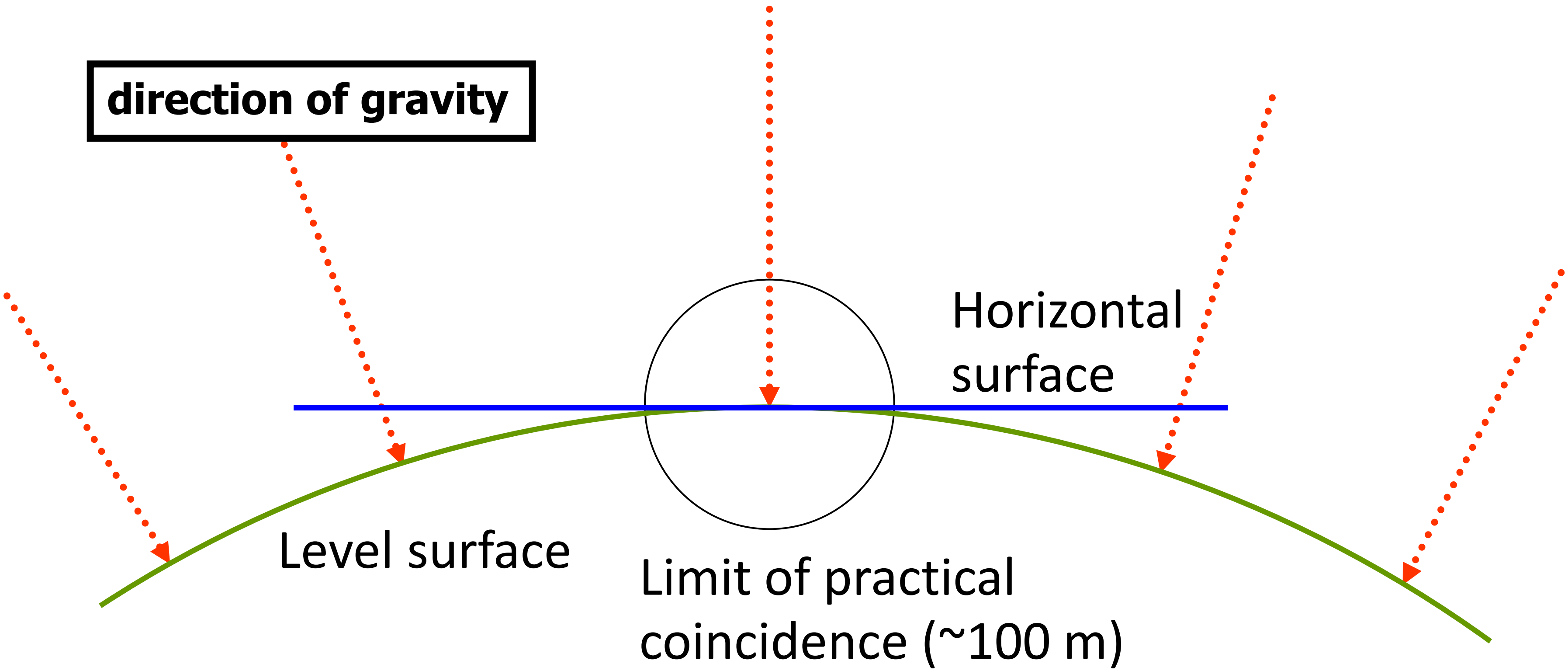
Levelling – Keywords

- **Level surface**
  - A surface over which water will not flow
  - The direction of gravity is always normal to a level surface

Levelling – Keywords

- **Level surface**
  - A surface over which water will not flow
  - The direction of gravity is always normal to a level surface
- **Horizontal surface**
  - A *horizontal* surface will be tangent to a *level* surface
  - Over short distances (<100 m) the horizontal surface and the level surface will coincide

Levelling – Keywords

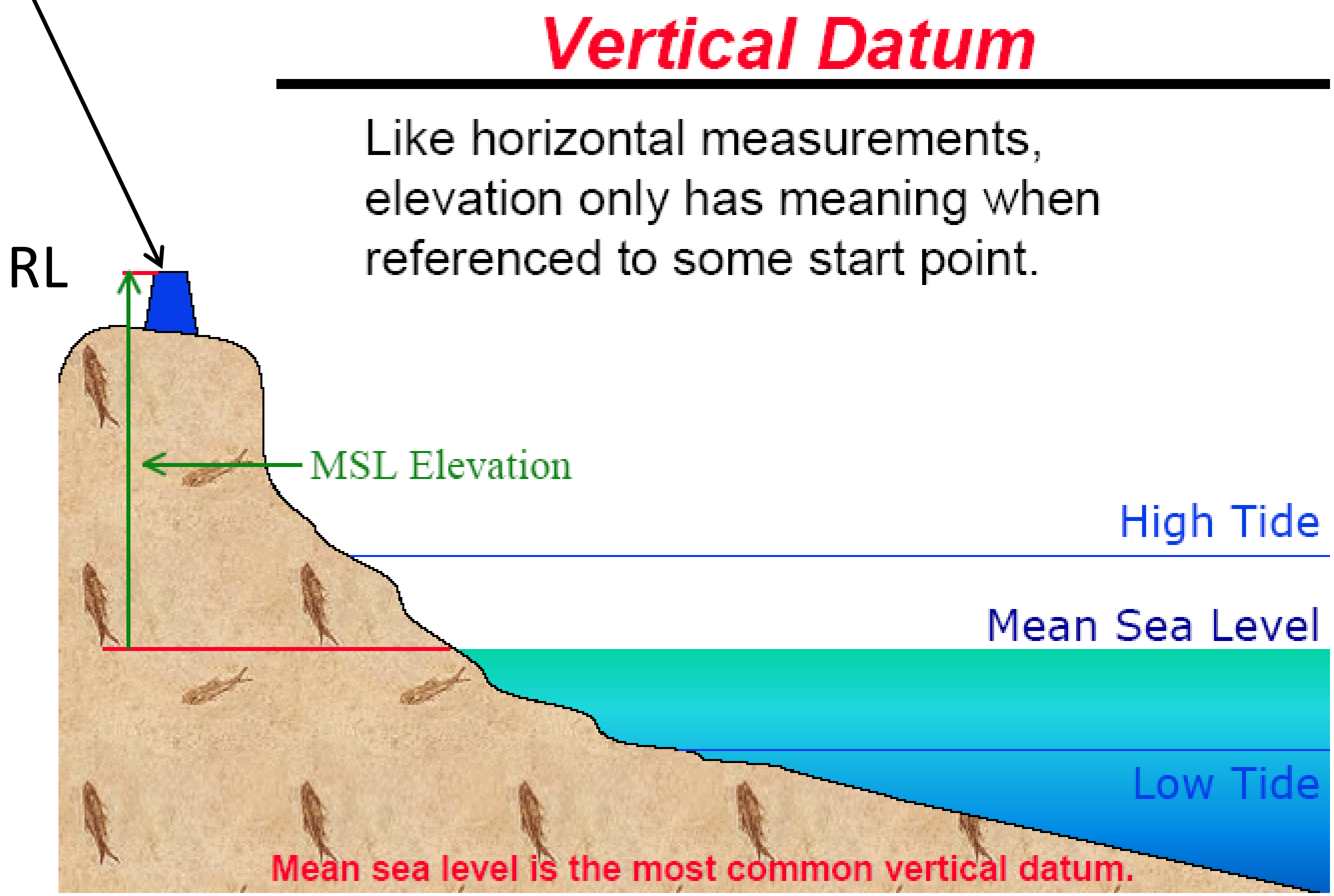


Levelling – Keywords

- **Datum**
  - A reference surface to which the heights of all points in a survey or on a site are referred
  - May be arbitrary or a national height datum
  - In Sri Lanka we have a National Datum as MSL
  - The surface which defines the MSL is (approximately) Mean Sea Level

Levelling – Keywords – Datum (MSL)

RL – Reduced Level – The Height of a Point Above the Datum



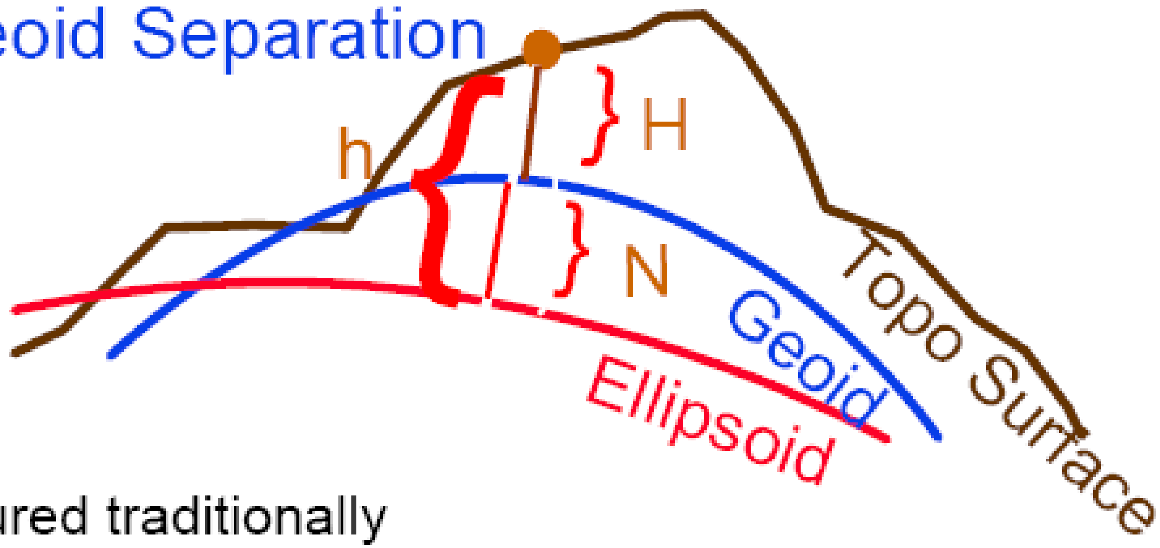
Levelling – Keywords – Height

Defining the Vertical Position

H - Orthometric Height
(Height above Mean Sea Level)

h - Geodetic Height
(Height above Ellipsoid)

N - Geoid Separation



H is measured traditionally
h is approximately = N+H
N is modeled using Earth Geoid Model

Levelling – Keywords

- **Reduced Level (RL)**
  - The height of a point above the datum

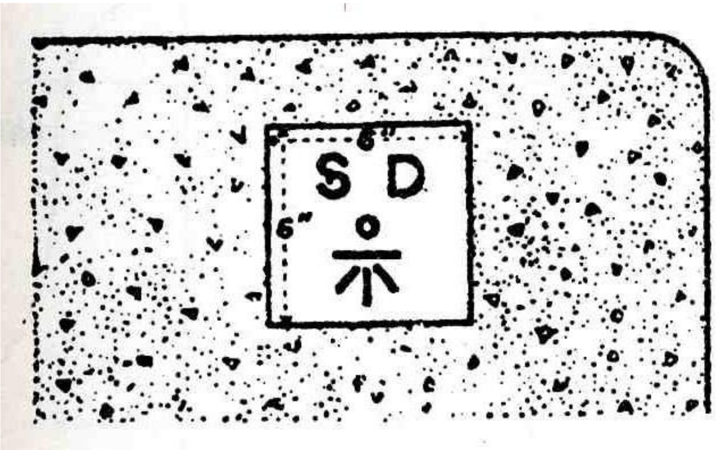
Levelling – Keywords

- **Reduced Level (RL)**
  - The height of a point above the datum
- **Benchmark (BM)**
  - A stable reference point of known RL
  - Usually used as the starting and finishing point when levelling

Levelling – Keywords

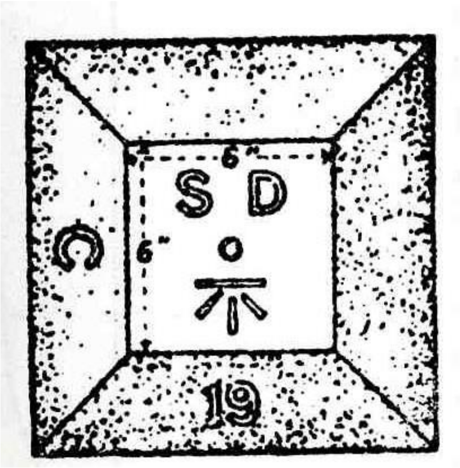
- **Reduced Level (RL)**
  - The height of a point above the datum
- **Benchmark (BM)**
  - A stable reference point of known RL
  - Usually used as the starting and finishing point when levelling
- **Temporary Bench Mark (TBM)**
  - A point placed (e.g. peg, nail, spike) to provide a temporary reference point

Levelling – Types of SDSL Benchmarks



TYPE C

Bronze bolt set in cement, in rock concrete or masonry above ground surface impressed with S. D. and Benchmark Sign.



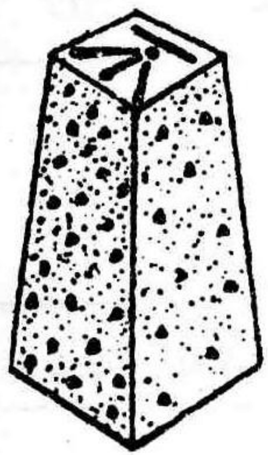
TYPE E

Bronze bolt set in rectangulation block (large). Surface of block 3 inches above ground surface.

TYPE F

Bronze bolt set in rectangulation block (small). Dressed surface same as Type E.

Levelling – Types of SDSL Benchmarks



TYPE H

Conerete block top 3" square, base 4" square, side 9" crowsfoot impressed on top; centre mark: $\frac{3}{4}$" diameter without bolt.

Buried flush with ground.

Levelling – Keywords

- **Backsight (BS)**
  - Always the ***first*** reading from a new instrument station

Levelling – Keywords

- **Backsight (BS)**
  - Always the ***first*** reading from a new instrument station
- **Foresight (FS)**
  - Always the ***last*** reading from the current instrument station

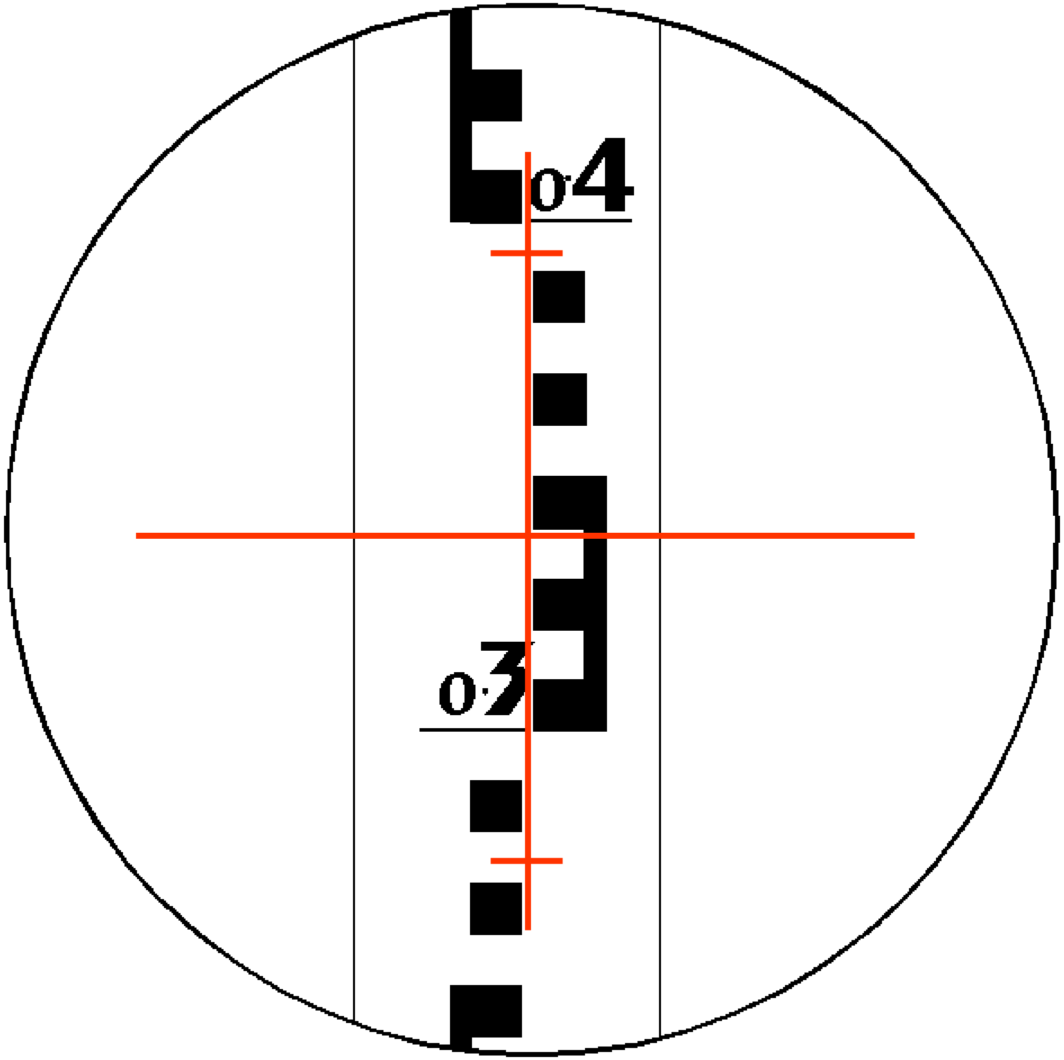
Levelling – Keywords

- **Backsight (BS)**
  - Always the ***first*** reading from a new instrument station
- **Foresight (FS)**
  - Always the ***last*** reading from the current instrument station
- **Intermediate sight (IS)**
  - Any sighting that is not a backsight or foresight

Levelling – Keywords

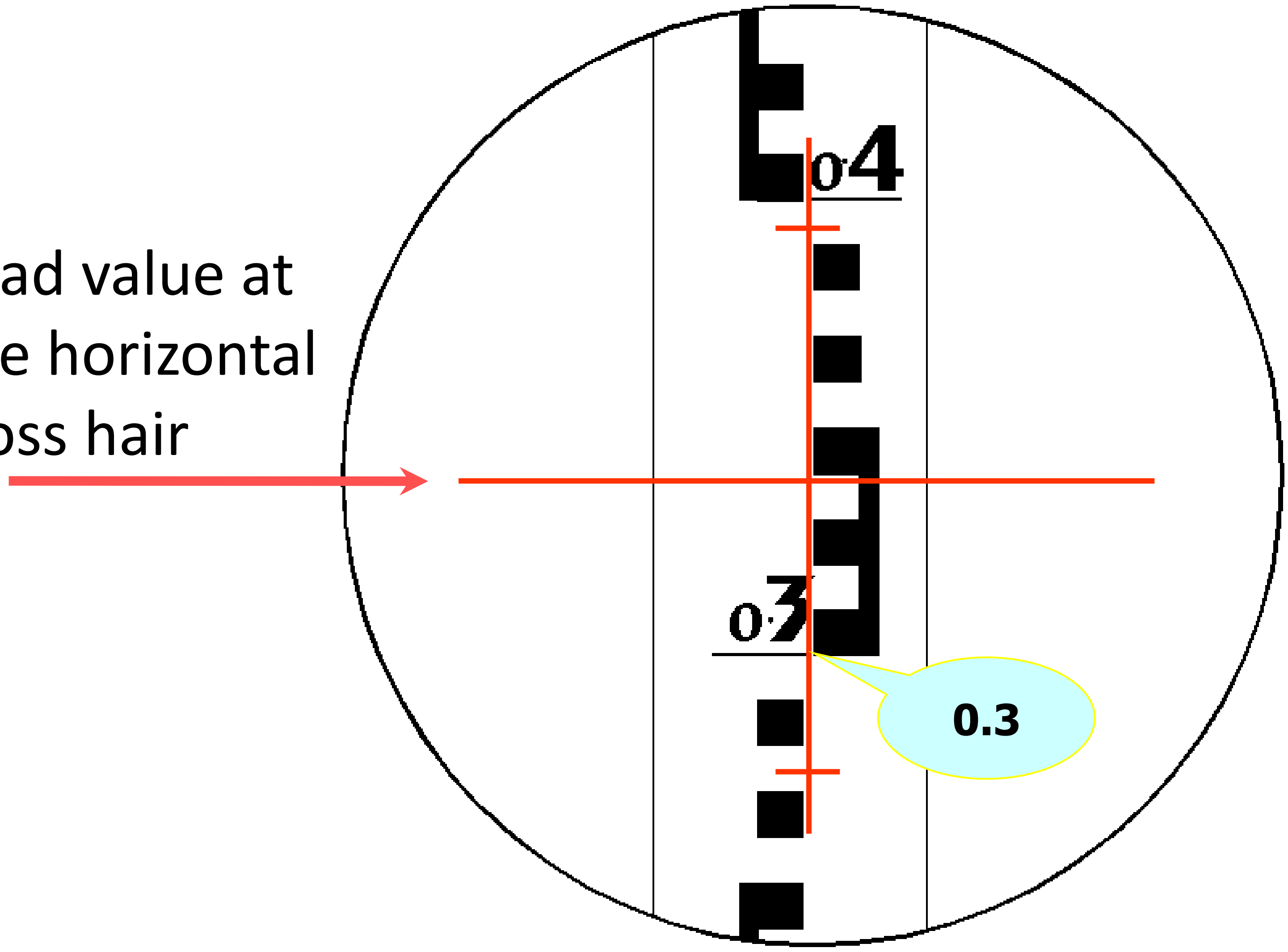
- **Change point (CP)**
  - Location of the staff when the level is moved
  - Change points should be
    - Stable
    - Well defined
    - Recoverable
    - e.g. sharp rock, nail, change plate

