Birzeit University
Civil Engineering Department
Surveying for Civil Engineering
ENCE337

Lecture 1-Introduction

- Textbook:
  - **Surveying Principles and Application- 7th ed.**
  - **Or any book listed in the References**

SURVEYING

- **Fieldwork**

- **Computations (office work)**

SURVEYING

- Webster:

  The practice of measuring angles and distances on the ground so that they can be accurately plotted on a map. (very old).

- That branch of applied mathematics which teaches the art of determining the area of any portion of the earth's surface, the length and directions of the bounding lines, the contour of the surface, etc., with an accurate delineation of the whole on paper; the act or occupation of making surveys.

  (better but also old).

- {Topographical surveying}, that branch of surveying which involves the process of ascertaining and representing upon a plane surface the contour, physical features, etc., of any portion of the surface of the earth.

Branches of Surveying

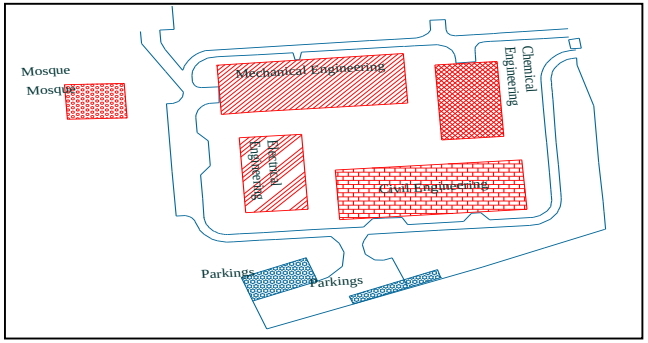
- Geometric Geodesy (Geodetic + Plane Surveying).
  - The surface of the earth is consider to be a plane for all X,Y dimensions.
  - Z dim. Are referenced to the MSL

- Physical Geodesy (Determination of gravity).
  - Surface of the earth is considered to be spherical of revolutions for X,Y dim.
  - Z dim. Are referenced to the MSL

- Hydrographic surveying.
  - Preliminary surveys are used to tie in underwater features to a surface control line.

Main Tasks

- Mapping
  - Satellite photos.
  - Aerial Photogrametry.
  - terrestrial (Land).

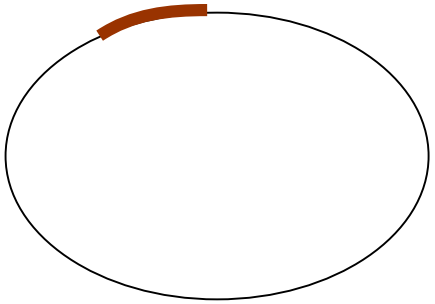


- Setting out
  - terrestrial (Land)

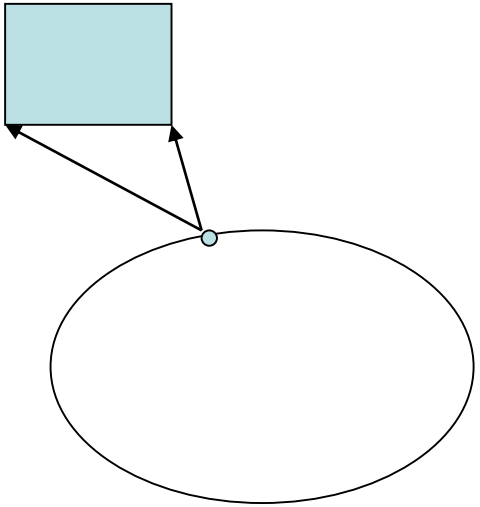
- Navigation

Types of Surveying

- Geodetic Surveying
  - Large Areas (Area > 50 km2)
  - Consider curvature of the earth
  - complex mathematics



- Plane Surveying
  - Small Areas (Area <= 50 km2)
  - Neglect curvature of the earth
  - simple mathematics



Plane Surveying

- Detailed Surveying

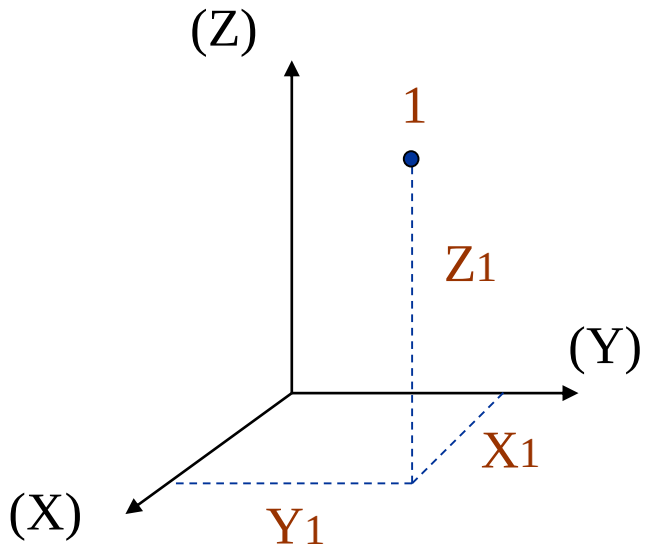
  - horizontal coordinates (X, Y)

    Draw detailed (Hz.) maps

- Topographic Surveying

  - Heights (z)

    Draw topographic maps.



In surveying the focus is on determination and using point coordinates in space.

Distance Measurements

- Measurements in surveying includes both distances and angles (H.A & V.A).
- The distance between the projections of 2 points on a reference horizontal plane known as H.D.
- H. plane at a point is defined as a plane perpendicular to the direction of gravity at that point.

Methods for measuring distances

1. Pacing
2. Taping
3. Tachometry (theodolite and staff)
4. EDM.

- Distance up to 100m long can be easily measured with a tape to an accuracy (at 1σ) of 1/3000.
- Mapping for a small area can be carried out using a tape with an accuracy that is adequate for many engineering projects.

Equipments used in chain surveying

- Equipments falls under 3 broad categories which are:

1. Equipments used for linear measurements.
    1. Tapes:

– Made of synthetic material, fiber glass or coated steel.
– Lengths ranging from 1 to 50 m are available (20,30,50m are the most commonly used).
– It is more accurate than chains but lack of robustness and difficulty in doing field repairs.

