# SURVEYING – I
## LABORATORY MANUAL

**CIVIL ENGINEERING**
**II – B. TECH (I Semester)**

**AURORA'S TECHNOLOGICAL AND RESEARCH INSTITUTE**
**Uppal, Parvathapur**

# PREFACE

For any Civil Engineering project like building a house, constructing a dam, laying out a road, setting up of an industry etc., the first requirement is to have a plan/map of the area. To have a plan/map of any area, it is required to collect information and data about the terrain as well as the objects present in the area by taking necessary measurements using different types of instruments. Data thus collected are being subsequently used to prepare the plan/map of the area. The domain of engineering which involves the collection of field data and subsequently preparation of plan/map of the area is termed as 'Surveying'. Surveying is defined as the science of making measurements of the earth specifically the surface of the earth. This is being carried out by finding the spatial location (relative/absolute) of points on or near the surface of the earth. Different methods and instruments are being used to facilitate the work of surveying.

Surveying is primarily utilised to fix the national and state boundaries, chart coastlines, navigable streams and lakes, establishing control points, execute hydrographic and oceanographic charting and mapping, prepare topographic map of land surface of the earth, prepare plan or map of the area surveyed, collect field data, analyse and to calculate the field parameters for setting out operation of actual engineering works. Moreover, during execution, project of any magnitude is constructed along the lines and points established by surveying. Thus, surveying is a basic requirement for all Civil Engineering projects.

Based upon the consideration of the shape of the earth, surveying is broadly classified as geodetic surveying and plane surveying. Most of the civil engineering works, concern only with a small portion of the earth which seems to be a plane surface. Based on the purpose for which surveying is being conducted, surveying has been classified into: control surveying, land surveying, topographic surveys, engineering surveys, route surveys, construction surveys, astronomic surveys and mine surveys. Engineering survey is of prime importance consisting of three broad steps: reconnaissance survey, preliminary survey, location survey; which helps in collecting requisite data for planning, design and execution of engineering projects such as construction of highways, bridges, tunnels, dams etc. The primary aims of field surveying are to measure horizontal distance, vertical elevation and relative direction of lines by measuring horizontal angles. In the present day scenario, it has become mandatory for every civil engineer to have the basic awareness of surveying. Identifying this need, the university has introduced this practice based course for core branch of Civil Engineering at the second year level for undergraduate students.

The main objective of this study is to help students in gaining the practical experience by exposing them to various techniques of field surveying. The students will have an understanding of the concepts involved in the preparation of layouts, plans, maps etc.

At this juncture, the present course on Surveying Lab - II plays a vital roll for enhancing the knowledge of an aspiring civil engineer. This lab course comprises of twelve experiments which are intended to make the students to understand and gain familiarity with latest surveying techniques. The study consists of Principles of Survey, Theodolite Survey, Tacheometric Survey, Setting Out Works and Total Station Survey. Further, different methods of curve setting have been emphasized.

At the end of this course, a student should be able to appreciate the role of the surveyor in the civil engineering industry: to plan and execute a topographical survey for engineering development; plan, design and set out engineering works; manage, organise and execute a given task to meet specifications within a strict deadline; work in groups

# CONTENTS

# Evaluation of Laboratory Marks for II Year (Internal Exams)

1. The internal lab examination schedules will be given by the Examination Branch.

2. During a year there will be three lab exams and each exam will be evaluated for 25 marks.

3. Average of three lab exams will be the final internal lab exam marks.

4. First laboratory exam will be conducted on First 1/3 of the total number of experiments, Second Laboratory Exam will be conducted on the Second 1/3 of experiments and the Third Laboratory Exam will be conducted on the last 1/3 of experiments.

The evaluation is as follows

| | | | |
|---|---|---|---|
| I. | Continuous evaluation | - | 15 marks |
| II. | Internal Laboratory Exam | - | 10 marks |

**I. Continuous Evaluation**

a) Day to day evaluation - 10 marks
Each experiment / program will be evaluated for 10 marks.
The splitting of marks is as follows

i) Attendance - 2 marks
The student should attend the lab regularly; if he/she is absent he/she will be losing 2 marks.

ii) Experiments / program and observation
The student should complete the program / experiment within the assigned time otherwise he / she will be losing 2 marks.

iii) Experiment result will carry 4 marks.

iv) Record 2 marks
Student must submit the record in the next lab session.

v) Average marks of the Half of the experiments will be considered for day to day evaluation for 10 marks separately for lab examination one and two.

b) Lab knowledge Test (Quiz) 5 marks

- A quiz will be conducted along with the internal lab exam and schedule will be given separately.

- The quiz will be conducted for 20 minutes. The quiz contains 20 questions of type multiple choice. Each question carrying 0.25 marks.