Levelling – Reading an E-face Staff



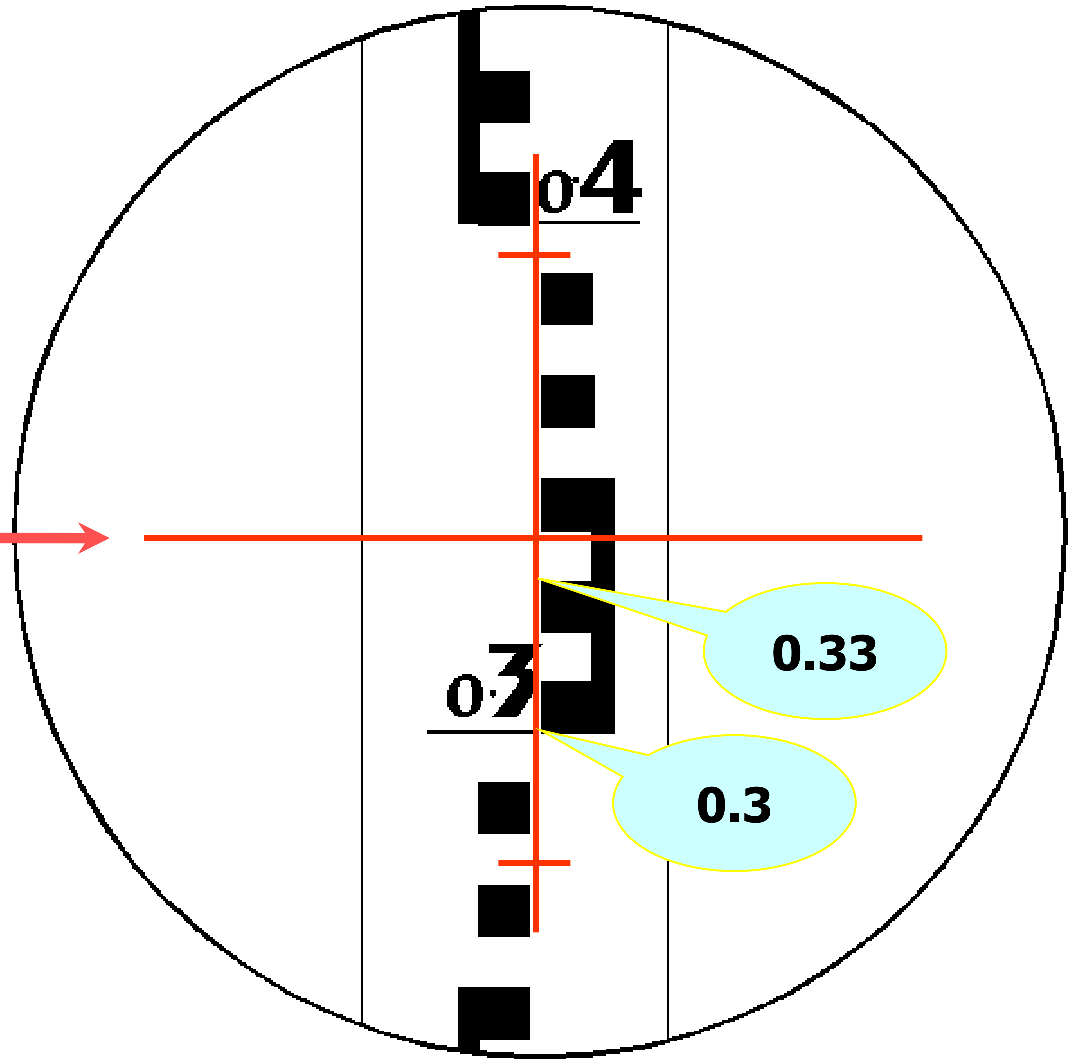
Levelling – Reading an E-face Staff

Read value at
The horizontal
cross hair



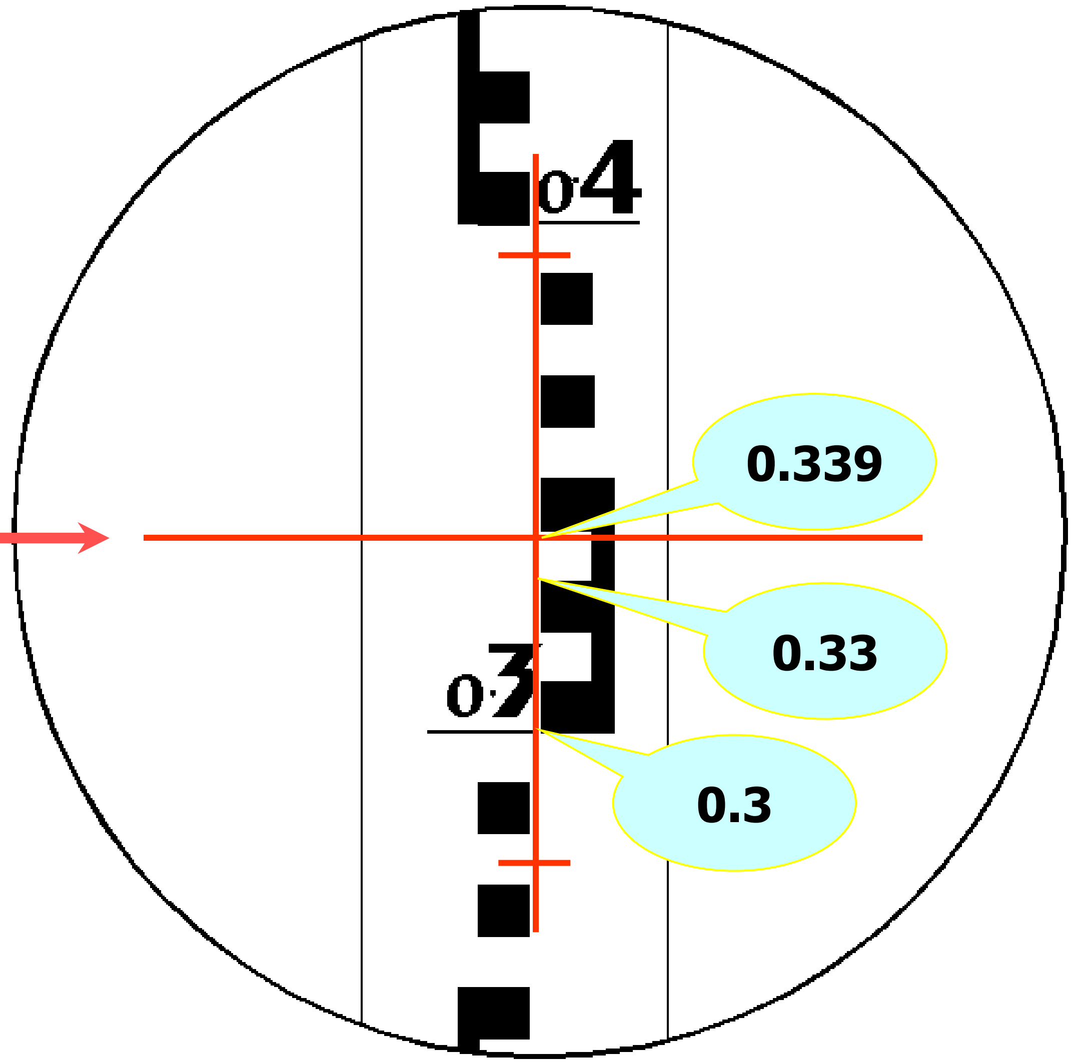
Levelling – Reading an E-face Staff

Read value at
The horizontal
cross hair



Levelling – Reading an E-face Staff

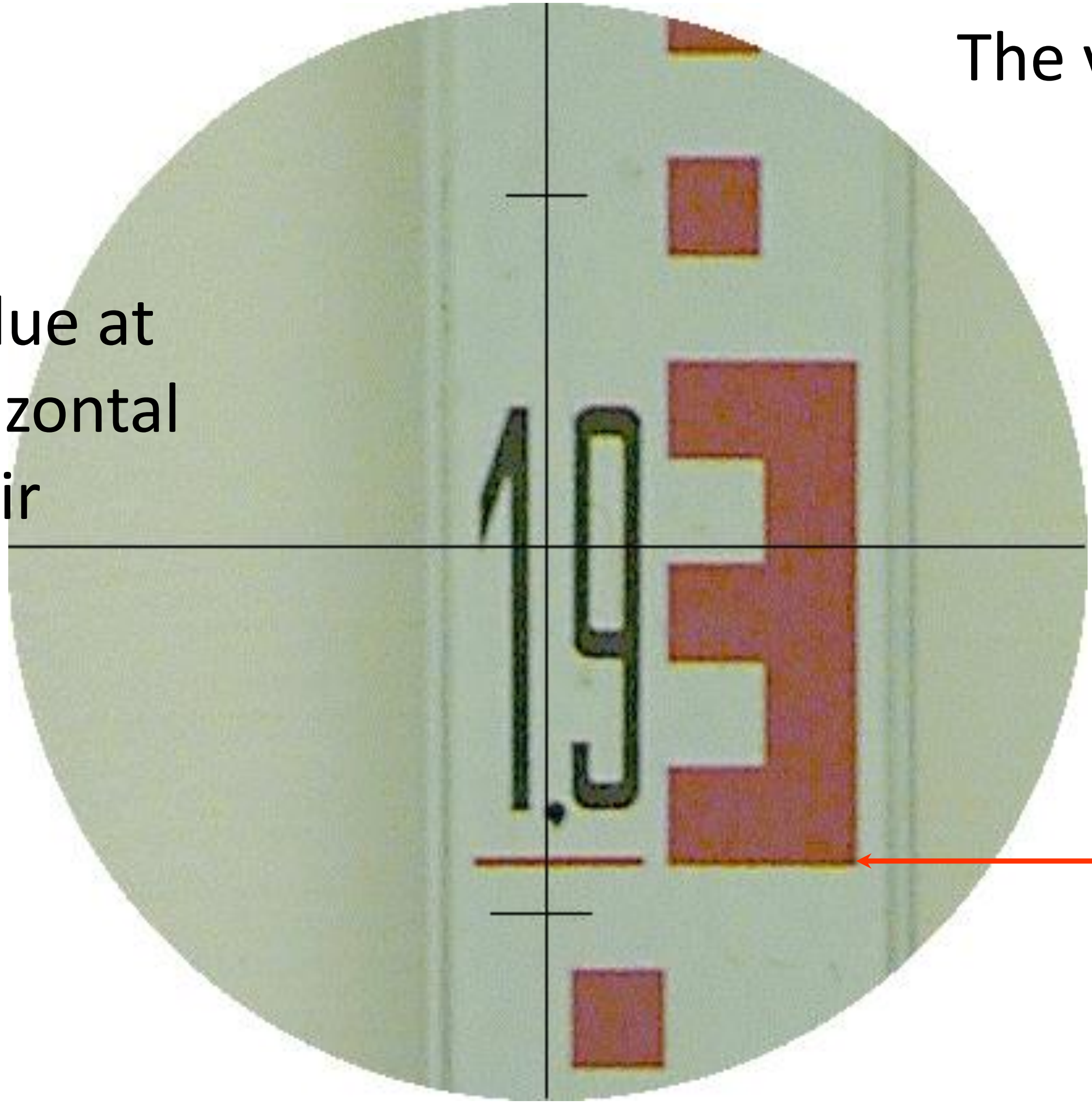
Read value at
The horizontal
cross hair



Levelling – Reading an E-face Staff

The value is ?

Read value at
The horizontal
cross hair

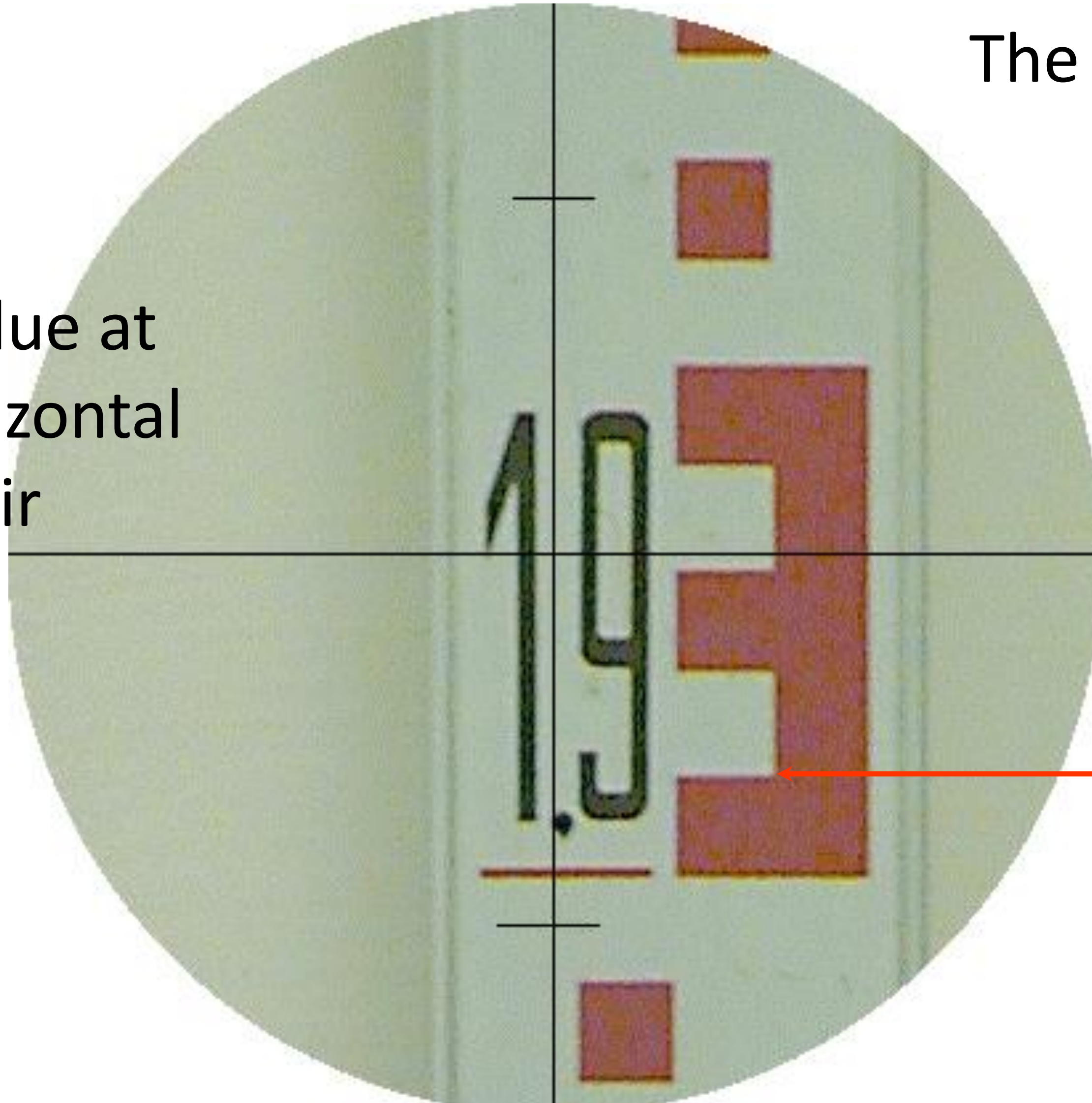


1.900

Levelling – Reading an E-face Staff

The value is ?

Read value at
The horizontal
cross hair

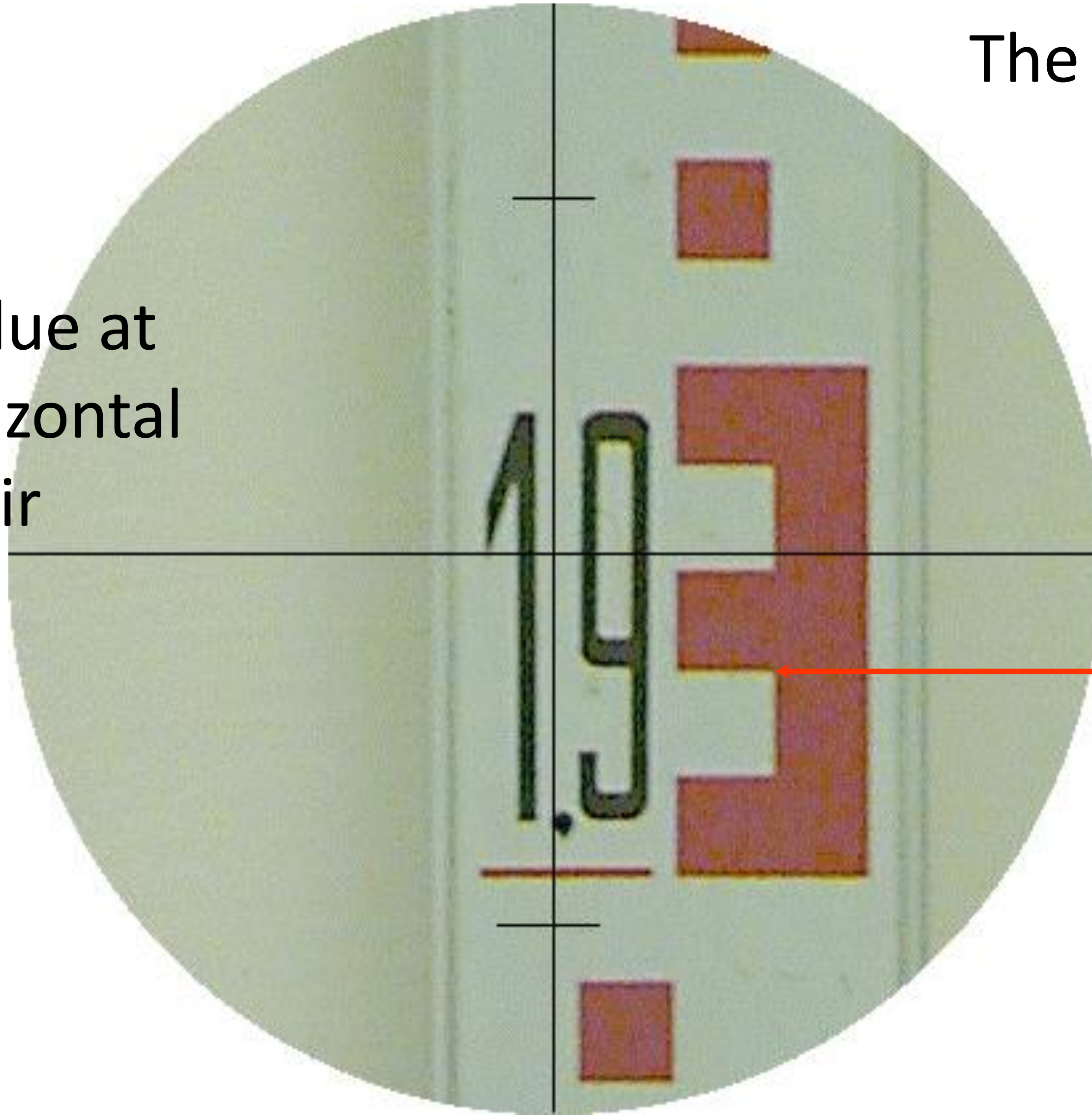


1.910

Levelling – Reading an E-face Staff

The value is ?