    2. Invar tapes

– Most accurate (least affected by temp.)
– Mixture of steel (65%) and nickel (35%)
– Low coff. Of thermal expansion = 1/30th of steel
– Very expensive (used for measuring lines that require a very high degree of accuracy)

Equipments used in chain surveying

- **Equipments used for making right angles:**

1. Optical square:
   - Simple and compact instruments
   - Most available kind having a cylindrical shape of 35mm dim. And 40mm thick.
   - More accurate than cross- staff.
   - 2 types:
     - 2 mirrors- rays of light reflected from 2 mirrors is turned through twice the angle between the mirrors
     - Prism- employs a pentagonal-shape prism, so cut these 2 faces contain an angle equal to 45 degree.

Equipments used in chain surveying

- Other equipments:
  1. Ranging rods:
     1. Poles of circular cross-section(1” diam. And 1-2m long)
     2. Painted with alternate bands of red and white that are usually 50cm long.
  2. Arrows :
     1. Steel skewers (40cm long and 3-4mm diam.)
     2. Used to mark intermediate points when measuring long line.
  3. Pegs:
     1. Points require to be more permanently marked.
     2. Can have 4*4 square cross-section, circular cross-section(3-5cm) dim. Both about 40 cm long.
     3. Steel angle is used in very hard or frozen ground.
     4. In asphalt road –small 5 or 6 mm square brads are used.

4. Plumb bob:
    1. Metallic object (shape of cone).
    2. Hung it freely by a strong string from the center of its base.
    3. The tip of the cone points towards the direction of gravity
    4. Used to project a point on the ground up to a tape.
5. Clinometers
    1. Small device to measure the angle of inclination (slope) of a uniformly sloping ground.
6. Abney level
    1. Alternative to measure the inclination angle of uniformly sloping line.

Ranging and measurements of lines

- Measuring distance is carried out by 2 persons (leader and follower).
- If the required measured distance is shorter than one tape length, it is directly measured by extending the tape.
- Intermediate points (equal or random) are required if the distance is longer than one tape length.
  - Measurements should be in a straight line.
  - Tape should be pulled to a reasonable point, in order to minimize sagging and to avoid over-stretching the tape material at the same time.
  - A Systematic way should be followed to count the no. of times the tape is used between the ends points of the line
  - The topography of the ground where the line to be measured is located controls the followed procedure

Ranging and measurements of lines

A. Level ground:

1. Position 2 ranging rods (RR) on both ends of the line. Rod should be vertical.
2. The leader holding a RR and the end of the tape and several arrows, extends the tape horizontally in the direction of point B.
3. The follower, holding the zero of the tape and standing behind the rod at A, looks in the direction of B and begins giving R& L signals to the leader until the rods at A,A1,B lie in a straight line
4. The follower moves the zero of the tape and a RR to A, then pulls out the arrow and drives the RR in its place. Process will be repeated until A2.
5. step.4 is repeated to locate the next point A3.
6. The previous steps are repeated until reaching a point, therefore the distance between this point and point B will be small than a tape length.

Ranging and measurements of lines

B. Uniformly sloping ground:

- When the ground between points A&B has a uniformly slope
- The slope distance is measured by the tape
- The slope angle is measured by clinometer or abney level
- H.D and elevation difference between the two points (A&B) will be:

$$D = S \times \cos\alpha$$

$$\Delta h = S \times \sin\alpha$$

- If between A&B is known, then there is no need to measure the slope angle…

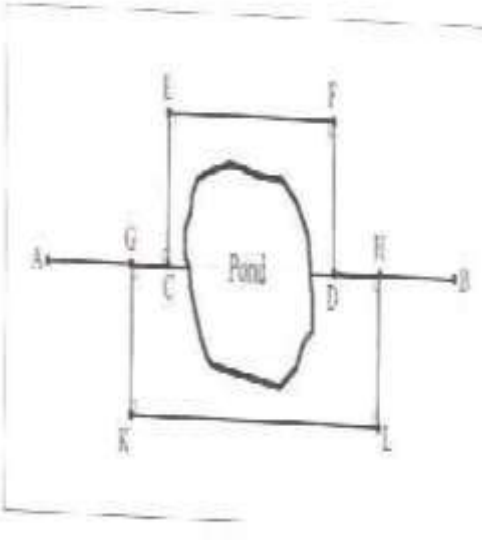
$$H.D. = \sqrt{S^2 - \Delta h^2}$$

Ranging and measurements of lines

C. Uneven ground (non-uniformly sloping ground)

- The process of measuring known as stepping
- Measurements is done in short H. increments of 10-15m long with the help of plump bob.
- Total length = summation of all short increments.