**II. Internal laboratory examination** - 10 marks

a) Exam - 7 marks

The Splitting of marks as follows

i) Experiments / Program write up - 4 marks

ii) Result and Graphs - 3 marks

b) Viva Voce - 3 marks

- The internal lab examination duration - 2 hours
- Every student will be given programs / experiments in the internal lab exam. In case the student wishes to change the programs / experiments 1 mark will be deducted. A time slot of 45 minutes is given for write up of programs / experiments.
- The student is expected to complete the assigned program / experiment within 1 hour and the remaining 15 minutes will be utilized for viva voce examination.

5. There shall be no supplementary exams in case the student fails to attend internal lab and quiz exam as per schedule.

# Evaluation of Laboratory Marks (End exams)

1. The external lab examination schedules will be given by the Examination Branch.

2. Duration of External lab examinations - 3 Hours

3. Exam will be evaluated for 50 Marks

   The Splitting of marks is as follows

| | | | |
|---|---|---|---|
| I. | Experiment write-up / Program with algorithm | - | 10 marks |
| II. | Experiment Setup / Program execution | - | 10 marks |
| III. | Result | - | 10 marks |
| IV. | Viva –Voce | - | 20 marks |
| | a) Written Viva | - | 10 marks |
| | b) Oral Viva | - | 10 marks |

   Written Viva–Voce Exam will be consisting of 10 questions of short answer type and fill in the blanks. Each question will carry equal marks and allotted time is 15 minutes.

**LAB CODE**

1. Students should report to the labs concerned as per the timetable.

2. Students who turn up late to the labs will in no case be permitted to perform the experiment scheduled for the day.

3. After completion of the experiment, certification of the staff in-charge concerned in the observation book is necessary.

4. Students should bring a notebook of about 100 pages and should enter the readings/observations/results into the notebook while performing the experiment.

5. The record of observations along with the detailed experimental procedure of the experiment performed in the immediate previous session should be submitted and certified by the staff member in-charge.

6. Not more than three students in a group are permitted to perform the experiment on a set up.

7. The group-wise division made in the beginning should be adhered to, and no mix up of student among different groups will be permitted later.

8. The components required pertaining to the experiment should be collected from Lab-in-charge after duly filling in the requisition form.

9. When the experiment is completed, students should disconnect the setup made by them, and should return all the components/instruments taken for the purpose.

10. Any damage of the equipment or burnout of components will be viewed seriously either by putting penalty or by dismissing the total group of students from the lab for the semester/year.

11. Students should be present in the labs for the total scheduled duration.

12. Students are expected to prepare thoroughly to perform the experiment before coming to Laboratory.

13. Procedure sheets/data sheets provided to the students' groups should be maintained neatly and are to be returned after the experiment.

14. DRESS CODE:

    Boys - Formal white shirt neatly tucked in, and white trousers, white / black / brown / tan shoes and belt, I-cards worn round neck

    Girls - Formal white Salwar Kameez, white / black / brown / tan shoes, I-cards worn round neck

# PRINCIPLES OF SURVEYING

The fundamental principles upon which the surveying is being carried out are

- working from whole to part.
- after deciding the position of any point, its reference must be kept from at least two permanent objects or stations whose position have already been well defined.

The purpose of working from whole to part is

- to localise the errors and
- to control the accumulation of errors.

This is being achieved by establishing a hierarchy of networks of control points (Stations having known position). The less precise networks are established within the higher precise network and thus restrict the errors. To minimise the error limit, highest precise network (primary network) Fig.1 of control points are established using the most accurate / precise instruments for collection of data and rigorous methods of analysis are employed to find network parameters. This also involves most skilled manpower and costly resources which are rare and cost intensive.

