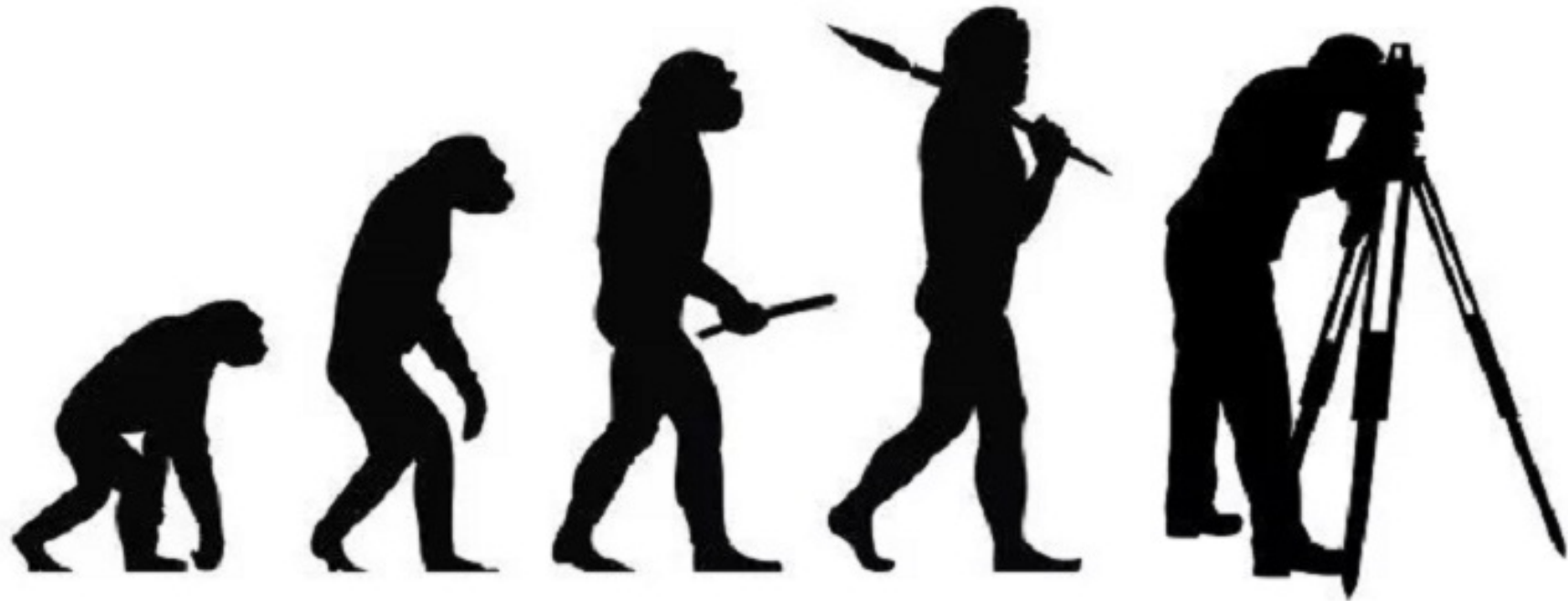


Lecture 10: Digital Surveying



<https://www.satpalda.com/blogs/evolution-in-surveying-techniques>

Before you ask.....

FEEDBACK



on your submitted Assessment
by **27th January.**

Assessment are required
to be second marked.

Programme January – May 2020:

Semester 1 (end)

Recap on Lectures

Practical Sessions on Land Surveying in Smaller Groups

Feedback on 1st Assessment

Semester 2:

2nd Assessment Data Collection

A group of people, mostly seen from the back, are standing on a grassy field at night, looking up at a large, vibrant fireworks display in the dark sky. The fireworks are exploding in various colors, including white, yellow, and blue. The people are wearing winter clothing like jackets and hats. In the background, some distant city lights are visible.

HAPPY NEW YEAR

HAPPY NEW ASSESSMENT

Assessment

Submission
deadline:

Friday 1st May 2020

Return date of provisional
marks & written feedback:

29th May 2020

Practical with Written Report (including work up material of semester and St Fagan's Trip)

Contents.

2000 word Report (with drawings)

Data collection will be in groups, but reports will be submitted individually.

Written report must include:

- Scope (brief, description, limitations)
- Techniques employed
- Findings (survey)
- Proposals (Proposed plans, setting and description)
- Supplementary Work (Developmental work from Semester one)

Assessment

Submission
deadline:

Friday 1st May 2020

Return date of provisional
marks & written feedback:

29th May 2020

Brief:

You have been asked by the client UWTSD to undertake a measured survey of the library building on the SA1 campus. The university plans to extend the building by 200m² into the adjacent carpark. In your teams you must prepare existing Building and Site survey drawings. The drawings must be collated into the report outlining the findings and include an individual outline proposal for the extension.

Group Work: Data gathering in teams of 3 (subject to numbers).

Building Survey: plan, typical section and principal elevation.

This shall include dimensioned survey drawings and accurately presented Plan and Elevation at 1:100 scale, and Section at 1:50 scale.

Site Survey: The survey should depicting at least 3 prominent features / points in the landscape giving positions, levels and angles in relation to other features.

A contoured topographical site plan at 1:500 indicating existing buildings.

Assessment

Submission
deadline:

Friday 1st May 2020

Return date of provisional
marks & written feedback:

29th May 2020

Individual work:

Formatted and structured report.

Proposed extension: suitably scaled proposed plan with a description of proposal.

Site Setting out plan.

Supplementary work - Individual practical material from Semester one.

Further Guidance:

- *Where techniques are suggested in the report, make reference to the range of sources used.*
- *Demonstrate your understanding of the methods and techniques of surveying.*
- *Show how you have evaluated your results from the survey and applied these outlining any assumptions made.*
- *Include your supplementary work to show your progression and understanding of the practical skills you have acquired.*
- *The report should be presented in a professional manner with all work clearly labelled and cross-referenced.*



PLANNING

Research, analysis,
and decision making.



**What existing information is
available ?**

- As built drawings
- Building File / O&M Manuals
- Original Property deeds
- Previous planning applications / building regulation work
- Fire plans
- Asbestos register plans
- OS Data / Historic Maps / Topography



Additional Useful Information (Basic Levelling)

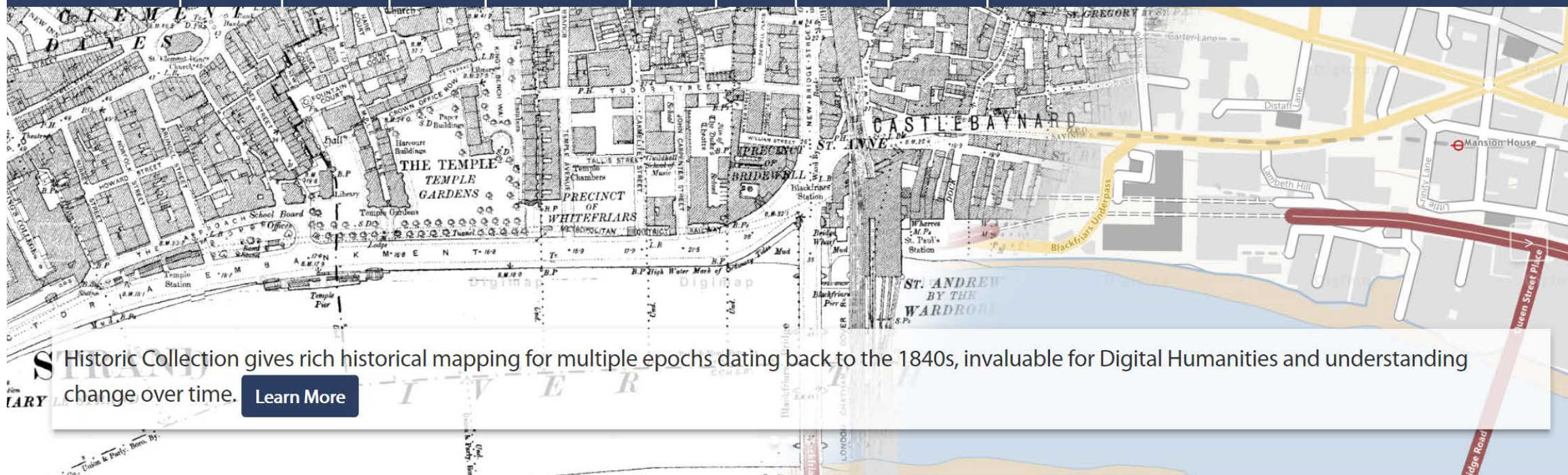
W Booking sheet (Rise and Fall Method)

W Booking Sheet (Collimation Method)

Project Title	
Site Location	
Surveyor	
Surveyor	
Surveyor	

BOOKING					REDUCTION		
Station	Points	BS	IS	FS	Rise	Fall	RL

Site					
Date					
Surveyor					
Surveyor					
Surveyor					
BACKSIGHT	INTERMEDIATE	FORESIGHT	HEIGHT of COLL.	REDUCED LEVEL	REMARKS

[Ordnance Survey](#)[Historic](#)[Geology](#)[Marine](#)[Environment](#)[Aerial](#)[Lidar](#)[Global](#)[Society](#)

Historic Collection gives rich historical mapping for multiple epochs dating back to the 1840s, invaluable for Digital Humanities and understanding change over time. [Learn More](#)

What is Digimap?

Digimap is an online map and data delivery service, available by subscription to UK Higher and Further Education establishments. Operated by EDINA at the University of Edinburgh, Digimap offers a number of data collections, including Ordnance Survey, historical, geological, LiDAR and marine maps and spatial data.

What are we offering?

Digimap offers access to a range of datasets for the purposes of education and research. Create or interrogate a map online by selecting an appropriate base map, adding annotations and customising the content, use measurement and query tools to learn more about any study area. Download the raw spatial data in a wide range of formats for use in local GIS, CAD or image processing software.

Subscription Information

Digimap is available to members of subscribing higher and further education institutions in the UK. Individual registration is required, but the service is free at the point of use. More information about subscription fees can be found on our [website](#).

<https://digimap.edina.ac.uk/>

What do you need to capture as part of a survey?

Form a Data collection Plan

Set roles responsibilities.

Preparation for survey –
what equipment will you need for a:

Building Survey?

Land Survey?



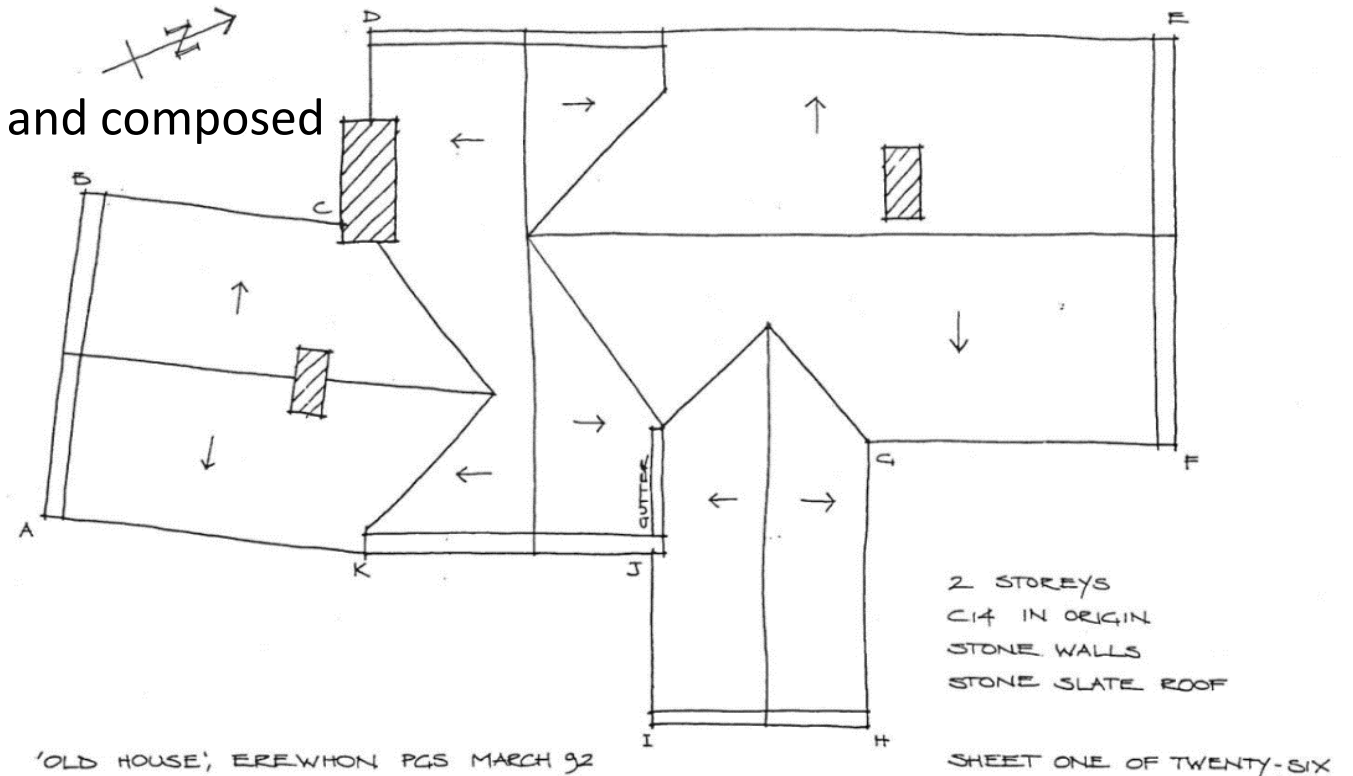


Refreshing QUIZ to welcome in the New Year



Surveying Procedure

- Before any measurement can take place prepare sketch plans, section and elevations
- Show as much information as possible include
 - A north point (use compass or OS sheet)
 - Arrangement of roof slopes, stacks and dormer windows
 - A reference letter for each corner
 - Note indicate number of storeys, age, and composed material
 - Surveyor name
 - Sheet number



Surveying Procedure

Starting with ground floor, draw floor plans for each level

- Drawn at a plane at 1200mm
- In order to keep ground floor plan roughly in proportion, start from outside by drawing the perimeter.
- Take each wall in turn record all details (projections, openings, steps, rails etc.).
- Prepare internal arrangement on completion of perimeter (work methodically on a room by room basis).
- Distinguish between load and non-load bearing walls
- Best to establish overall plan before adding detail, e.g. Reveals, door swings, plant, fittings, etc.
- Stairs and stair well, showing landings, risers numbers of risers, arrows up or down. Note any intricate detail.
- Note direction of floorboards and floor, wall, ceiling finishes

Surveying Procedure

If accessible, draw a roof plan showing the following features

- Roof pitches and direction of slope.
- All hips, valleys and ridges, parapets, gutters, roof lights, dormer windows, chimneys etc.

Draw sections conveying maximum the amount of information

- Shape and arrangement of timber roof
- Levels of floors and thickness
- Relationship between ground and basement/ground floor levels
- Staircases (including headroom)
- Heights of ceilings, doors windows and sills

Draw elevations for each face of building

- Windows and doors
- Plinths and string courses
- Rainwater goods and pipework
- Roof, chimney stacks etc.

Basic Land Surveying



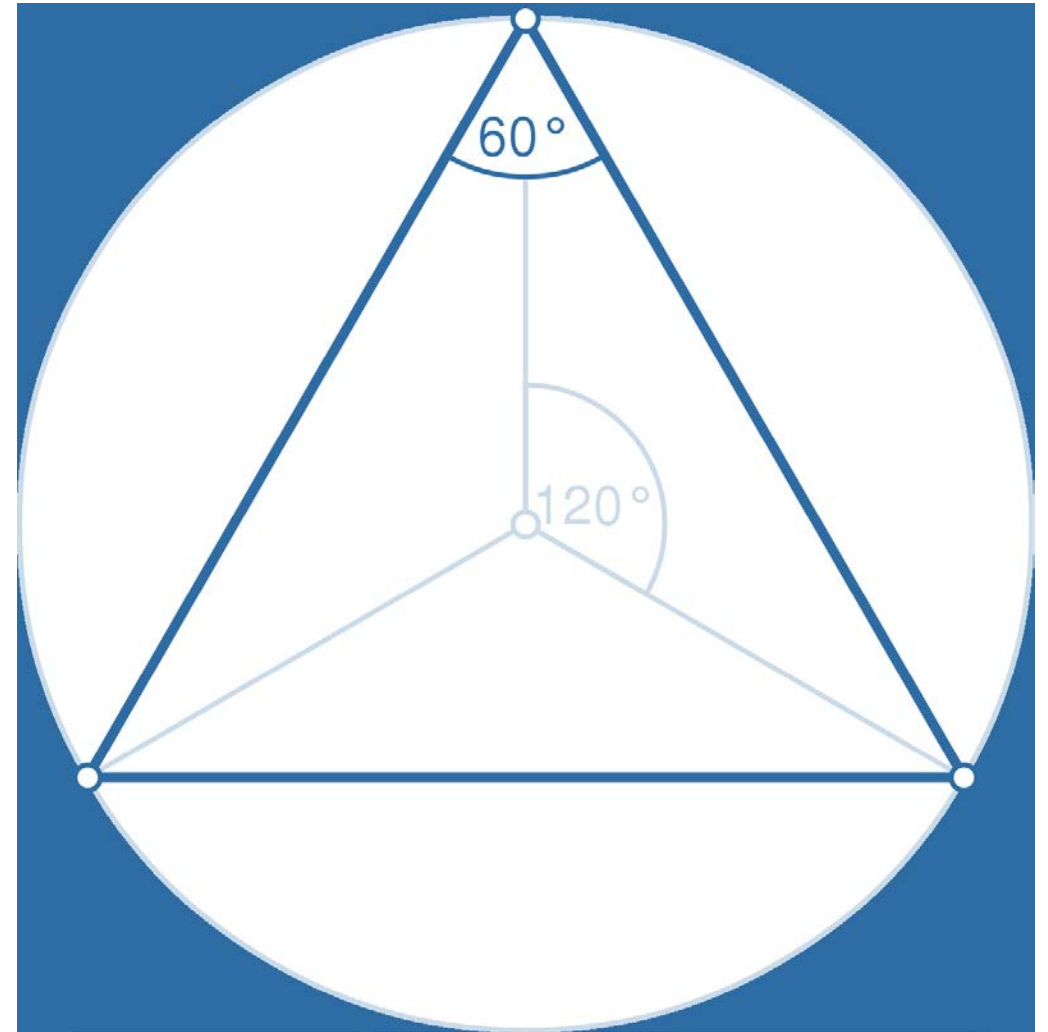
Basic Land Surveying

Trigonometry

Triangulation

Trilateration

Traversing



Basic Land Surveying Tools



Tripod



Electronic Level



Measuring Tape



Umbrella



Field Book



Safety Vest



Hammer



Grade Rod



Marking Paint



Theodolite

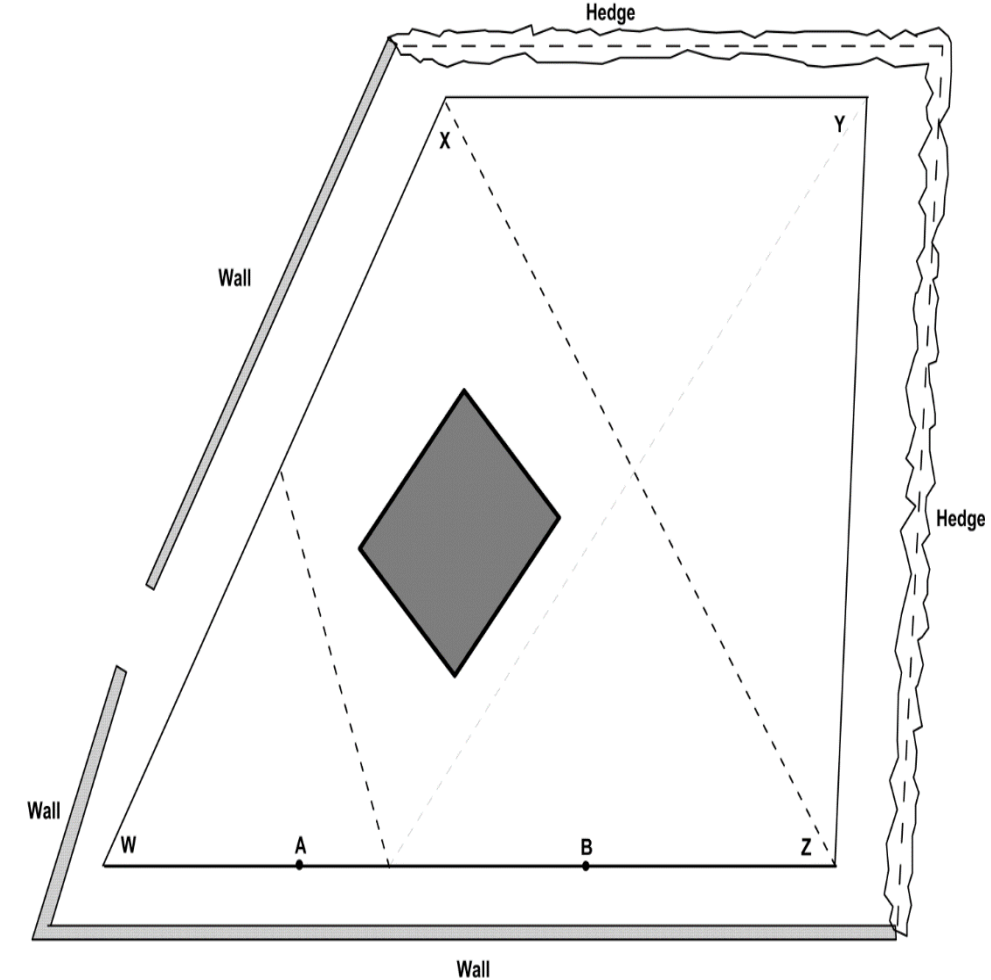
Basic Equipment for Larger and External Surveys

- Available drawings estate agent's particulars, OS Maps, Cadastral maps
- Notebook and pencil/pen
- Binoculars and a camera with flash facility
- Tape measure, spirit level and plumb line
- Hammer, and peg, and survey pins, screwdriver and manhole lifting irons
- Sealable bags for taking samples, e.g. Soil samples
- Quick set level, tripod, and staff.