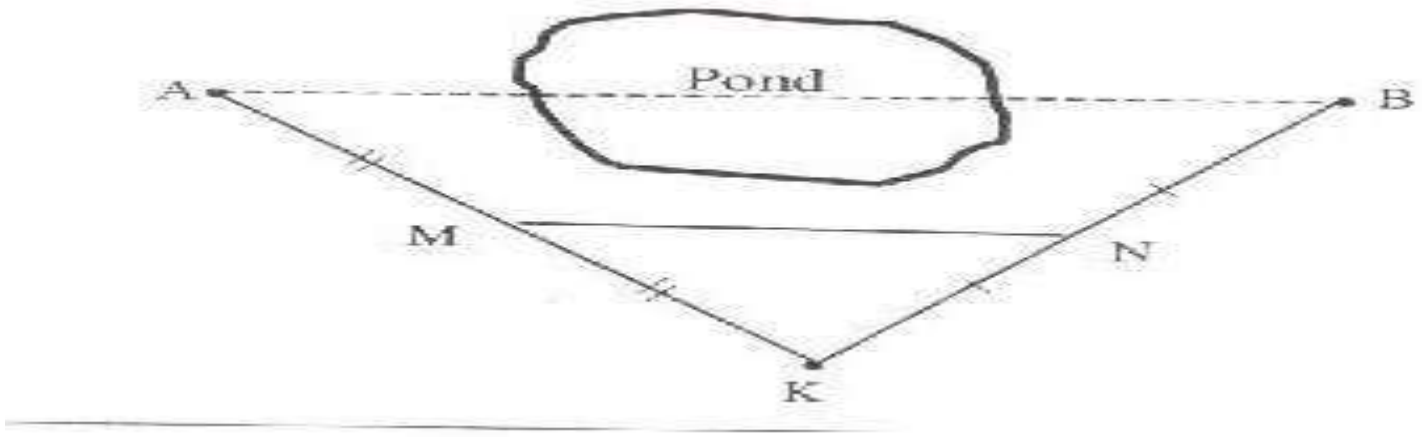
Types of obstacles



- **Vision obscured, chaining possible**
  1. Repeated alignment (repeated forward ranging)
- **Vision possible, chaining prevented**
  1. Two types
     1. Closed obstacles like (pond)
        1. Parallel line method
           - A distance that is parallel and equal in length to the missing one is made on the ground.
           - CE,FH are equal offsets set out perpendicular to AB
           - Then EF is chained to supply the missing length CD.
           - Using GK, HL on the other side as check if possible
           - AB= AC+EF+DB

2. Capital Letter A method

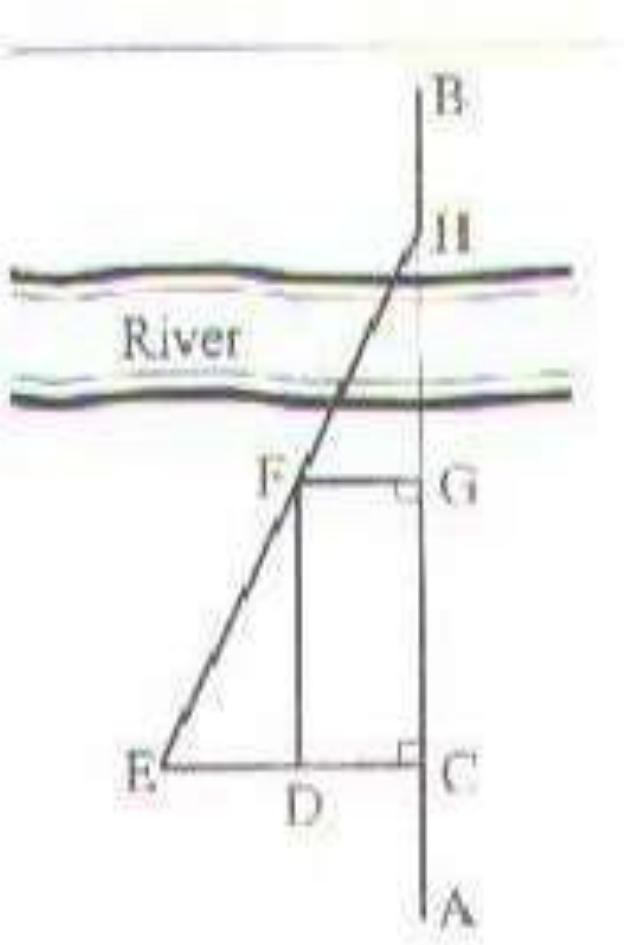
- If the distance AB needs to be known
- Choose an arbitrary point K but from which A,B can be seen.
- Bisect KA@M and KB@N
- Measure distance MN
- From similar triangles KMN&KAB---AB=2*MN
- Or any ratio other than 2 can be used.



2. **Linear Obstacles (River)** The river or stream width more than tape length

- Ranging rod is placed at H on the far bank of the river
- CE is constructed on the near bank perpendicular to AB
- Rod is ranged into F between E&H
- Perpendicular is drop from F on to AB meeting it at G
- From the similar triangle EDF&FGH
- HG/FD=FG/ED

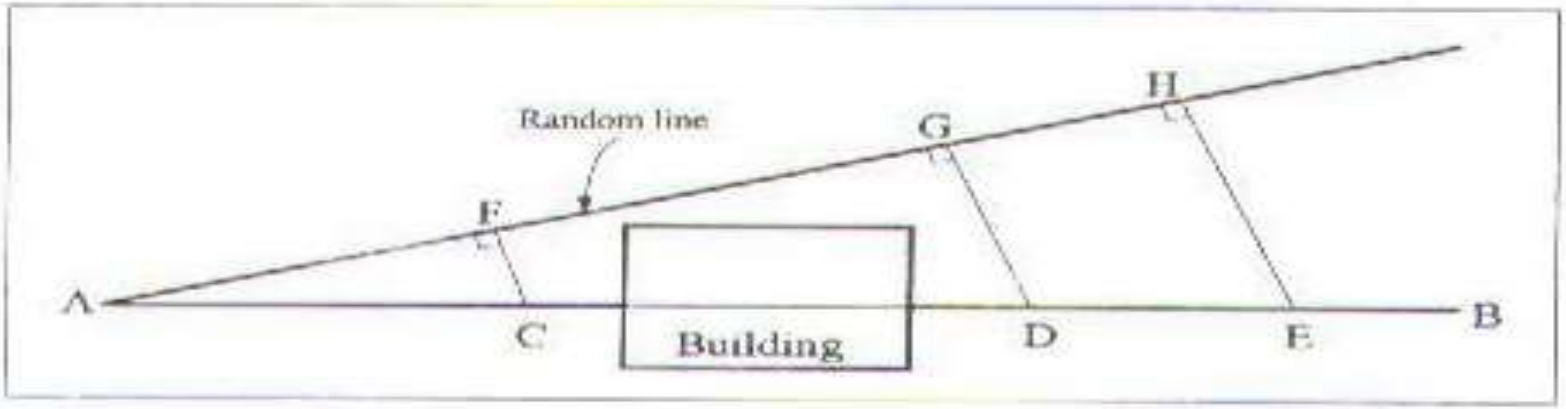
  HG=CG*FG/(EC-FG)