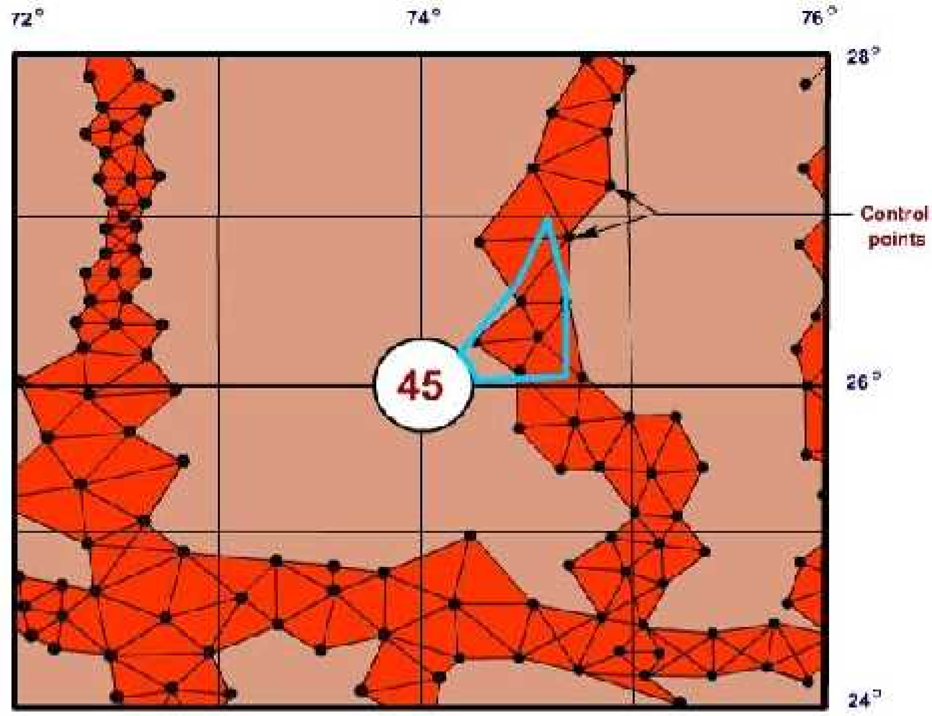



**Fig.1 Network of control points**

# CHAIN SURVEY

# INTRODUCTION

This method of surveying derives its name from the fact that the principal item of equipment used in is the measuring chain. The equipment used in this type of survey are simple in construction. However work of a sufficiently high order of accuracy to cover the requirements of much ordinary engineering work is possible, especially when large-scale plans of relatively small area are required. In addition to being a complete method of surveying, some operations of chain surveying occur in other methods of surveying. A good knowledge of chain surveying is therefore essential to a proper knowledge of surveying as a whole.

## 1) EQUIPMENT AND ACCESSORIES:

### *Chain*

A chain is mainly used in chain surveying to measure the distances. A chain may be metric or non-metric. Generally a chain consists of 100 or 150 links each 300 mm or 200 mm length. The link is made of galvanized mild steel wire 4 mm to 6mm diameter. The ends of each link are bent into a loop and connected together by means of three oval rings. The ends of the chain are provided with handles for dragging the chain on the ground, each wire with a swivel joint so that the chain can be turned without twisting. The length of the chain is measured from the outside of one handle to the outside of another handle.

**Fig.2 Chain**

### Types of chains

**i. Metric chains**

Metric chains of length 20m, 30m, 50m and 100m are used now-a-days for measuring the distances in metres and its fractions.

### ii. Non-metric chains

The following are the non metric chains in which the unit of measurement is foot.

a) Engineers chain

It is 100 feet long and consists of 100 links, each of 1 foot length.

b) Gunter's chain or surveyor's chain

It is 66 feet in length, consists of 100 links each being 0.66 foot long

c) Revenue chain

It is 33 feet long and consists of 16 links. It is used in cadastral survey.

### iii. Steel band or Band chain

It is made of steel ribbon 16 mm wide and is available in 20 and 30m lengths. It is wound on an open steel cross in a closed case.

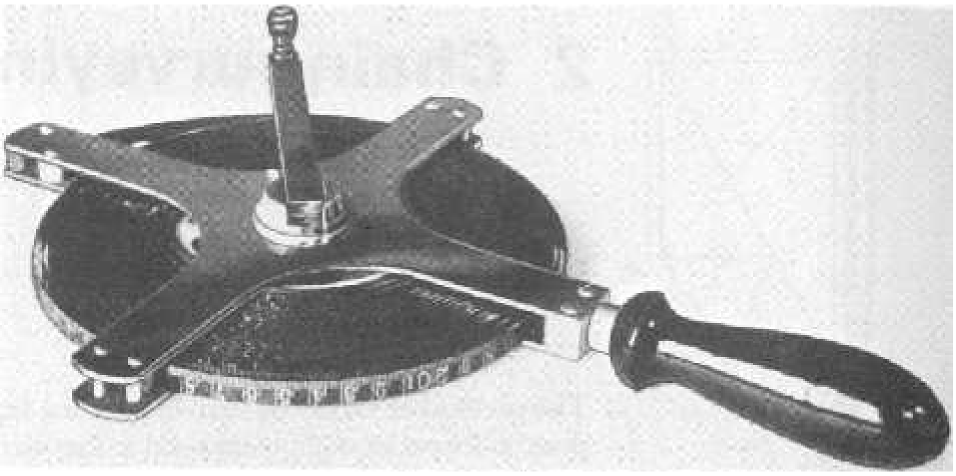


**Fig.3. Steel band or band chain**

***Tapes***

Tapes are used for measuring the distances in precise work. Following are the various types of tapes.