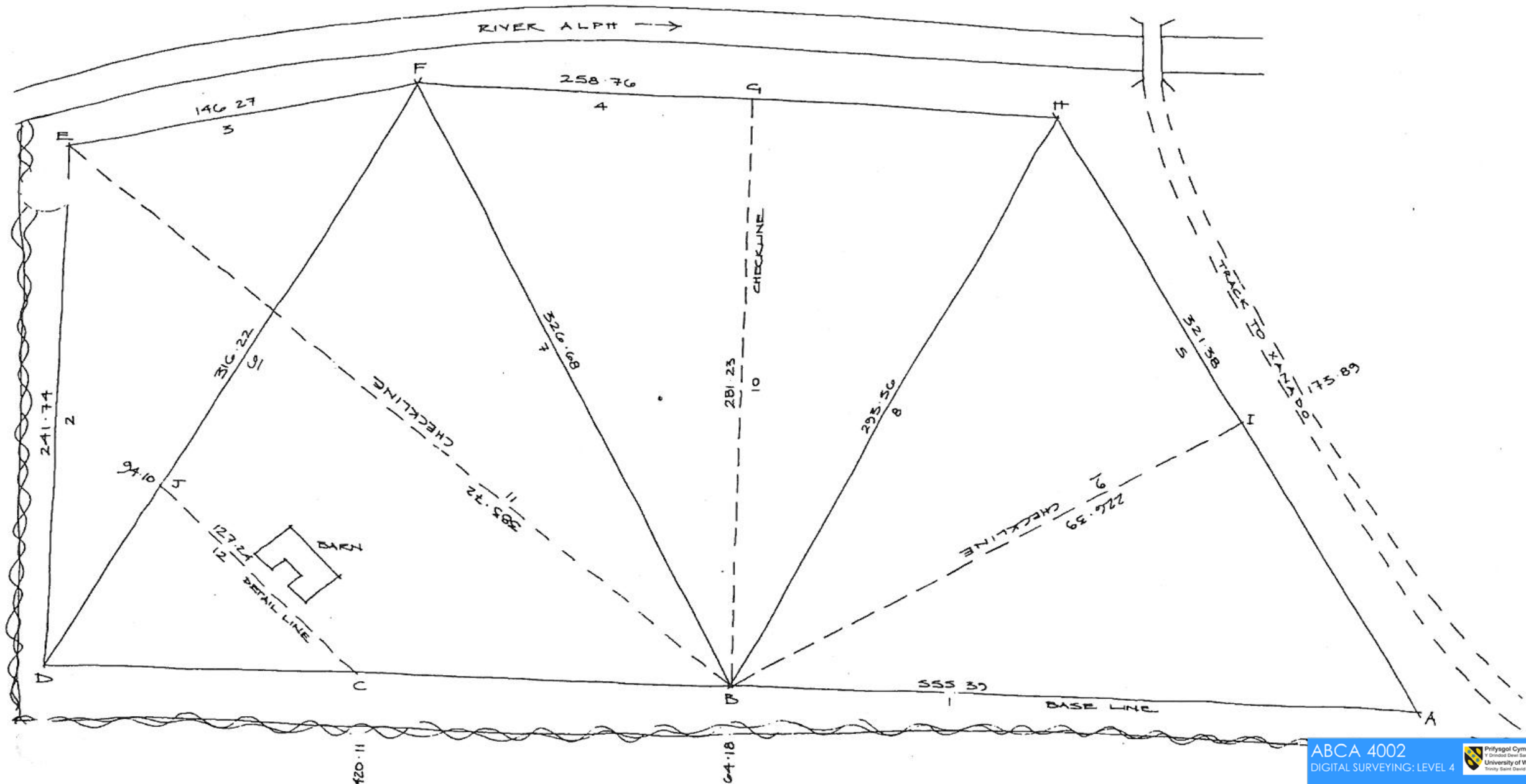
Elementary Land Surveys

Procedure;

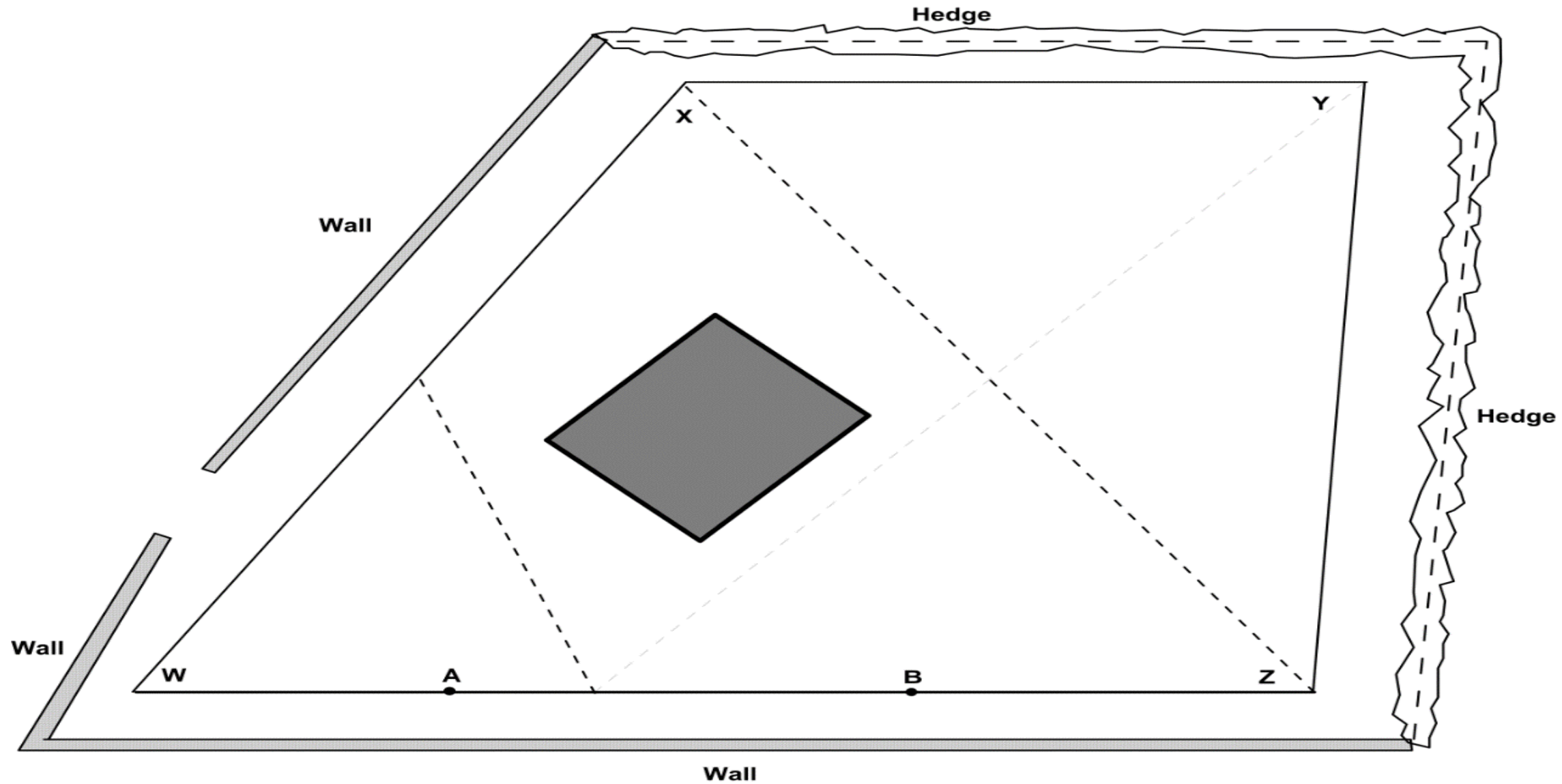
1. Establish a control frames work
2. Record on a rough sketch
3. Reference all control points
4. Record measured length of each control line



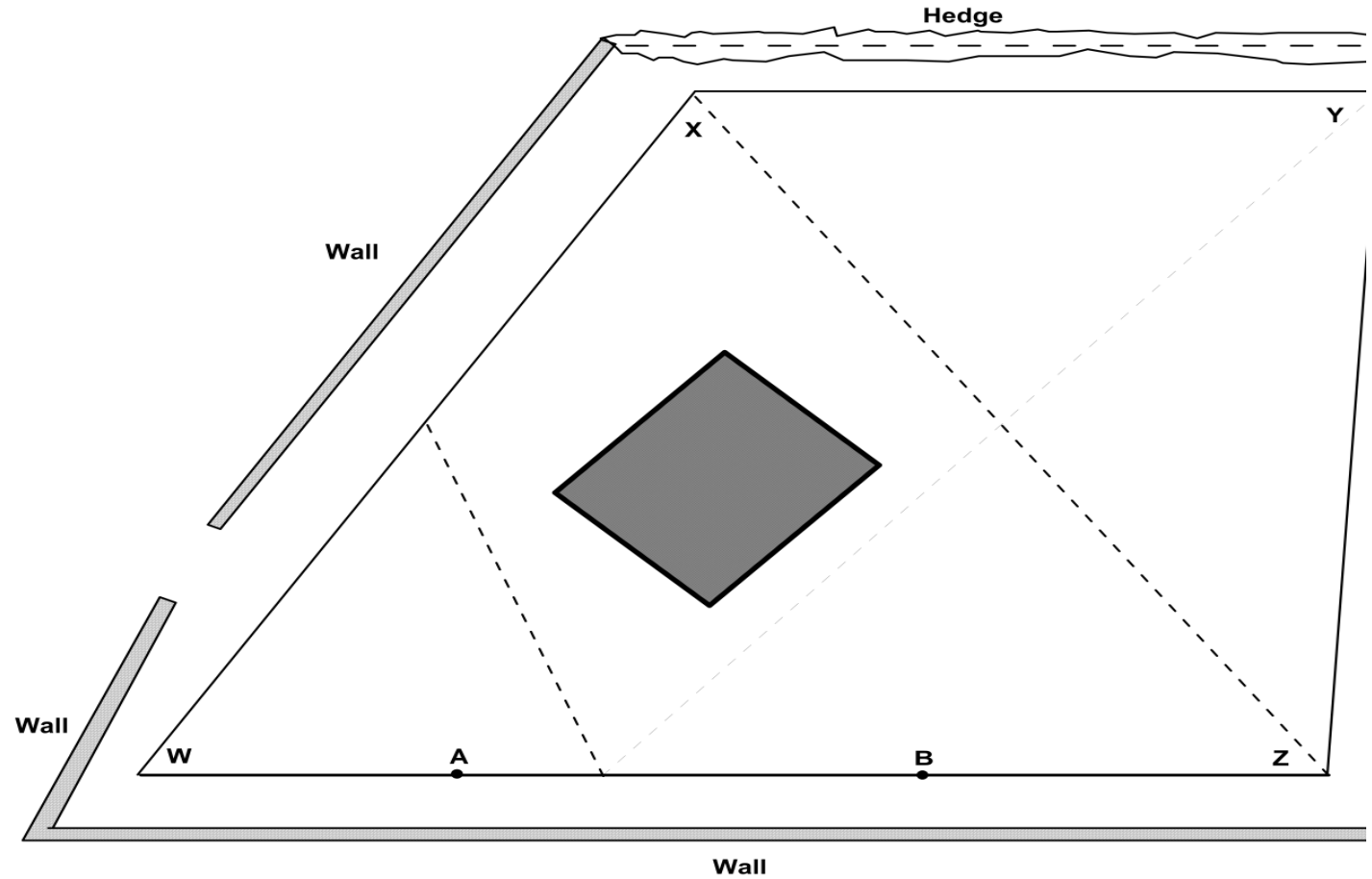
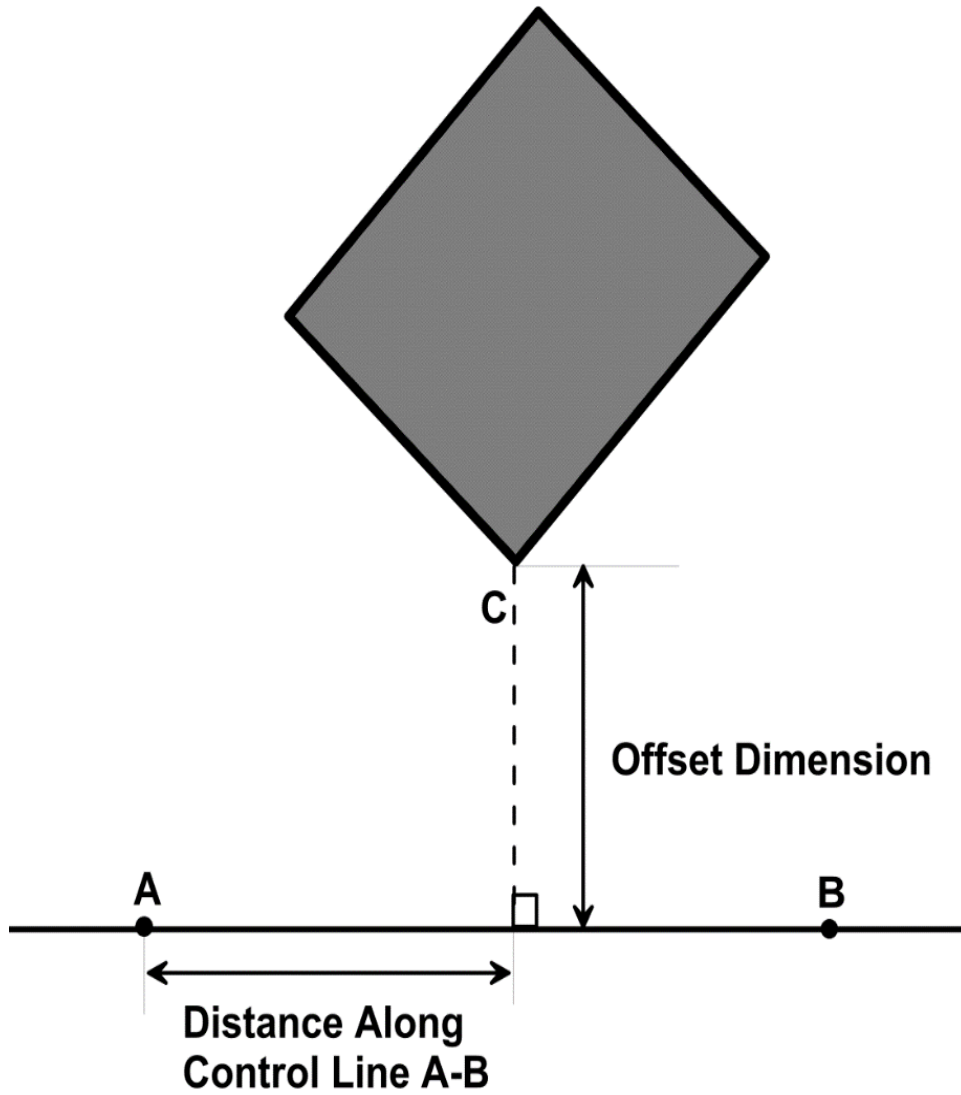
Control Framework