3. Both Chaining and Vision prevented

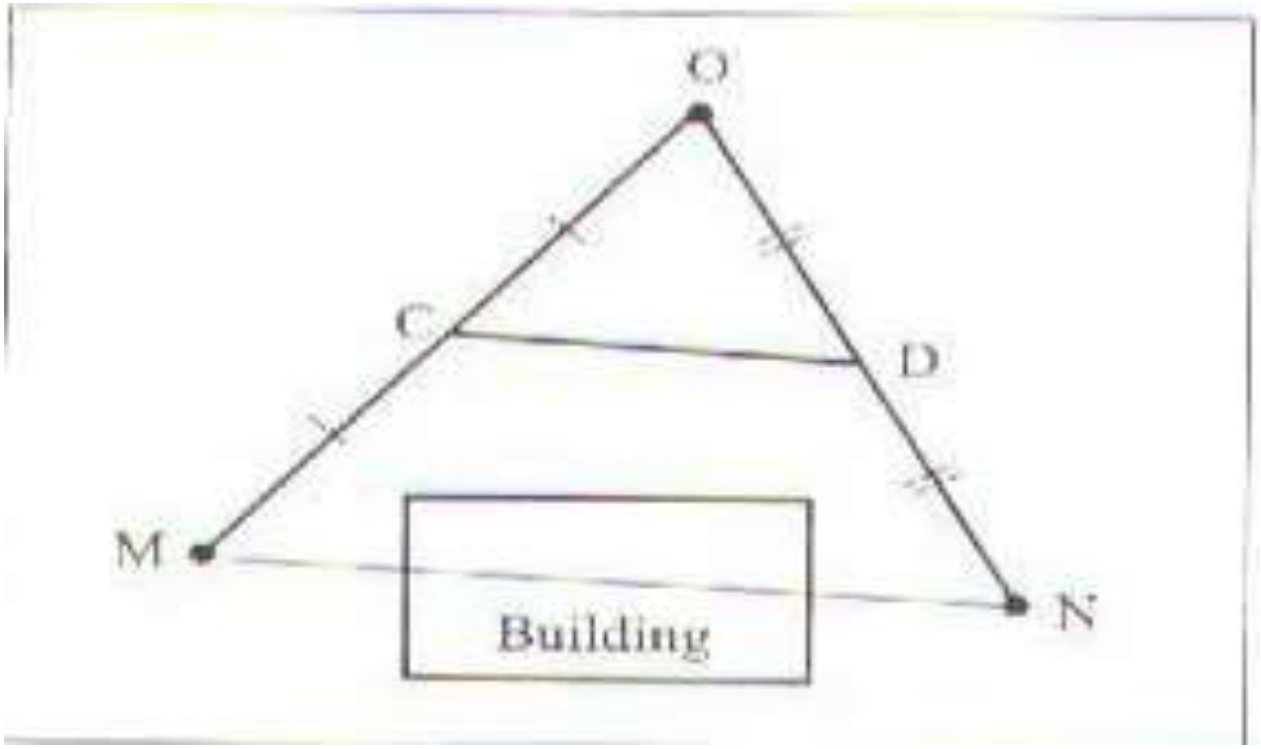
- This type of obstacle is encountered into 2 diff. situations
- When prolong a C.L. past a fixed object (building)

1. Random line method is used
    1. AH random line is constructed near to the building
    2. Lengths AF,AG,& AH are measured
    3. Length of perpendicular CF is measured
    4. GD/FC=GA/FA, HE/FC=HA/FA
    5. Erecting perpendicular on AH from GH with lengths GD&HE respectively. D&E located.
    6. They lie on the extension of line AC point B can be located by extending Line DE



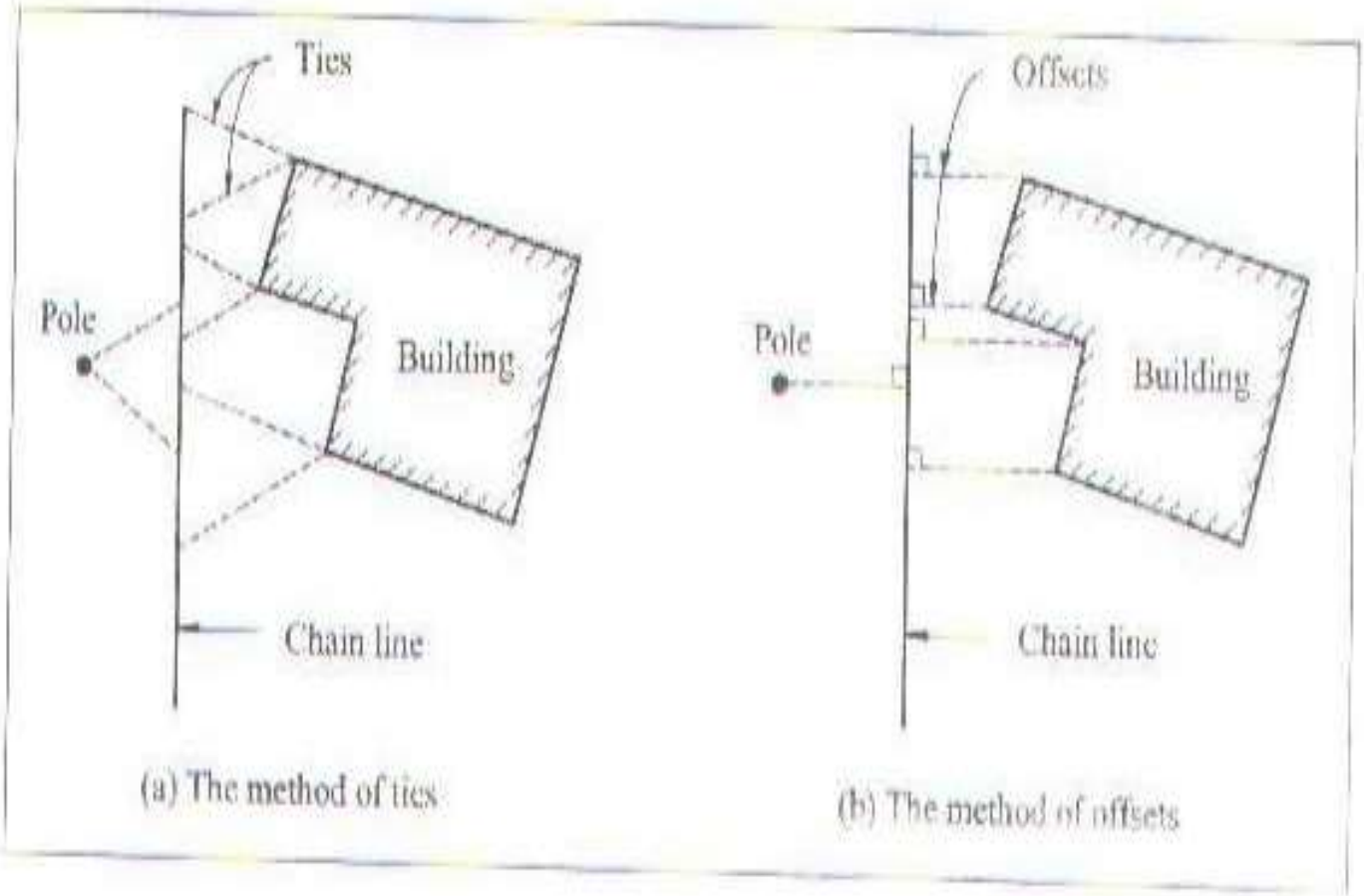
2. Trying to measure a distance between 2 points obstructed by a building