Read value at
The horizontal
cross hair

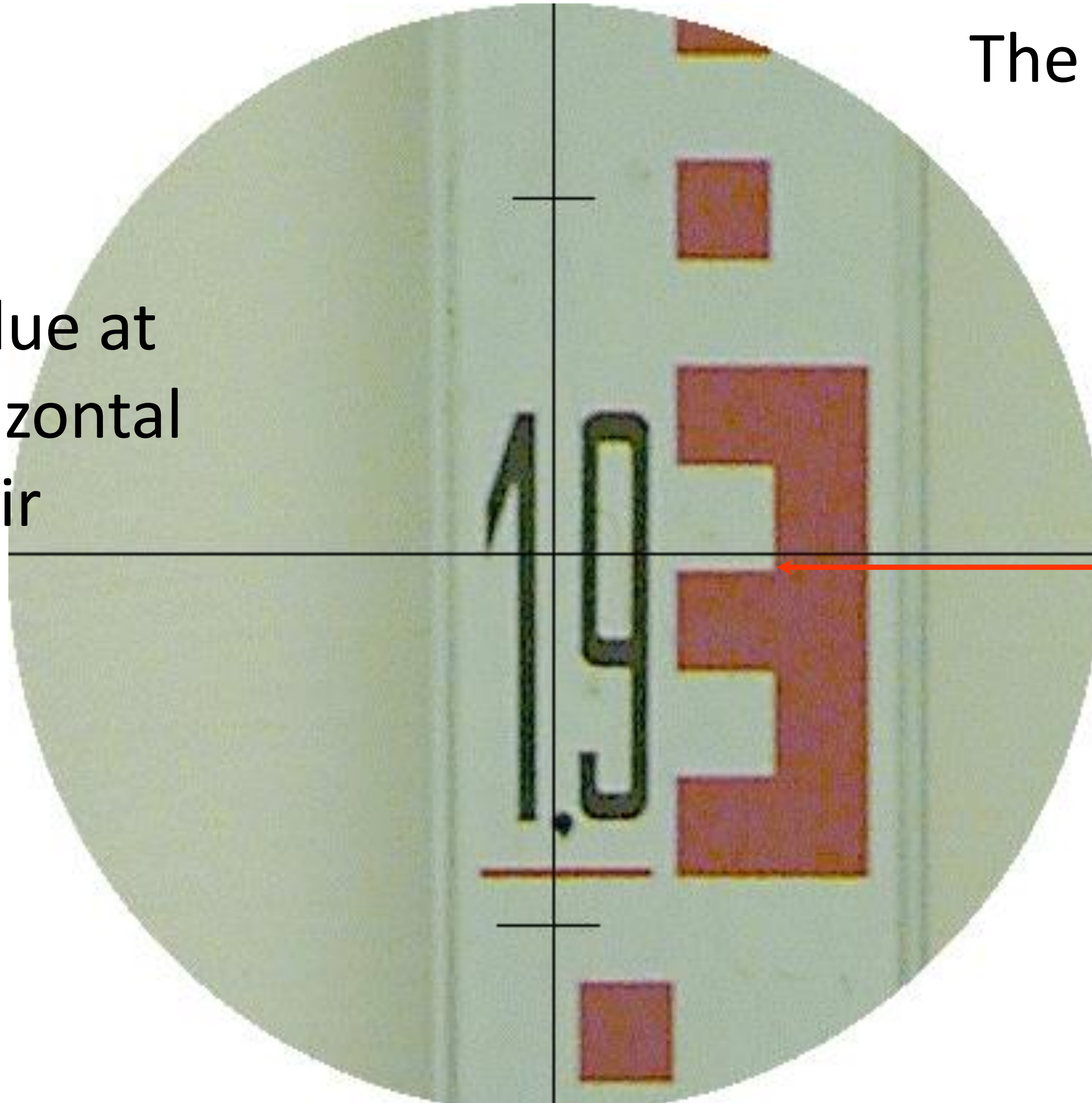


1.920

Levelling – Reading an E-face Staff

The value is ?

Read value at
The horizontal
cross hair

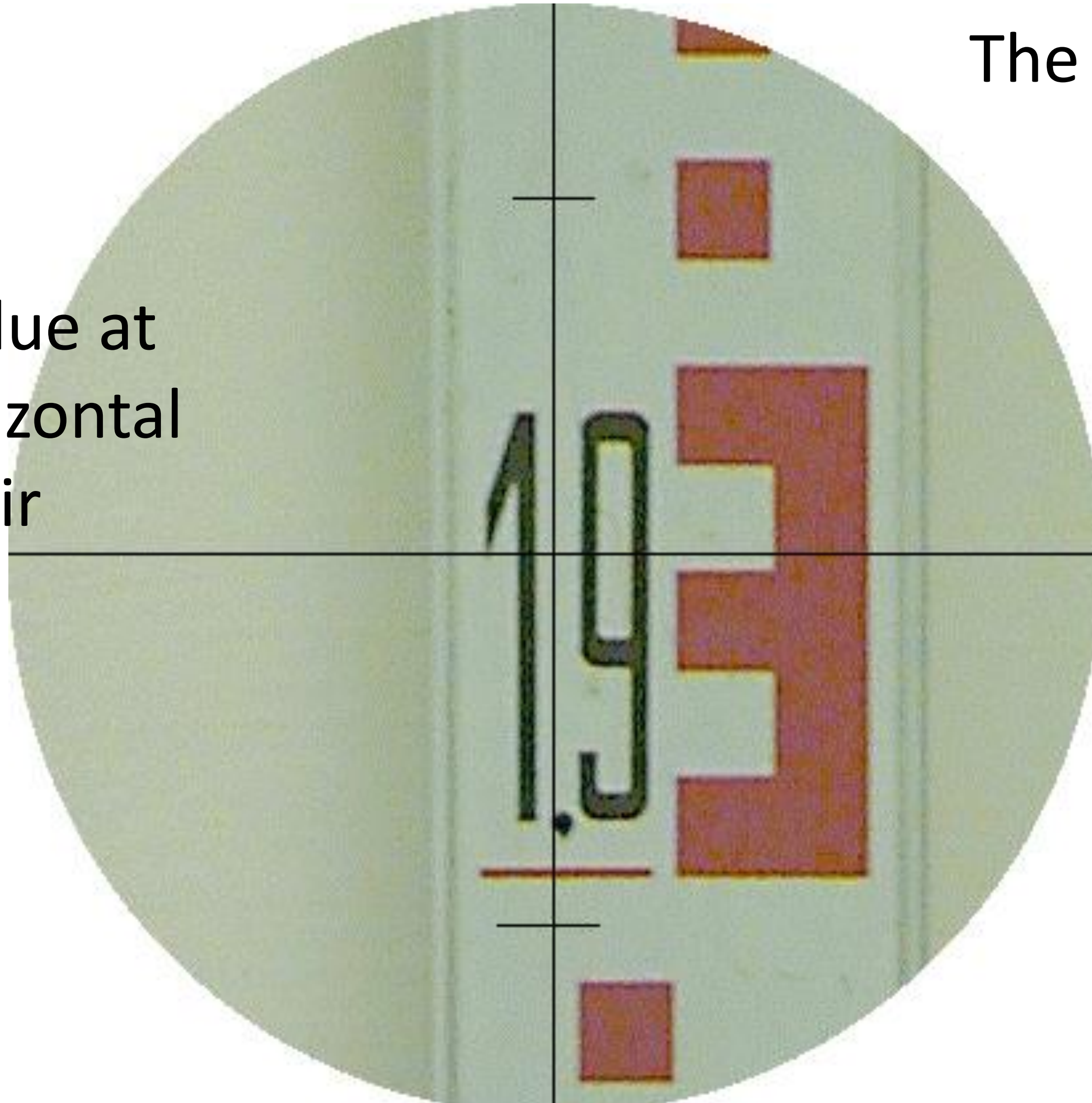


1.930

Levelling – Reading an E-face Staff

The value is ?

Read value at
The horizontal
cross hair

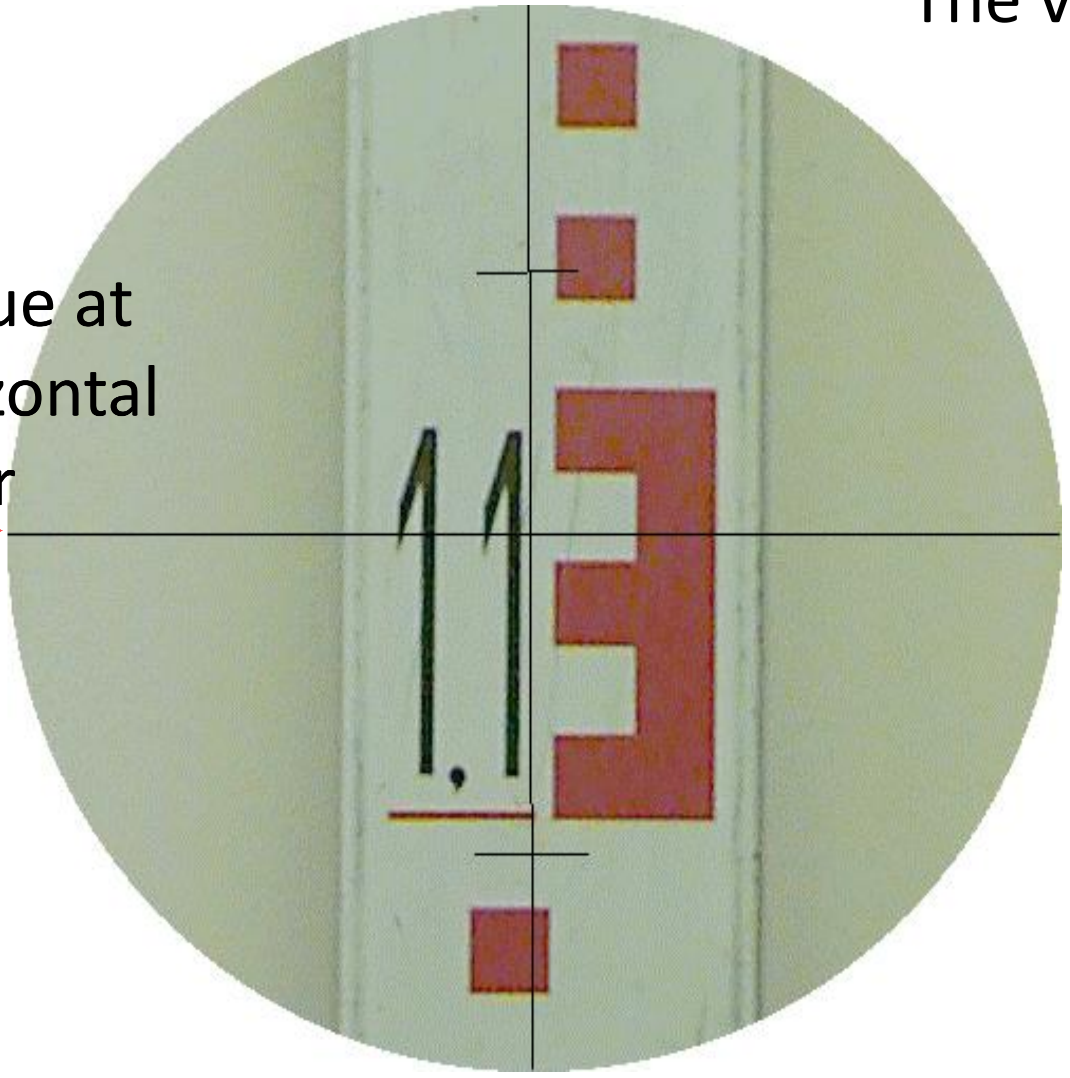


1.932

Levelling – Reading an E-face Staff

The value is ?

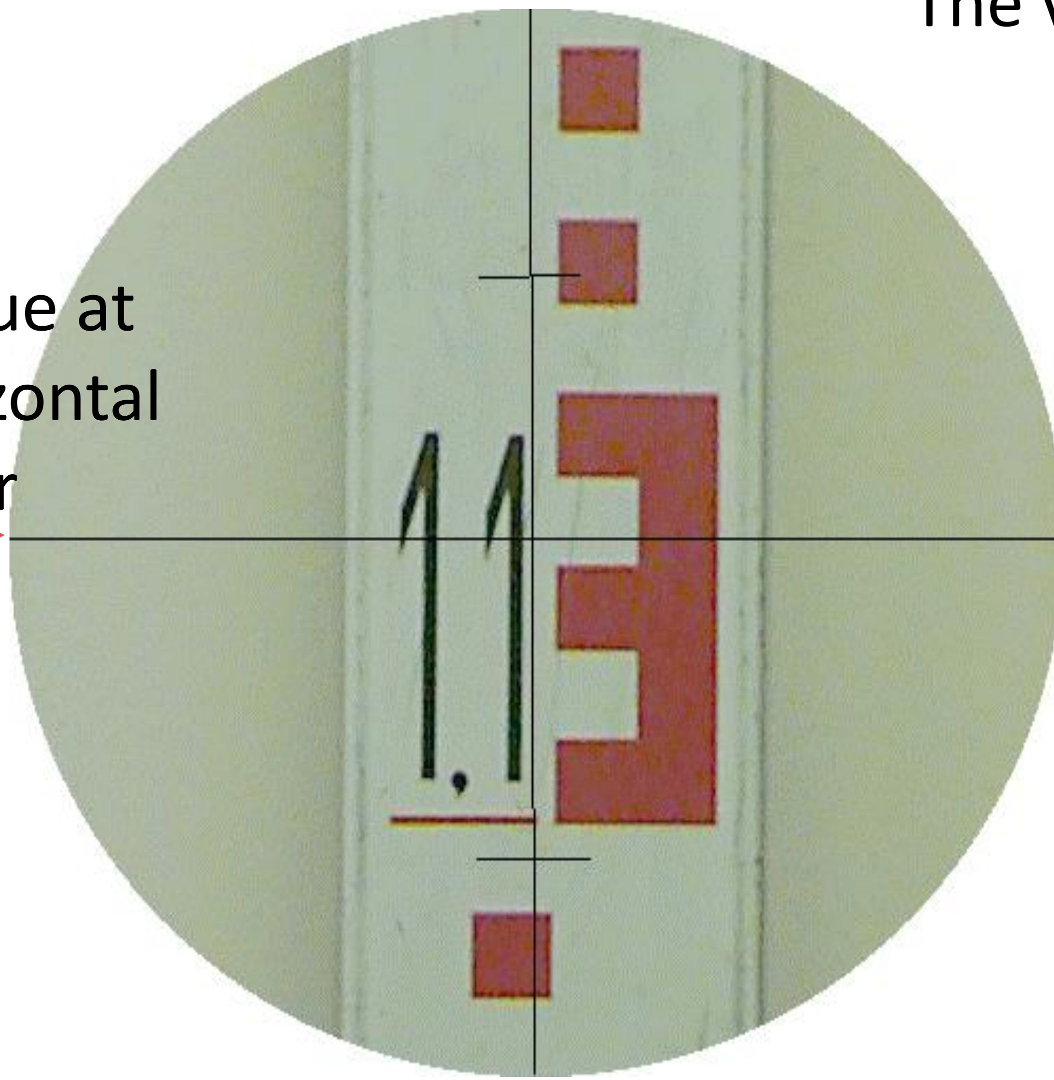
Read value at
The horizontal
cross hair



Levelling – Reading an E-face Staff

The value is ?