Control Framework



Offsetting



Trigonometry

SOH CAH TOA

$$\sin \alpha = \frac{a}{c}$$

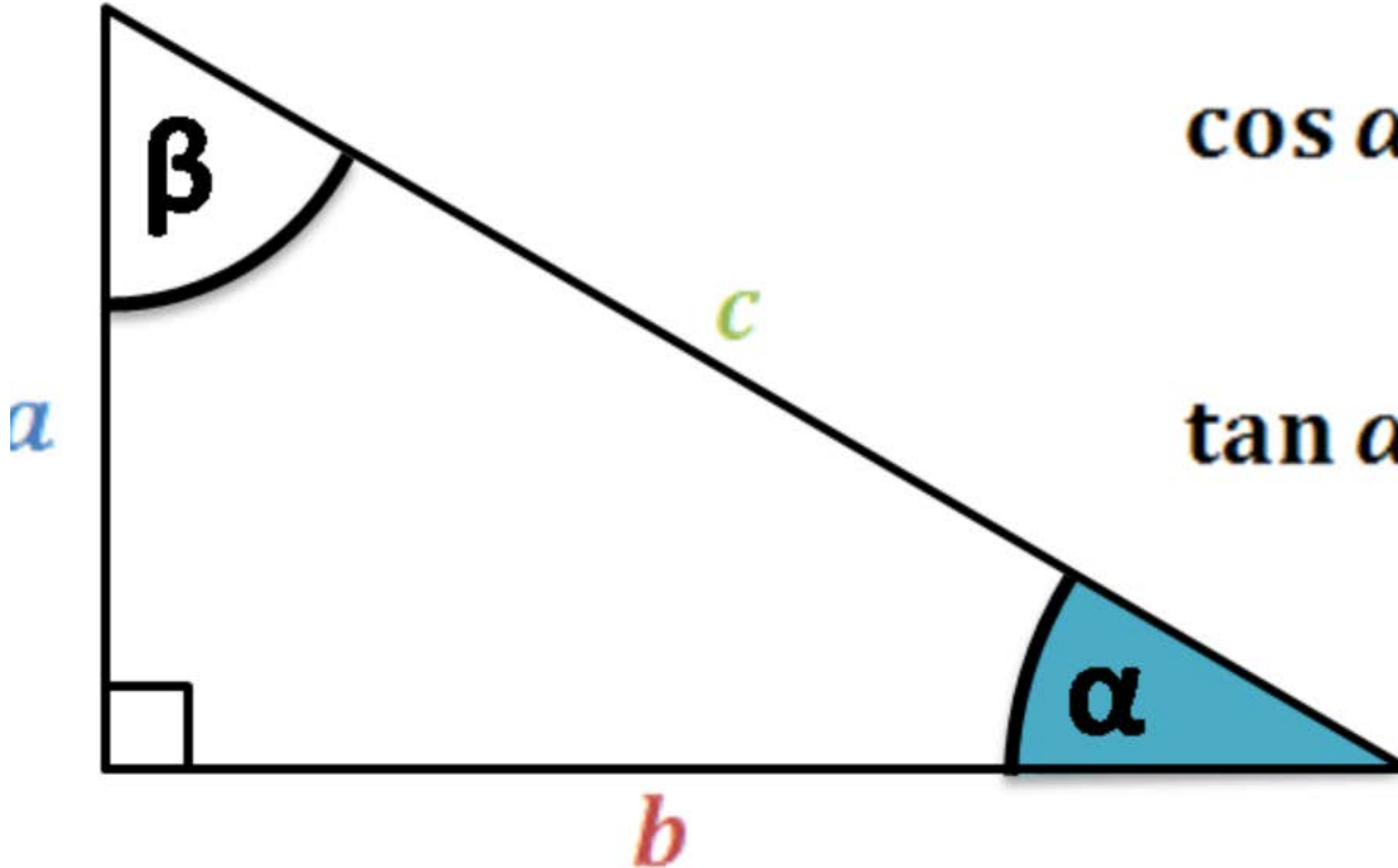
Opposite
Hypotenuse

$$\cos \alpha = \frac{b}{c}$$

Adjacent
Hypotenuse

$$\tan \alpha = \frac{a}{b}$$

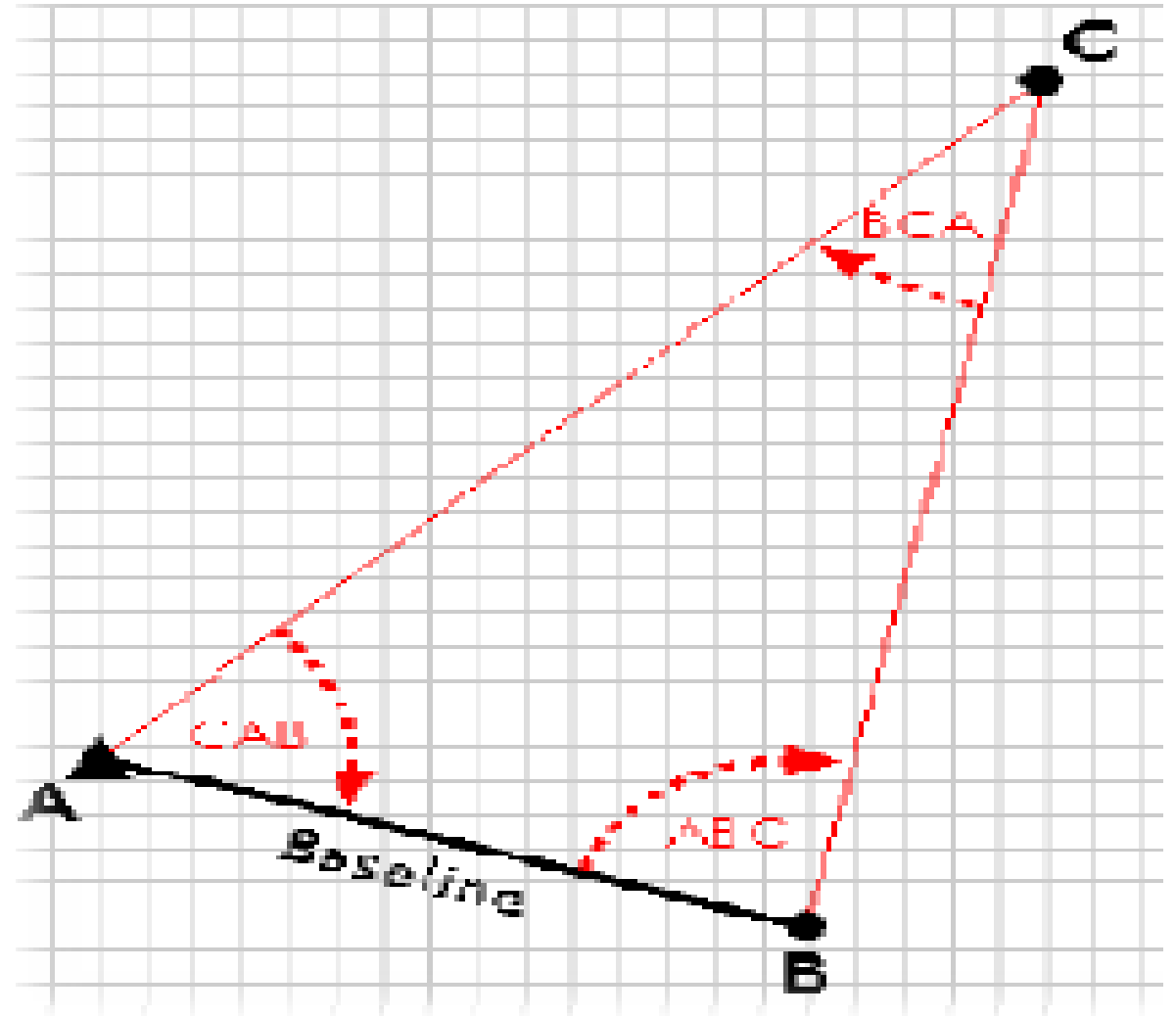
Opposite
Adjacent

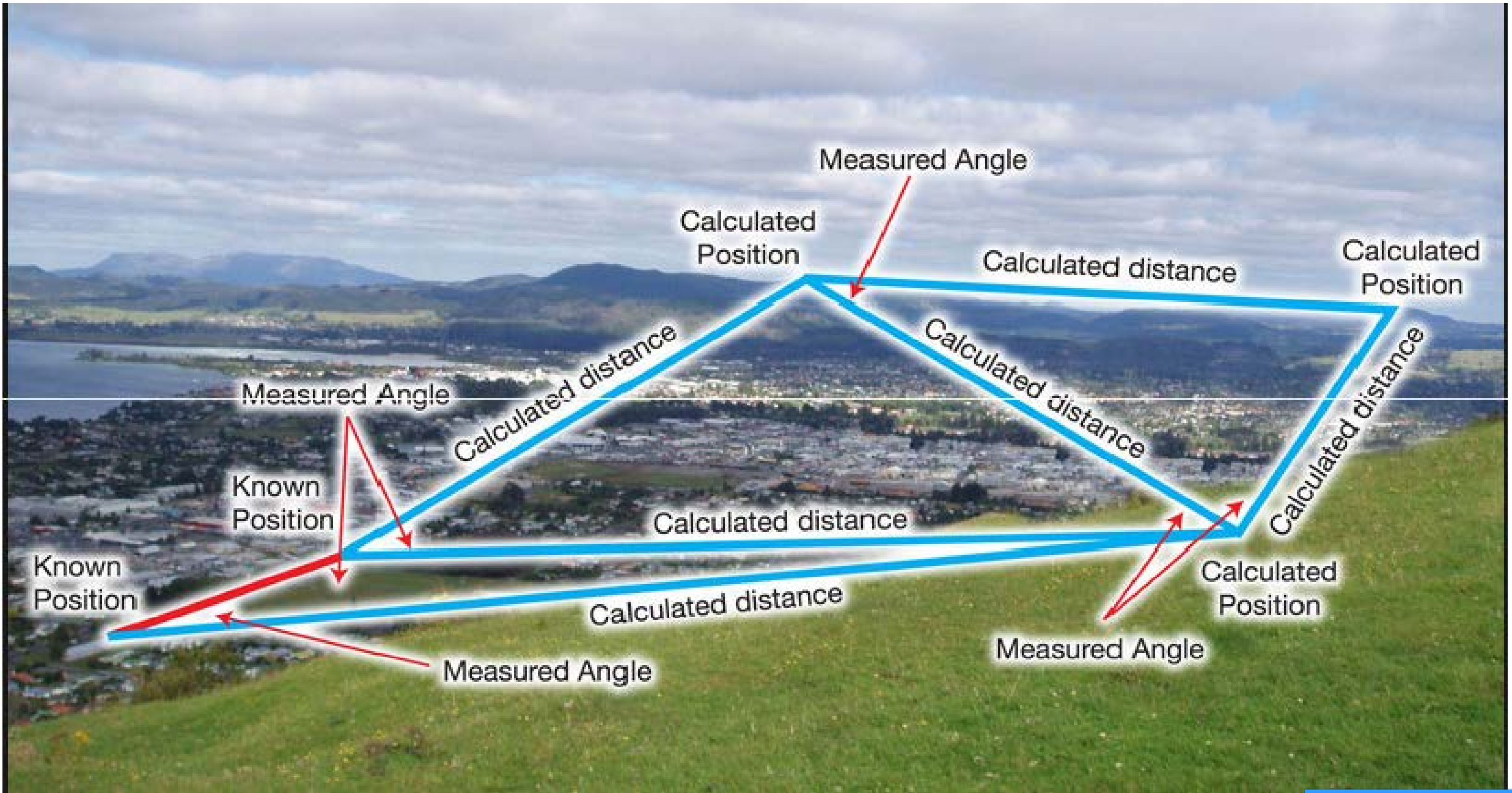


Triangulation

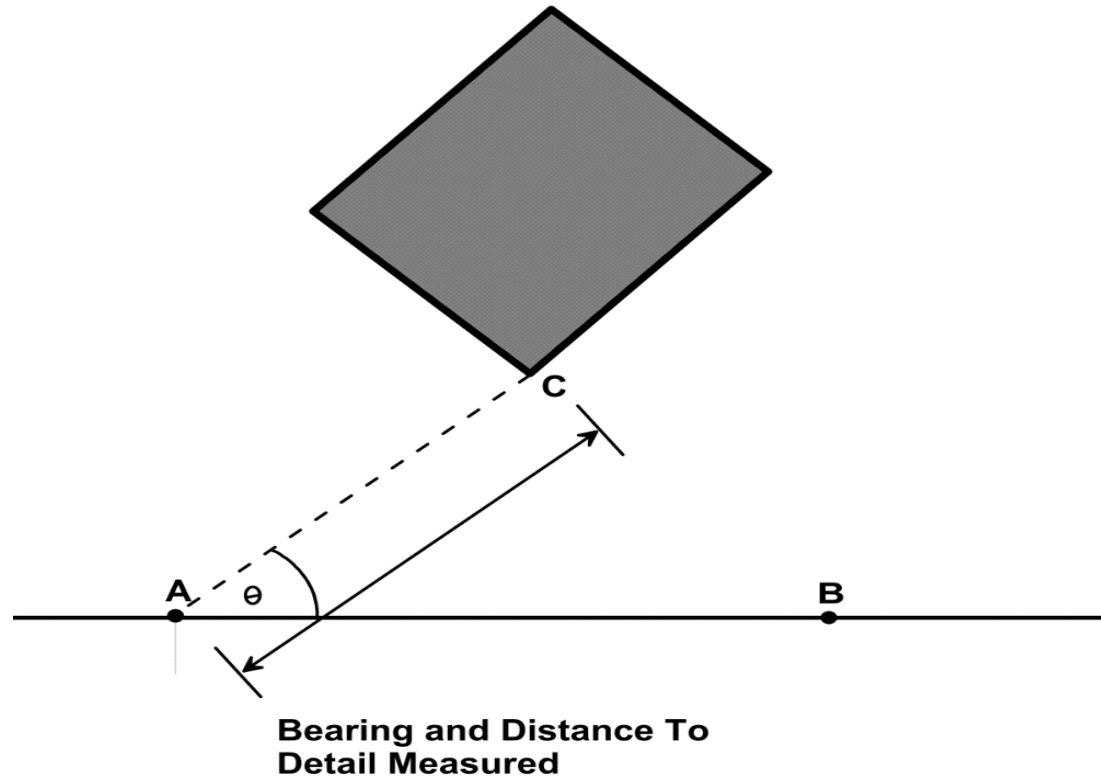
Triangulation and its Principles

- It is the process of measuring the angles of a chain or network of triangles formed by stations marked on the surface of the earth.
- The system consists of a number of interconnected triangles in which the length of only one base line and the angles of the triangles are measured very precisely which are used to calculate the coordinate of vertices.

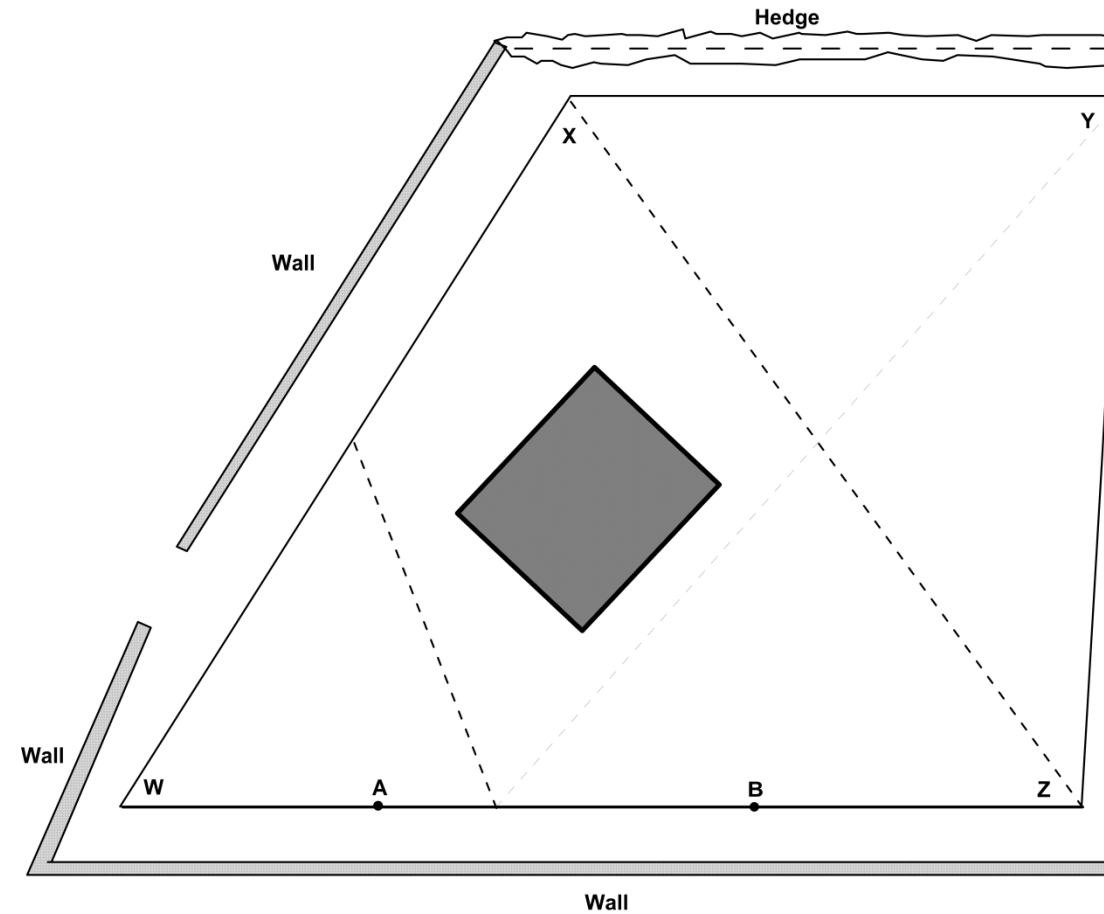




Radiation or Polar Co-ordinates



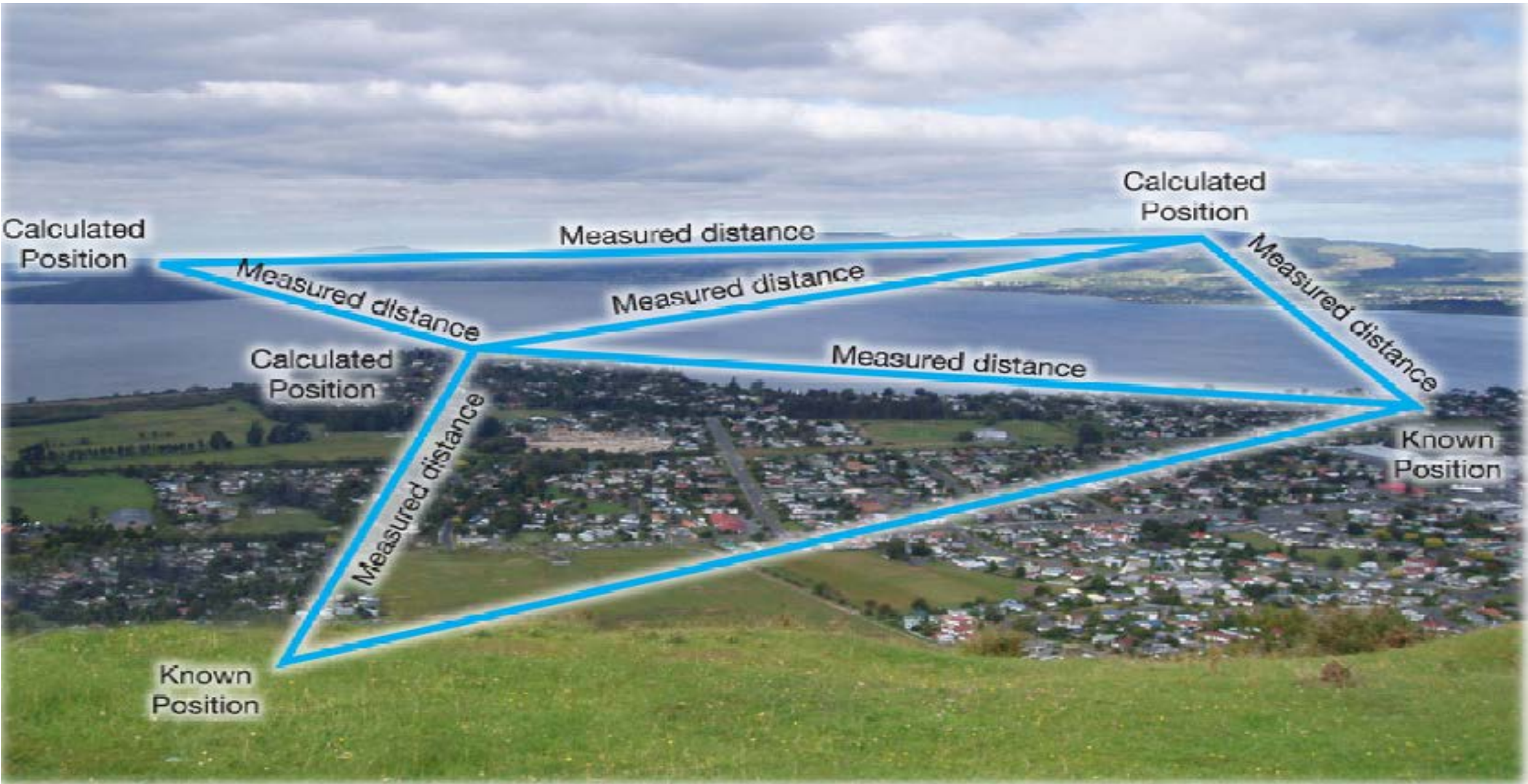
Bearing and distance



Trilateration

Trilateration

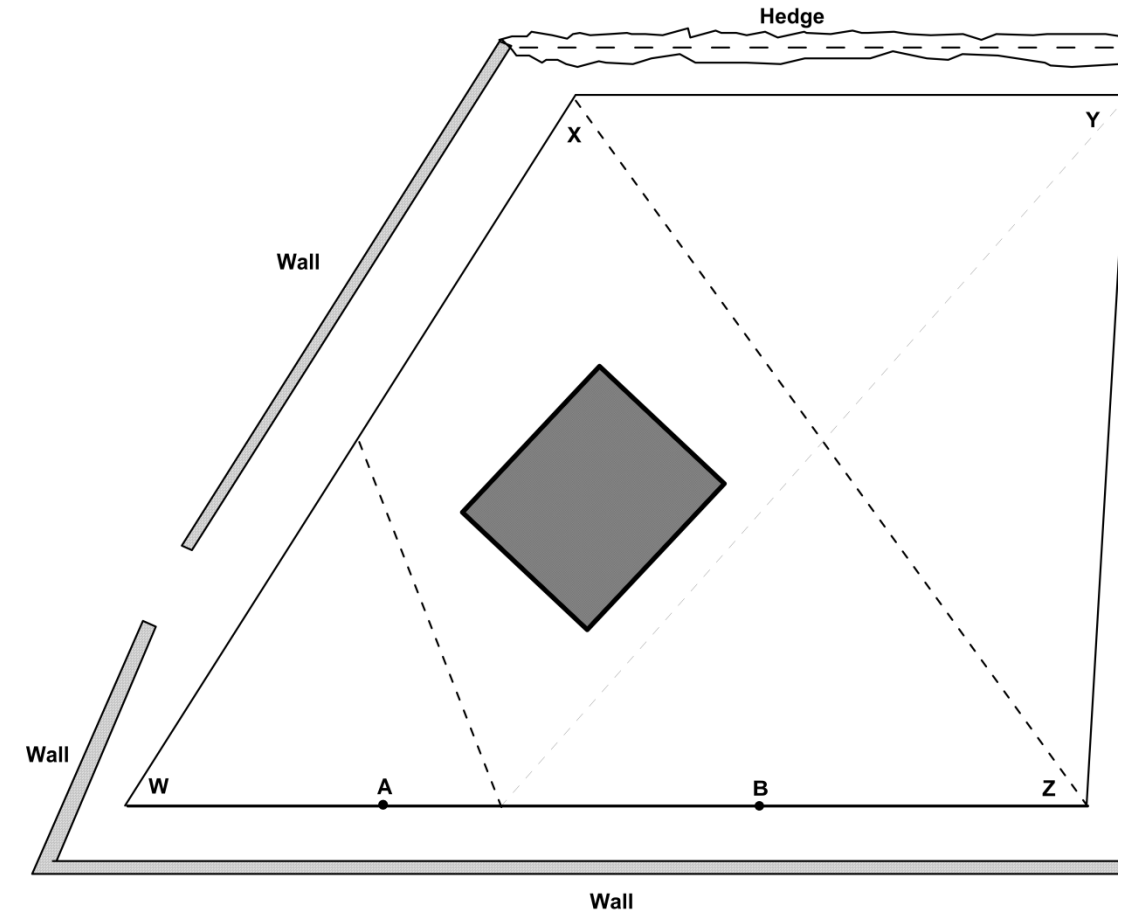
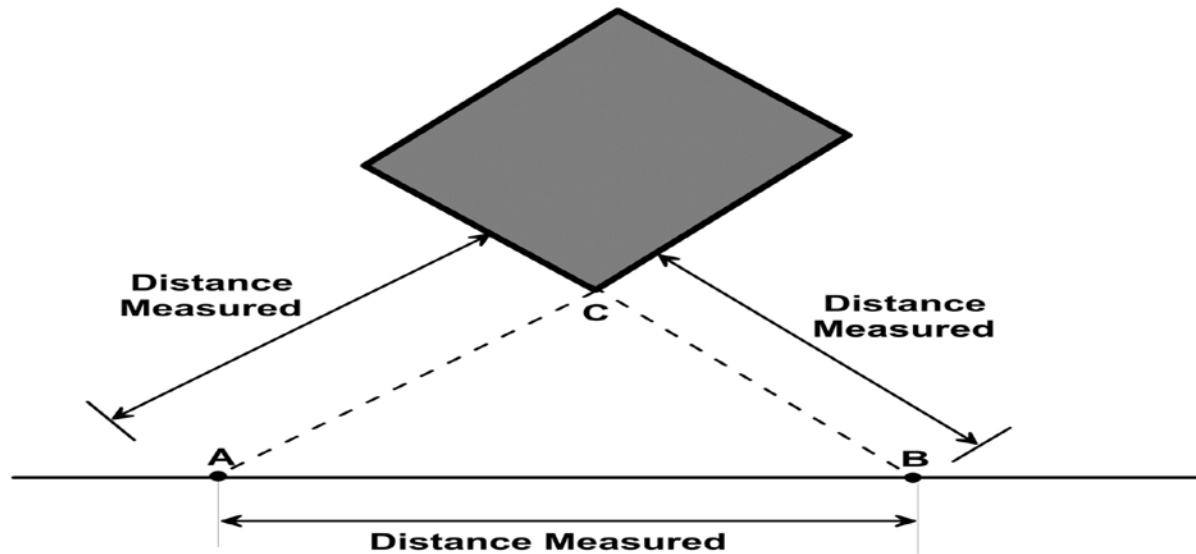
- A surveying method in which the lengths of all sides of a chain of triangles, polygons, or quadrilaterals (or any combination of them) are measured with an electronic instrument or others; the angles then may be computed from these field measurements.
- Uses in the construction of a chain or network of interconnected triangles in a given area and the measurement of all three sides of each triangle.
- Angles of the triangles and the coordinates of their vertices are re-determined by trigonometric computations.
- **In contrast to triangulation, it does not involve the measurement of angles.**
- Trilateration has the same purpose as triangulation.