- Capital Letter A



Mapping:

- In chain surveying, the topographical and man-made features are located and mapped.
- Which could be done by measuring with the tape the lengths of a series of selected reference straight lines (chain lines).
- locating the points on the ground relative to these lines by two methods:
    - Method of ties: a point is located by measuring 2 reasonable distances between this point and 2 selected points on the C.L.
    - Offsets method: a point is projected on the C.L. and the distance between the point and its projection and the distance from the beginning point of line to the projected point are measured.



(a) The method of ties

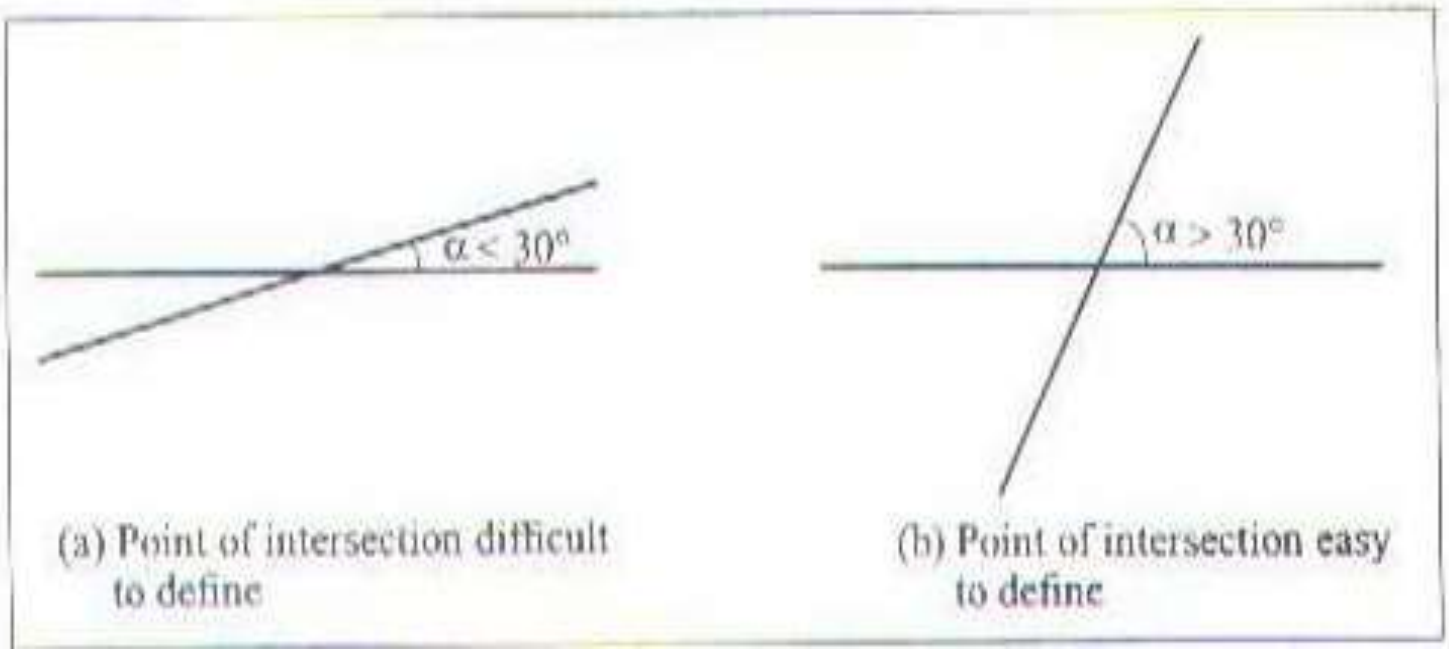
(b) The method of offsets

Cont. Introduction:

- The surveyor should visit the area to be mapped (shape of area, existing details, draws a reasonable sketch of the area).
- All the details such as roads, buildings, fences, electric poles, etc. should be included in the sketch.
- Approximate north direction should be included in the sketch.