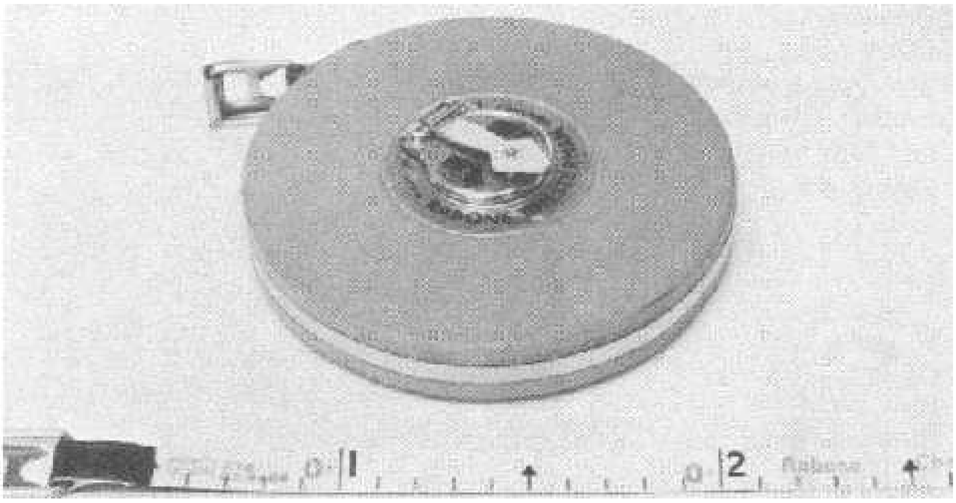


**Fig.4 Tape**

i) Cloth or linen tape
ii) Metallic tape
iii) Steel tape
iv) Invar tape

**a) Cloth or linen tape**

It is made of woven linen strip 5 mm to 15 mm wide and varnished. It is easily affected by damp.

**b) Metallic tape**

It is made of linen strip inserted with metallic wires.

**c) Steel tape**

It is made of thin steel strip and is available in 10, 20, 30 and 50 metre lengths. It is widely used for measurements.

**d) Invar tape**

It is made of an alloy of steel and nickel. It is used for the work of highest precision.

***Arrows***

Arrows are made of good quality hardened steel wire of 4 mm diameter.The arrows are made 400 mm in length, are pointed at one and the other end is bent into a loop or circle.

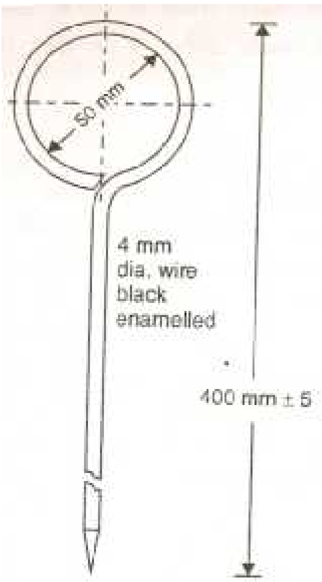



**Fig.5 Arrow**

***Ranging rods***

Ranging rods are used to range some intermediate points in the survey line. The length of the ranging rod is either 2m or 3m. They are shod at bottom with a heavy iron point. Ranging rods are divided into equal parts 0.2m long and they are painted alternately black and white or red and white or red, white and black. When they are at considerable distance, red and white or white and yellow flags about 25 cm square should be fastened at the top.

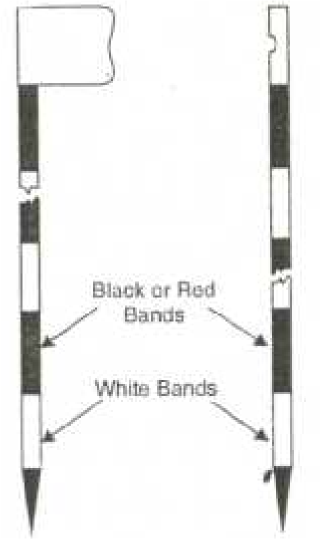



**Fig.6 Ranging rod and offset rod**

### *Offset Rod*

An offset rod is similar to ranging rod, but it is provided with a hook at the top for pulling or pushing the chain through a hedge. It is divided into metres and decimeters with alternate bonds of paints. Offset rods are mainly used for measuring offsets.

### *Cross staff*

The simplest instrument used for setting out a right angle. The common forms of cross staff are: Open cross staff, French cross staff, Adjustable cross staff.

### *Pegs*

These are rods made from hard timber and tapered at one end, generally 25mm or 30mm square and 150mm long wooden pegs are used to mark the position of the stations on the ground.

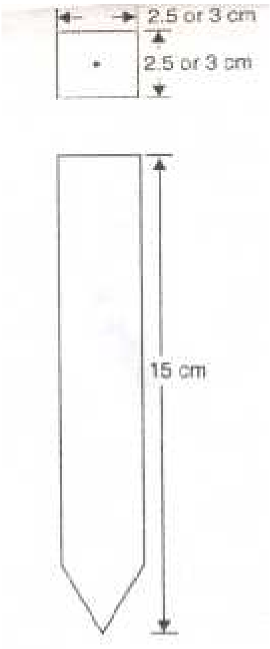



**Fig.7 Peg**

***Plumb Bob***

It is a solid cone attached to a thread. It is used when measuring distances along slopes to transfer points to the ground.

## 2) TERMINOLOGY:

***Main Station***

Main station is a point in chain survey where the two sides of a traverse or triangle meet. These stations command the boundaries of the survey and are designated by capital letters such as A, B, C etc.

***Tie Station or Subsidiary Station***

Tie station is a station on a survey line joining two main stations. These are helpful in locating the interior details of the area to be surveyed and are designated by small letters such as a, b, c etc.

***Main Survey Line***

The chain line joining two main survey stations is called main survey line. AB, BC are examples of main survey lines.