Trilateration

Using the control line as a base,

Measurements are taken along baseline (A-B) and to C from A- B

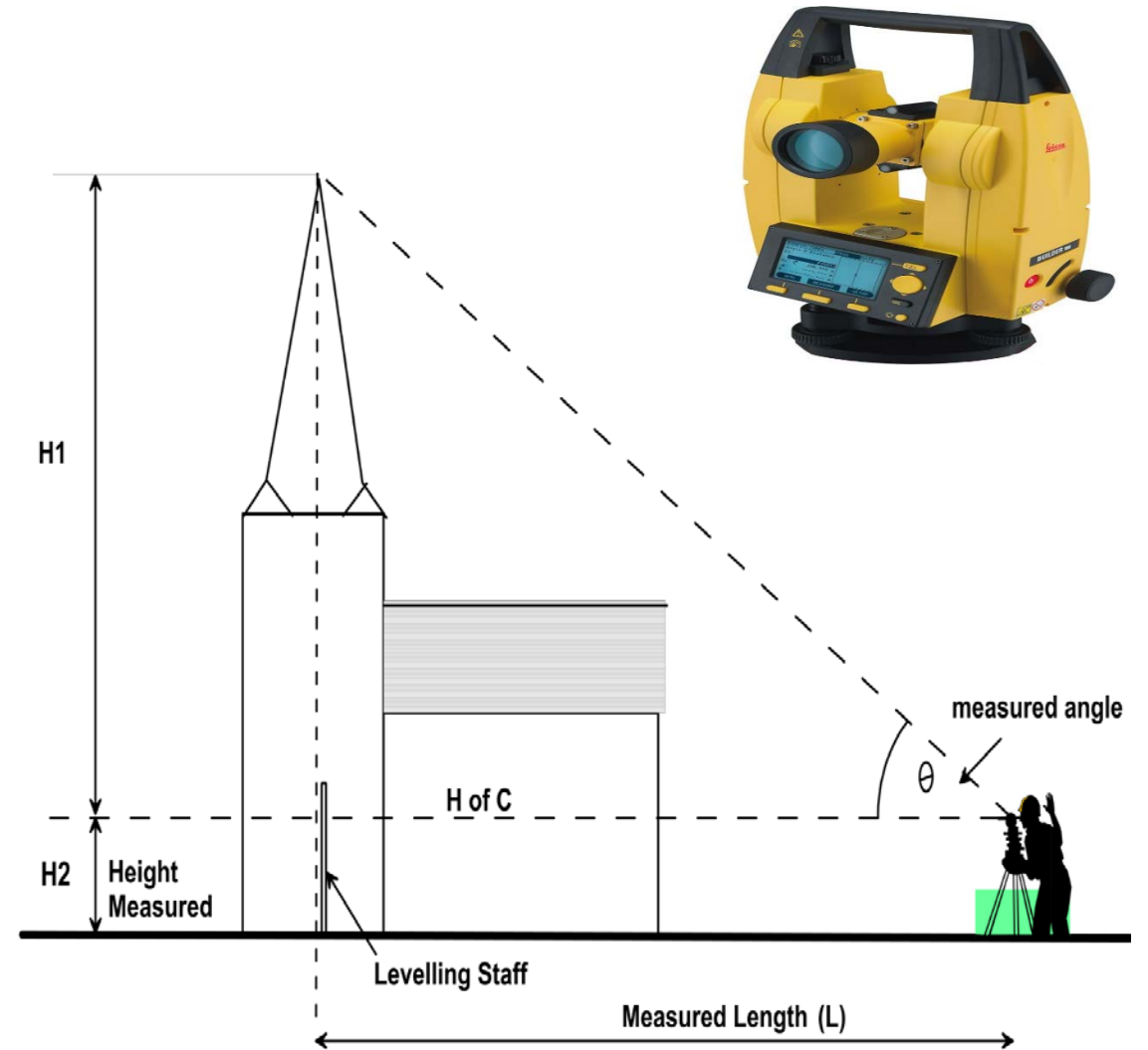


Height Measurement

Trigonometric Heighting using theodolite

Procedure:-

- Set up instrument
- Measure vertical angle between horizontal and object to be measured
- Measure horizontal distance using tape or stadia method
- Measure height between ground level and horizontal plane or datum



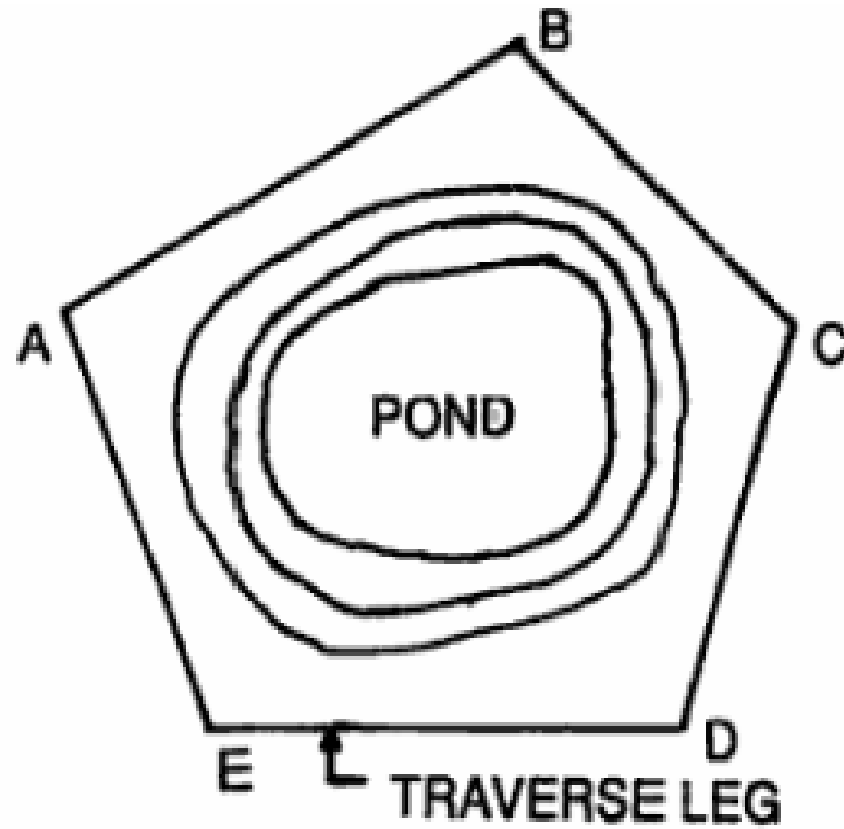
$$\text{Height } (H1 + H2) = (\tan \theta \times L) + H2$$

Traversing

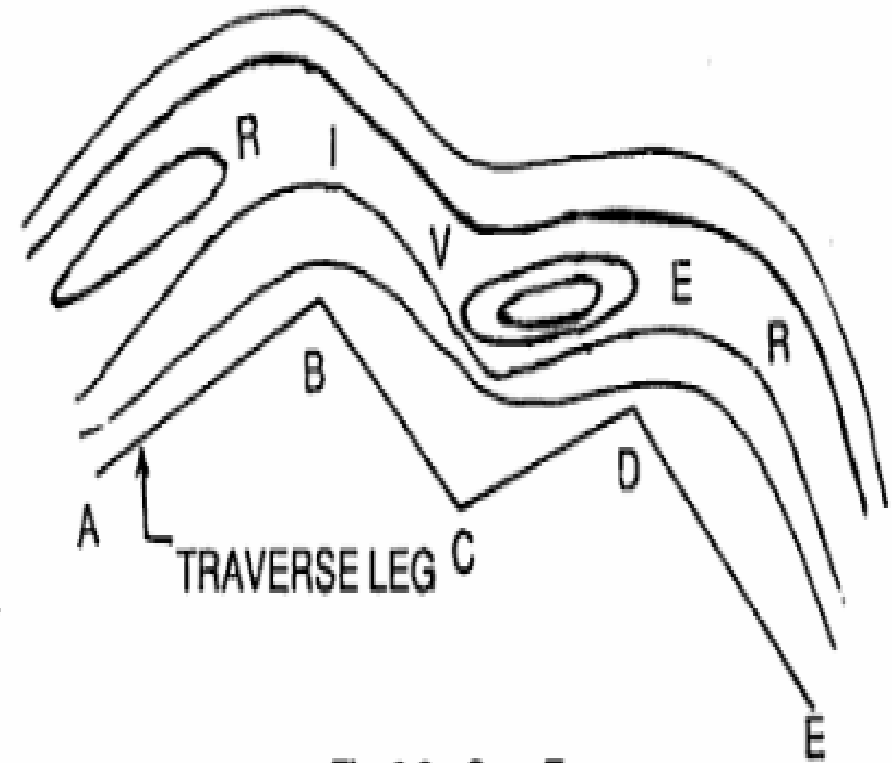
What is Traversing ?

- A traverse consists of a series of straight lines connecting successive points.
- The points defining the ends of the traverse lines are called traverse stations or traverse points
- Distance along the line between successive traverse points is determined either by direct measurement using a tape or electronic distance measuring (EDM) equipment, or by indirect measurement using tachometric methods.
- At each point where the traverse changes direction, an angular measurement is taken using a theodolite.

Close and Open Traverse



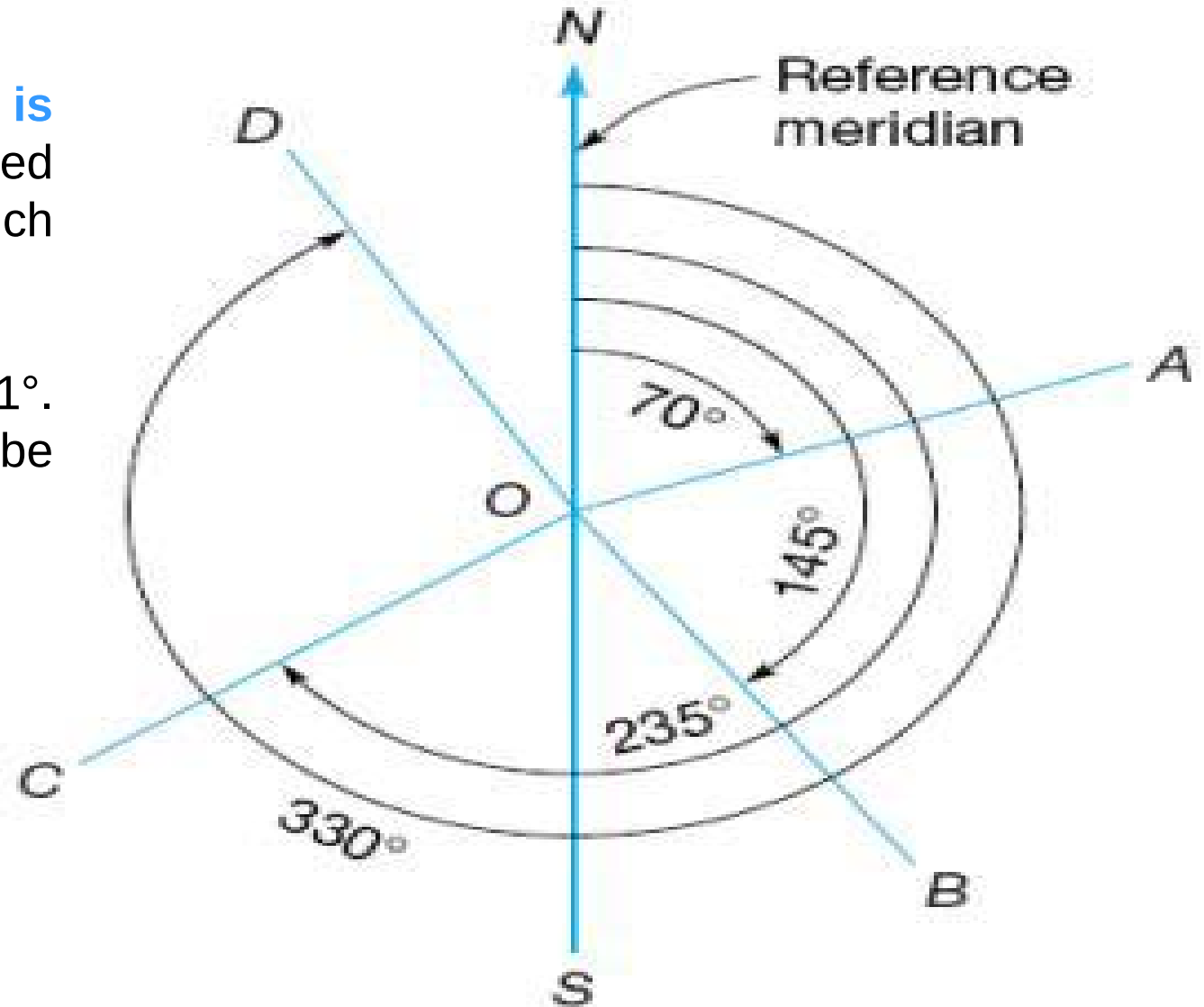
Close Traverse



Open Traverse

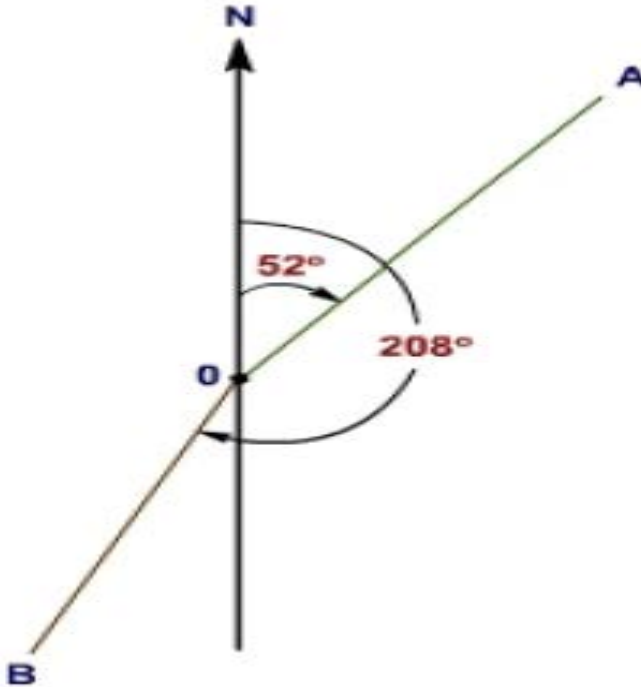
Terms in Traversing

- **Whole Circle Bearing or Azimuth** is defined as horizontal angle turned clockwise from the reference line. Which is between the ranges from 0° to 360° .
- For example: 128° , 239° and 351° . Generally, the angles should be measured only from the north.



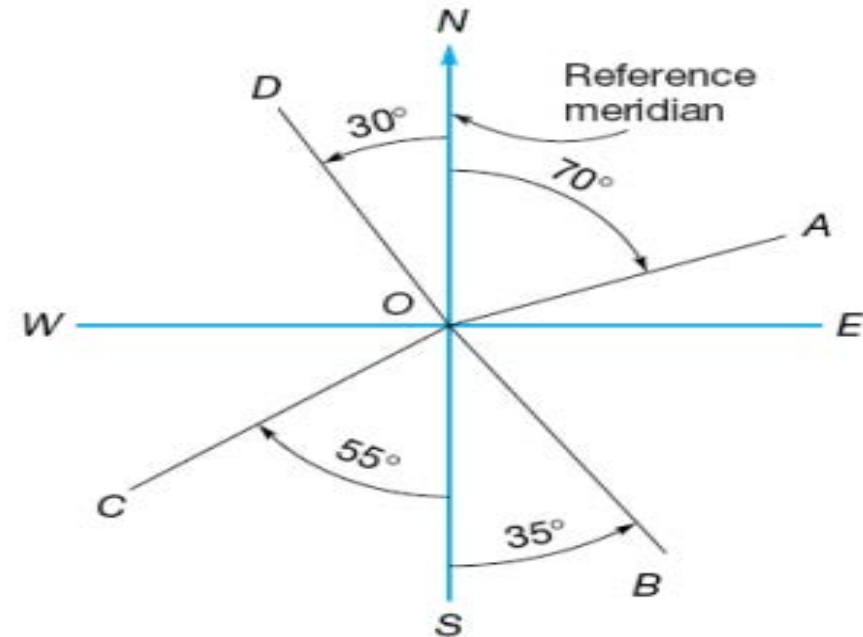
Whole Circle Bearing

Whole circle bearing (W.C.B) of a line is the horizontal angle measured clockwise from the North limb of the meridian. It varies from 0° to 360°



Bearing

- Bearings is defined as an acute angle which is less than 90° . It is a horizontal angles measured from the meridian either east or west.
- Usually required two letter with an acute angle which is North (N), South (S), East (E) & West (W).
- The different between azimuths and bearing is bearing can be measured both either clockwise or counter clockwise. It can be measured from North or South axis of the meridian.



Angular Measurement

Angles in traversing are measured in degrees, minutes, seconds

How to convert degrees, minutes, seconds to decimal degrees

One degree is equal to 60 minutes and equal to 3600 seconds:

$$1^{\circ} = 60' = 3600''$$

One minute is equal to 1/60 degrees:

$$1' = (1/60)^{\circ} = 0.01666667^{\circ}$$

One second is equal to 1/3600 degrees:

- $1'' = (1/3600)^{\circ} = 2.77778e-4^{\circ} = 0.000277778^{\circ}$

- One minute is equal to 1/60 degrees:

$$1' = (1/60)^{\circ} = 0.01666667^{\circ}$$

- One second is equal to 1/3600 degrees:

$$1'' = (1/3600)^{\circ} = 2.77778e-4^{\circ} = 0.000277778^{\circ}$$

- For angle with d integer degrees m minutes and s seconds:

- $d^{\circ} m' s''$

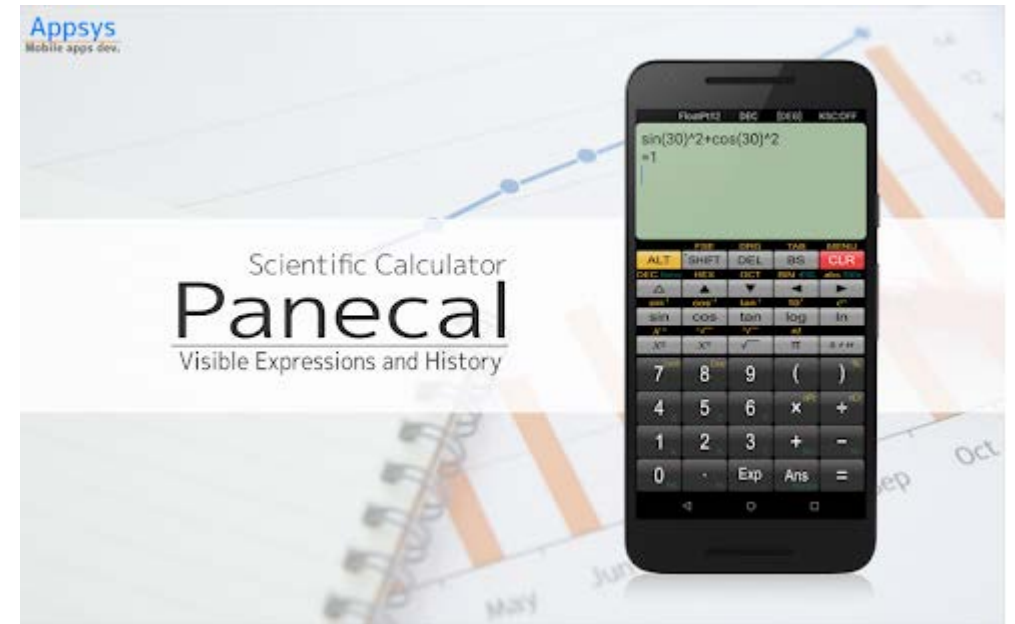
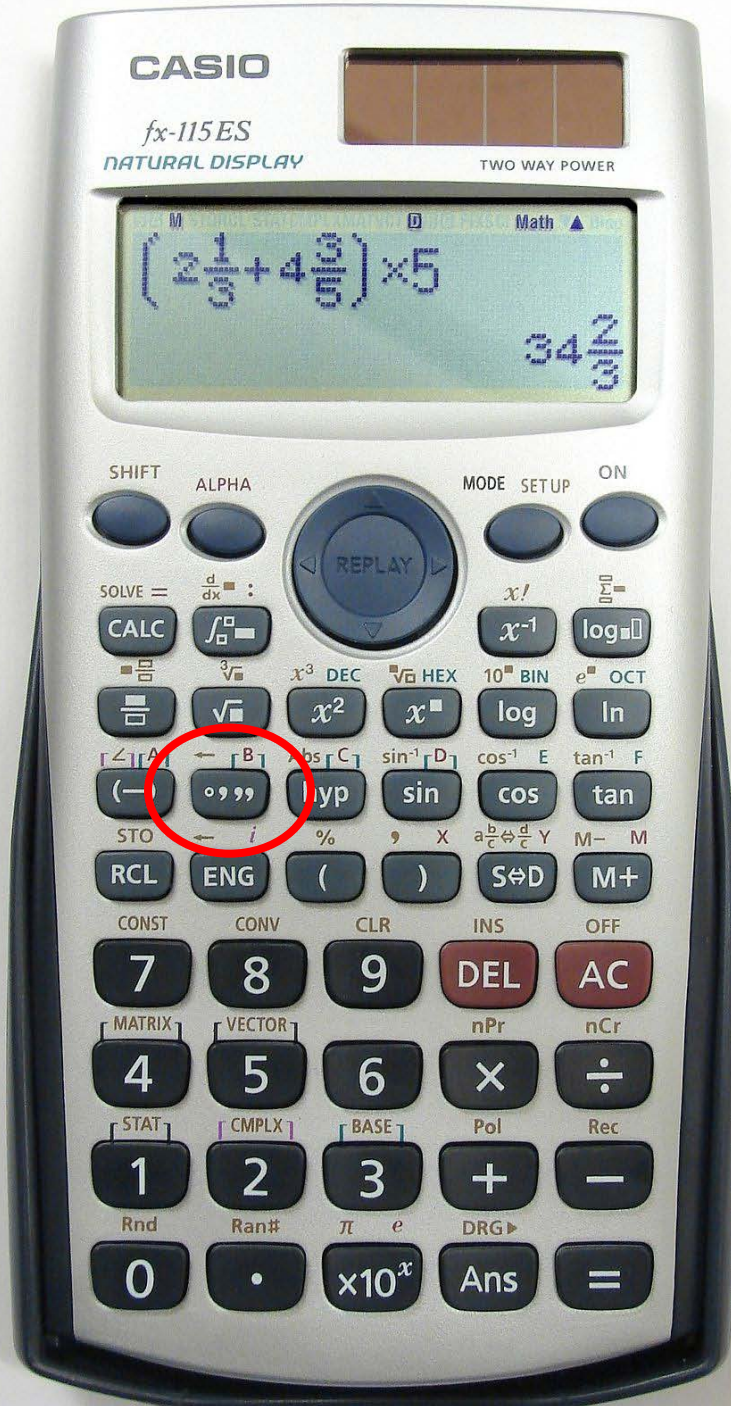
Example

Convert 30 degrees 15 minutes and 50 seconds angle to decimal degrees:

$$30^{\circ} 15' 50''$$

The decimal degrees dd is equal to:

$$\text{dd} = d + m/60 + s/3600 = 30^{\circ} + 15'/60 + 50''/3600 = 30.263888889^{\circ}$$



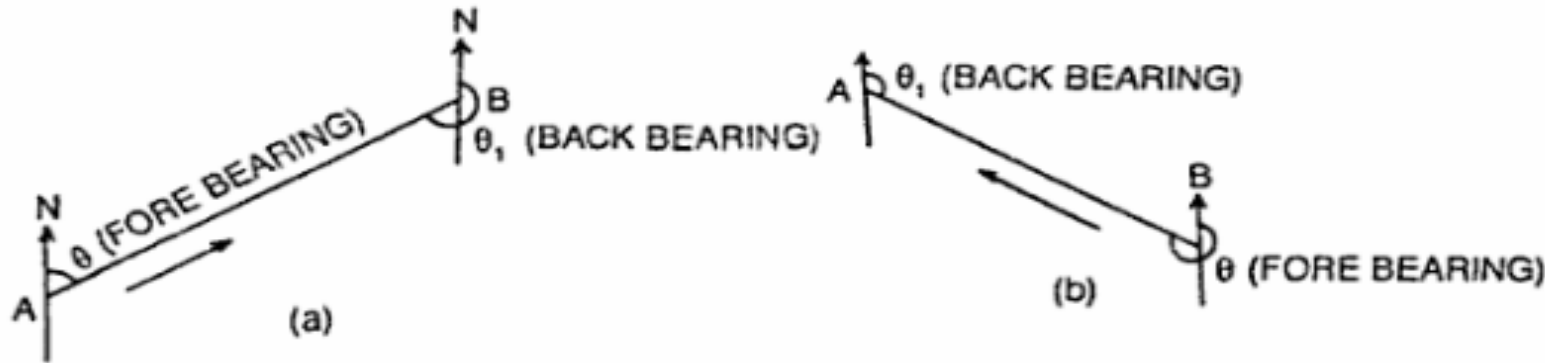
Fore Bearing and Back Bearing

➤ Fore bearing or Forward Bearing:
The bearing of a line measured in the forward direction (i.e., along the progress of survey) is known as fore bearing.