Read value at
The horizontal
cross hair

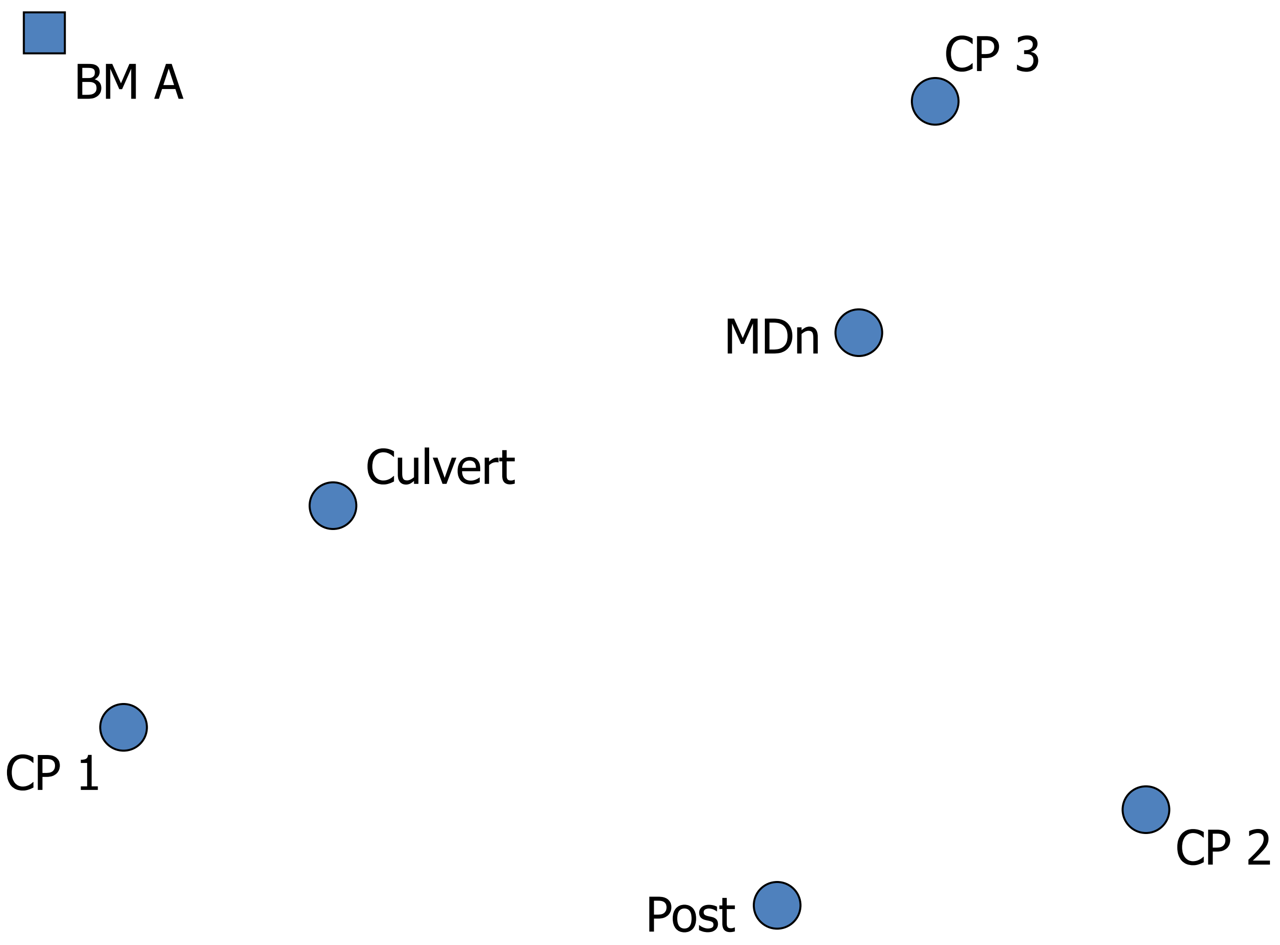


1.133

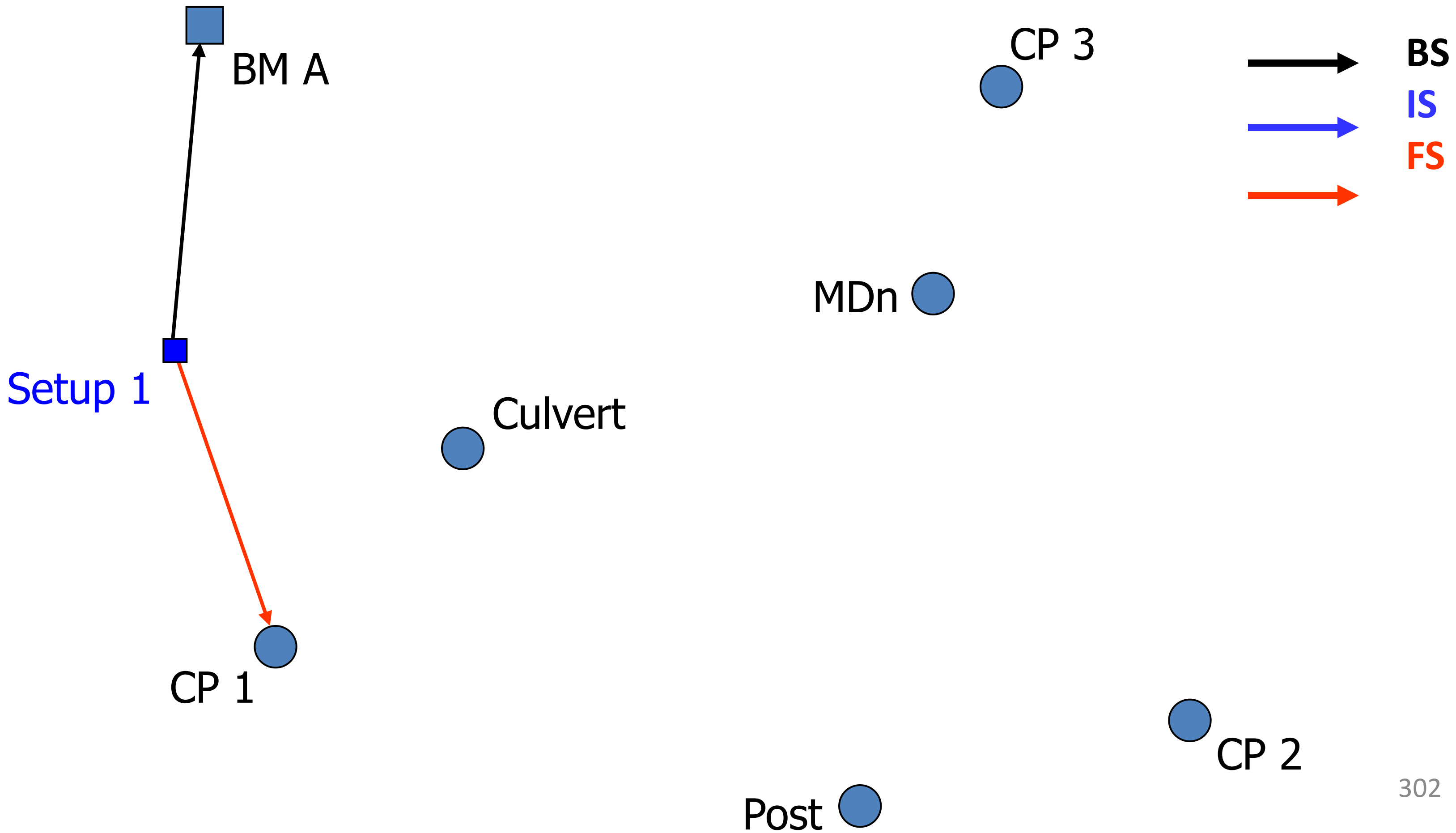
Levelling – Rules

- Always commence and finish a level run on a Benchmark (BM or TBM)
- Keep foresight and backsight distances as equal as possible
- Keep lines of sight short (normally < 50m)
- Use stable, well defined change points