***Tie Line or Subsidiary Line***

A chain line joining two tie stations is called tie line such as ab or cd. It is also called auxiliary line. These are provided to locate the interior details which are far away from the main lines.

***Base Line***

It is the longest main survey line on a fairly level ground and passing through centre of the area. It is most important line as the direction of all other survey lines are fixed with respect to this line.

***Check Line***

Check line or proof line is a line which is provided to check the accuracy of the field work. The measured length of the check line and computed (scaled off the plan) must be the same. AD is an example of check line.

***Offset***

It is the distance of the object from the survey line. It may be perpendicular or oblique.

***Chainage***

It is the distance of a well defined point from the starting point. In chain surveying it is normally referred to as the distance of the foot of the offset from the starting point on the chain line.

## 3) ERRORS IN CHAINING:

Errors in chaining are classified as follows

a) Compensating errors
b) Cumulative errors
c) Gross errors

### *Compensating errors*

These errors are liable to occur in both the directions and tend to compensate. These errors occur due to:

1) Incorrect holding and marking of the arrows.
2) Fractional parts of the chain may not be correct, that is, the chain may not be calibrated uniformly.
3) Plumbing may be incorrect while chaining by stepping on slopes.
4) In setting chain angles with a chain.

### *Cumulative errors*

These errors are liable to occur in the same direction and tend to accumulate. The error thus considerably increase or decrease the actual measurements. The cumulative errors are proportional to the length of line and may be positive or negative.

Positive cumulative errors: These are the errors which make the measured lengths more than the actual. Therefore, the actual length can be found by subtracting the error from the measured length.

1) The length of the chain is shorter than the standard length.
2) Bending of links, knots in links, removal of rings during adjustment of the chain, clogging of rings with mud etc.
3) Not applying slope correction to the length measured along slopes.
4) Not applying sag correction.
5) Not applying temperature correction when temperature during measurements is less than the standard temperature.
6) Bad ranging, bad straightening and wrong alignment.

Negative cumulative errors: These are the errors which make the measured length less than the actual. Therefore the actual length can be found by adding the error to the measured length.

1) Length of chain is more than the standard length, which may be due to flattening of rings, opening of joints etc.
2) Not applying the temperature correction when temperature during measurements is more than the standard temperature.

***Gross errors***

The four sources of mistakes are the following

1) Displacements of arrows or station marks.
2) Miscounting tape lengths
3) Misreading the tape
4) Wrong booking

## 4) PRECAUTIONS:

In every fieldwork exercise relevant precautions have to be taken to minimize the errors that are mentioned in the previous paragraphs.

## 5) APPLICATIONS:

This surveying method can be used to measure distances between two survey stations and also to prepare topographic maps of small parcel of land.

# EXERCISE 1
## INSTRUMENTS AND TECHNIQUES - CHAIN SURVEYING

***Aim:***

Study of various instruments used in chain surveying.

***Equipment and Accessories:***

Chain, Tape, Arrows, Ranging rods, Cross- staff and Pegs.

***Principle:***

Chain and Tape are used for linear measurement in horizontal plane. Metric chains are made in lengths 20m and 30m.The chain is composed of 100 pieces of links of galvanized mild steel wire of 4mm diameter. The ends of each link are bent into a loop and connected together by means of three oval rings. The ends of the chain are provided with handles for dragging the chain on the ground, each wire with a swivel joint so that the chain can be turned without twisting. The length of the chain is measured from the outside of one handle to the outside of another handle. In chain surveying along with chain or tape, arrows, ranging rods, cross-staff, pegs and plumb bob are employed.

***Procedure:***

***Unfolding of Chain***

1) Remove the strap of the folded chain and take both the handles in the left hand and hold the remaining portion of the chain in the right hand.
2) Holding both the handles in the left hand, throw the remaining portion o f the chain in the forward direction on the ground.
3) Now the '**follower'** stands at the starting station by holding one handle and directs the **'leader'** to move forward by holding the other handle until the chain is fully stretched.

***Reading the Chain***

Chain can be read from both the ends. While taking the measurement, observe the tag immediately before the point to be measured. Then count the number of links in the forward direction up to the point of measurement.

***Folding of Chain***

1) Bring the two handles together on the ground by pulling the chain at the center.
2) Commencing from the center two pairs of links are taken at a time with the right hand and placed alternatively in both directions in the left hand.
3) When the chain is completely folded the two brass handles will appear at the top.
4) Now tie the chain with leather strap.

### *Ranging*

1) To range a long line AB whose length is more than the length of a chain or tape: fix ranging rods at the end of the line AB, that is, ranging rods are placed at points A and B on the ground.
2) The follower stands 2m behind the ranging rod at the starting point A.
3) The leader holds a ranging rod at arms length at C, approximately on the line AB.
4) The follower then directs the leader to move his ranging rods to the right or left as required till all the three ranging rods are in one line.
5) The leader then fixes a rod or an arrow or a peg in the ground to establish the point ‘C’ in line with AB.
6) Similarly, other points are established on the line AB.