➤ Fore bearing = Back bearing $\pm 180^\circ$

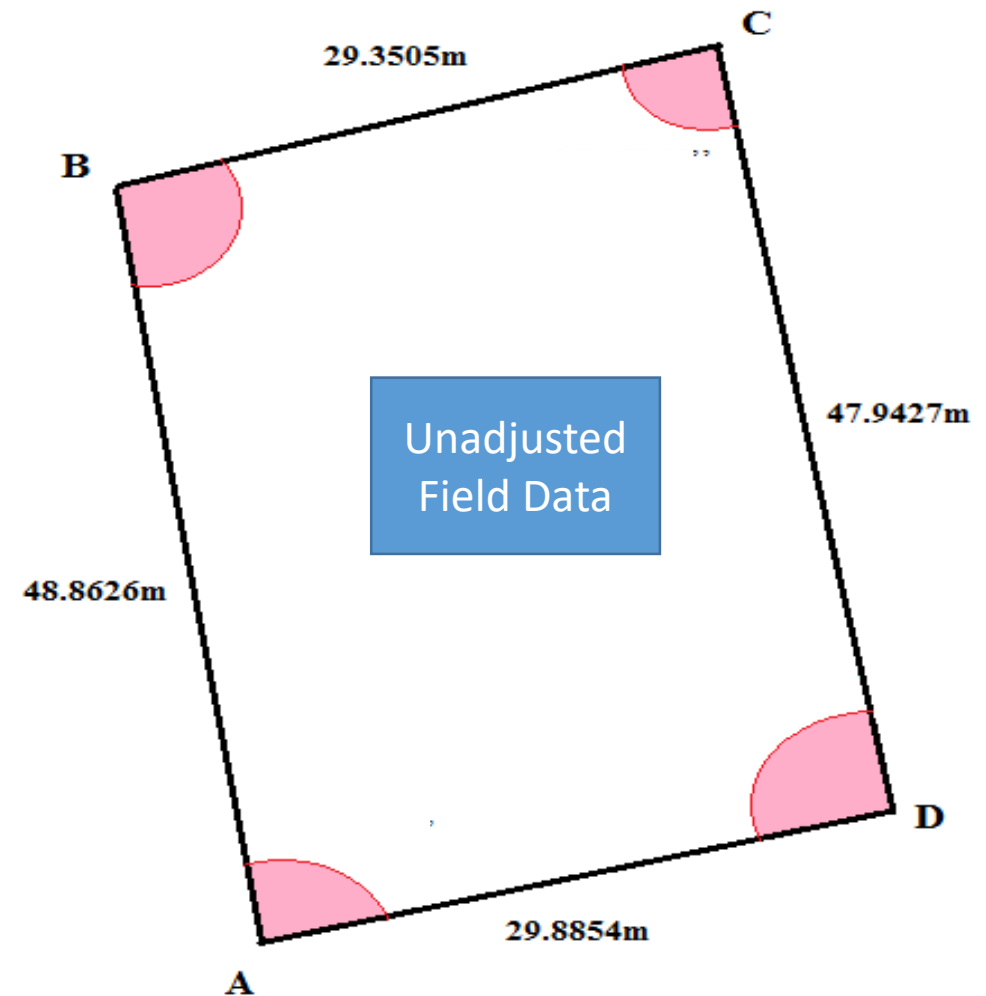
➤ Back Bearing: The bearing of a line measured in the backward direction (i.e., opposite to the direction of progress of survey) is known as back bearing.

➤ Back Bearing = Fore Bearing $\pm 180^\circ$



Example of Field Data

Station	Field Angles
A	$86^{\circ} 44' 20''$
B	$92^{\circ} 39' 40''$
C	$86^{\circ} 46' 20''$
D	$93^{\circ} 46' 40''$
Total	$357^{\circ} 175' 120''$



Computation of Angular Error and Adjustments of Angles

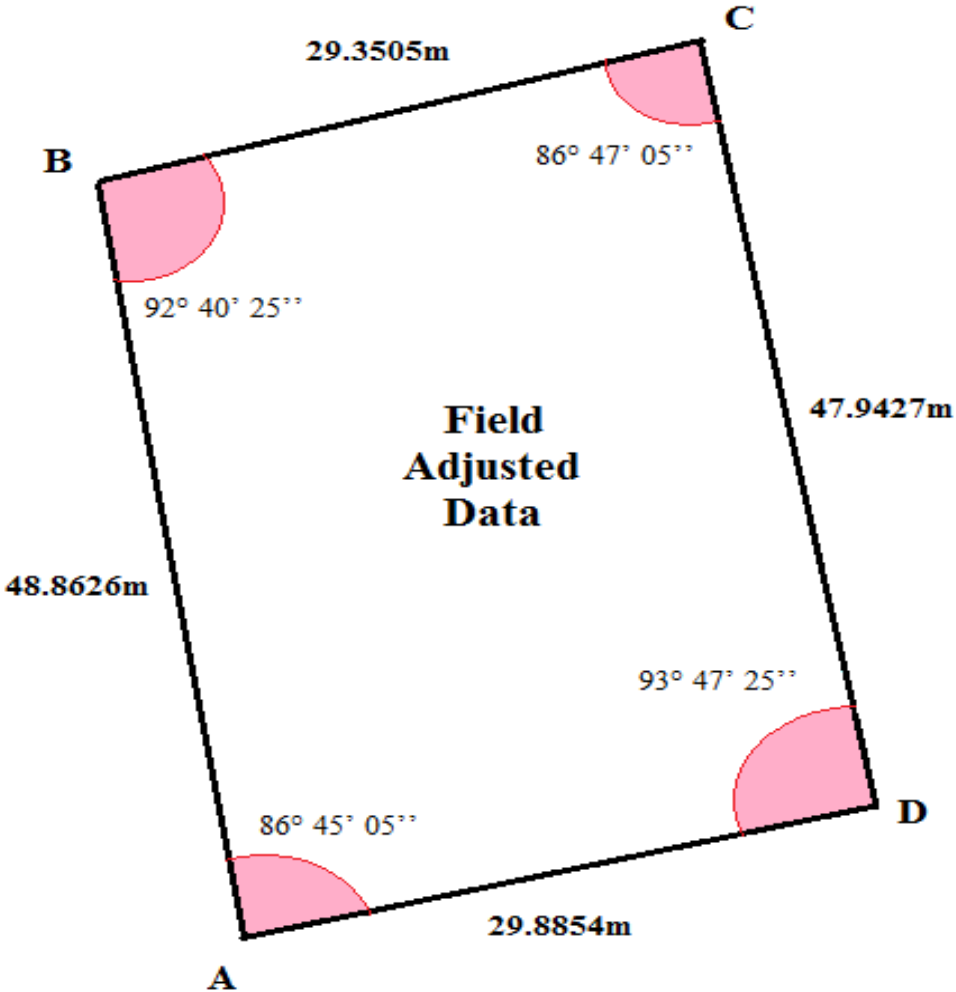
The sum of the interior angles in any loop traverse must equal to 360° .

$$\begin{aligned}\text{Total angular error} &= 360^\circ - 359^\circ 57' 00'' \\ &= 00^\circ 03' 00''\end{aligned}$$

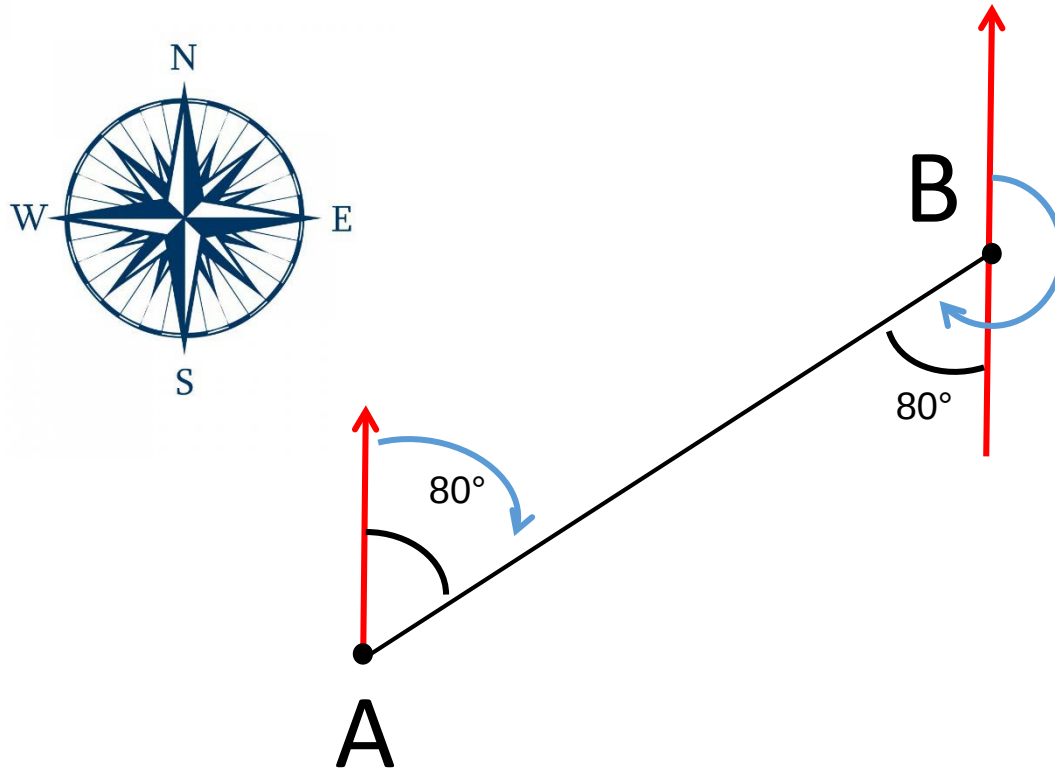
$$\text{Error per angle} = 00^\circ 03' 00'' / 4$$

$$= 00^\circ 00' 45'' / 45'' \text{ per angle}$$

Station	Field Angle	Correction	Adjusted Angles
A	86° 44' 20"	+ 00° 00' 45"	86° 45' 05"
B	92° 39' 40"	+ 00° 00' 45"	92° 40' 25"
C	86° 46' 20"	+ 00° 00' 45"	86° 47' 05"
D	93° 46' 40"	+ 00° 00' 45"	93° 47' 25"
Total	359° 57' 00"		360° 00' 00"



Calculating Bearings and Whole Circle Bearings



- Bearing from A – B is N80°E
- WCB A - B is 80°
- The Bearing from B – A is S80°W
- WCB B-A is 260°(80 + 180)

Closed Traverse

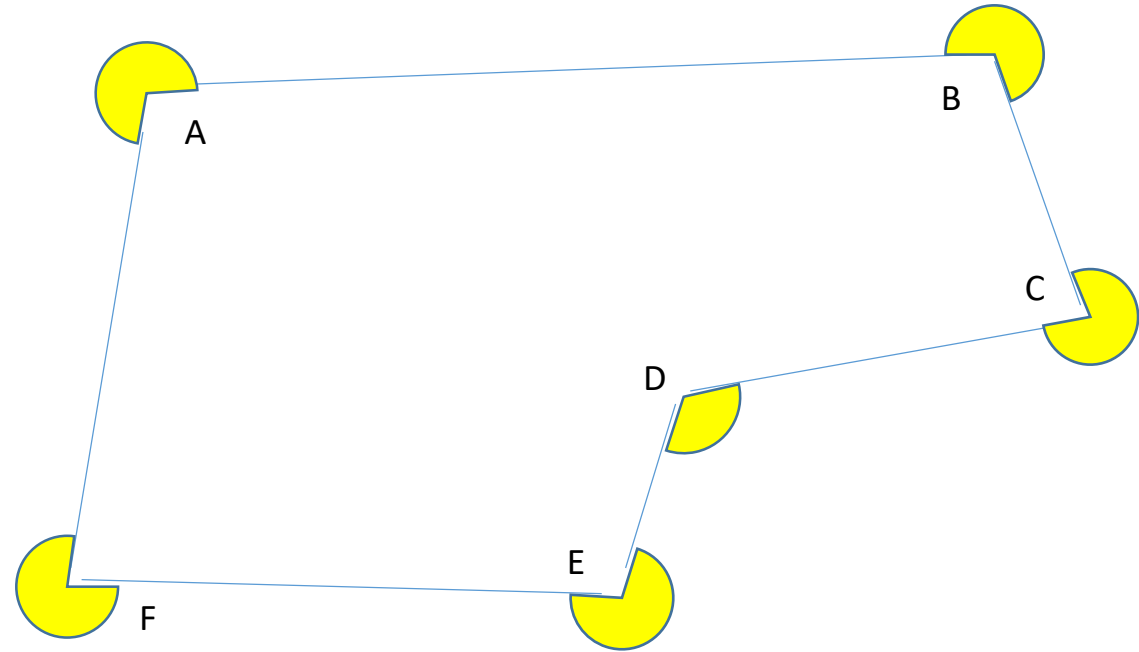
In a closed traverse the lines form a closed polygon.

Exterior angles are measured in a clockwise direction. (Interior angles in an anticlockwise direction can also be measured instead).

To check the accuracy of the measured exterior angles this small formula is used:-

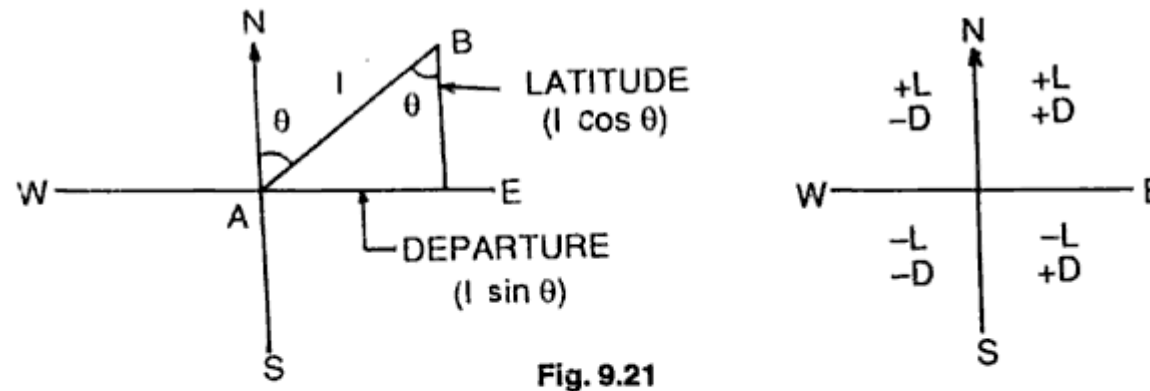
$(2n+4)90$ where 'n' is the sum of the number of sides.

$$((2 \times 6) + 4) \times 90 = 1440$$



Computation of Latitude and Departure (Northings and Eastings)

- Latitude (Northing) of a line is the distances measured parallel to the north south of the North-South direction
- Departure (Easting) of the line is the distance measured parallel to the east-west direction



The latitude and departure of lines are also expressed in the following ways:

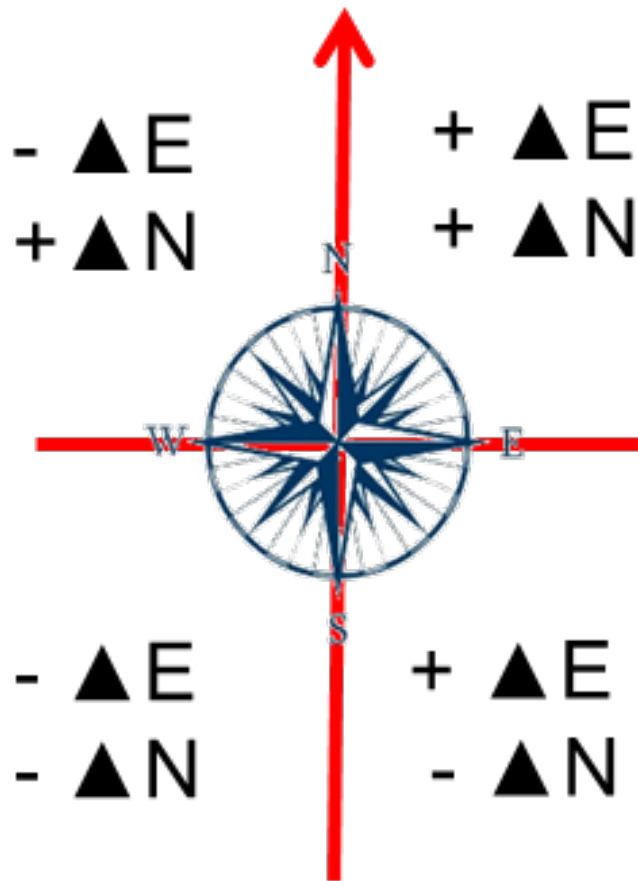
Northing = latitude towards north = $+L$

Southing = latitude towards south = $-L$

Easting = departure towards east = $+D$

Westing = departure towards west = $-D$

Computation of Latitude and Departure (Northings and Eastings)



Latitudes and Departures are now considered positive and negative Northings and Eastings

Class Exercise 1

A contractor requires new fencing to the one edge of a site boundary.

The two end points of the boundary 'A and B' have given Northing and Eastings positions.

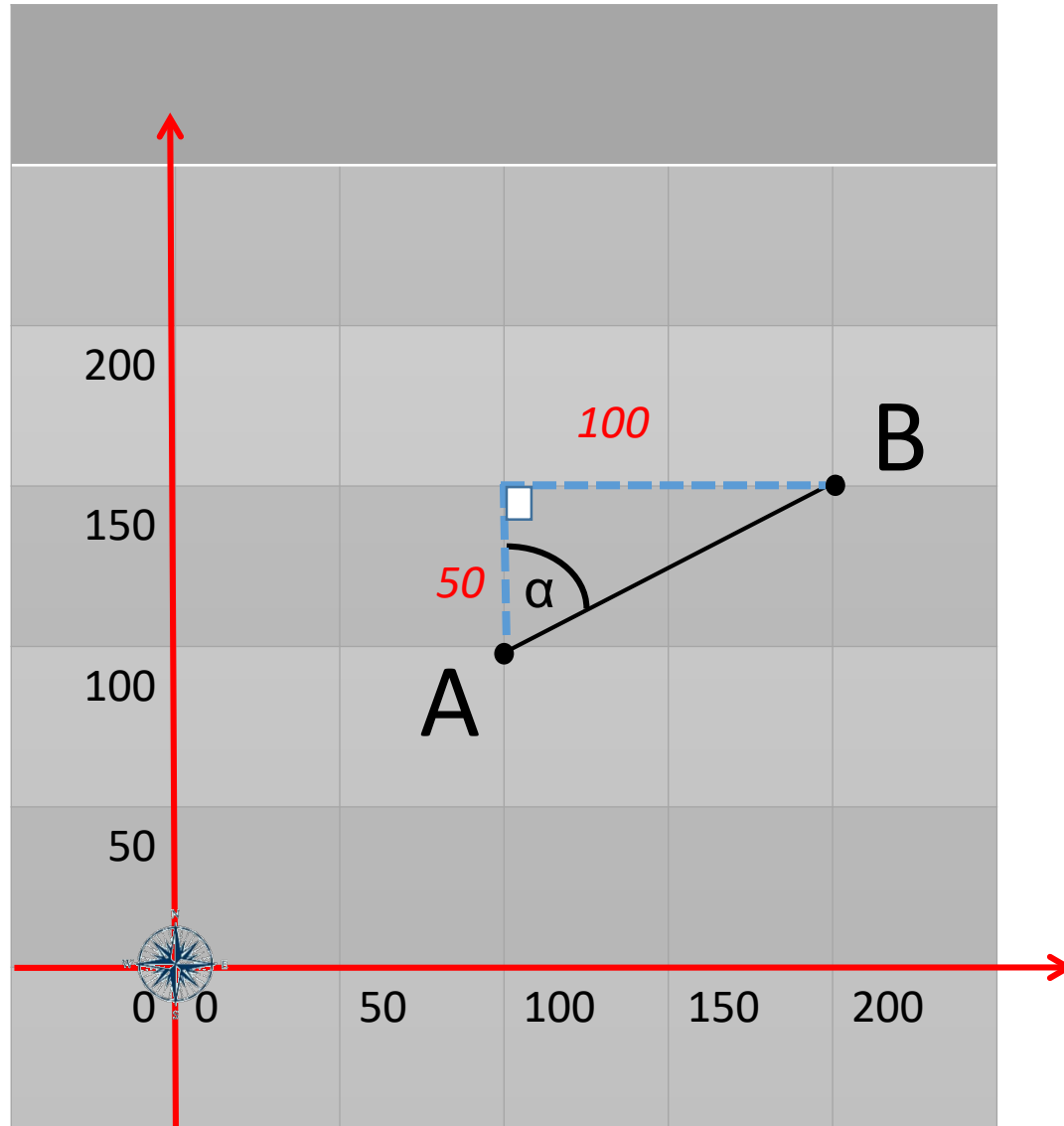
Calculate the distance between the two points to determine the length of fencing required, and calculate the Whole Circle Bearing from A – B to allow setting out of the fencing along the angle.

WCB must be expressed in Degrees, Minutes and Seconds.

Point A 100N 100E

Point B 150N 200E

Class Exercise 1



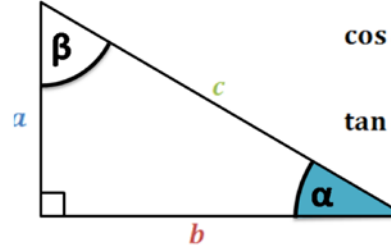
Trigonometry

SOH CAH TOA

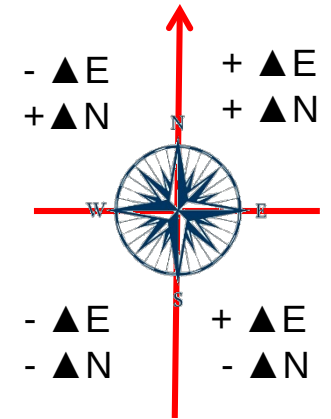
$$\sin \alpha = \frac{a}{c} \quad \begin{array}{l} \text{Opposite} \\ \text{Hypotenuse} \end{array}$$

$$\cos \alpha = \frac{b}{c} \quad \begin{array}{l} \text{Adjacent} \\ \text{Hypotenuse} \end{array}$$

$$\tan \alpha = \frac{a}{b} \quad \begin{array}{l} \text{Opposite} \\ \text{Adjacent} \end{array}$$



Pythagorean Theorem $a^2 + b^2 = c^2$



Distance AB

$$50^2 + 100^2 = AB^2$$

$$\sqrt{(50^2 + 100^2)} = AB$$

$$AB = 111.803\text{m}$$

Whole Circle Bearing α

$$\tan \alpha = \text{Opp/Adj}$$

$$\tan \alpha = 100/50$$

$$\alpha = (100/50)\tan^{-1}$$

$$\alpha = 63.43494882^\circ$$

$$\alpha = 63^\circ 26' 06''$$

Class Exercise 2

A new swale is required to cross a proposed wetland site. You have been asked to mark out the position of the swale from limited field data.