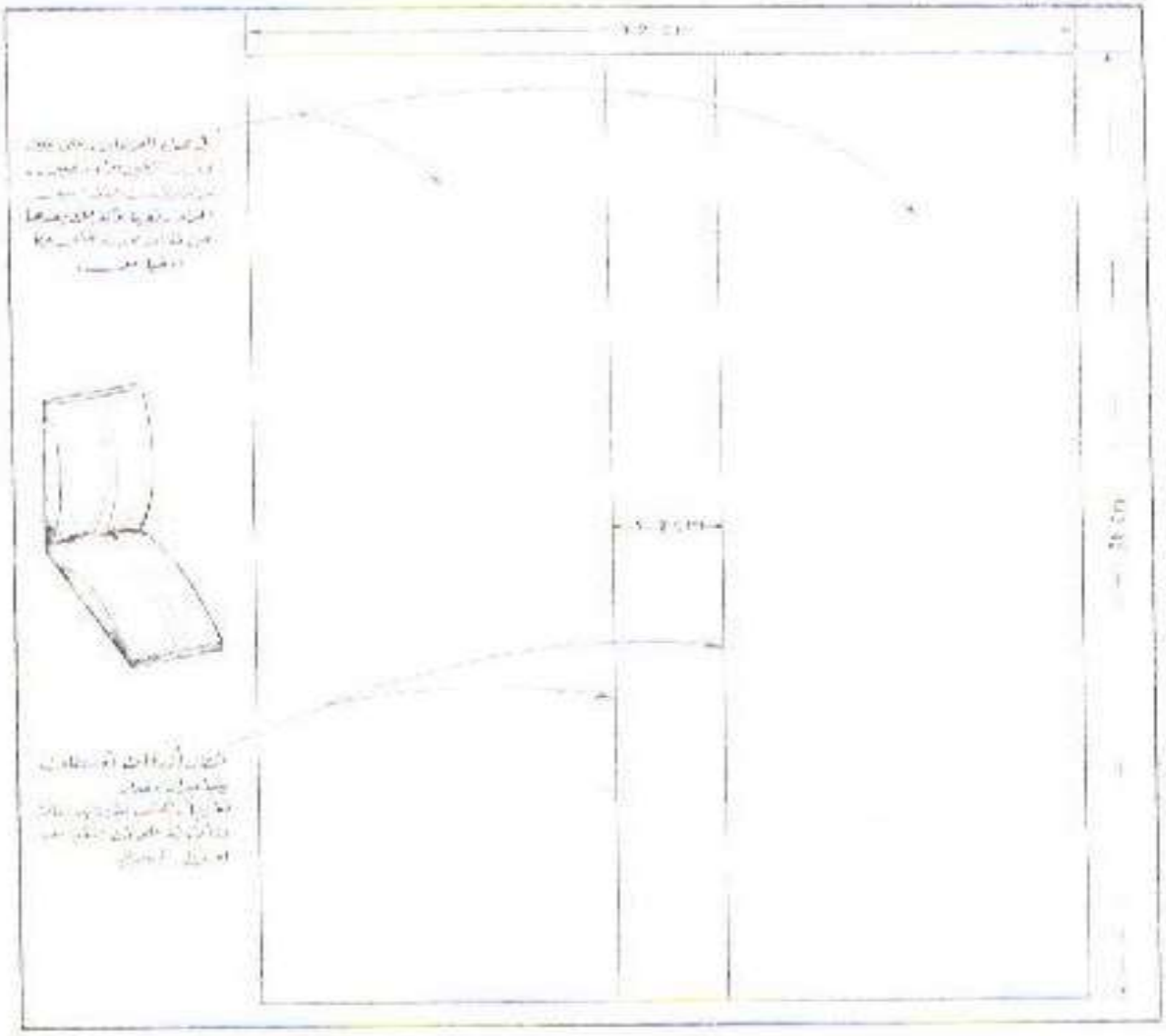
How to choose the chain lines:

- Chain lines should form well-conditioned triangles (all internal angles fall between 30-120 degree).



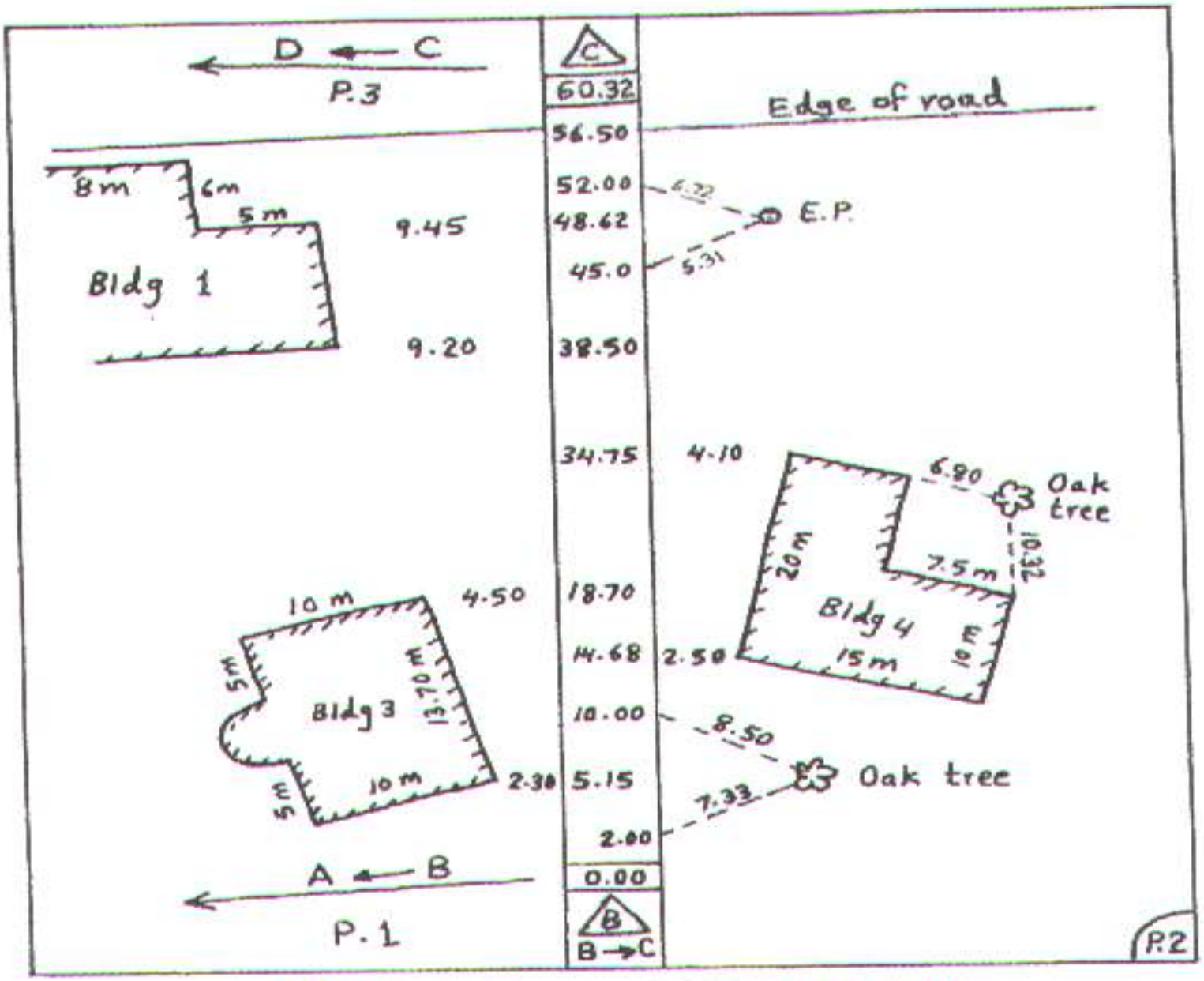
How to choose the chain lines:

- C.L. should be chosen as close as possible to the boundaries of the area or details to be measured.
- From each station, it should be possible to see at least 2 other stations
- No. of C.L. should be kept to a min. but enough to locate all the details
- Stations should be chosen in a way such that check lines will be provided.
- Obstacles along C.L. should be avoided as much as possible



Booking the measurement:

- Begin each line at the bottom of a fresh page. If one page not enough for a particular long line, other pages can be used.
- Record all the measurement at the time of measure in the direction of chaining (L or R of the chain line.
- All details surveyed must be sketched to scale in the appropriate place in the F.B.
- Offsets from the points of detail to C.L. are not drawn(booked by writing their values near the detail with the accompanying distance written in the space between the 2 middle lines
- Ties are drawn by dashed lines with their values indicated on these lines


D ← C
P.3
C
60.32
Edge of road
56.50
52.00
6.32
E.P.
48.62
5.31
45.0
8m
6m
5m
9.45
Bldg 1
9.20
38.50
34.75
4.10
6.80
Oak tree
10.32
20m
7.5m
Bldg 4
15m
10m
10 m
4.50
18.70
5m
Bldg 3
13.70m
14.68
2.50
10.00
8.50
Oak tree
10m
2.30
5.15
7.33
2.00
A ← B
0.00
P.1
B
B → C
P.2

Booking the measurement:

- Names of houses, roads,… should be recorded as well as any information might be helpful when plotting.
- Names of surveyed area, name of surveyor, units of measurements, date of survey should also be indicated.

Plotting:

- Choose the appropriate scale and hence size of drawing paper to be used.
- Plot offsets and ties systematically in the same order in which they were measured and booked.
- North direction should be indicated.
  - Make the N arrow direction pointing towards the top of the sheet.
- After finishing the first draft, check the details…
- Center the drawing in the middle of the sheet.
  - Use 3-4 cm margins from the 4 sides.
  - The extra space left on the right and bottom sides of the sheet should be used to write the relevant information which indicates (legend, scale, north arrow, surveyor name,…)
- Using software like AutoCAD to draw, make it easy to revise, correct and update the drawings faster…
- Scale 1-100, and the accuracy is near to 1 cm.

Accuracy of measurements

- It depends on the plotting scale.
- Suggested to be made to the nearest 10mm.
- Example:
    1. If the draughtsman can plot a length to within 0.2mm.
        1. If the plotting scale is 1/500---10 cm on the ground
        2. If the plotting scale is 1/100---2 cm on the ground

Units of Measurements

1. **Measuring the length**
   - English system (inch, foot, yard, and mile)
     - 1foot= 12inches
     - 1mile=5280ft
   - Metric system
     - 1m=100cm
     - 1km=1000m
2. **Area Measurement**
     - Metric
       - 1 hectare= 10,000m2
       - 1Km2=100ha
3. **Volume**
- **Metric**
  - **1m3=1000,000cm3**
  - **1m3=1000liters**

- **Converting**
  - **1inch = 2.54 cm**

Angle measurement

1. Sexagesimal System
   - Circle=360, degree=60mintues, minute= 60 seconds
2. Radian
   - 2Π=360=400g

Lecture Two- Theory of Errors

Sources of errors

- Instrument imperfections
- Human operator errors
- Environmental nature

❖ **No surveying measurement are exact (unless by chance), so it is very important to understand the sources of the error and the methodology to achieve acceptable accuracy (Control, Avoid, and minimize it).**

  – True error (e)= Measured value- true value …hard to know so..

  – Residual error (v) =measured –mean

Types of Errors

- Blunders:
  - Main Causes: human carelessness, fatigue
  - Could be +ve or –ve, large or small
  - Sighting wrong target when measuring an angle or errors in recording are examples of it,
- Systematic Errors
  - Maladjustment of the instruments and nature of the environment
  - It can calculated and eliminated such as the error in chain surveying due to length of tape…
  - Arising from known sources

1. Examples of Systematic errors and their correction are
    1. Temp. correction

$$C_t = 0.0000116(T_1 - T_\circ)L$$

$0.0000116 \rightarrow$

$T_1 \rightarrow$

$T_o \rightarrow$

$L \rightarrow$

2.Sag correction

1. Related to tape weight and the amount of pull
2. Caused recorded distance to be greater than actual length being measured
3. Supported tape at its midpoint, effect sag in the 2 spans less than when it is supported at the ends only
4. Total sag correction for a tape resting on multiple supports= summations of the sag correction for separate interval

$$C_s = -\frac{W^2 * L}{24P^2} = \frac{W_{L_i}^2 * L_i}{24P^2}$$

$$or$$

$$C_s = -\frac{w^2 * L^3}{24P^2}$$

3.0Tension correction

- Tape material is elastic to small extent
- Then it changed by vibration in tension applied
- Not related to sag but elastic deformation of the tape

$$C_P = \frac{(P_1 - P_0) * L}{AE}$$

4.0Length correction

- Checking tape frequently is necessary since tape length changes due to wear and tear.
- Diff. between actual length and nominal length of tape is known as length correction

$$C_l = (l_a - l_o) * \frac{L}{l_o}$$

- When the length correction is the only correction to be considered
- Correct line length=measured length *actual length of tape/nominal length of the tape
- Correct area=measured area *(actual length of tape/nominal length of the tape)2

Example

- A 50-m tape was calibrated under a tension of 7 kg and a temperature of 20C while fully supported. When carefully checked, the tape was found to be 50.005 m long. In the field it was used under a tension of 7 kg, a temperature of 35 c and supported at 2 ends only. A line was measured in 4 sections with the following results: 50, 50, 50 and 48.631 (all measurements were in meter). Determine the correct length of the line. The tape weighted 0.50 kg.