### *Erecting a perpendicular line on a chain line*

Cross-staff is a simplest instrument used to erect perpendicular lines/off-sets on a survey line.

1) Hold the cross-staff vertically on the chain line at a point where the perpendicular has to be erected.
2) Turn it so that one line of sight passes through the ranging rods fixed at the end of the survey line.
3) Looking through the other pair of slits fix the ranging pole at a required distance and mark the point on the ground using either an arrow or a peg.

### *Comments/Inference*

Write your opinion about the usefulness of each equipment and also their limitations.

# EXERCISE 2
## CLOSED TRAVERSE – CHAIN SURVEY

***Aim:***

To conduct the chain survey closed traverse around a building and plot the existing building.

***Equipment and Accessories:***

Chain, Tape, Arrows, Ranging rods, Cross-staff, Pegs, plumb bob, hammer, field-book, pencils, eraser.

***Principle:***

Traversing is a method of control surveying. Traverse is the framework of survey lines connecting the control points. A series of control points (stations), each one being intervisible with its adjacent stations are chosen. The survey lines joining the control points are called traverse lines. In chain traverse work linear measurements (entire work is done by chain and tape) are taken to establish the lengths and directions of the traverse lines. The offsets necessary to locate the details are taken along the traverse lines in the usual way and recorded in the field-book.

***Procedure:***

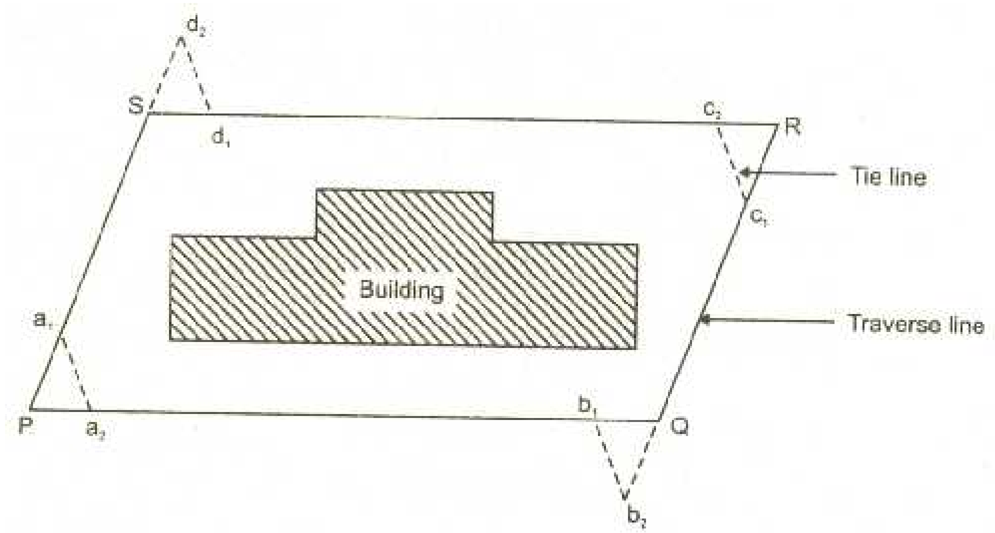



**Fig.8 Position of a given building**

It is required to plot the position of a given building (for example the building shown in Fig.7 given above).

1. Walk over the area to have the general idea about the main features and boundries. Then prepare a neat free-hand sketch in the field book called ‘key plan’ which shows the boundaries, main features, positions of chain lines and survey stations. Draw the north direction on the right hand top corner by an arrow pointing vertically upward.
2. With reference to the key plan drawn, mark all the survey stations (for example *P*, *Q*, *R* and *S* as shown in figure) on the ground using pegs.
3. Range a survey line (say survey line *SR*) on an any one side of the building.

4. Stretch the chain in true alignment along survey line keeping one end of the chain at the starting station. Fix an arrow at the other end of the chain while it is kept laying on the ground.
5. Walk along the chain line and take either perpendicular offsets or oblique offsets to the corners of the building and to any other feature that is to be included in plan.
6. Record chainages and offsets in the field-book.
7. Repeat the process of chaining and offsetting until you reach the end of survey line.
8. Complete the survey work along the remaining survey lines.
9. At each survey station take tie lines connecting two survey lines and record the measurements in field-book.

***Observations and Calculations:***

10. The complete record of the chain survey in addition to all the measurements taken in the field should also include, the date of survey, name of the survey site and the names of the surveyors.
11. It is required to draw the plan to a suitable scale. Having chosen a scale obtain the plan dimensions from the field measurements.

***Result:***

1. Using the data recorded in the field-book prepare a plan of the area surveyed to a suitable scale on an *A3* drawing sheet.
2. The plan should be oriented in such a way that the north line points more or less upwards.

# EXERCISE 3
## CHAINING ACROSS OBSTACLES

***Aim:***

To run a survey line across an obstacle obstructing both ranging and chaining using chain survey technique.