Point A 100E 100N

Point B 50E 75N

Point C is 75m away from Point A and an exterior angle BAC of 170deg was measured.

Calculate:

The distance between B and A

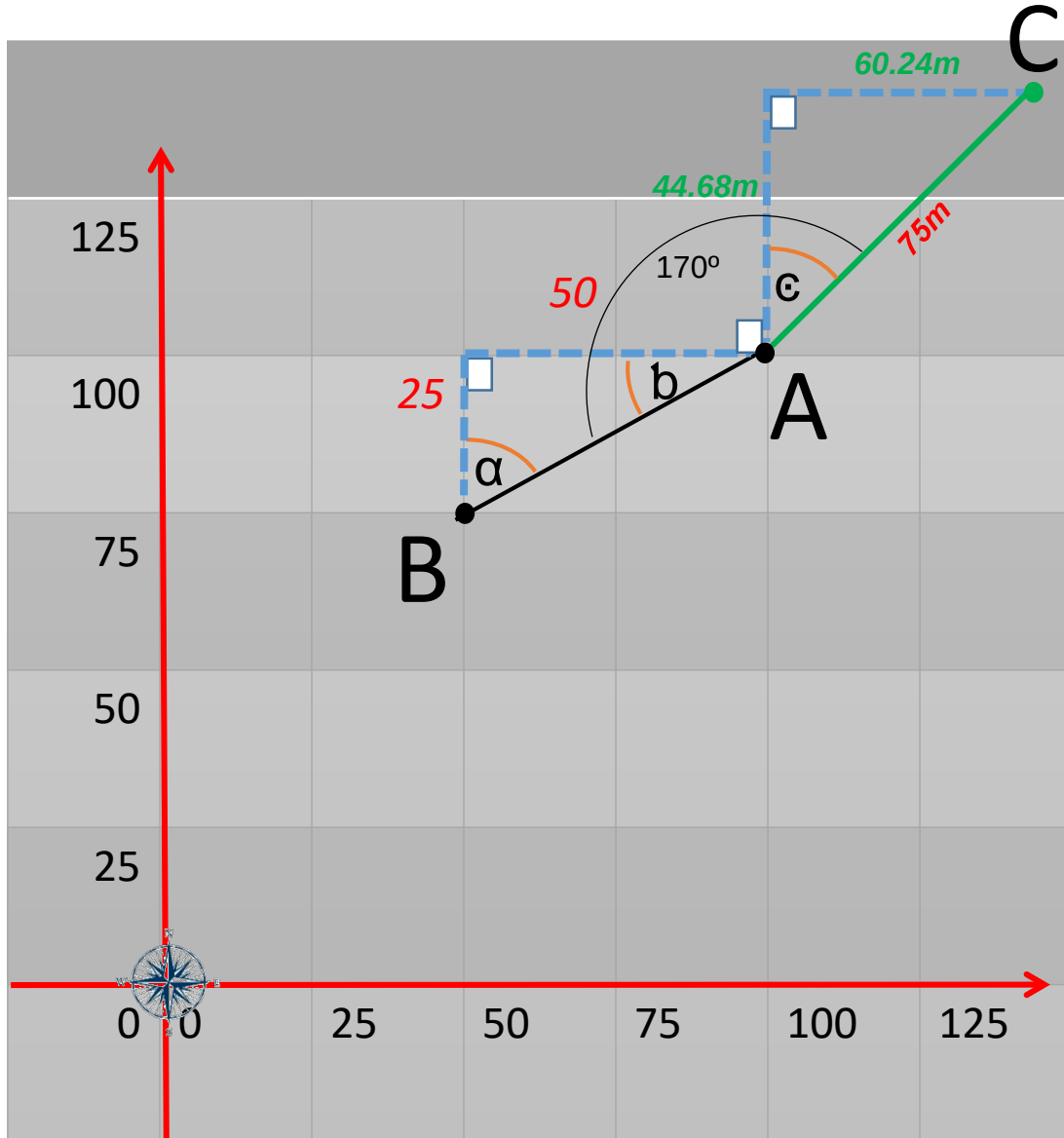
The Whole Circle Bearing from B – A

WCB from A – C

The Northings and Eastings of point C

WCB must be expressed in Degrees, Minutes and Seconds.

Class Exercise 2



Distance AB

$$25^2 + 50^2 = AB^2$$

$$\sqrt{(25^2 + 50^2)} = AB$$

$$AB = 55.902m$$

WCB α

$$\tan \alpha = \text{Opp/Adj}$$

$$\tan \alpha = 100/50$$

$$\alpha = (50/25)\tan^{-1}$$

$$\alpha = 63.43494882^\circ$$

$$\alpha = 63^\circ 26' 06''$$

As all angles in a triangle add to 180°

$$b = 180^\circ - 90^\circ - \alpha$$

$$b = 26^\circ 33' 54''$$

WCB c

$$= 170^\circ - 90^\circ - b$$

$$= 170^\circ - 90^\circ - 26^\circ 33' 54''$$

$$\text{WCB } c = 53^\circ 26' 06''$$

Northings & Eastings of C

$$\sin c = \text{opp/hyp}$$

$$\sin (53^\circ 26' 06) = \text{opp} / 75$$

$$\text{Opp} = 60.24m$$

$$\text{Eastings of Point C}$$

$$= 100 + 60.24 = 160.24E$$

$$\cos c = \text{adj/hyp}$$

$$\cos (53^\circ 26' 06) = \text{Adj} / 75$$

$$\text{Adj} = 44.68m$$

$$\text{Northings of Point C}$$

$$= 100 + 44.68 = 144.68N$$

Levelling



What is Levelling?

- Levelling is the general term applied to any of the various processes by which elevations of points or differences in elevation are determined.
- Levelling is defined as 'an art of determining the relative height of different points on, above or below the surface'.
- The principle of levelling is to obtain the horizontal reference line to which vertical distances of points can be measured.
- Instruments of levelling can be used for building and infrastructure projects thus assisting in the design the highways, sewers, railways and other built forms of construction.
- It can used to calculate the volumes of earthworks and used as site layout for new foundations, contouring, drainage and estimate the fall / gradient of pipework.

When do we level?

- To determine the difference in height between two or more points.
- To determine the height of discrete points.
- To provide spot heights or contours on plan.
- To provide the data for road cross-sections or volume of the earthworks.
- To provide a level or inclined plane in the setting out of construction works.

Levelling Equipment

For carrying out your project work you need to borrow the following equipment:

➤ Level

➤ Tripod

➤ Staff (5 metre)

➤ Staff bubble

➤ Field book

➤ Measuring tape (50 metre)

➤ Plumb bob

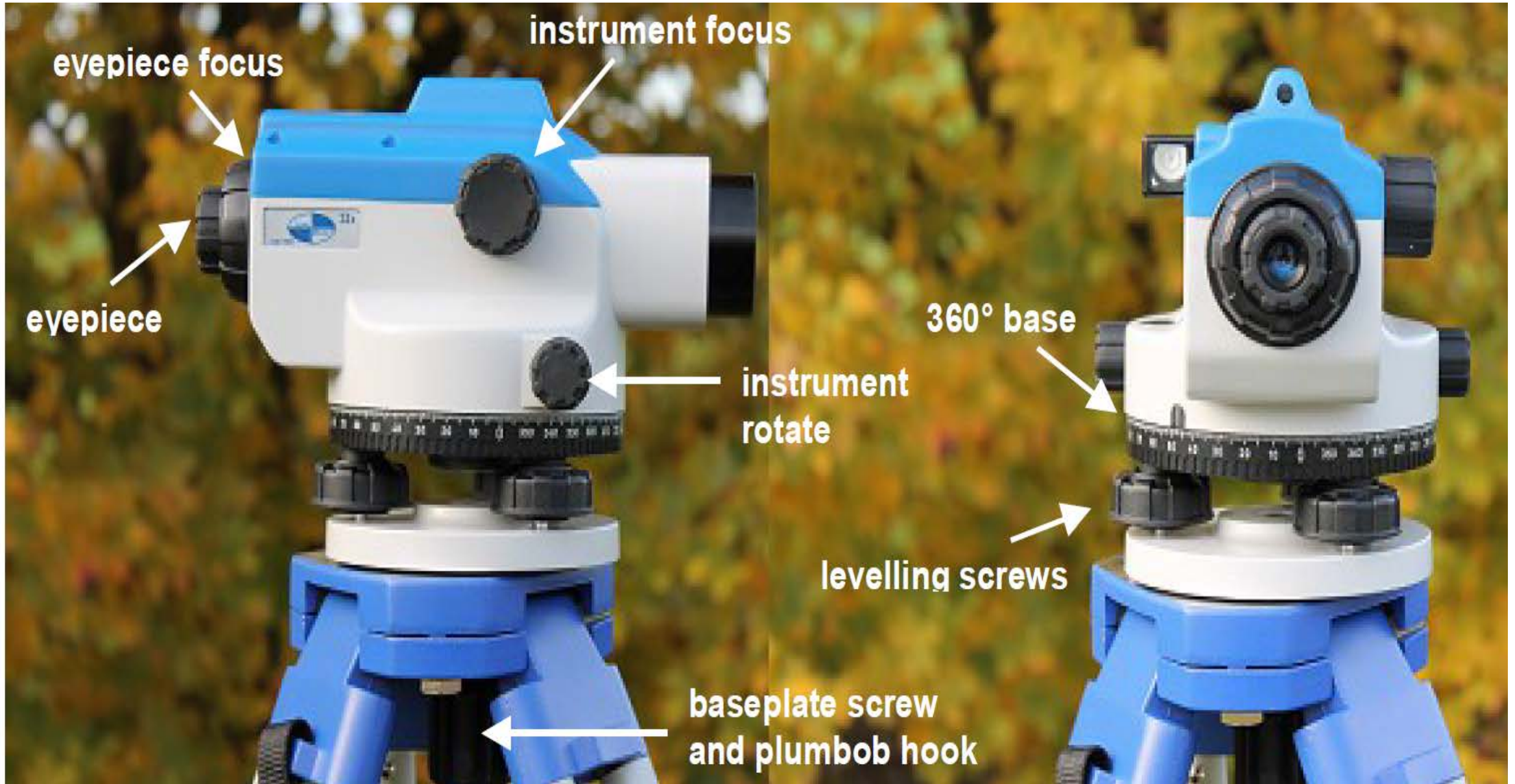


Care of Equipment

- Ensure that tripod screws and hinges are kept tight.
- Always transport the level in a padded box.
- When removing from the box lift it by the centre and not by the eyepiece or objective end of the telescope.
- Screw it firmly onto the tripod, whilst holding it in one hand (make certain that it is not cross-threaded and that threads are compatible).
- When carrying the level tripod assembly in the field, support it over the shoulder or, in bush, crooked over an arm with the telescope unclamped (i.e. free to rotate).
- Automatic levels should not be carried in a vertical or near-vertical position, as the compensator will swing about and be prone to damage

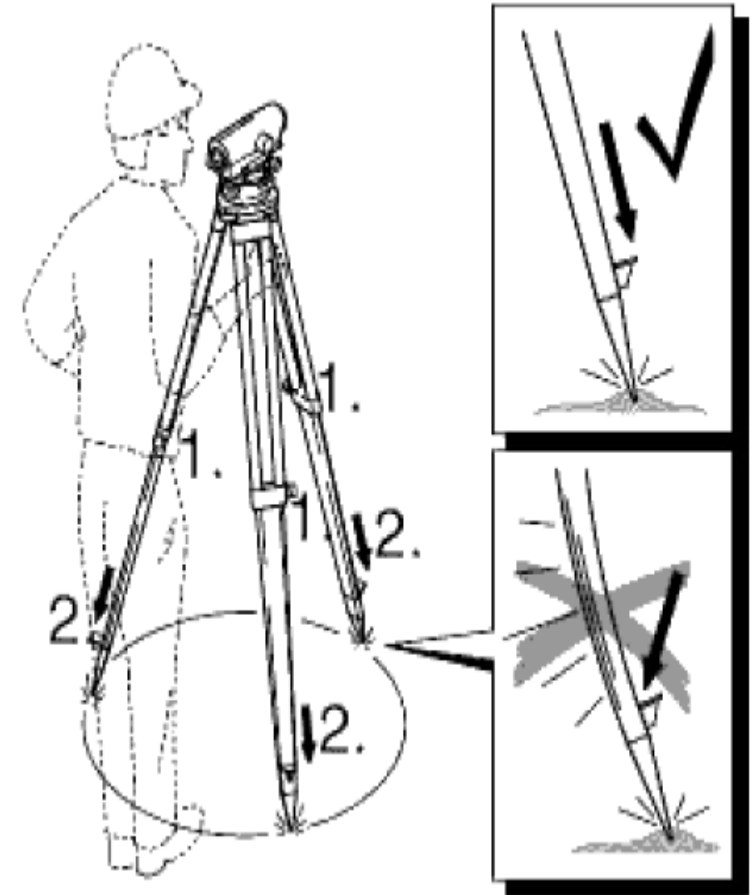
Care of Equipment

- Staves are too much of a precision item of equipment to be used in place of a slasher, vaulting pole, etc.
- Staves shall be transported in their protective cases to protect the face from damage.
- Wooden staves which become wet should be dismantled and dried out before storing away.
- Any moisture which is evident in an instrument must be allowed to disperse by storing the level out of its case in a warm room. Should it persist after several days the instrument may require specialist servicing.



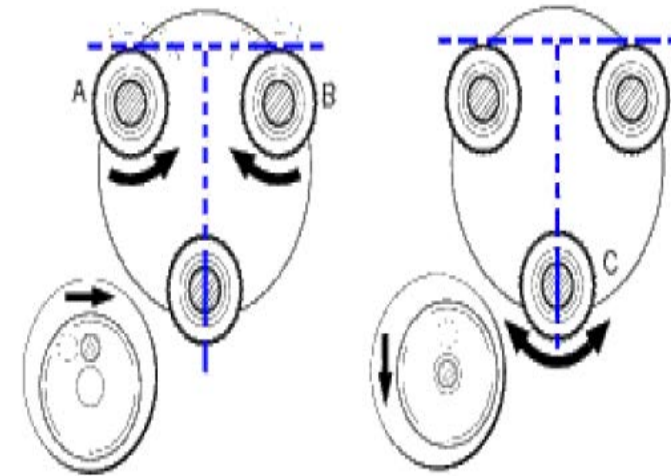
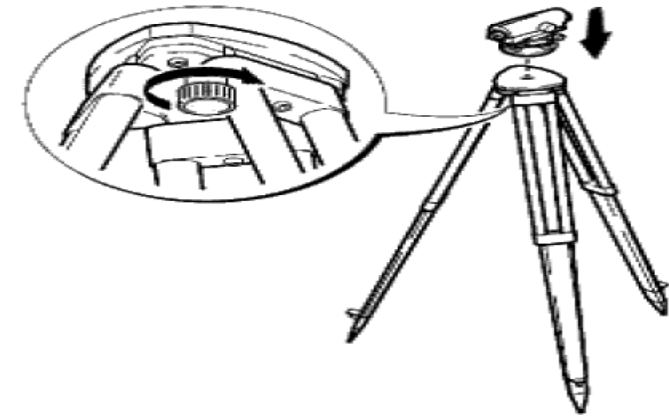
Setting up - the tripod

1. Loosen screws of tripod legs, pull out to required length and tighten screws.
2. In order to guarantee a firm foothold sufficiently press the tripod legs into the ground. When pressing the legs into the ground note that the force must be applied along the legs.
3. Check all screws and bolts for correct fit.



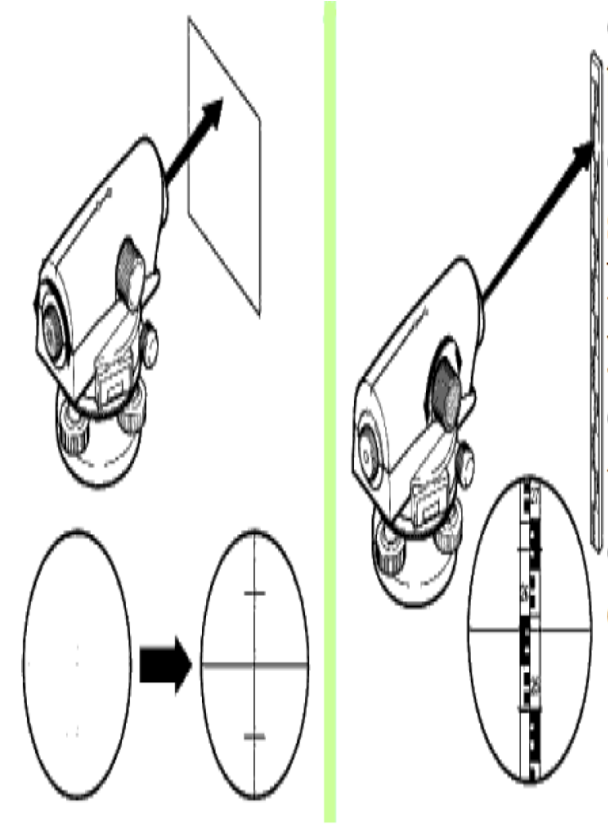
When setting up the tripod pay attention to the horizontal position of the tripod plate. Minor inclinations of the tripod can be corrected with the foot screws of the tribrach.

- Place level onto tripod head. Tighten central fixing screw of tripod.
- Turn foot screws A and B simultaneously in opposite directions until bubble is in the centre (on the imaginary "T").
- Turn the instrument 90° and then turn the foot screw C until bubble is centred.

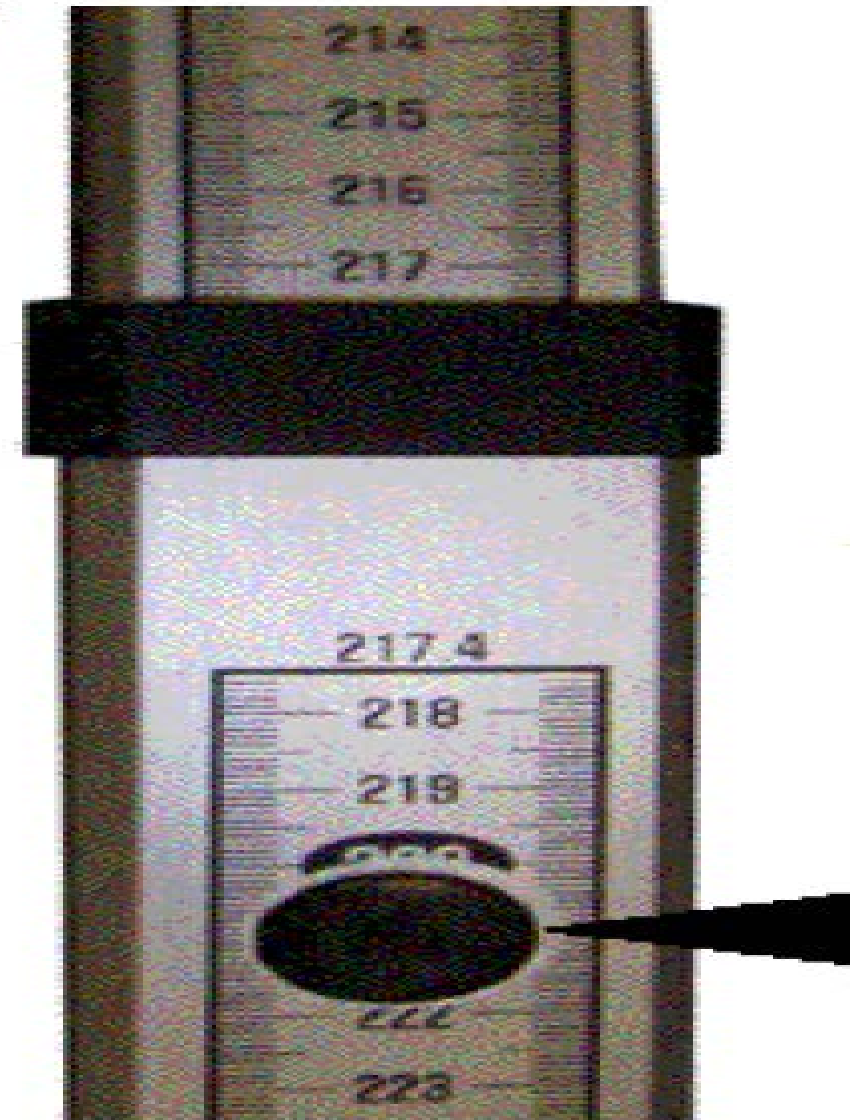
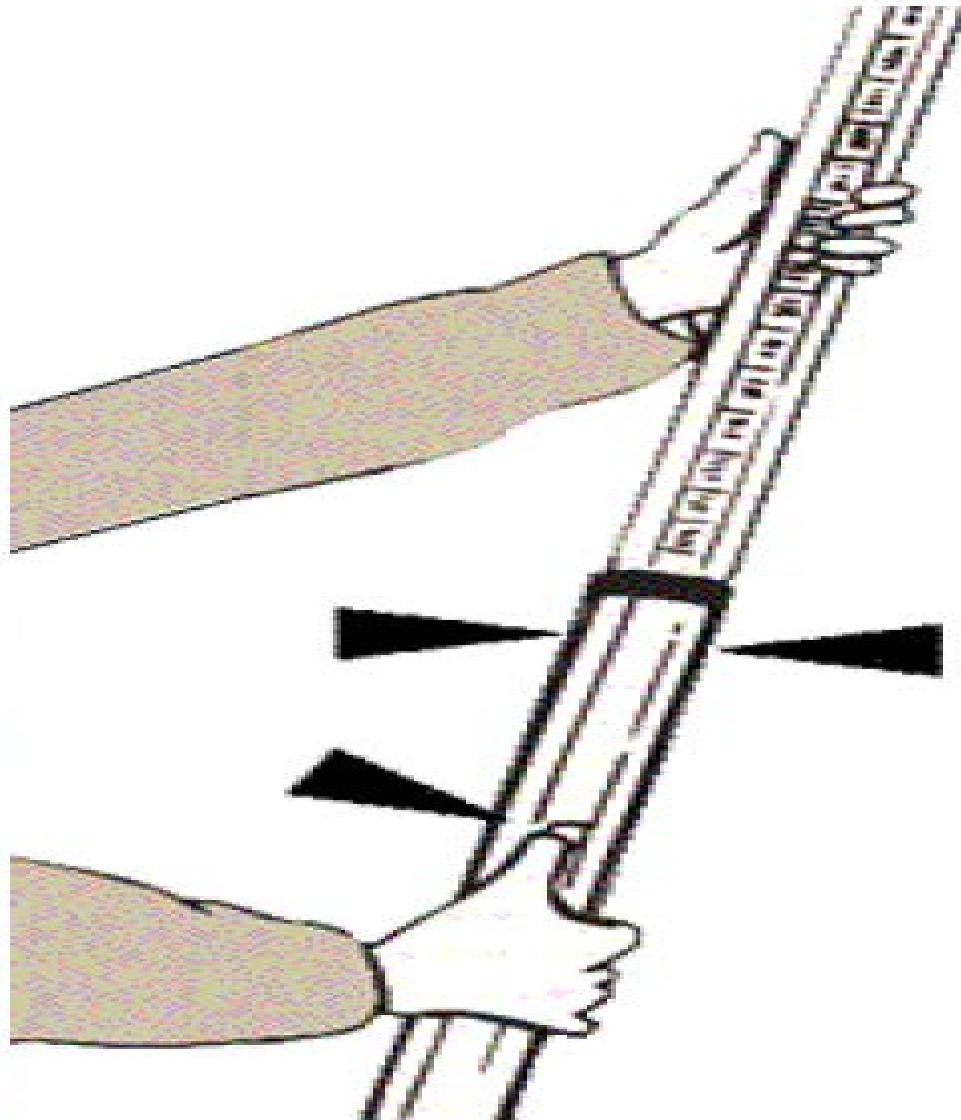


Focusing telescope

- Aim telescope against a bright background (e.g. white paper).
- Turn eyepiece until reticule is sharp-focused and deep black. Now the eyepiece is adapted to your eye.
- Aim telescope on staff using the coarse aiming device.
- Turn focusing knob until image of staff is sharply focused.