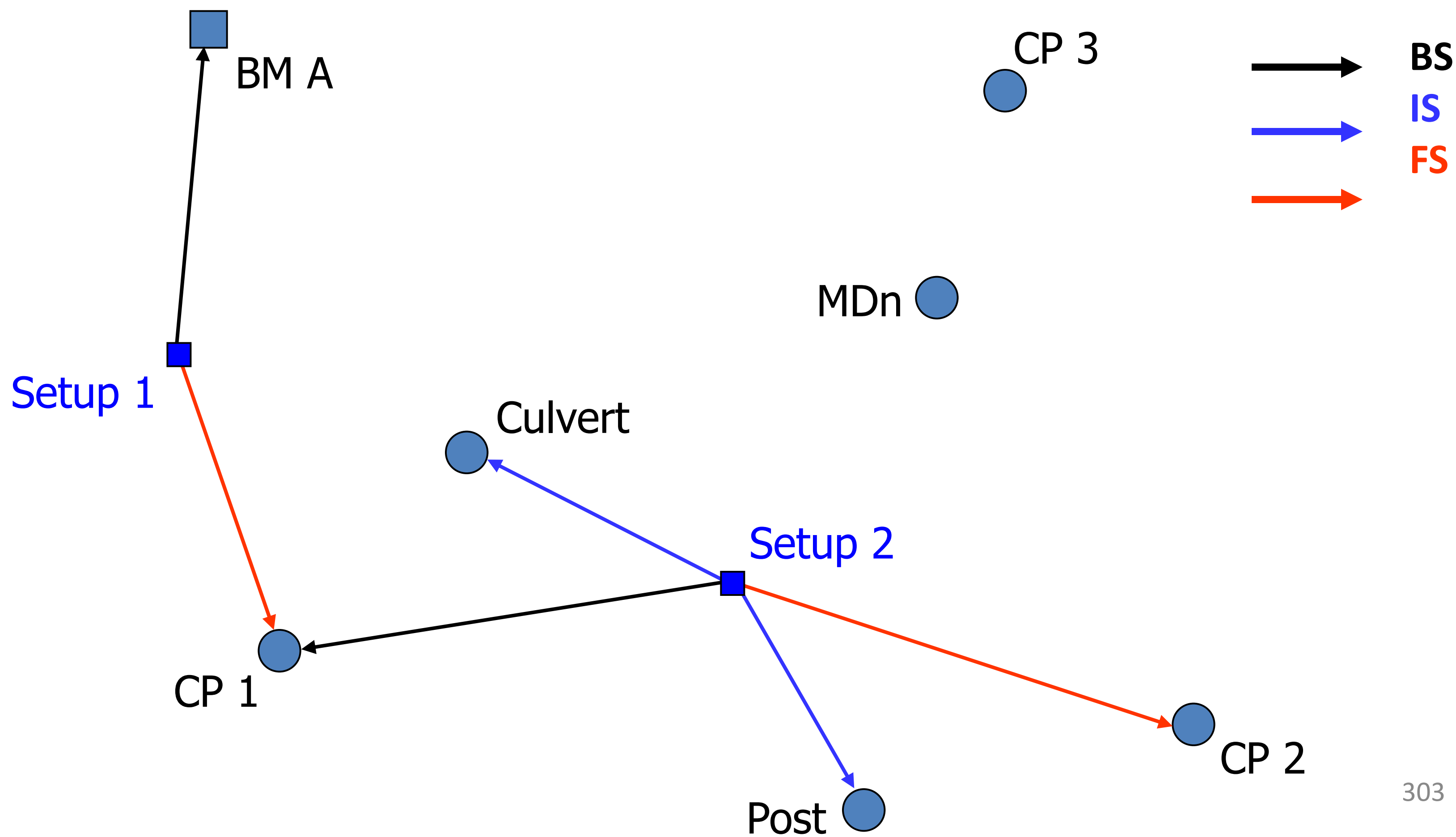
Levelling – A Sample Looped Line



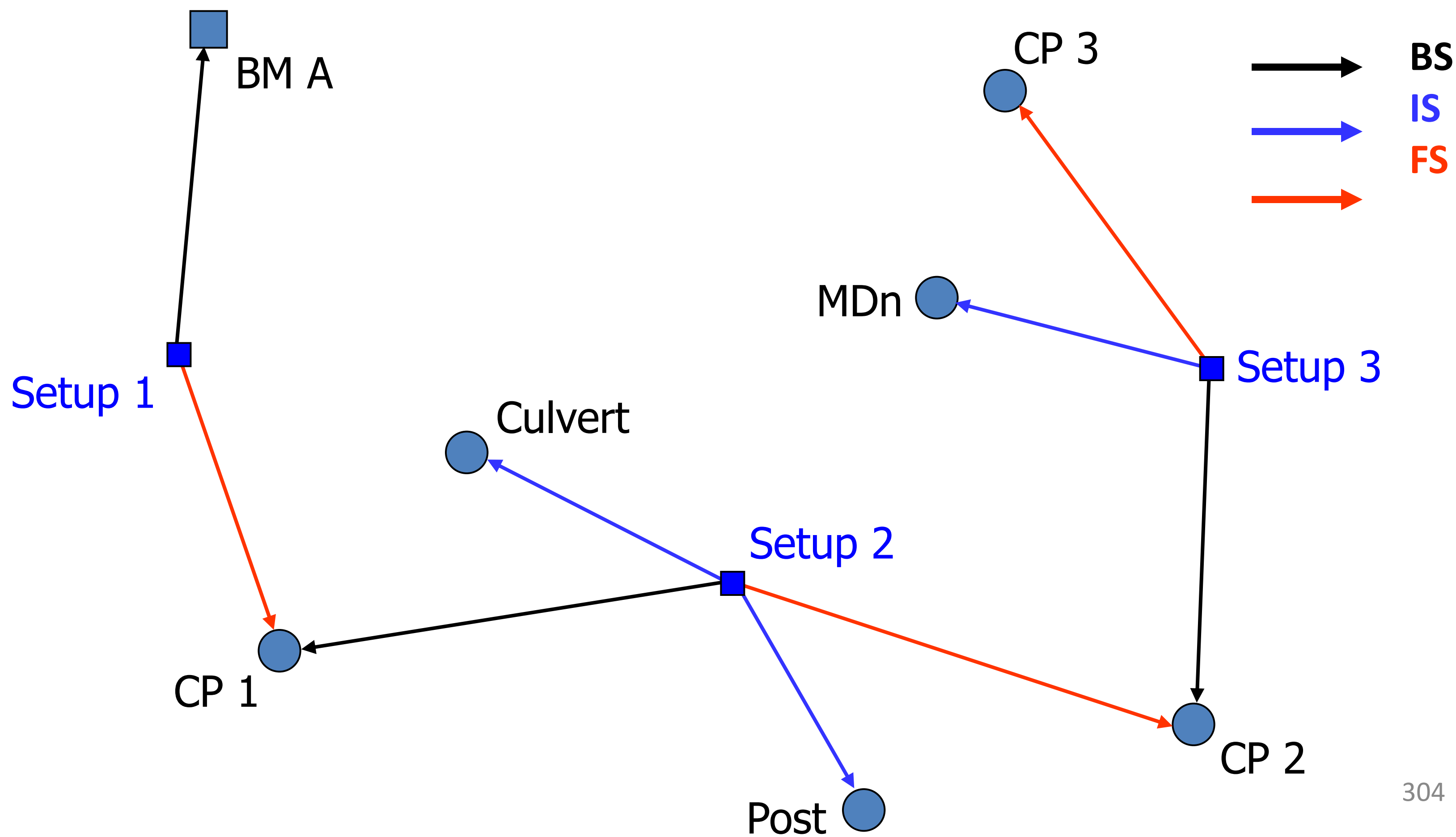
Levelling – A Sample Looped Line



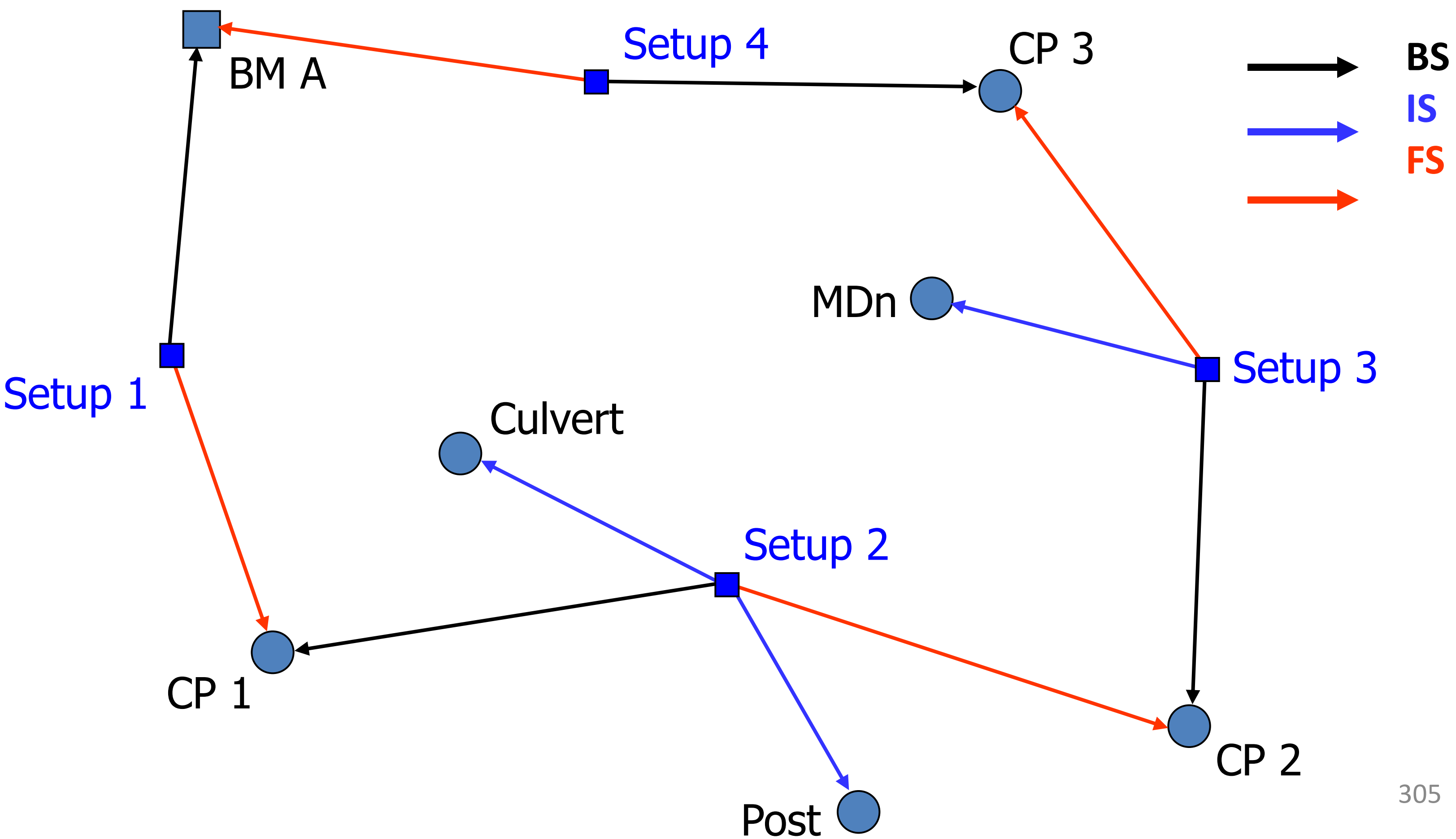
Levelling – A Sample Looped Line



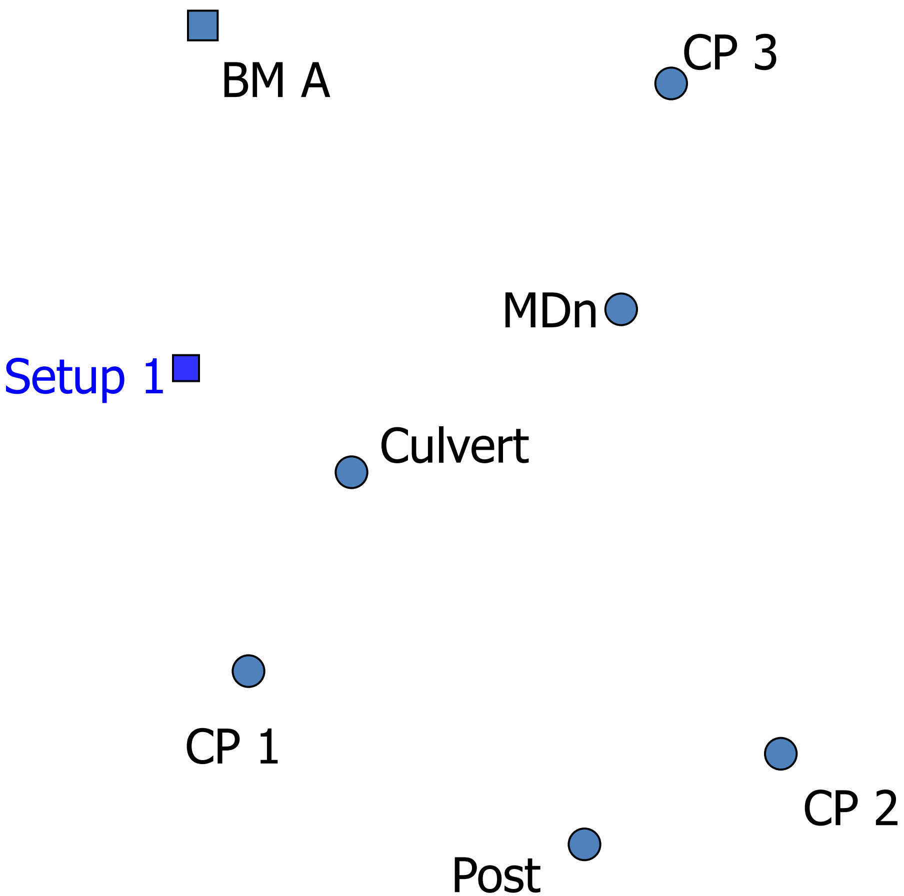
Levelling – A Sample Looped Line



Levelling – A Sample Looped Line

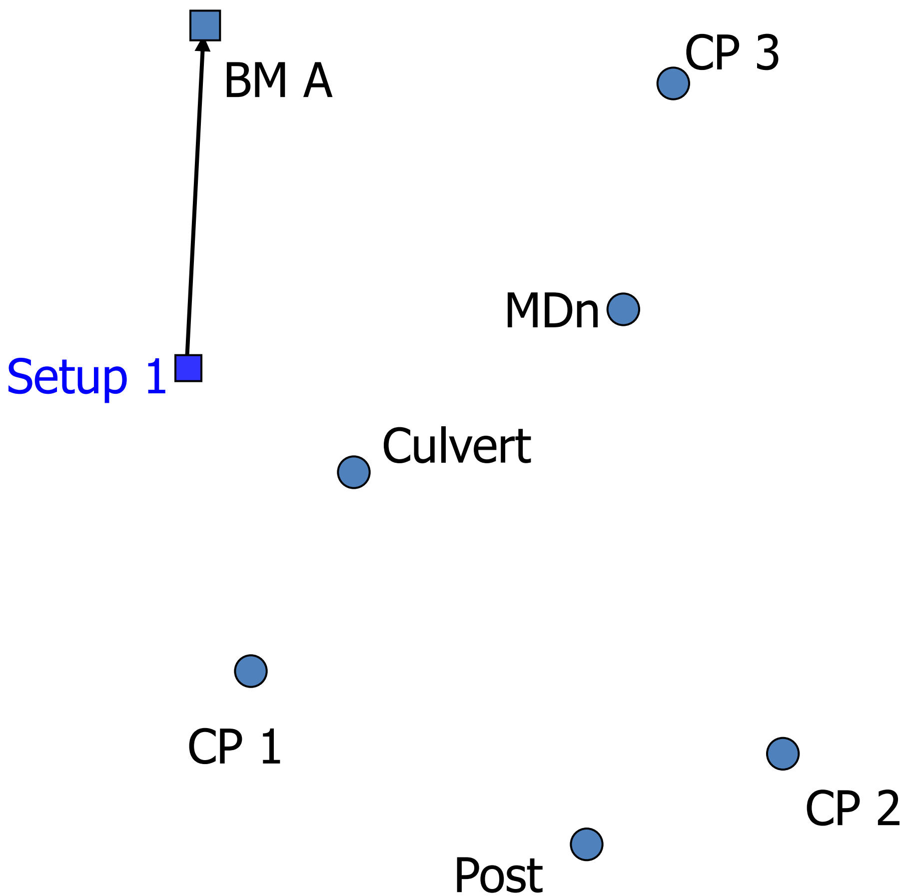


Levelling – Booking the Observations



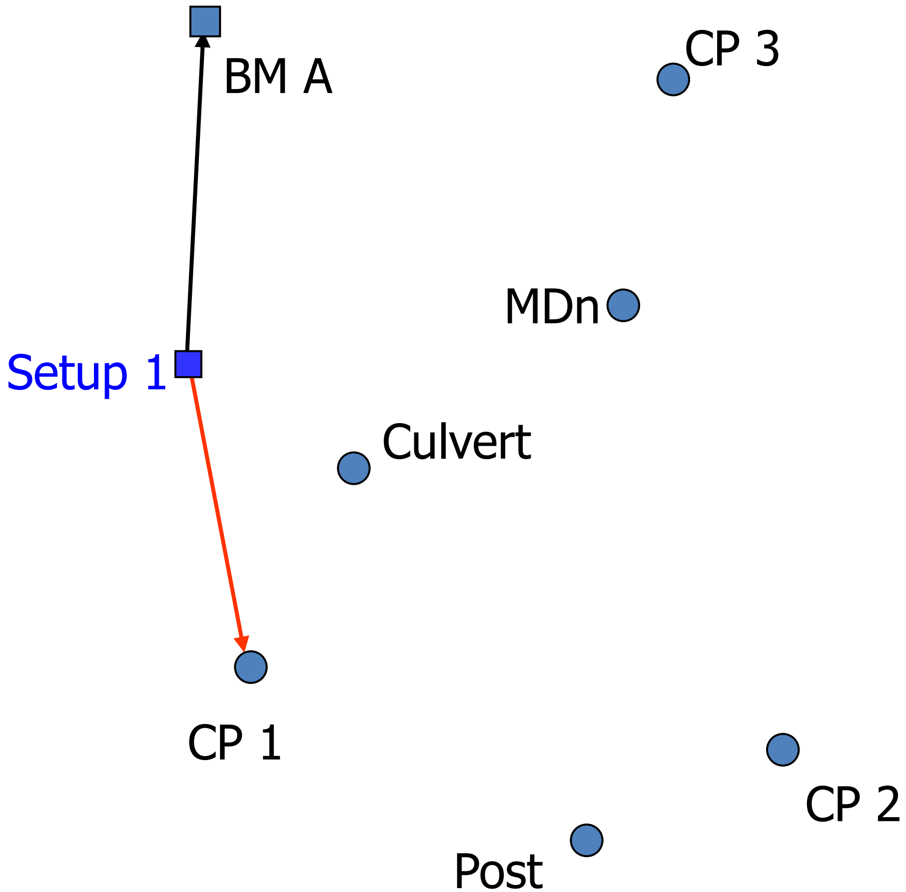
Back	Inter	Fore	Point
			BM A
			CP 1

Levelling – Booking the Observations



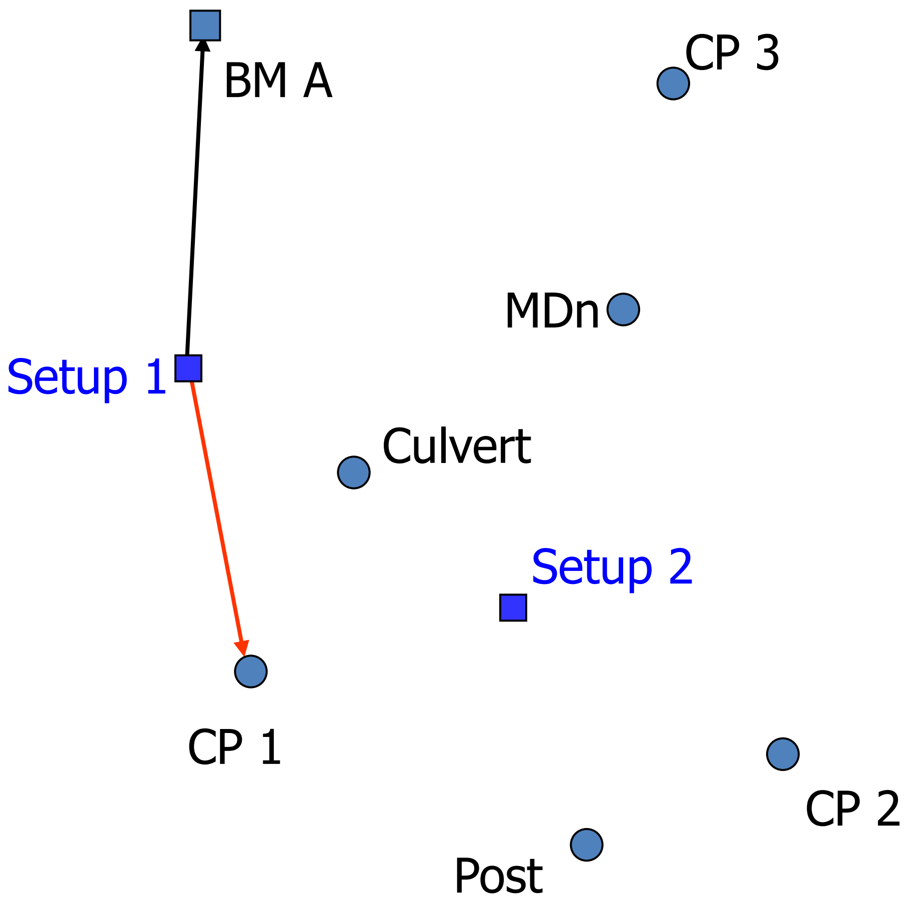
Back	Inter	Fore	Point
1.32			BM A
			CP 1

Levelling – Booking the Observations



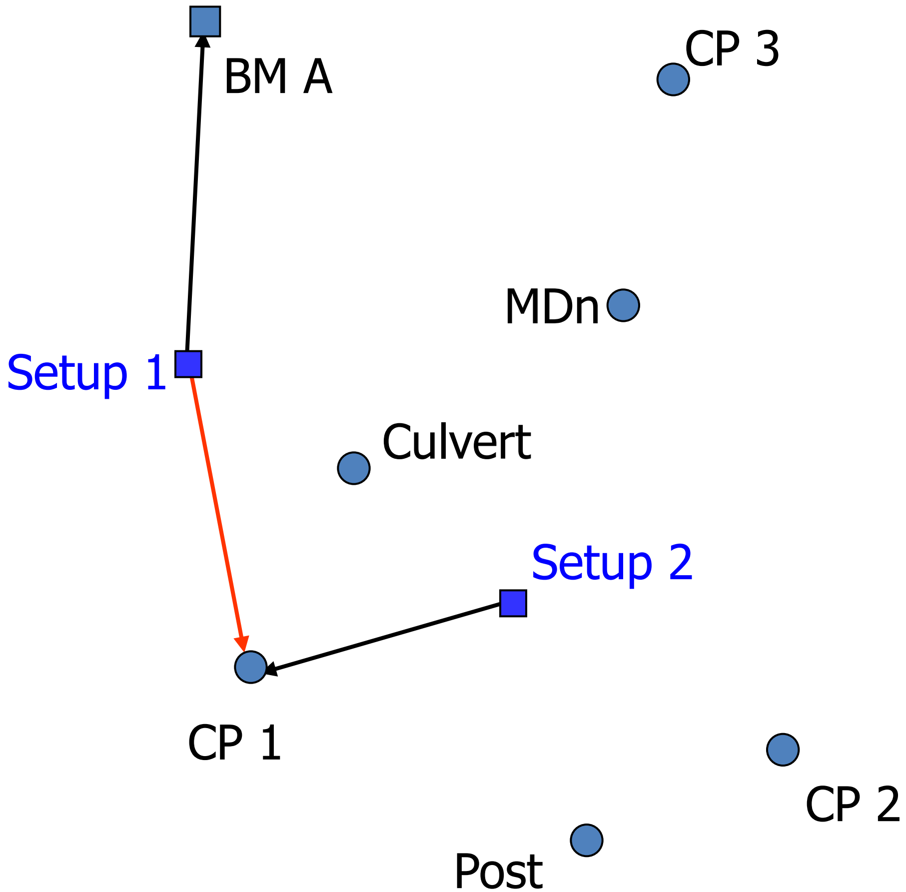
Back	Inter	Fore	Point
1.32			BM A
		3.98	CP 1

Levelling – Booking the Observations



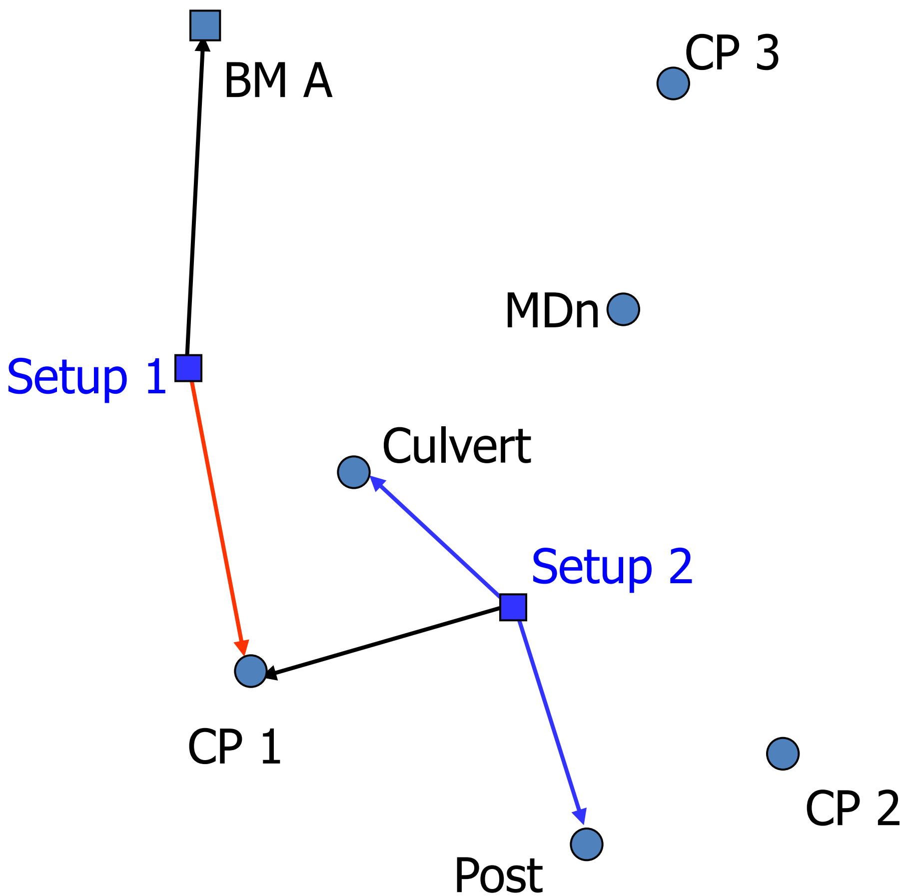
Back	Inter	Fore	Point
1.32			BM A
		3.98	CP 1
			Culvert
			Post
			CP 2

Levelling – Booking the Observations



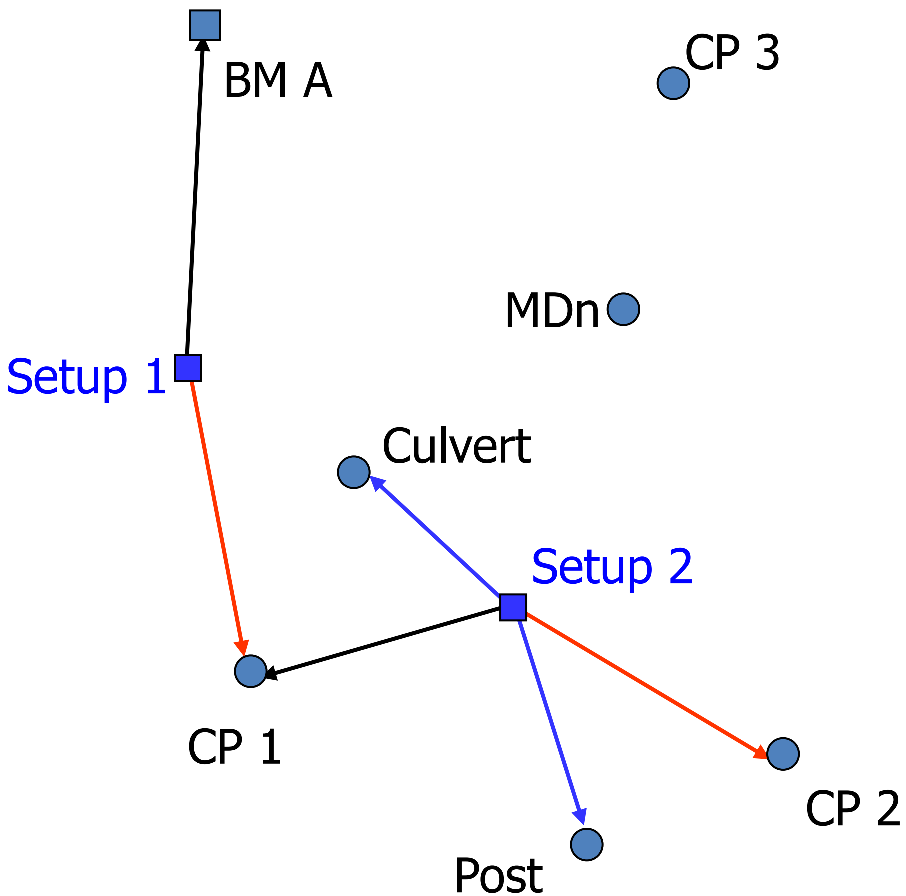
Back	Inter	Fore	Point
1.32			BM A
2.56		3.98	CP 1
			Culvert
			Post
			CP 2

Levelling – Booking the Observations



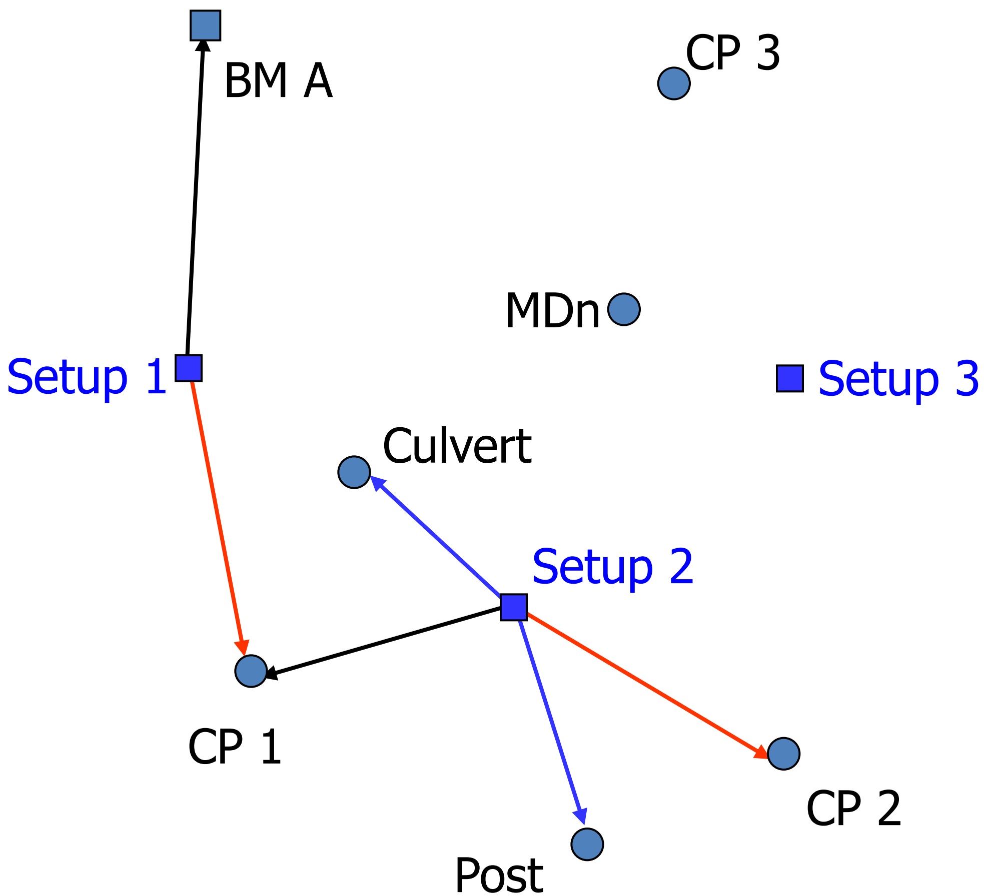
Back	Inter	Fore	Point
1.32			BM A
2.56		3.98	CP 1
	1.25		Culvert
	3.65		Post
			CP 2

Levelling – Booking the Observations



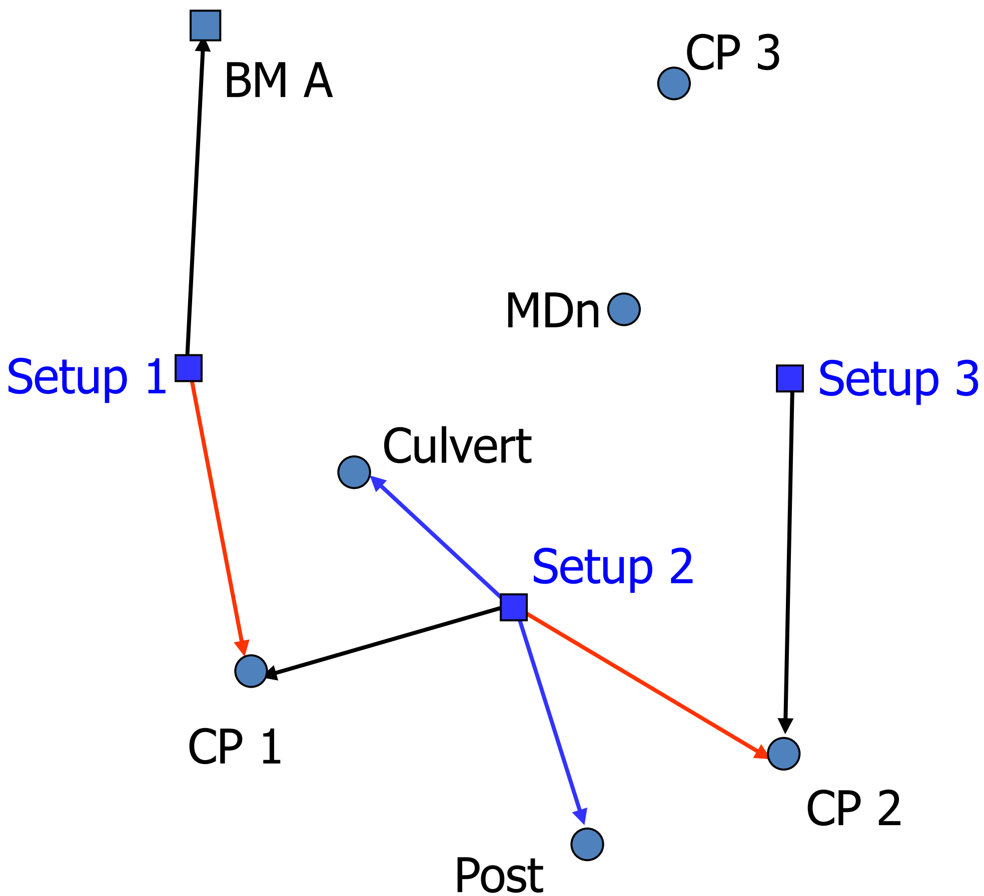
Back	Inter	Fore	Point
1.32			BM A
2.56		3.98	CP 1
	1.25		Culvert
	3.65		Post
		0.67	CP 2