***Equipment and Accessories:***

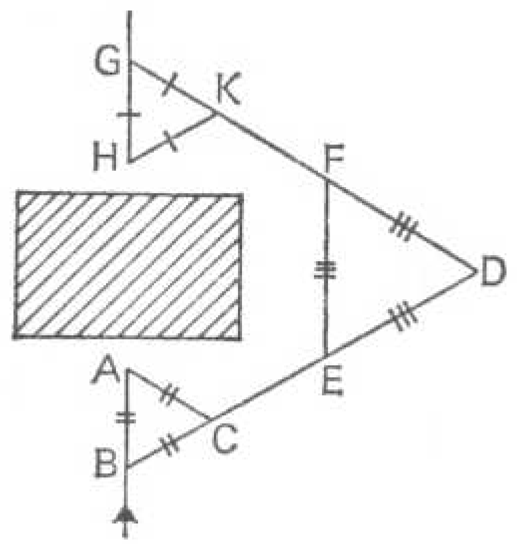
Chain, tape, arrows, ranging rods, pegs, plumb bob, hammer, field-book, pencils, eraser.

***Principle:***

The main steps involved in chain survey are chaining and taking offsets. During chaining a survey line it may not be always possible to chain line in a straightforward method because of a variety of obstructions to chaining and ranging in the field. The difficulties can be overcome by running perpendicular and parallel lines or by running lines at some suitable angle.

The obstacles may be divided into two classes. Those which do not obstruct the ranging (view) like ponds, rivers etc. fall in the category of obstacles to measurement. The others are those which we cannot see across, i.e., both the chaining and ranging are obstructed, e.g., houses, hay stacks, etc., and are known as obstacles to alignment.

***Procedure:***




BD = DG = GB
AH = BD − AB − GH

**Fig.9 Survey line which is obstructed by a building**

It is required to range a survey line which is obstructed by a building. The ranged line as shown in figure proceeds as far as *A* and can go no farther.

1. Mark a point *B* on the survey line at a convenient distance such that *AB* forms a base.
2. From the base *AB* set out a point *C* on the ground such that *AB* = *AC* = *BC*. This results in the equilateral triangle *ABC*.
3. Produce the line *BC* to set out point *D* on the ground such that it is clear of the obstacle.
4. On the line *BD* thus formed set out a point *E* on the ground at a convenient distance such that *DE* forms a base.
5. From the base *DE* set out a point *F* on the ground such that *DE* = *EF* = *DF*. This results in the equilateral triangle *DEF*.
6. Produce the line *DF* to set out point *G* on the ground such that BD = *DG*, so that the triangle *BDG* is also equilateral. *(G now lies on the extension of AB. But the direction of the line cannot be established until the third equilateral triangle GHK is set out.)*
7. On the line *DG* thus formed set out a point *K* on the ground at a convenient distance such that *GK* forms a base.
8. From the base *GK* set out a point *H* on the ground such that *GK* = *GH* = *KH*. This results in the equilateral triangle *GHK*.
9. Produce *HG* forward to continue the survey. *(HG Produced provides the extension of the survey line AB on the other side of the building)*

***Observations and Calculations:***

1. The complete record of the chain survey in addition to all the measurements taken in the field should also include, the date of survey, name of the survey site and the names of the surveyors.
2. It is required to draw the plan to a suitable scale. Having chosen a scale obtain the plan dimensions from the field measurements.

***Result:***

Using the data recorded in the field-book prepare a plan to a suitable scale.

# COMPASS SURVEY

# INTRODUCTION

If two lines are required to be plotted in chain surveying, the third line to form the triangle must also be measured. However, if the bearings of the two lines are known they can be plotted by scaling the angle they make with a reference direction without the need for making further linear measurements.

By setting up a compass at the intersection of the lines and by observing their magnetic bearings their directions may be plotted. This process may be extended through successive lines, forming a compass traverse, which enables a complete network of survey lines to be plotted without the need for a base line or check lines.

If the series of lines closes back on to the starting point, the work may be checked because the plotted figure must also close back on to its starting point.

Compass surveys are mainly used for rapid filling in of detail in larger surveys and for exploratory work and not for accurate, large-scale plans. Compasses do not provide a very accurate determination of the bearing of a line as the compass needle aligns itself to the earth’s magnetic field, which does not provide a constant reference direction.

## 1) EQUIPMENT AND ACCESSORIES:

The magnetic compasses used in surveying may be classified as:

- Prismatic compass
- Surveyor's compass
- Trough compass
- Tubular compass

The general principle on which the compasses work is same for all types of compass. If a long and narrow magnetized iron or steel strip suspended on a pivot at its centre, is allowed to oscillate freely about its vertical axis passing through the pivot, it will always tend to assume a direction of the magnetic meridian at the place.

In our fieldwork exercises we will use the prismatic compass

***Prismatic compass***

It is the most suitable portable form of compass used for surveying. Main parts of a prismatic compass are shown in figure given below.