Levelling Staff



Staff Reading

The figure below shows three different staff readings:

It is easy to read (b) and (c) because the cross-hair is exactly on a mark division.

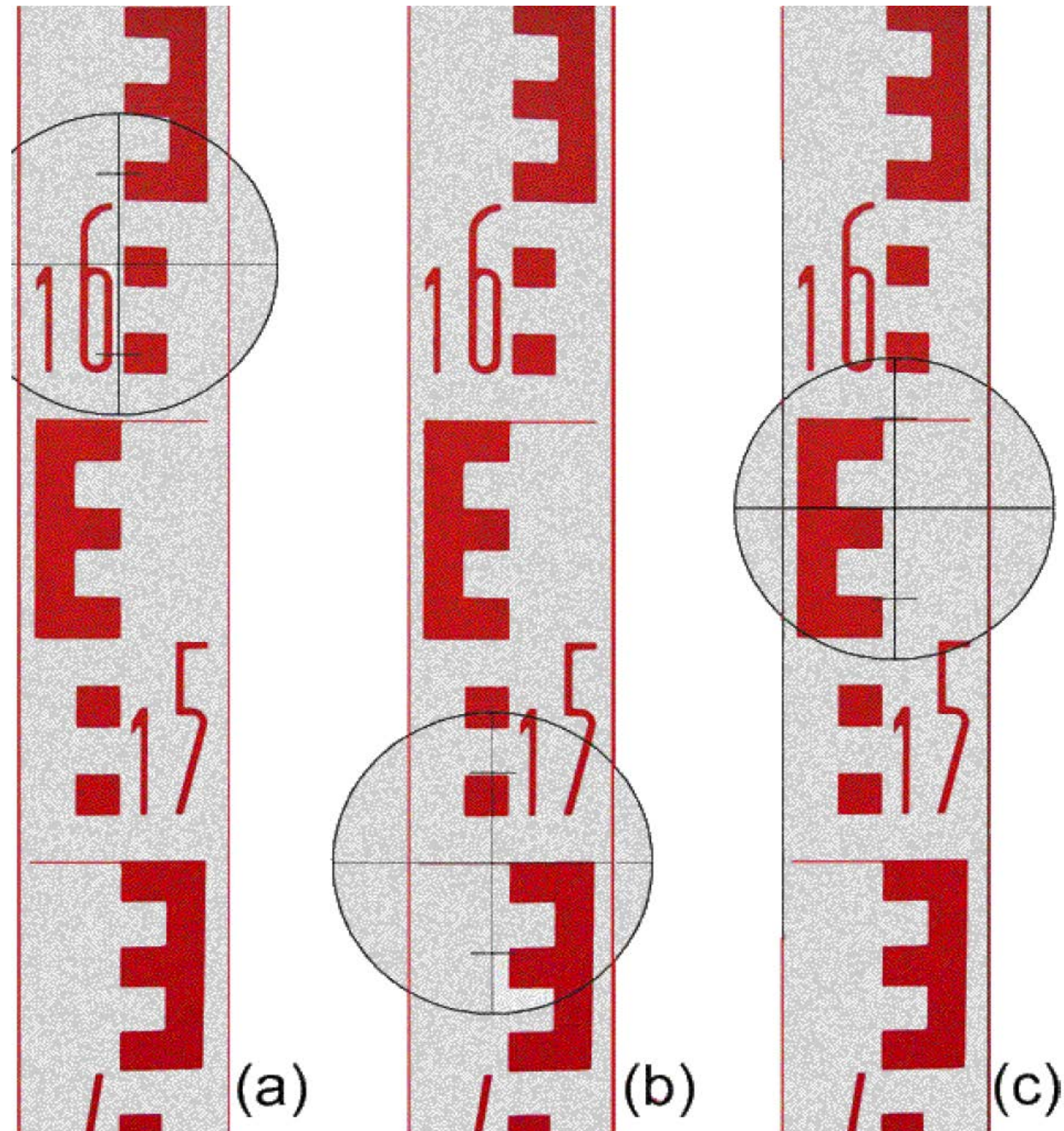
The reading for (a) is between 1.630 and 1.640.

To assess the mm reading you have to estimate where the position of the cross-hair is.

For (a) the reading is 1.636.

The millimetre reading is to be estimated and can vary between ± 1 mm.

a.) 1.636 b.) 1.500 c.) 1.580



Plumb bobs

- A plumb-bob or a plummet is a weight with a pointed tip on the bottom that is suspended from a string and used as a vertical reference line.
- Small plumb bobs are often included in the kits of various instruments such as levels and theodolites.
- They are used to set the instrument exactly over a fixed datum marker, prior to taking fresh readings

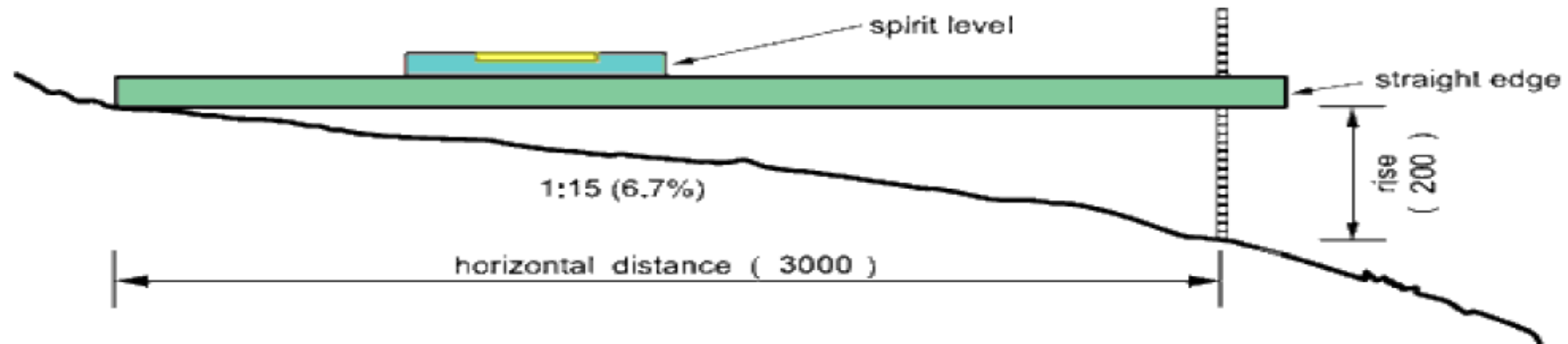


Methods of Levelling



Basic Straight Edge Levelling

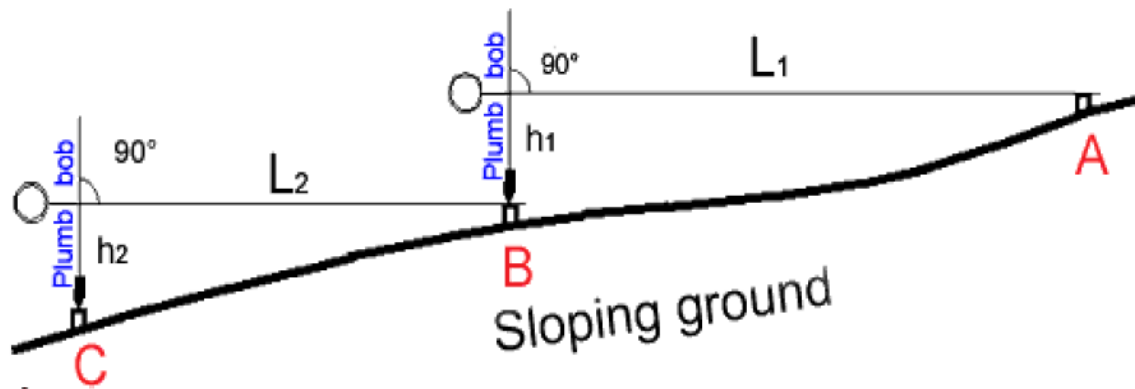
- A 'straight edge' in conjunction with a spirit level and tape measure can be used to establish a gradient.
- The straight edge is usually 3 to 5 metres long and set horizontally with the aid of a spirit level.
- This method should be used for the measurement of gradients which continue only for short distances, e.g. to calculate the horizontal distance shown in plan-views. The figure below shows how a gradient for the ground profile is found.



Gradient = Rise / horizontal distance

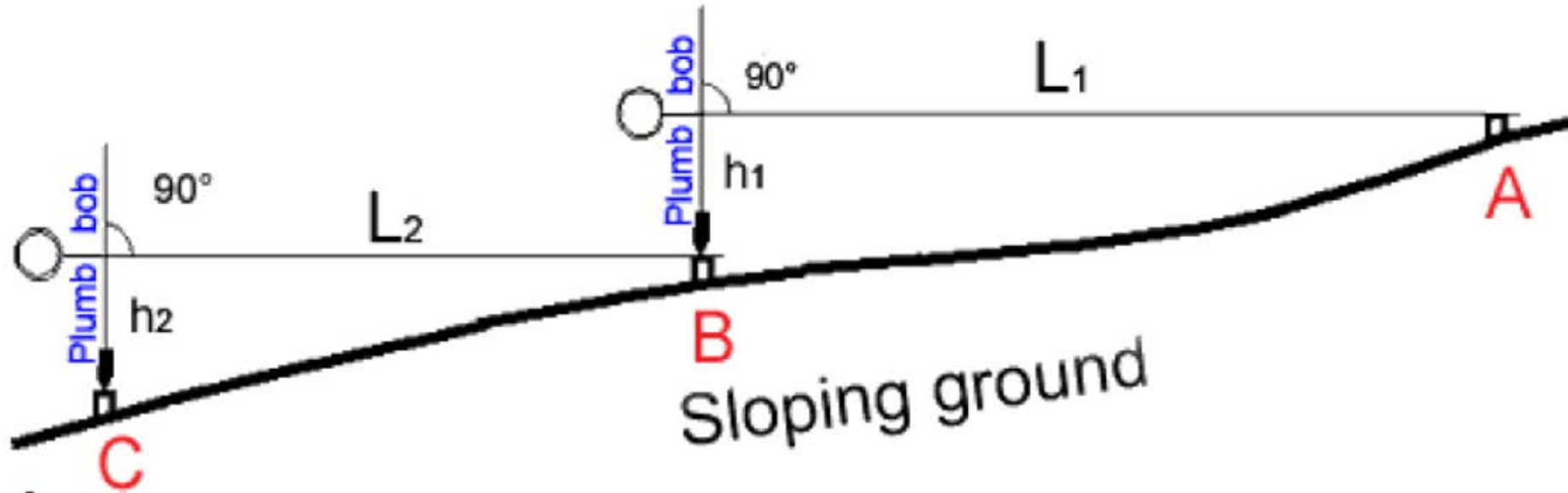
Measurements along a Slope

- All distances should be measured '**horizontally**'.
- Do not measure along slopes. Sag (*tape are not supported for its length will sag under the influence of gravity*) and to a lesser extent temperature may have an effect on the distance measurement also.
- To reduce the sag break tape measurement into shorter lengths.



The sum of horizontal lengths (L_1 & L_2) equals the horizontal distance of the slope from **A** to **C**. Remember the horizontal distance is always shorter than the measurement on the slope.

For an accurate measurement, the tape should be held horizontal and straight with a specified tension applied to it.



Slopes - Gradient Calculations

Here are the calculation example of the figures shown in the "**Straight edge**" section

(a) **Gradient** $200 : 3000 = 1 : x$ $x = 15$ **Gradient = 1 : 15**

(b) **Decimal fraction** $200/3000 = 0.066666$ **Fraction = 0.0667**

(c) **Percentage** multiply decimal fraction by 100
 $0.06666 \times 100 = 6.6666$ **Percentage = 6.667%**

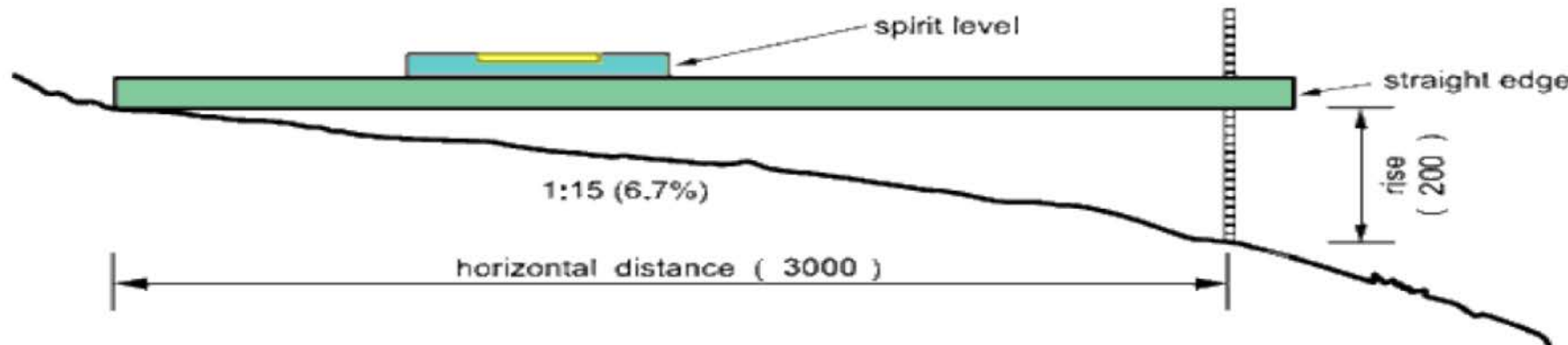
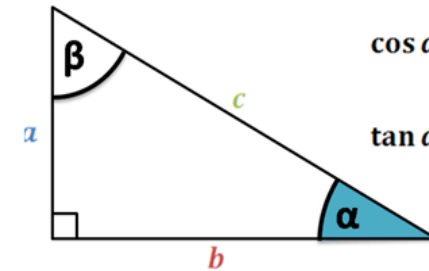
(d) **Angle** in degree inverse tan-function rise over run ($\tan^{-1}$ function on calculator)
 $\tan a = 200/3000 = 0.06666$ **$a = \underline{3.814^\circ}$**

SOH CAH TOA

$$\sin \alpha = \frac{a}{c} \quad \begin{array}{l} \text{Opposite} \\ \text{Hypotenuse} \end{array}$$

$$\cos \alpha = \frac{b}{c} \quad \begin{array}{l} \text{Adjacent} \\ \text{Hypotenuse} \end{array}$$

$$\tan \alpha = \frac{a}{b} \quad \begin{array}{l} \text{Opposite} \\ \text{Adjacent} \end{array}$$



Levelling Terms

- **Datum** line is the reference line with respect to which the levels of other station points are fixed.
- **Height of instrument:** It is the elevation of the plane of sight with respect to assumed datum. It is also known as **Height /Plane of Collimation**.
- **Back sight(BS):** It is the sight taken on the level staff, of a known elevation with the intention to obtain the elevation of plane of collimation. **(First reading)**
- **Intermediate sights(IS):** These are the sight taken after back sight and before sighting the final point. These are called MINUS sights. These are subtracted from plane of collimation to find the reduced level of different points. **(second reading)**

- **Fore sight(FS):** The last reading taken from the instrument. This is also a MINUS sight.
(Last Reading)
- **Change point(CP) or turning point(TP):** The point at which both BS and FS are taken.
- **Benchmark (BM).** A relatively permanent object, natural or artificial, having a marked point whose elevation above or below a reference datum is known or assumed.
- **Reduced Level** is the vertical difference between the level point and datum line or the mean sea level

Methods of Levelling

There are two methods for obtaining the elevations at different points:

- Height of instrument / or Height of Collimation method
- Rise and Fall method

Height of Instrument / Height of Collimation Method

The basic equations are:

- Height of instrument for the first setting = $RL \text{ of BM} + BS(\text{at BM})$
- Subtract the IS and FS from HI to get RL of intermediate stations and change points.

Example 1

When the difference in the elevation of two nearby points is required then simple levelling is performed.

Assume the elevation of BM Rock is known to be 820.00 m

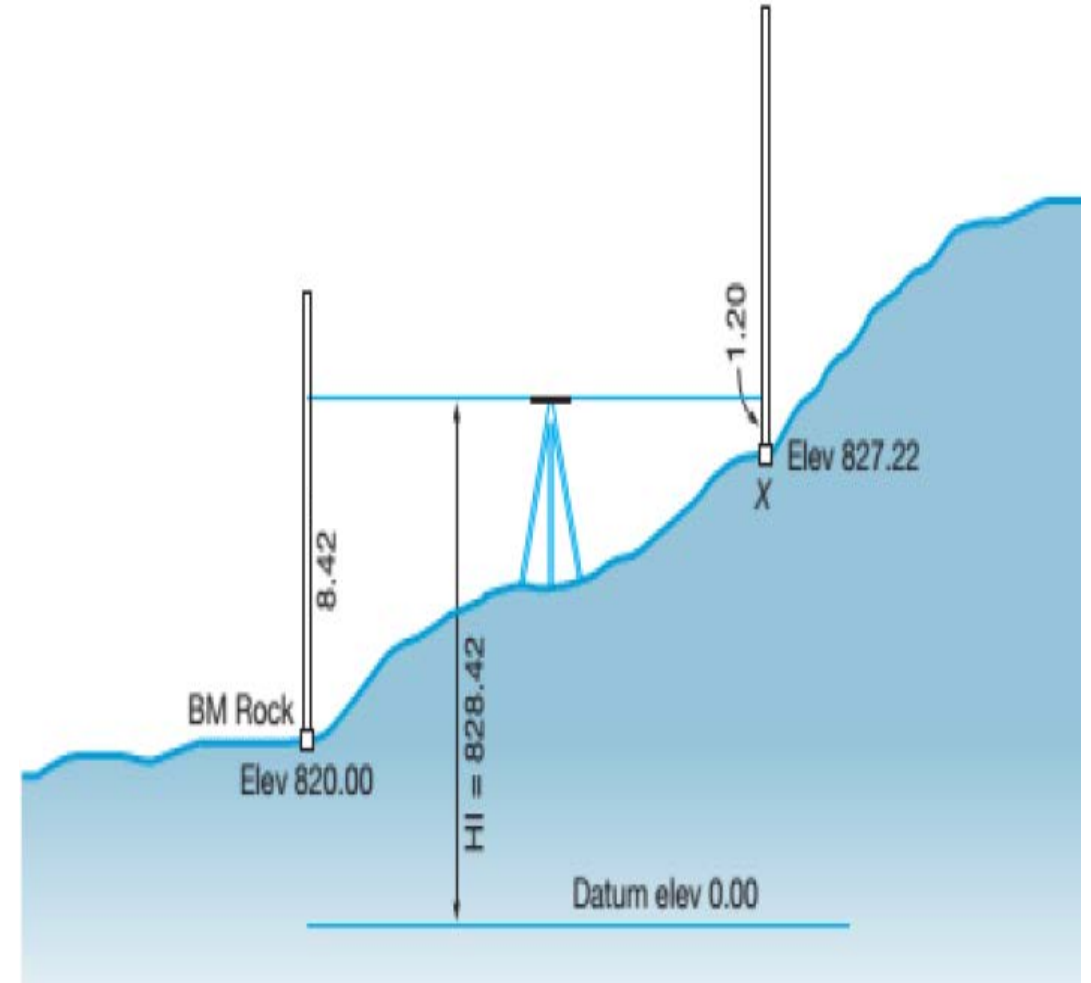
The BS at BM Rock is 8.42m

So $HI/HPC = (820 + 8.42)m$.

Now the FS on "X" is 1.2m.

So the RL at "X" = $HI - FS = 828.42m$

Note: the RL of the instrument station is never used in the calculation.



Example 2

Performed when the final point is very far from the final point.