Levelling – Booking the Observations



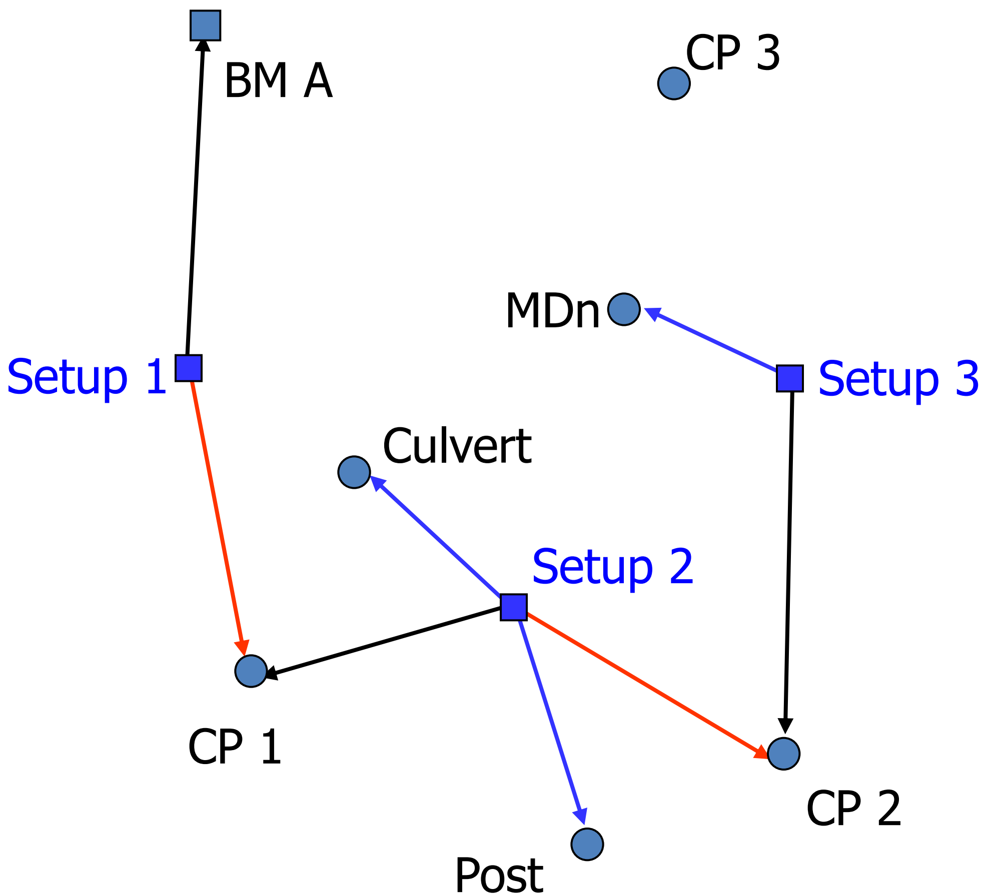
Back	Inter	Fore	Point
1.32			BM A
2.56		3.98	CP 1
	1.25		Kerb
	3.65		Post
		0.67	CP 2
			MDn
			CP 3

Levelling – Booking the Observations



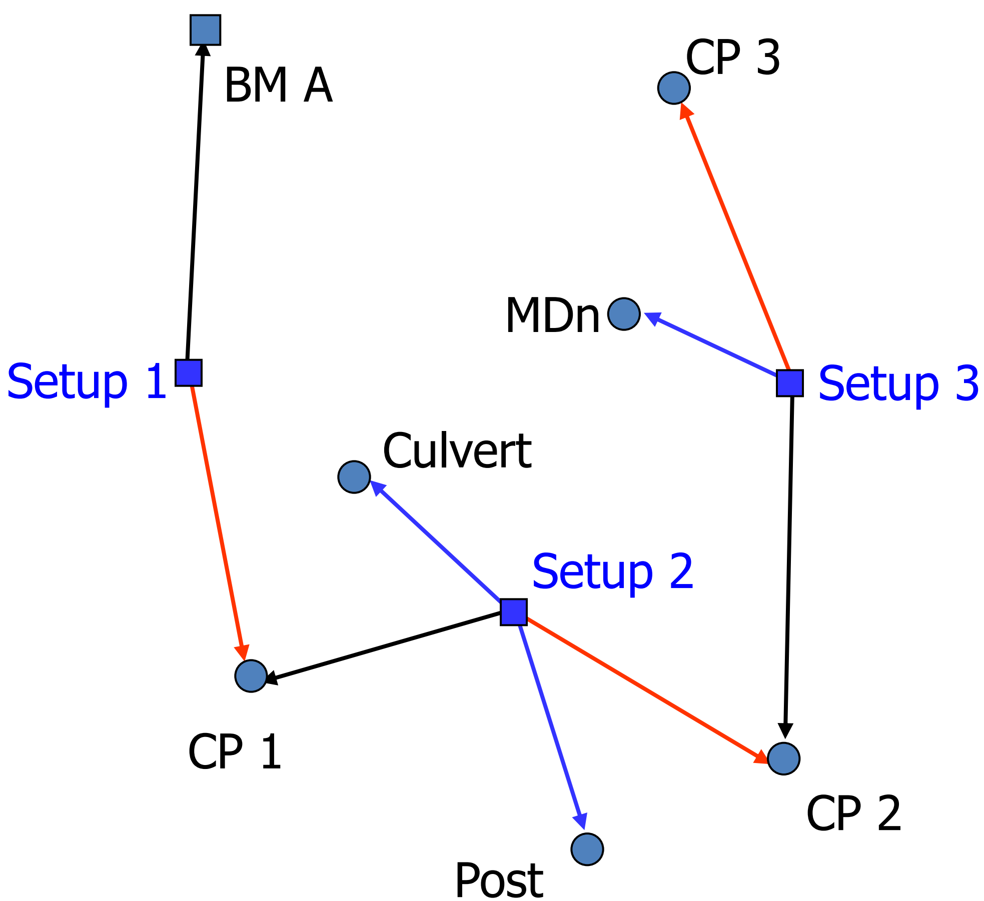
Back	Inter	Fore	Point
1.32			BM A
2.56		3.98	CP 1
	1.25		Kerb
	3.65		Post
3.49		0.67	CP 2
			MDn
			CP 3

Levelling – Booking the Observations



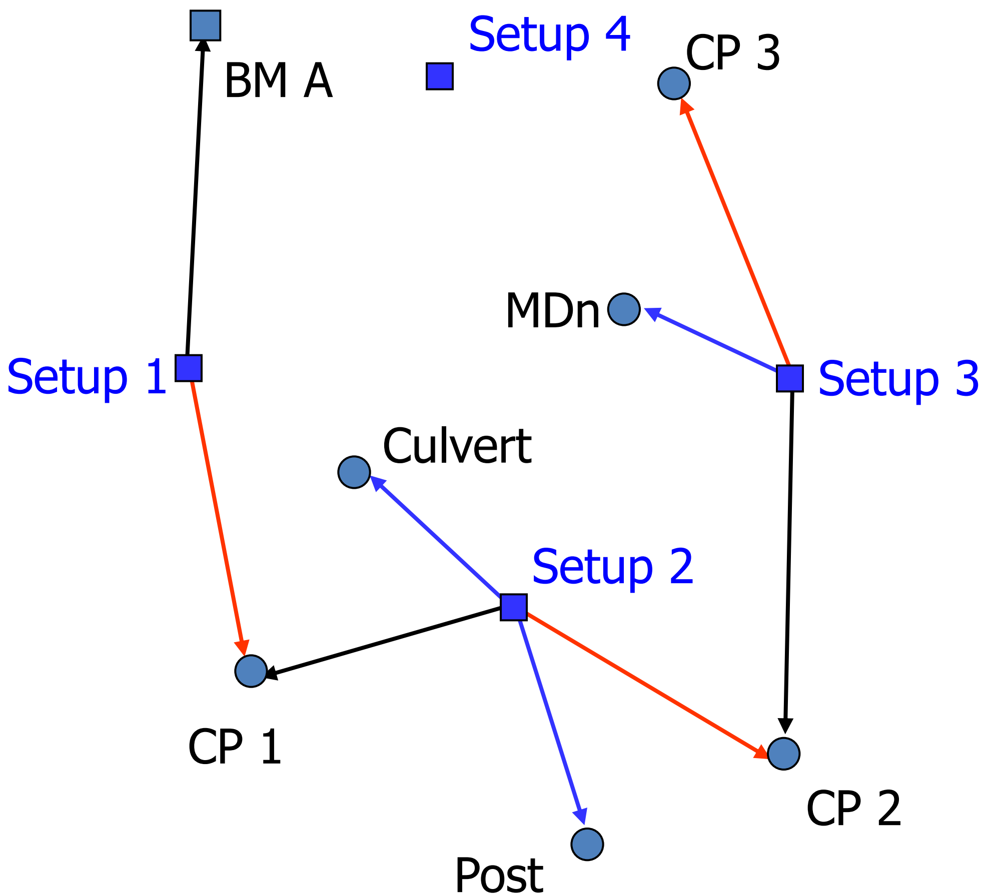
Back	Inter	Fore	Point
1.32			BM A
2.56		3.98	CP 1
	1.25		Kerb
	3.65		Post
3.49		0.67	CP 2
	2.58		MDn
			CP 3

Levelling – Booking the Observations



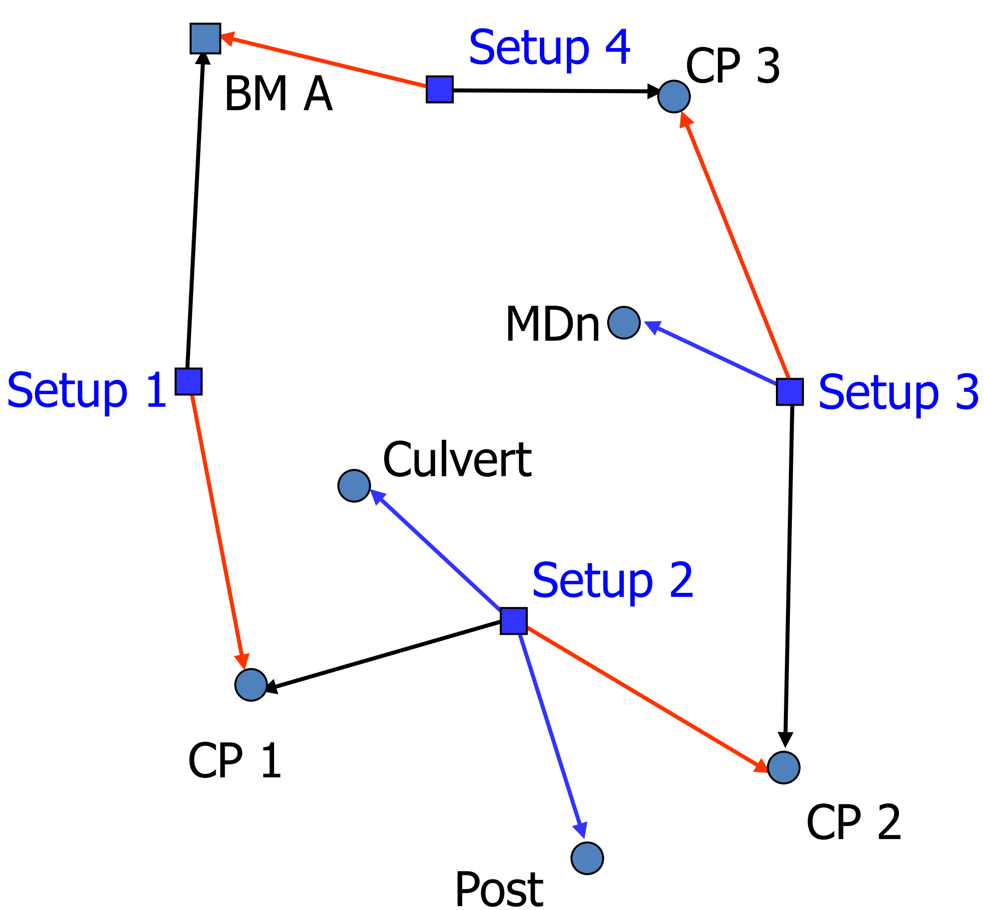
Back	Inter	Fore	Point
1.32			BM A
2.56		3.98	CP 1
	1.25		Kerb
	3.65		Post
3.49		0.67	CP 2
	2.58		MDn
		1.54	CP 3

Levelling – Booking the Observations



Back	Inter	Fore	Point
1.32			BM A
2.56		3.98	CP 1
	1.25		Culvert
	3.65		Post
3.49		0.67	CP 2
	2.58		MDn
		1.54	CP 3
			BM A

Levelling – Booking the Observations



Back	Inter	Fore	Point
1.32			BM A
2.56		3.98	CP 1
	1.25		Culvert
	3.65		Post
3.49		0.67	CP 2
	2.58		MDn
2.64		1.54	CP 3
		3.79	BM A

Levelling – Reducing Levels – Rise and Fall

Back	Inter	Fore	Rise	Fall	RL	Comment
1.32					50.00	BM A
2.56		3.98				CP 1
	1.25					Culvert
	3.65					Post
3.49		0.67				CP 2
	2.58					MDn
2.64		1.54				CP 3
		3.79				BM A
						Σ
						Δ

Levelling – Reducing Levels – Rise and Fall

Back	Inter	Fore	Rise	Fall	RL	Comment
1.32					50.00	BM A
2.56		3.98		2.66	47.34	CP 1
	1.25					Culvert
	3.65					Post
3.49		0.67				CP 2
	2.58					MDn
2.64		1.54				CP 3
		3.79				BM A
						Σ
						Δ

Levelling – Reducing Levels – Rise and Fall

Back	Inter	Fore	Rise	Fall	RL	Comment
1.32					50.00	BM A
2.56		3.98		2.66	47.34	CP 1
	1.25		1.31		48.65	Culvert
	3.65					Post
3.49		0.67				CP 2
	2.58					MDn
2.64		1.54				CP 3
		3.79				BM A
						Σ
						Δ

Levelling – Reducing Levels – Rise and Fall

Back	Inter	Fore	Rise	Fall	RL	Comment
1.32					50.00	BM A
2.56		3.98		2.66	47.34	CP 1
	1.25		1.31		48.65	Culvert
	3.65			2.40	46.25	Post
3.49		0.67				CP 2
	2.58					MDn
2.64		1.54				CP 3
		3.79				BM A
						Σ
						Δ

Levelling – Reducing Levels – Rise and Fall

Back	Inter	Fore	Rise	Fall	RL	Comment
1.32					50.00	BM A
2.56		3.98		2.66	47.34	CP 1
	1.25		1.31		48.65	Culvert
	3.65			2.40	46.25	Post
3.49		0.67	2.98		49.23	CP 2
	2.58					MDn
2.64		1.54				CP 3
		3.79				BM A
						Σ
						Δ

Levelling – Reducing Levels – Rise and Fall

Back	Inter	Fore	Rise	Fall	RL	Comment
1.32					50.00	BM A
2.56		3.98		2.66	47.34	CP 1
	1.25		1.31		48.65	Culvert
	3.65			2.40	46.25	Post
3.49		0.67	2.98		49.23	CP 2
	2.58		0.91		50.14	MDn
2.64		1.54				CP 3
		3.79				BM A
						Σ
						Δ

Levelling – Reducing Levels – Rise and Fall

Back	Inter	Fore	Rise	Fall	RL	Comment
1.32					50.00	BM A
2.56		3.98		2.66	47.34	CP 1
	1.25		1.31		48.65	Culvert
	3.65			2.40	46.25	Post
3.49		0.67	2.98		49.23	CP 2
	2.58		0.91		50.14	MDn
2.64		1.54	1.04		51.18	CP 3
		3.79				BM A
						Σ
						Δ

Levelling – Reducing Levels – Rise and Fall

Back	Inter	Fore	Rise	Fall	RL	Comment
1.32					50.00	BM A
2.56		3.98		2.66	47.34	CP 1
	1.25		1.31		48.65	Culvert
	3.65			2.40	46.25	Post
3.49		0.67	2.98		49.23	CP 2
	2.58		0.91		50.14	MDn
2.64		1.54	1.04		51.18	CP 3
		3.79		1.15	50.03	BM A
						Σ
						Δ

Levelling – Reducing Levels – Rise and Fall

Back	Inter	Fore	Rise	Fall	RL	Comment
1.32					50.00	BM A
2.56		3.98		2.66	47.34	CP 1
	1.25		1.31		48.65	Culvert
	3.65			2.40	46.25	Post
3.49		0.67	2.98		49.23	CP 2
	2.58		0.91		50.14	MDn
2.64		1.54	1.04		51.18	CP 3
		3.79		1.15	50.03	BM A
10.01		9.98				Σ
						Δ

Levelling – Reducing Levels – Rise and Fall

Back	Inter	Fore	Rise	Fall	RL	Comment
1.32					50.00	BM A
2.56		3.98		2.66	47.34	CP 1
	1.25		1.31		48.65	Culvert
	3.65			2.40	46.25	Post
3.49		0.67	2.98		49.23	CP 2
	2.58		0.91		50.14	MDn
2.64		1.54	1.04		51.18	CP 3
		3.79		1.15	50.03	BM A
10.01		9.98				Σ
		(0.03)				Δ

Levelling – Reducing Levels – Rise and Fall

Back	Inter	Fore	Rise	Fall	RL	Comment
1.32					50.00	BM A
2.56		3.98		2.66	47.34	CP 1
	1.25		1.31		48.65	Culvert
	3.65			2.40	46.25	Post
3.49		0.67	2.98		49.23	CP 2
	2.58		0.91		50.14	MDn
2.64		1.54	1.04		51.18	CP 3
		3.79		1.15	50.03	BM A
10.01		9.98	6.24	6.21		Σ
		(0.03)				Δ

Levelling – Reducing Levels – Rise and Fall

Back	Inter	Fore	Rise	Fall	RL	Comment
1.32					50.00	BM A
2.56		3.98		2.66	47.34	CP 1
	1.25		1.31		48.65	Culvert
	3.65			2.40	46.25	Post
3.49		0.67	2.98		49.23	CP 2
	2.58		0.91		50.14	MDn
2.64		1.54	1.04		51.18	CP 3
		3.79		1.15	50.03	BM A
10.01		9.98	6.24	6.21		Σ
		(0.03)		(0.03)		Δ

Levelling – Reducing Levels – Rise and Fall

Back	Inter	Fore	Rise	Fall	RL	Comment
1.32					50.00	BM A
2.56		3.98		2.66	47.34	CP 1
	1.25		1.31		48.65	Culvert
	3.65			2.40	46.25	Post
3.49		0.67	2.98		49.23	CP 2
	2.58		0.91		50.14	MDn
2.64		1.54	1.04		51.18	CP 3
		3.79		1.15	50.03	BM A
10.01		9.98	6.24	6.21		Σ
		(0.03)		(0.03)	(0.03)	Δ

Levelling – Reducing Levels – Rise and Fall

Back	Inter	Fore	Rise	Fall	RL	Comment
1.32					50.00	BM A
2.56		3.98		2.66	47.34	CP 1
	1.25		1.31		48.65	Culvert
	3.65			2.40	46.25	Post
3.49		0.67	2.98		49.23	CP 2
	2.58		0.91		50.14	MDn
2.64		1.54	1.04		51.18	CP 3
		3.79		1.15	50.03	BM A
10.01		9.98	6.24	6.21		Σ
		(0.03)		(0.03)	(0.03)	Δ

Levelling – Misclosure

- **Misclosure**
  - The amount by which the **measured** height difference ($DH_{measured}$) differs from the **known** height difference derived from the RLs of the starting and finishing benchmarks (DH_{known})

$$\textbf{Misclosure} = \Delta H_{known} - \Delta H_{measured}$$

Levelling – ‘Acceptable’ Misclosure?