- Random error

  - Causes: imperfection of the measuring instruments, environment and imperfection of the surveyor.
  - Minimized using: repeated measurements, better instruments and suitable field procedures
  - Have many characteristics

    1. +ve and-ve of the same magnitude occur with same frequency.
    2. Small errors occur more than large
    3. Very large are rarely occur
    4. The true value is the mean of infinite no. of observations

Mean, standard deviation and standard error of the mean:

σ

Max. and probable Error

- Probable error of a measurement =0.6745 σ
- 50% probability that the actual error exceeds the probable error and 50% prob. that it is less than probable error.
- Max Error = 3 σ
- 99.7% probability that the actual error falls within 3 σ
- Example

- Example 1:

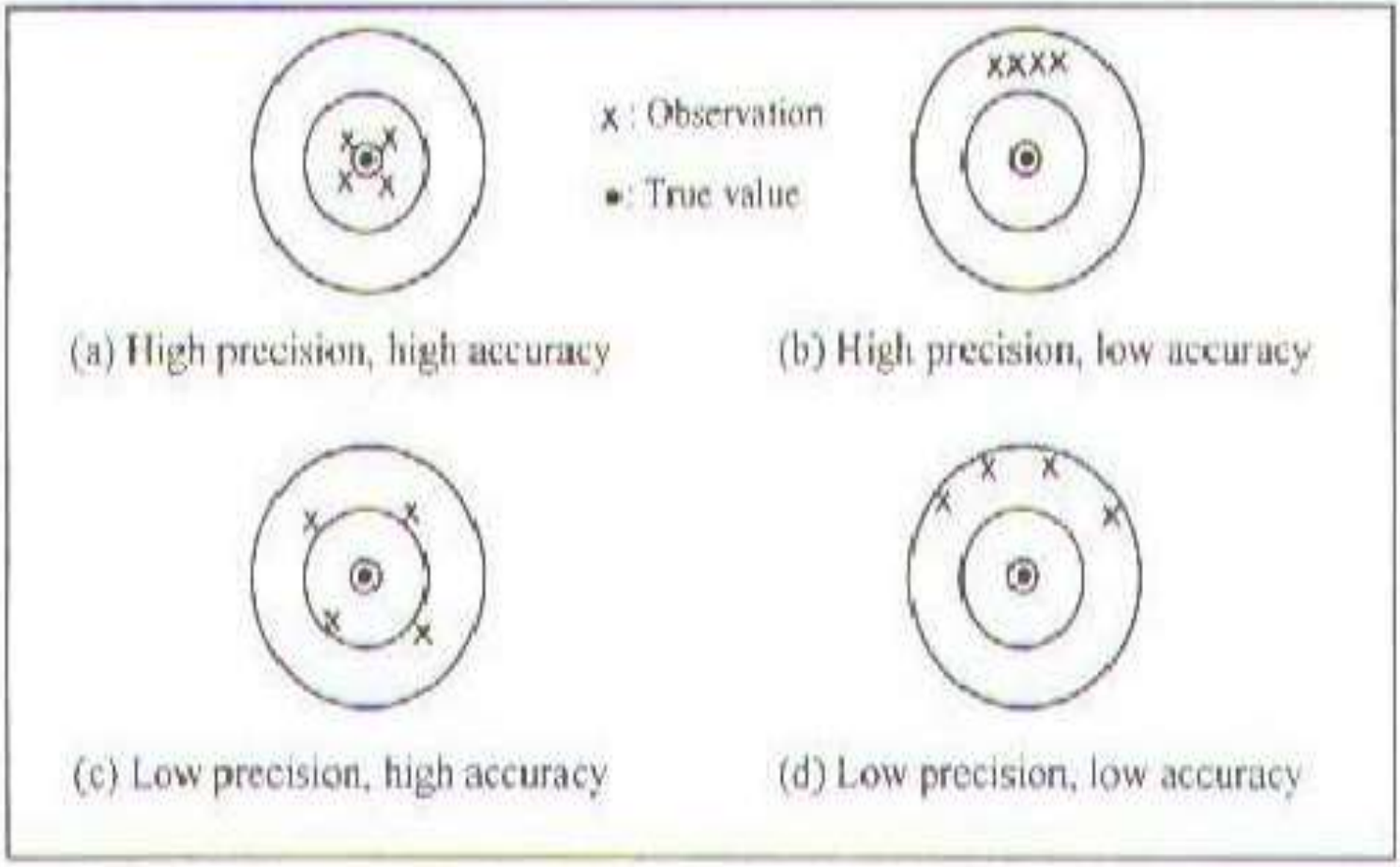
  A distance was repeatedly 12 times and the following results (in meters) were recorded:

  68.78, 68.83, 68.80,68.85, 68.77, 68.18, 68.79, 68.80, 68.81, 68.82,68.79, 68.82

  Check these measurements of the existence of any blunders then compute mean, standard deviation and estimate standard error of the mean?

Precision and Accuracy

- **Precision**
  - **Small standard deviation means high precision**
  - **Graph:**
- **Accuracy:**
  - **Near the true value- higher accuracy**
  - **High accuracy doesn't mean high precision**


x : Observation
•: True value
(a) High precision, high accuracy
(b) High precision, low accuracy
(c) Low precision, high accuracy
(d) Low precision, low accuracy

How to obtain high accuracy and precision:

- Detect and eliminate all blunders
- Eliminate and remove systematic errors by frequent calibration and adjustments of the instruments.
- Minimize random errors by making repeated measurements, good instruments and field procedures

Relative precision

- It is usually used to describe the precision of distance measurements.

Repeated Measurements:

- There is inverse relation between standard deviation and square root of n.
- The no. of repetitions required In order to achieve a certain value standard error of the mean…
- Example…

Propagation and random errors:

- Previously errors of directly measured value were discussed
- But in this section the standard error of quantity calculated from measured value will be discussed..
- Using law of propagation …
- Example