We have to find RL at B. It is given that RL at A is 100m and BS at A is 2.45m

Therefore:

$$\text{HI at } L_1 = (100 + 2.45) = 102.45\text{m}$$

$$\text{FS at } CP_1 = 2.41\text{m}$$

$$\text{RL at } CP_1 = (102.45 - 2.14) = 100.31\text{m}$$

$$\text{Now BS at } CP_1 = 1.43\text{m}$$

$$\text{HI at } L_2 = (100.31 + 1.43) = 101.74\text{m}$$

$$\text{FS at } CP_2 = 2.18\text{m}$$

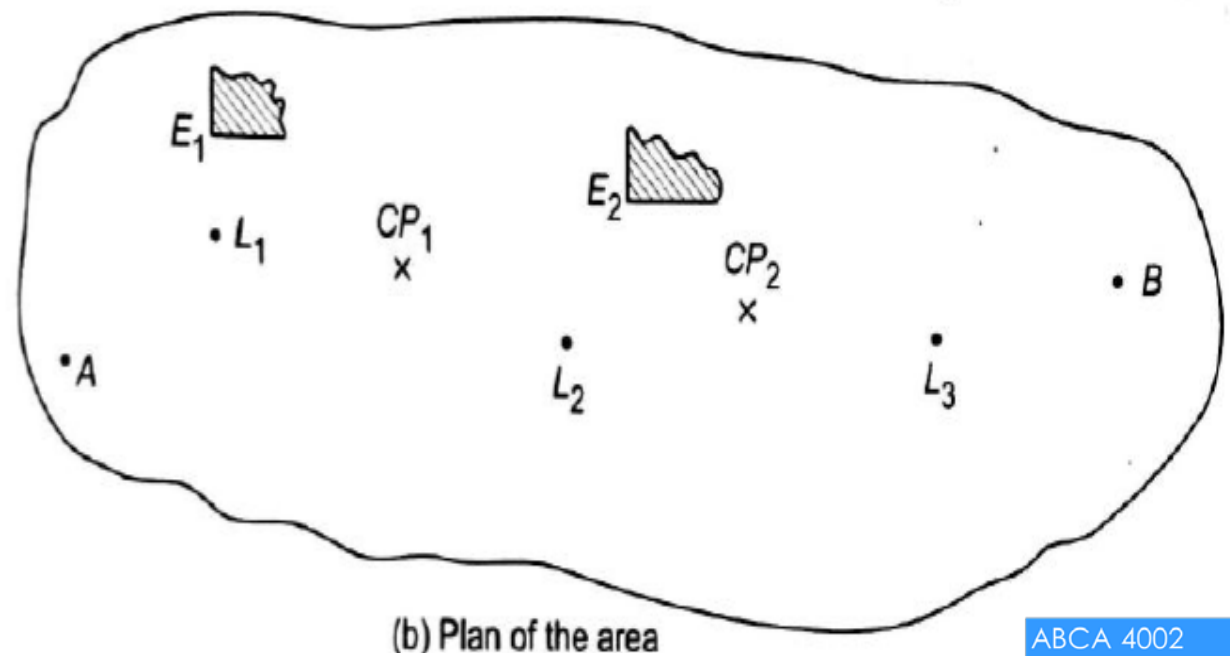
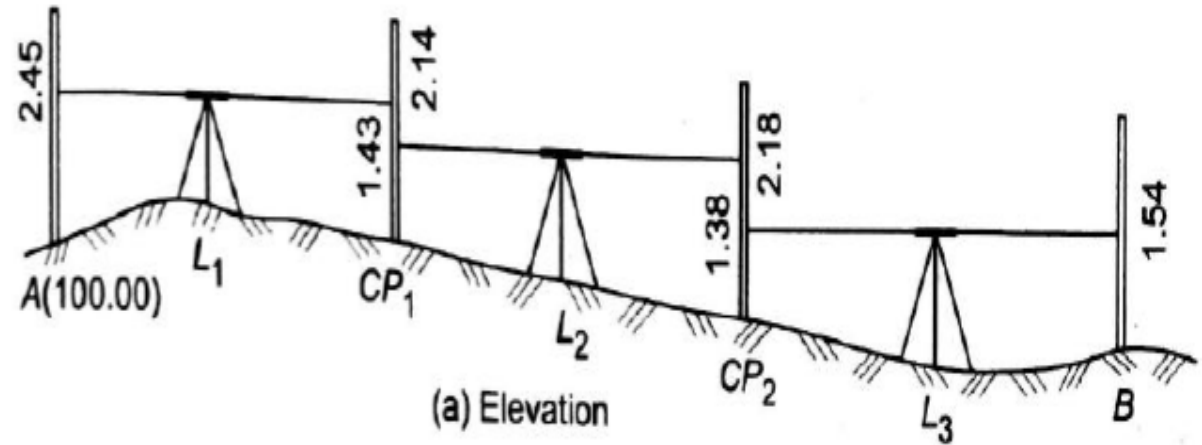
$$\text{RL at } CP_2 = (101.74 - 2.18) = 99.56\text{m}$$

$$\text{BS at } CP_2 = 1.38\text{m}$$

$$\text{HI at } L_3 = (99.56 + 1.38)\text{m} = 100.94\text{m}$$

$$\text{FS at } B = 1.54\text{m}$$

$$\text{RL at } B = (100.94 - 1.54) = 99.4\text{m (ans)}$$



Collimation Method of Booking Levels

Station	Reading			Height of Instrument	R.L	Remark
	BS	IS	FS			
A	2.45			102.45	100.00	Bench Mark
E ₁		0.86			101.59	Plinth of Building
CP ₁	1.43		2.14	101.74	100.31	Change Point
E ₂		0.76			100.98	Plinth of Building
CP ₂	1.38		2.18	100.94	99.56	Change Point
B			1.54		99.40	Station B, the last point shown

Check $\Sigma 5.26$

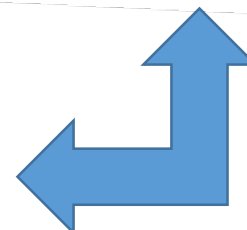
$\Sigma 5.86$

Diff = -0.60 (Fall)

-0.60 (Fall)



CHECK

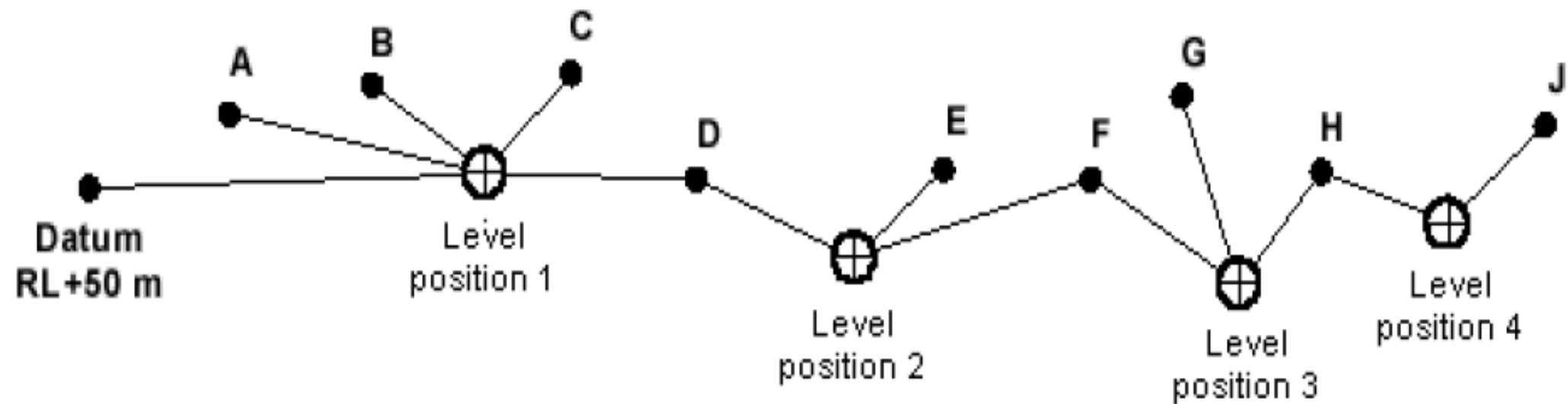
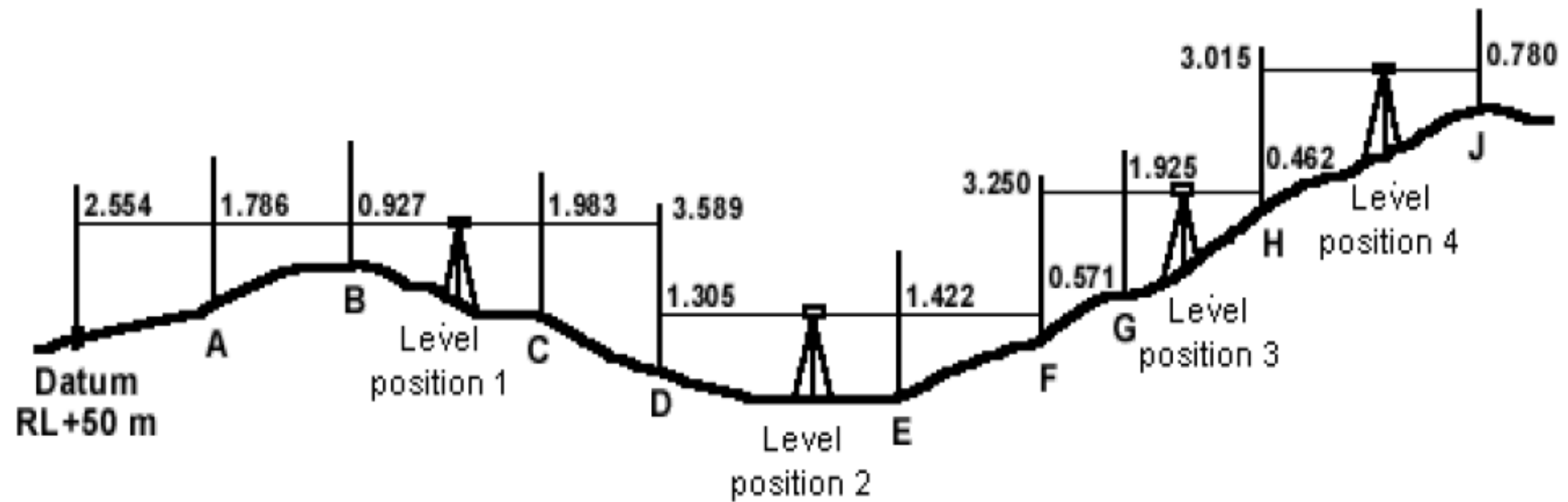


Rise and Fall Method of Booking Levels

Station	BS	IS	FS	Rise	Fall	R.L	Remarks
A	2.45					100.00	Bench Mark
		0.86		1.59		101.59	E_1
	1.43		2.14		1.28	100.31	CP_1
		0.76		0.67		100.98	E_2
	1.38		2.18		1.42	99.56	CP_2
			1.54		0.16	99.40	Last-Point
Σ	5.26		5.86	2.26	2.86		
$\Sigma BS - \Sigma IS = -0.6$				$\Sigma Rise - \Sigma Fall = -0.6$		Last RL – First RL = -0.6	
						Checked	

Note the rise and fall calculations:

From A to E_1 , difference = $2.45 - 0.86 = 1.59$, rise
 From E_1 to CP_1 , difference = $0.86 - 2.14 = -1.28 = 1.28$ m, fall
 From CP_1 to E_2 , difference = $1.43 - 0.76 = 0.67$, rise
 From E_2 to CP_2 , different = $0.76 - 2.18 = -1.42 = 1.42$, fall
 From CP_2 to Last Point, difference = $1.38 - 1.54 = -0.16 = 0.16$, fall.



Procedures

1. Set up the levelling instrument at Level position 1.
2. Hold the staff on the Datum (RL+50 m) and take a reading. This is a back sight, because it is the first staff reading after the levelling instrument has been set up.
3. Move the staff to A and take a reading. This will be an intermediate sight.
4. Move the staff to B and take a reading. This is a intermediate sight.
5. Move the staff to C and take a reading. This is another intermediate sight.
6. Move the staff to D and take a reading. This is a foresight; because after this reading the level will be moved. (This is a change point and the staff is held at this position).
7. The distance between the stations should be measured and recorded in the field book.
8. Set up the level at Level position 2 and take a reading at D. This is a back sight.
9. Move the staff to E and take a reading. This is a intermediate sight.
10. Move the staff to F and take a reading. This is a foresight; because after taking this reading the level will be moved.
11. Now move the level to Levelling position 3 and leave the staff at F on the change plate.

Collimation Method of Booking Levels

Back-sight	Inter-mediate	Fore-sight	Height of collimation	Reduced level	Distance	Remarks
2.554			52.554	50.000	0.000	Datum RL+50 m
	1.783			50.771	14.990	A
	0.926			51.628	29.105	B
	1.963			50.591	48.490	C
1.305		3.587	50.272	48.967	63.540	D / change point 1
	1.432			48.840	87.665	E
3.250		0.573	52.949	49.699	102.050	F / change point 2
	1.925			51.024	113.285	G
3.015		0.496	55.468	52.453	128.345	H / change point 3
		0.780		54.688	150.460	TBM J 54.688
10.124		5.436		54.688		Sum of B-sight & F-sight, Difference between RL's
-5.436				-50.000		Take smaller from greater
4.688				4.688		Difference should be equal

Common Sources of Errors in Levelling

- Instrument not correctly levelled
- Telescope not correctly focused.
- The wrong cross-hair reading recorded (e.g. top instead of middle).
- Staff incorrectly read or not held vertical.
- Staff incorrectly booked. All the above are mistakes (blunders) and cannot be corrected unless the work is repeated.

Types of Levelling

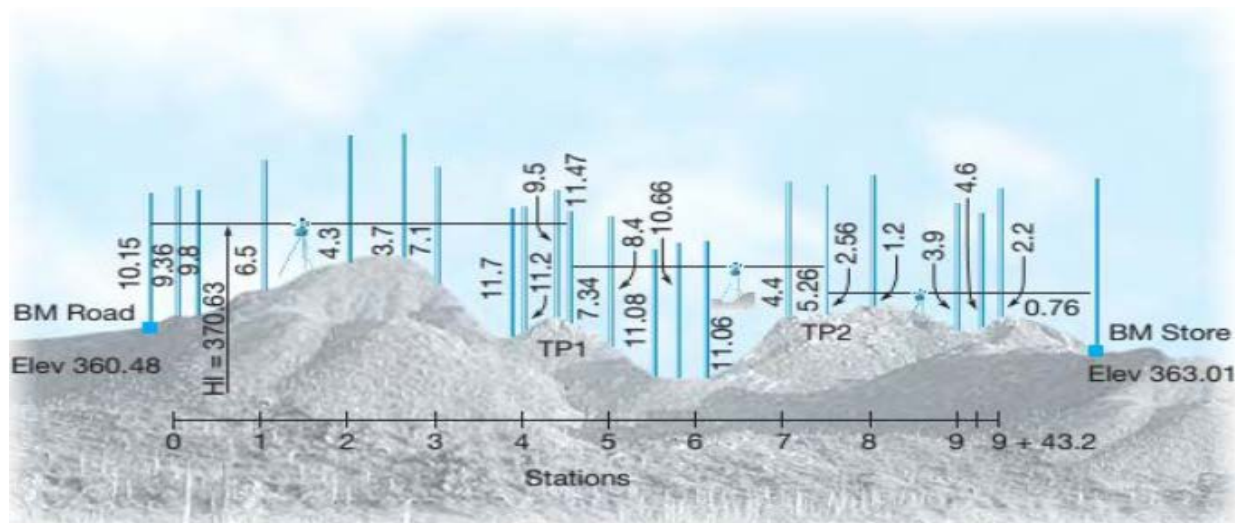
- Simple levelling
- Differential levelling
- Fly levelling
- Profile levelling
- Cross sectional levelling
- Reciprocal levelling

Fly Levelling

- Performed when the work site is very far away from the bench mark.
- The surveyor starts by taking BS at BM and proceed towards worksite till he finds a suitable place for temporary BM. All works are done with respect to temporary BM.
- At the end of the day the surveyor comes back to original BM.
- This is called fly levelling.

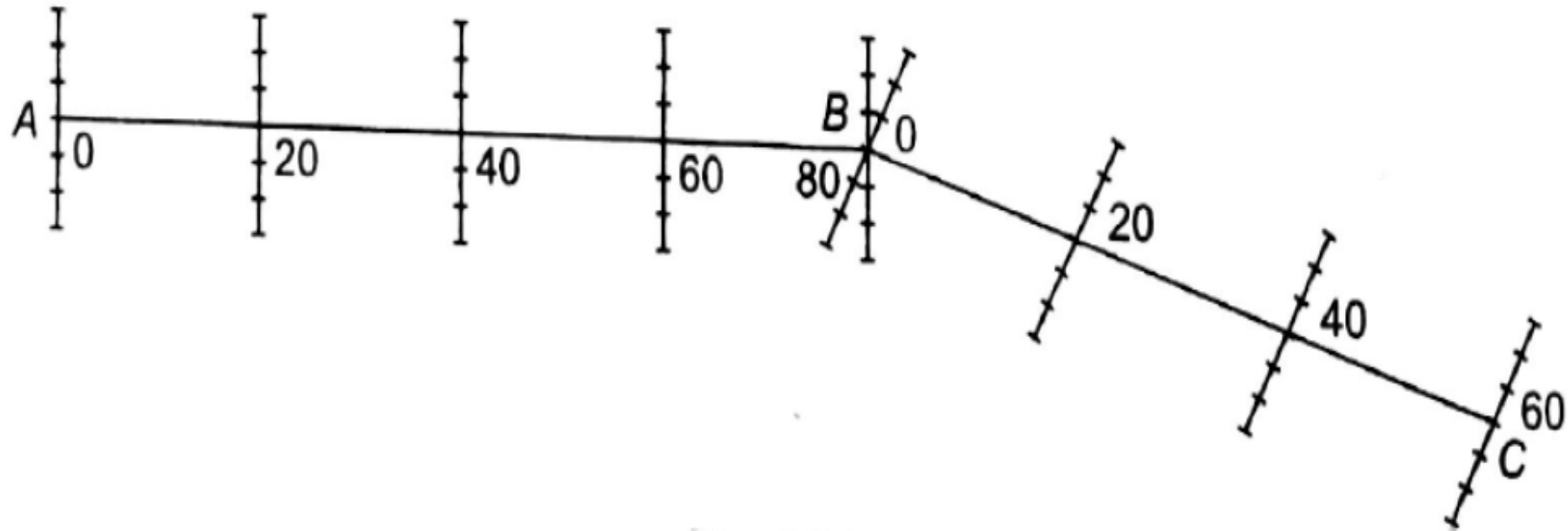
Profile Levelling

- Profile levelling, which yields elevations at definite points along a reference line, provides the needed data for designing facilities such as highways, railroads, transmission lines.
- Reduced levels at various points at regular interval along the line is calculated.
- After getting the RL of various points the profile is drawn. Normally vertical scale is much larger than horizontal scale for the



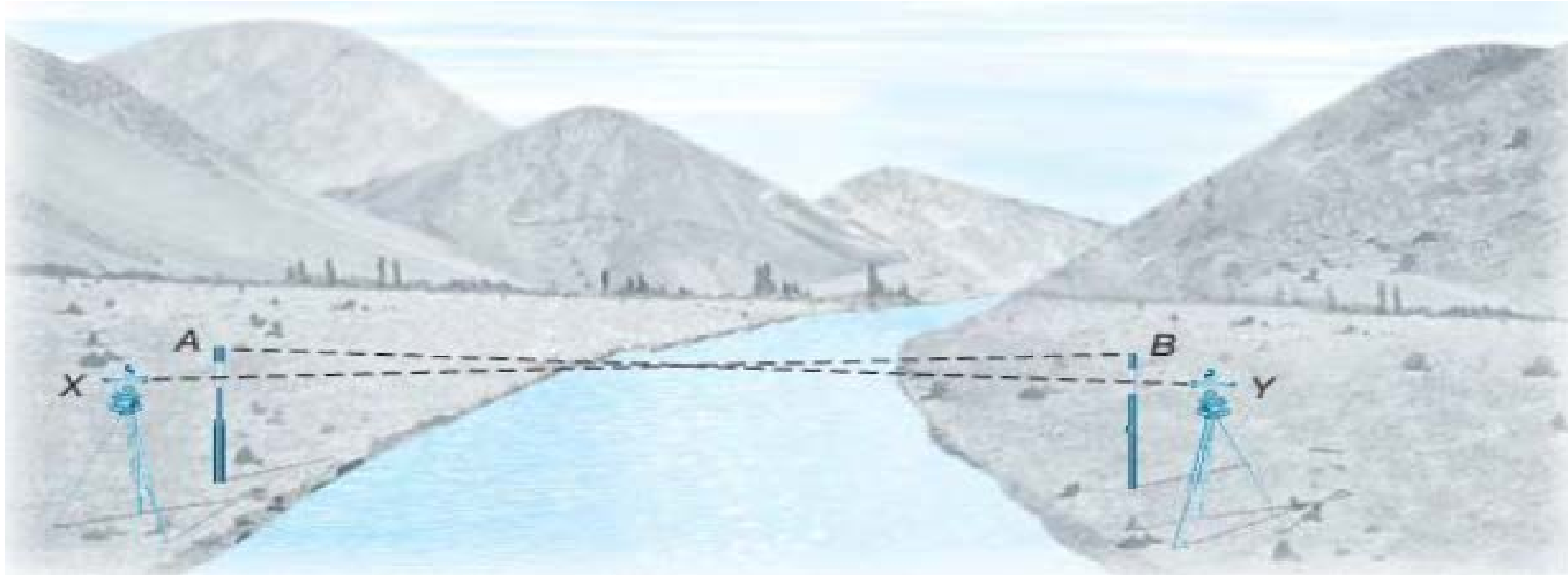
Cross Sectional Levelling

- In many projects not only profile along the line is required but also profile of cross – section at a regular interval is required. (here 20m)
- Levels are taken at every 3m distance (till 9m i.e. 3 readings on one side) to left and right of the line AB and BC for cross section profile



Reciprocal Levelling

- When levelling across river is required then this method is applied to get rid of various errors.





Refreshing QUIZ to welcome in the New Year

1. In a building survey what three types of drawing would normally be produced?
2. In a section drawing of a building what 5 key things would you record?
3. Name 3 types of equipment required in building surveys?
4. All angles in a triangle are equal to how many degrees?
5. Name the sides of a right angled triangle?
6. Name the theorem associated with the sum of the squared lengths of a right angled triangle?
7. Name 5 pieces of equipment required for basic land surveying?
8. What is the name given to a sketch plan outlining the scope and parameters of the survey?
9. What mathematical theorem uses SIN COS and TAN in right angled triangles?
10. What is the name given to the process of measuring angles in a chain?
11. What is the name given to the process of measuring lengths of all sides of triangles in a chain?
12. What is the formula for calculating heights of buildings?
13. True or false – A traverse is a series of interconnected curves similar to contour lines?
14. Name two different types of traverse?
15. What is the Azimuth more commonly known as?
16. One minute is equivalent to how many degrees?
17. The sum of the interior angles of any closed traverse must equal how many degrees?
18. What formula is used to correct exterior angles in a closed traverse and what does 'n' represent?
19. Latitudes and Departures are now considered what?
20. Give 4 examples where levelling is required?
21. What is the name given to the adjustable bracket that links the instrument to the tripod?
22. The height of the instrument is also known as?
23. What do CP and TP represent in levelling?
24. The vertical difference between the level and datum line is referred to as?
25. What are to two methods of Levelling?