- *Small* misclosures in closed level loops are expected because of the accumulation of errors
- If the misclosure is *small*, it can be adjusted
- If the misclosure is *large*, the loop (or part of it) must be repeated
- Misclosures can also result from errors in published BM levels and from BM instability

Levelling – Testing the Misclosure

- The amount of misclosure we are prepared to accept depends on the accuracy we are hoping to achieve
- For routine levelling, the *third order* levelling standard is adopted

$$\text{misclosure} \leq 12\sqrt{k} \text{ mm}$$

where k is the length of the loop in km

Levelling – Continuing the Example …

- The misclosure is +30 mm (i. e. +0.03 m)
- The length of the loop is 0.7 km (Assumed)
- The misclosure limit is

  $12\sqrt{(0.7)} = \pm 10$ mm
- The misclosure of +30 mm is too big
- The loop must be repeated

Levelling – Adjusting the Misclosure

- Adjustment is carried out to ensure that the measured and known RLs of the closing benchmark agree
- The misclosure is linearly distributed according to the number of *set-ups*
- The adjustment per set-up for the previous example is (0.03/4) m

Levelling – Adjusting the Misclosure

Measured RL	Point	Adjustment	Adjusted RL
50.00	BM A		
47.34	CP 1		
48.65	Culvert		
46.25	Post		
49.23	CP 2		
50.14	MDn		
51.18	CP 3		
50.03	BM A		

Levelling – Adjusting the Misclosure

Measured RL	Point	Adjustment	Adjusted RL
50.00	BM A	0.000	50.000
47.34	CP 1	0.008	47.332
48.65	Culvert		
46.25	Post		
49.23	CP 2		
50.14	MDn		
51.18	CP 3		
50.03	BM A		

=1*(0.03/4)

Levelling – Adjusting the Misclosure

Measured RL	Point	Adjustment	Adjusted RL
50.00	BM A	0.000	50.000
47.34	CP 1	0.008	47.332
48.65	Culvert	0.015	**48.635**
46.25	Post	0.015	**46.235**
49.23	CP 2	0.015	**49.215**
50.14	MDn		
51.18	CP 3		
50.03	BM A		

=2*(0.03/4)

Levelling – Adjusting the Misclosure

Measured RL	Point	Adjustment	Adjusted RL
50.00	BM A	0.000	50.000
47.34	CP 1	0.008	47.332
48.65	Culvert	0.015	48.635
46.25	Post	0.015	46.235
49.23	CP 2	0.015	[illegible]
50.14	MDn	0.023	**50.117**
51.18	CP 3	0.023	**51.157**
50.03	BM A		

=3*(0.03/4)

Levelling – Adjusting the Misclosure

Measured RL	Point	Adjustment	Adjusted RL
50.00	BM A	0.000	50.000
47.34	CP 1	0.008	47.332
48.65	Culvert	0.015	48.635
46.25	Post	0.015	46.235
49.23	CP 2	0.015	49.215
50.14	MDn	0.023	50.117
51.18	CP 3	0.023	[illegible]
50.03	BM A	0.030	**50.000**

=4*(0.03/4)

Levelling – Adjusting the Misclosure

Measured RL	Point	Adjustment	Adjusted RL
50.00	BM A	0.000	50.000
47.34	CP 1	0.008	47.332
48.65	Culvert	0.015	48.635
46.25	Post	0.015	46.235
49.23	CP 2	0.015	49.215
50.14	MDn	0.023	50.117
51.18	CP 3	0.023	51.157
50.03	BM A	0.030	**50.000**

Levelling – Question

The following staff readings were observed successively with a level. The instrument was removed after the 2nd, 5th, and 8th readings, and the recorded values are; 0.675, 1.230, 0.750, 2.565, 2.225, 1.935, 1.835, 3.220, 3.115, and 2.875. The first staff reading was taken with a staff held on a benchmark of reduced level 165.000 m. Enter the readings in the level book form, and find the reduced levels of all points by the 'Rise and Fall' method.

Levelling – Reducing Levels (Instrument Height)

Back	Inter	Fore	IH	RL	Comment
1.32				50.00	BM A
2.56		3.98			CP 1
	1.25				Culvert
	3.65				Post
3.49		0.67			CP 2
	2.58				MDn
2.64		1.54			CP 3
		3.79			BM A
					Σ
					Δ

Levelling – Reducing Levels (Instrument Height)

Back	Inter	Fore	IH	RL	Comment
1.32			51.32	50.00	BM A
2.56		3.98			CP 1
	1.25				Culvert
	3.65				Post
3.49		0.67			CP 2
	2.58				MDn
2.64		1.54			CP 3
		3.79			BM A
					Σ
					Δ

Levelling – Reducing Levels (Instrument Height)

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2.56		3.98		47.34	CP 1
	1.25				Culvert
	3.65				Post
3.49		0.67			CP 2
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2.64		1.54			CP 3
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					Δ

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	3.65			46.25	Post
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2.64		1.54			CP 3
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3.49		0.67		49.23	CP 2
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2.64		1.54			CP 3
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	1.25			48.65	Culvert
	3.65			46.25	Post
3.49		0.67	52.72	49.23	CP 2
	2.58				MDn
2.64		1.54			CP 3
		3.79			BM A
					Σ
					Δ

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2.56		3.98	49.90	47.34	CP 1
	1.25			48.65	Culvert
	3.65			46.25	Post
3.49		0.67	52.72	49.23	CP 2
	2.58			50.14	MDn
2.64		1.54			CP 3
		3.79			BM A
					Σ
					Δ

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2.56		3.98	49.90	47.34	CP 1
	1.25			48.65	Culvert
	3.65			46.25	Post
3.49		0.67	52.72	49.23	CP 2
	2.58			50.14	MDn
2.64		1.54		51.18	CP 3
		3.79			BM A
					Σ
					Δ

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Back	Inter	Fore	IH	RL	Comment
1.32			51.32	50.00	BM A
2.56		3.98	49.90	47.34	CP 1
	1.25			48.65	Culvert
	3.65			46.25	Post
3.49		0.67	52.72	49.23	CP 2
	2.58			50.14	MDn
2.64		1.54	53.82	51.18	CP 3
		3.79			BM A
					Σ
					Δ

Levelling – Reducing Levels (Instrument Height)

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1.32			51.32	50.00	BM A
2.56		3.98	49.90	47.34	CP 1
	1.25			48.65	Culvert
	3.65			46.25	Post
3.49		0.67	52.72	49.23	CP 2
	2.58			50.14	MDn
2.64		1.54	53.82	51.18	CP 3
		3.79		50.03	BM A
					Σ
					Δ

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1.32			51.32	50.00	BM A
2.56		3.98	49.90	47.34	CP 1
	1.25			48.65	Culvert
	3.65			46.25	Post
3.49		0.67	52.72	49.23	CP 2
	2.58			50.14	MDn
2.64		1.54	53.82	51.18	CP 3
		3.79		50.03	BM A
10.01		9.98			Σ
					Δ

Levelling – Reducing Levels (Instrument Height)

Back	Inter	Fore	IH	RL	Comment
1.32			51.32	50.00	BM A
2.56		3.98	49.90	47.34	CP 1
	1.25			48.65	Culvert
	3.65			46.25	Post
3.49		0.67	52.72	49.23	CP 2
	2.58			50.14	MDn
2.64		1.54	53.82	51.18	CP 3
		3.79		50.03	BM A
10.01		9.98			Σ
		(0.03)			Δ

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	2.58			50.14	MDn
2.64		1.54	53.82	51.18	CP 3
		3.79		50.03	BM A
10.01		9.98			Σ
		(0.03)		0.03	Δ

Levelling – Reducing Levels (Instrument Height)

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	3.65			46.25	Post
3.49		0.67	52.72	49.23	CP 2
	2.58			50.14	MDn
2.64		1.54	53.82	51.18	CP 3
		3.79		50.03	BM A
10.01		9.98			Σ
		(0.03)		0.03	Δ

Levelling – Adjusting the Misclosure

- Same as before
- Same for the Connecting Level Lines

Levelling – Observations

Must be to THREE decimal places

Levelling – Sample Level Book

SUSL – Level Book Cover/Index Page

SABARAGAMUWA UNIVERSITY
OF
SRI LANKA

LEVEL BOOK
NO:

300801

FACULTY OF GEOMATICS

LEVEL BOOK NO. 300801

Class of Levelling Control/Detail

Survey of SUSL Engineering Survey

Province Sabaragamuwa

Page	Village	Nature of Work
1 – 2	*Pambahinna*	*Level Line 2005/1*
3	*- do -*	*Level Line 2005/2*
4 – 5	*SUSL*	*Road from Main Gate to Auditorium (Cross Section)*

Signature.................

Date....................

Levelling – Sample Level Book

SUSL – Level Book Page

Details of Line Levelled Detailed Level Line from BM 1 to BM 6

Horizontal Distance in meters	Staff Readings			Difference of Level		Reduced Level	REMARKS
	Back	Inter mediate	Forward	+	-		Number and Description etc.

[34 Blank Rows]

Levelling – Errors in the Equipment

- Parallax
  - Focus eyepiece on cross-hairs, then focus telescope on staff

Levelling – Errors in the Equipment

- Parallax
  - Focus eyepiece on cross-hairs, then focus telescope on staff
- Collimation Error - Line of sight not horizontal
  - Keep sight lengths from each instrument position the same
  - Check collimation error

Levelling – Errors in the Equipment

- Parallax
  - Focus eyepiece on cross-hairs, then focus telescope on staff
- Collimation Error - Line of sight not horizontal
  - Keep sight lengths from each instrument position the same
  - Check collimation error
- Magnetic field effects on Auto Level

Levelling – Errors in the Equipment

- Staff Errors
  - Zero error - base may be worn - doesn't matter as long as same staff is always used

Levelling – Errors in the Equipment

- Staff Errors
  - Zero error - base may be worn - doesn’t matter as long as same staff is always used
- Tripod Errors
  - Must be stable

Levelling – Errors in the Field

- Staff not vertical
  - Use pond bubble on staff

Levelling – Errors in the Field

- Staff not vertical
  - Use pond bubble on staff
- Unstable equipment
  - Watch out for soft ground under tripod or staff
  - Don’t touch (or kick!) tripod

Levelling – Errors in the Field

- Staff not vertical
  - Use pond bubble on staff
- Unstable equipment
  - Watch out for soft ground under tripod or staff
  - Don’t touch (or kick!) tripod
- Change point instability
  - Use stable, well defined, recoverable change points
  - e.g. sharp rock, nail, change plate

Levelling – Errors in Reading and/or Booking

- Keep sightings short to estimate mm on staff accurately
- Double check all readings
- Write clearly
- Carry out calculation checks

Levelling – Errors due to Weather

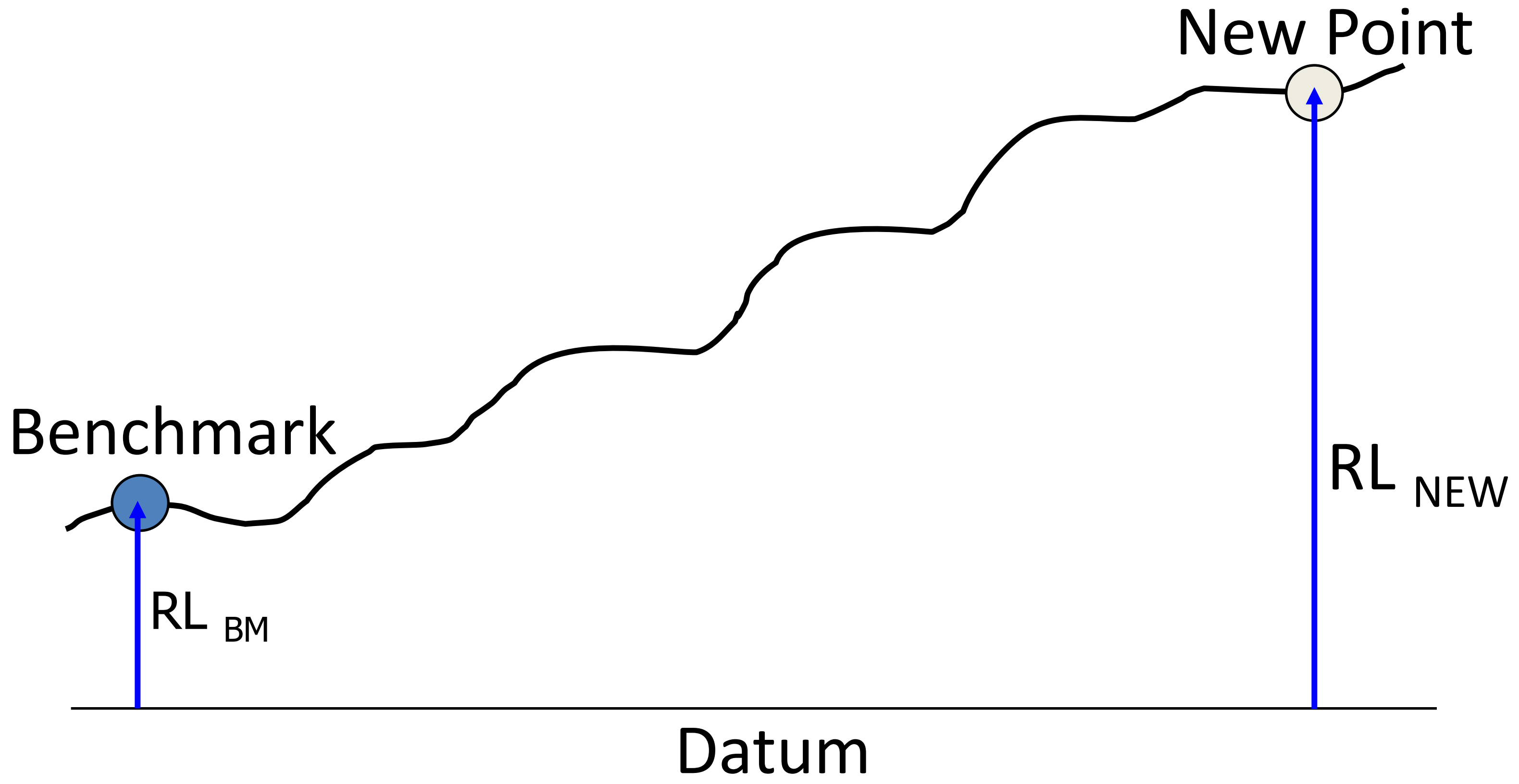
- Wind causes level to vibrate, heat causes ‘shimmer’

- Refraction
  - Readings below 0.5 m on a staff may be affected by refraction

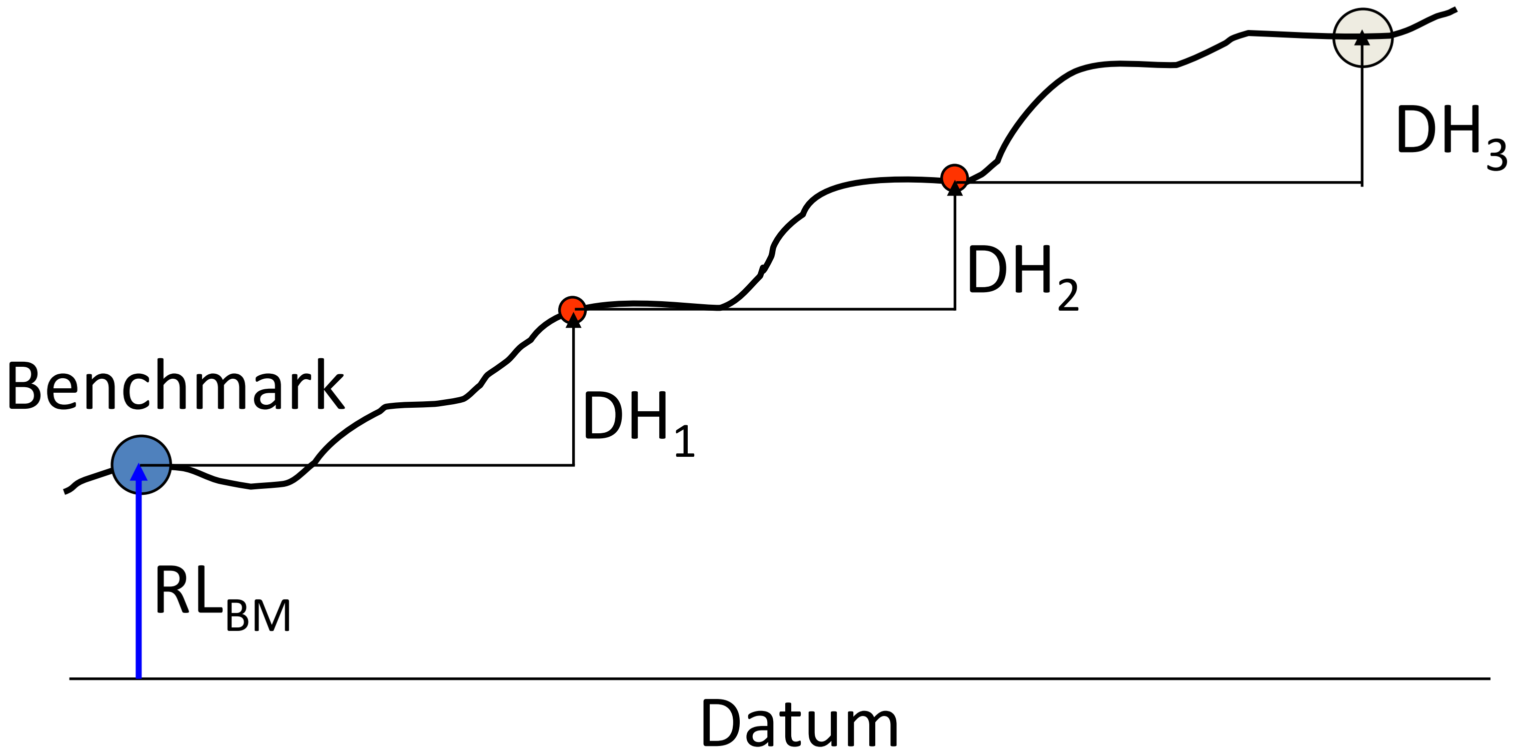
Levelling – Applications

- Point heights (relative to a datum)
- Height differences (independent of datum)
- Longitudinal Sections and Cross Sections
- Data for volume calculations
- Contouring
- Setting Out

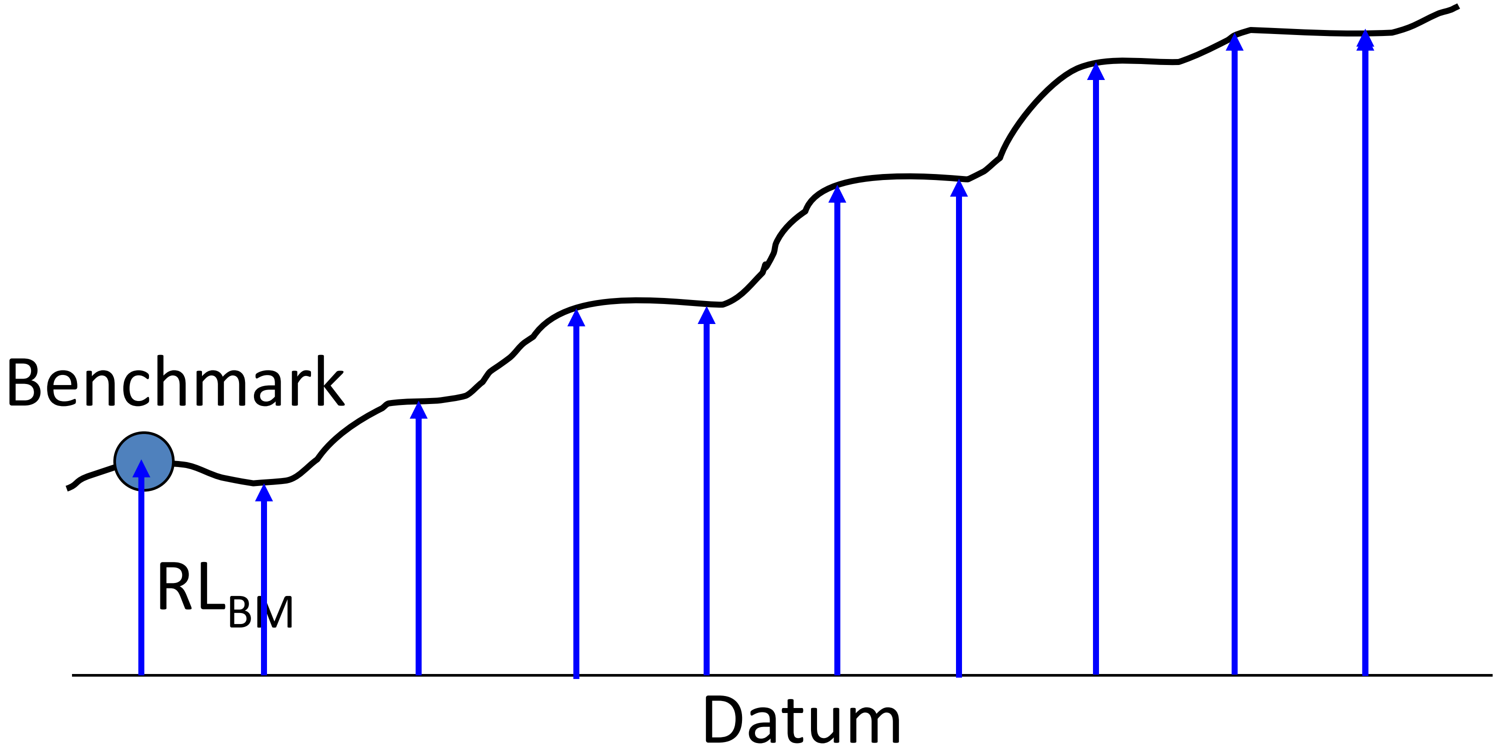
Levelling – Establishing a NEW Point



Levelling – Measuring Height Differences



Levelling – Profiles and Cross Sections



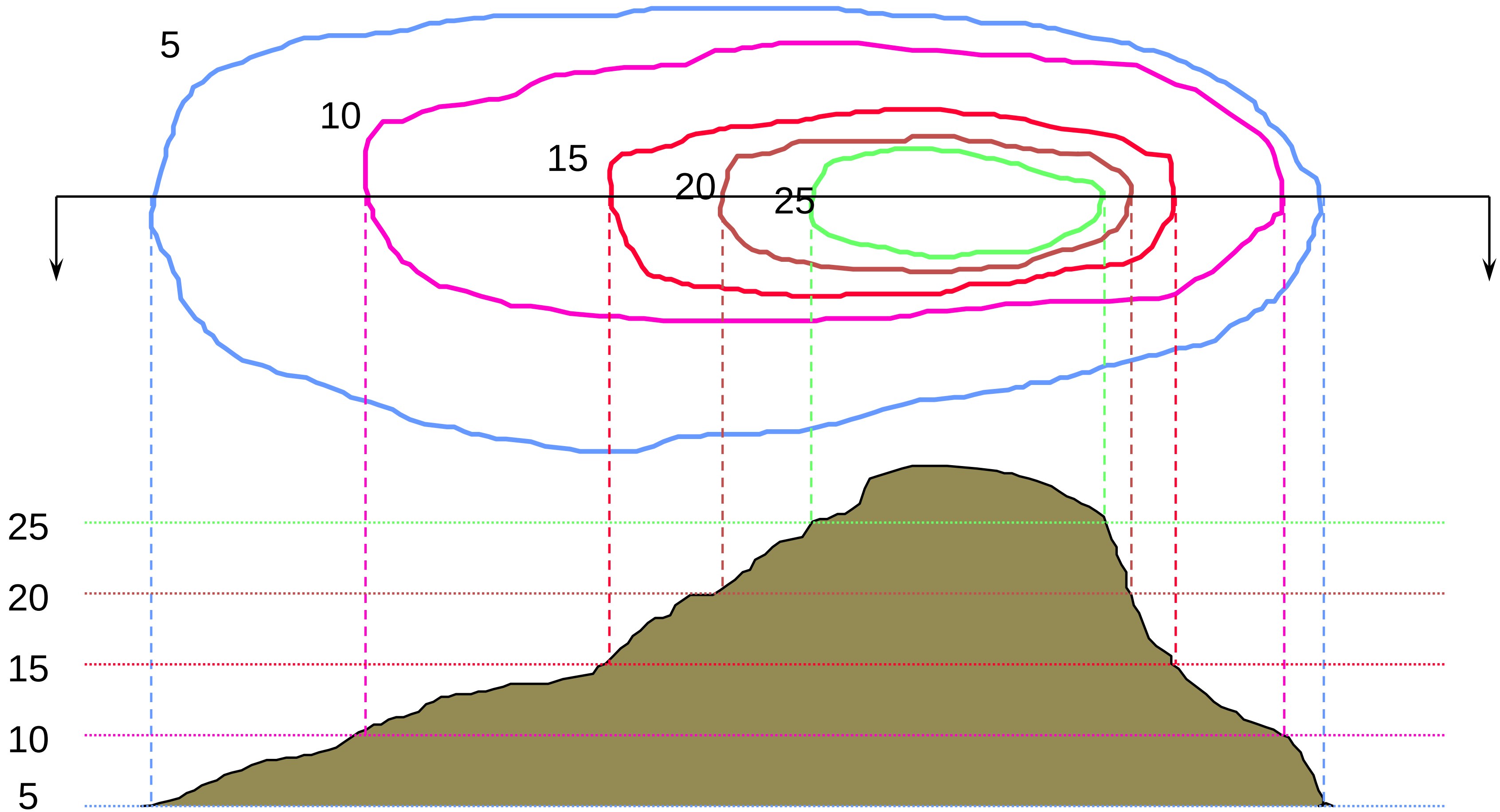
Levelling – Contouring

- Contour – line drawn on a plan joining all points of the same height above or below a datum
- Contours cannot cross, split or join other contours, except in the case of an overhang. e.g. a cliff.
- The height between successive contours – vertical interval/contour interval
- Its value depends on the variation in height of the area being contoured

Levelling – Contouring

- Contour interval is kept constant for a plan or map
- Plan spacing between contour line indicates steepness of slopes
- Closely spaced lines indicates a steep gradient
- Widely spaced lines indicate a flatter gradient

Levelling – Contouring



Levelling – Plotting Contours

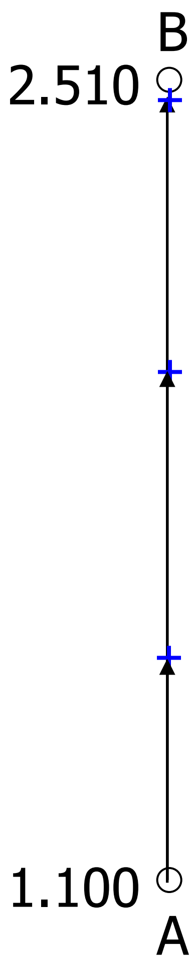
B
2.510

C
2.905

The RL's for points A, B and C have been determined by levelling. We are now required to determine the location of the contours using a 0.5 m contour interval

1.100
A

Levelling – Plotting Contours



LINE AB

ΔH_{AB} = 2.51 - 1.10 = 1.410

D_{AB} = 10 m

For the 1.5 m contour:

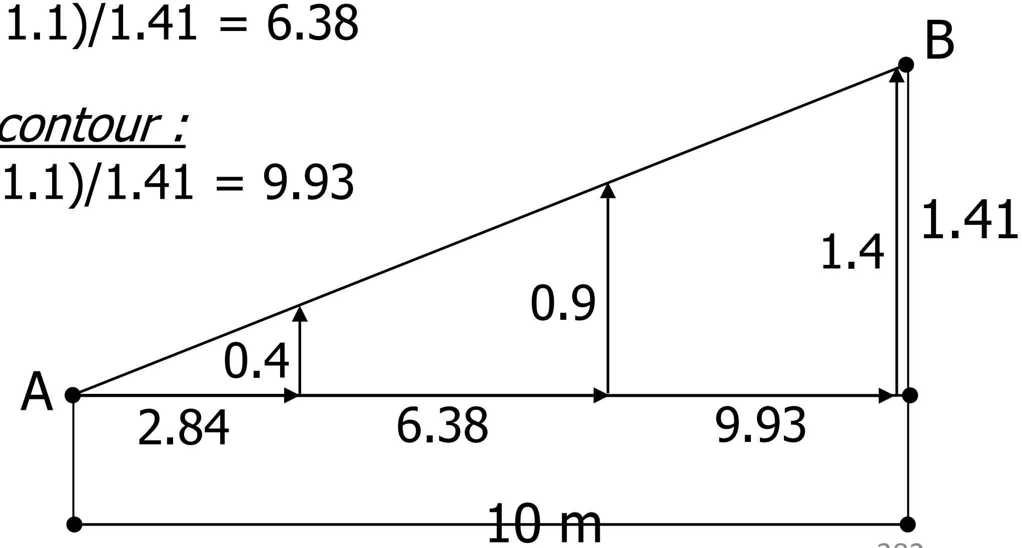
D = 10*(1.5 – 1.1)/1.41 = 2.84

For the 2.0 m contour :

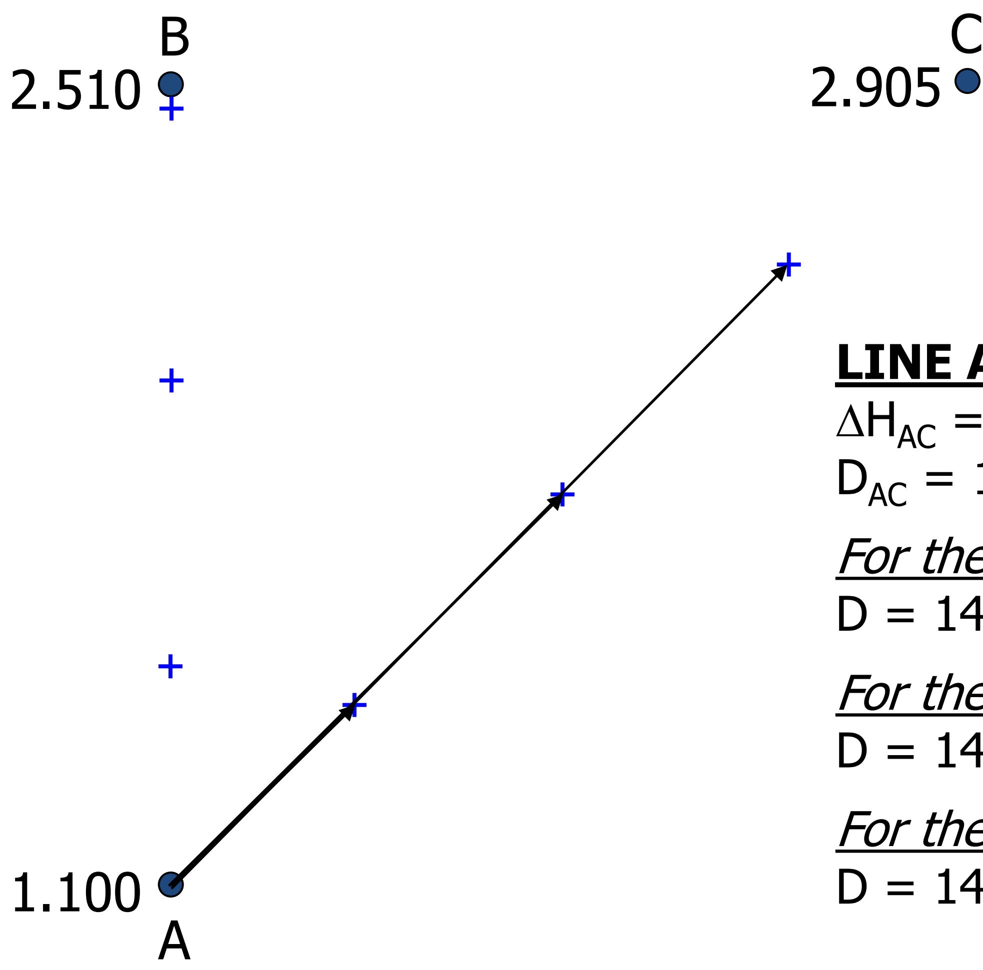
D = 10*(2.0 - 1.1)/1.41 = 6.38

For the 2.5 m contour :

D = 10*(2.5 - 1.1)/1.41 = 9.93



Levelling – Plotting Contours



<u>LINE AC</u>

$\Delta H_{AC} = 2.905 - 1.100 = 1.805$

$D_{AC} = 14.14$ m

<u>For the 1.5 m contour</u> :

$D = 14.14*(1.5 - 1.1)/1.805 = 3.13$

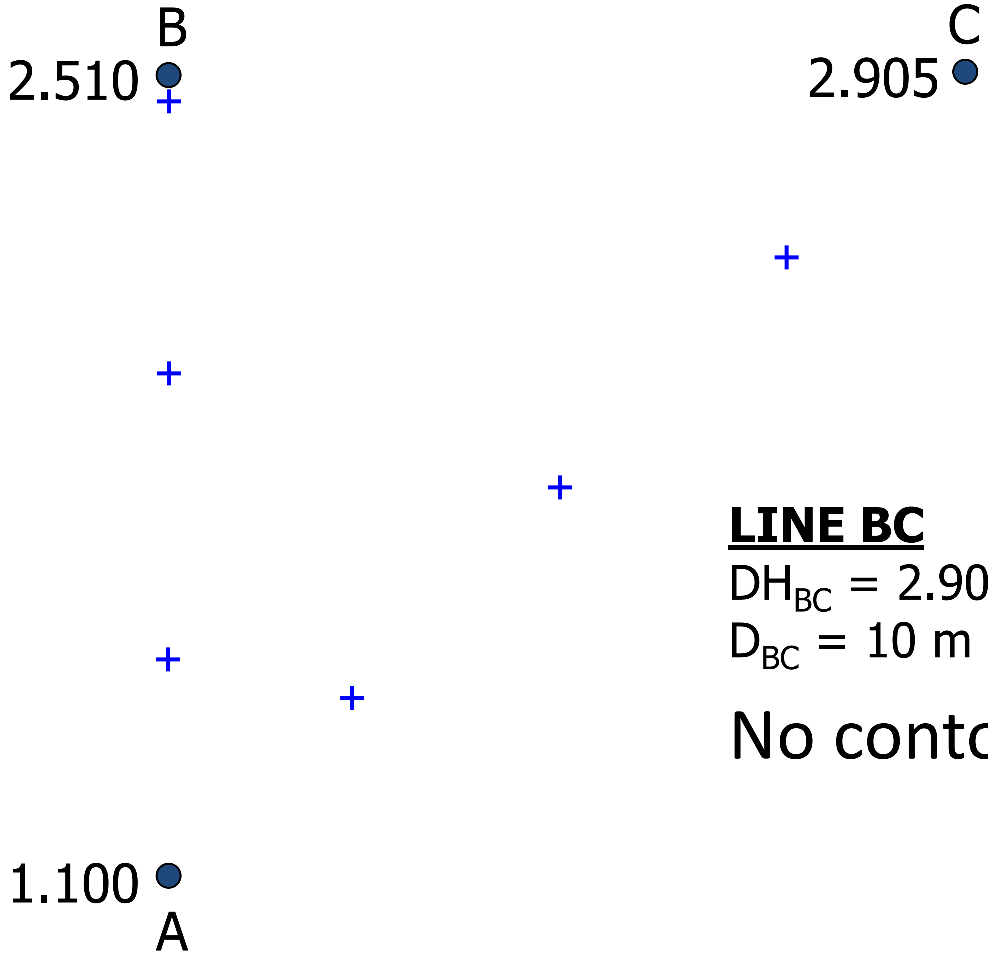
<u>For the 2.0 m contour :</u>

$D = 14.14*(2.0 - 1.1)/1.805 = 7.05$

<u>For the 2.5 m contour :</u>

$D = 14.14*(2.5 - 1.1)/1.805 = 10.97$

Levelling – Plotting Contours



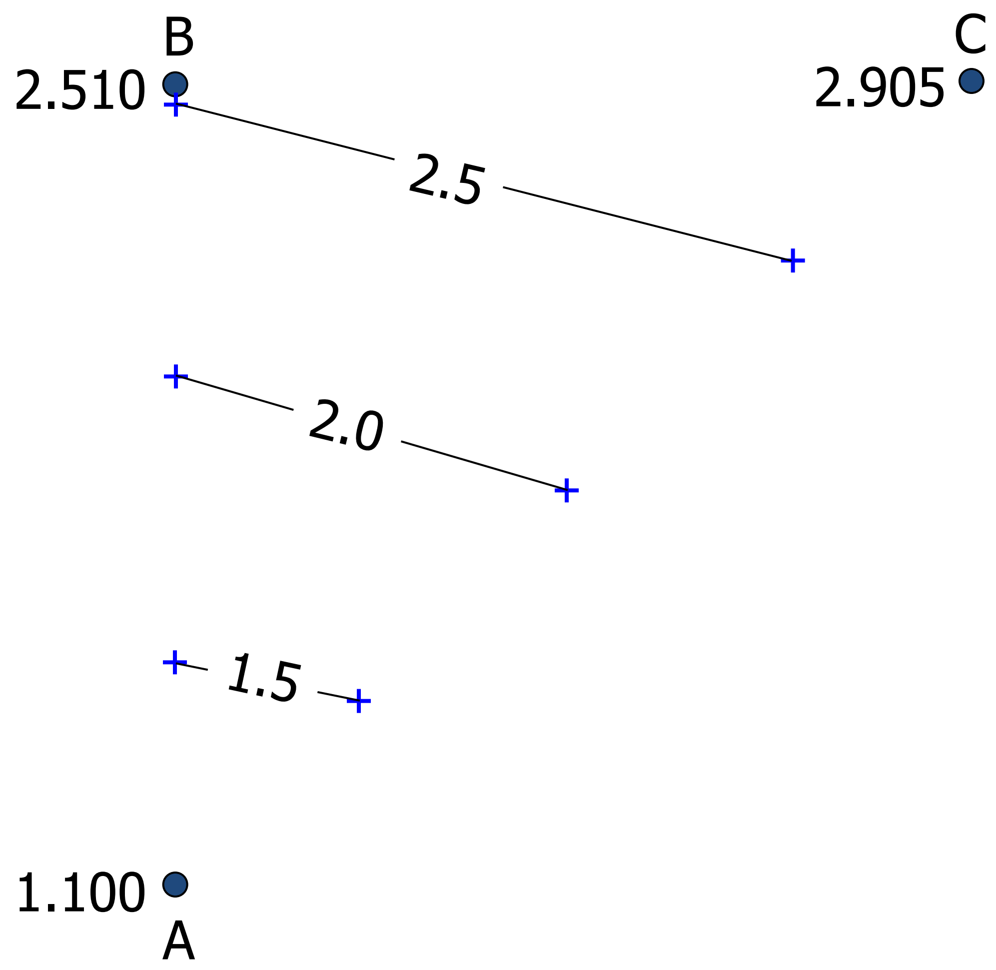
<u>LINE BC</u>

DH_{BC} = 2.905 - 2.510 = 0.395

D_{BC} = 10 m

No contours cross this line

Levelling – Plotting Contours



Thank you …