**Fig.10 Prismatic compass**

A prismatic compass consists of a circular box of about 100 mm diameter. A magnetic needle is attached to a light circular aluminium ring balanced on a hard steel pointed pivot. The ring is graduated to degree and half degree with 0° mark at the south end of the needle and 180° mark at its north end. The graduations run clockwise, therefore, 90° mark is towards west and 270° mark is towards east as shown in figure.

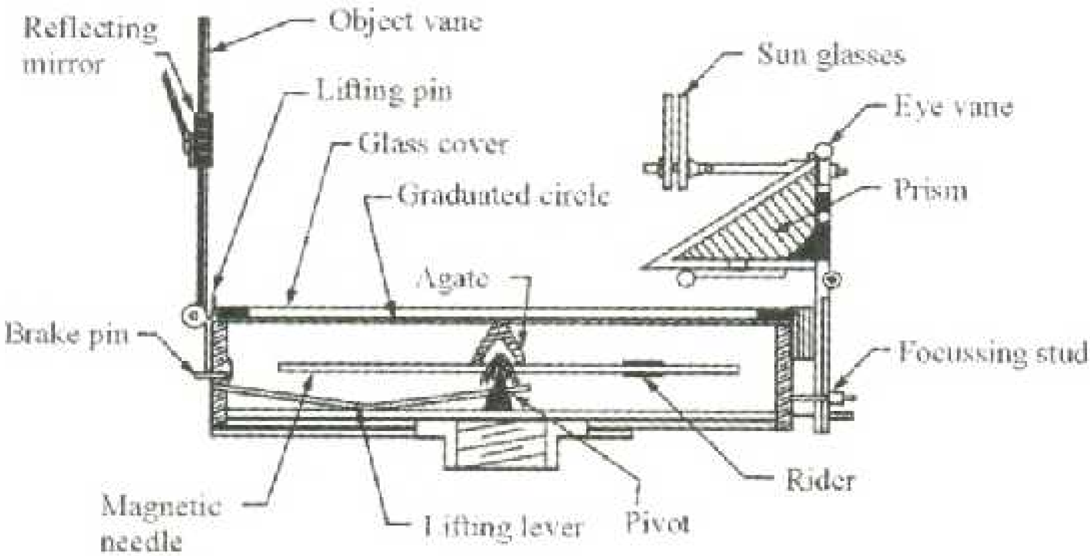


**Fig.11 Section through prismatic compass**

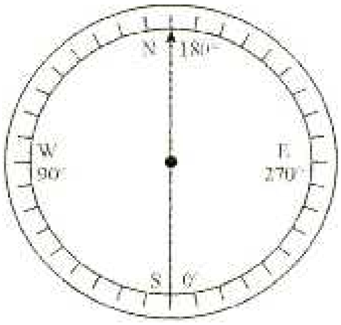



**Fig.12 Graduations in prismatic compass**

The figures on the ring are written inverted. When these are read using a prism, they are erected and magnified. The object vane carries a vertical hair attached to a suitable frame. Sight vane or eye slit consists of a vertical slit cut into the upper assembly of the prism. The object vane and sight vane are hinged to the box, diagonally opposite at the top.

To sight an object, the sight vane is rotated with respect to N-S ends of the ring through an angle which the line makes with the magnetic meridian. The angle read is the whole-circle bearing of the line at the compass station. Brake pin may be used to dampen the oscillations of the needle by pressing it. The sun glasses provided at the eye vane may be used to sight the bright objects. When the instrument is not in use, the object vane frame may be folded on the glass lid. It automatically presses against a bent lever, which lifts the needle off the pivot and holds it against the glass lid.

The other equipment and accessories used in this type of surveying are tripod stand, chain, tape, ranging rods, pegs, plumb bob, hammer, field-book, pencils, eraser.

**2) TERMINOLOGY:**

***Bearing***

Bearing of a line is its direction relative to a given meridian. A meridian in any direction such as (1) True Meridian (2) Magnetic Meridian (3) Arbitrary Meridian

***True Meridian***

True meridian through a point i.e., the line in which a plane, passing that point and the north and south poles, intersects with surface of the earth. It thus, passes through the true north and south. The direction of true meridian through point can be established by astronomical observations.

***True Bearing***

True bearing of a line is the horizontal angle which it makes with the true meridian through one of the extremities of the line. Since the direction of the meridian through a point remains fixed, the true bearing of a line is a constant quantity.

***Magnetic Meridian***

Magnetic meridian through a point is the direction shown by a freely floating and balanced magnetic needle free from all other attractive forces. The direction of magnetic meridian can be established with the help of a magnetic compass.

***Magnetic Bearing***

The magnetic bearing of a line is the horizontal angle which it makes with the magnetic meridian passing through one of the extremities of the line. A magnetic compass is used to measure, it.

***Arbitrary Meridian***

Arbitrary meridian is any convenient direction towards a permanent and prominent mark or signal, such as a church spire or top of a chimney. Such meridians are used to determine the relative positions of lines in a small area.

***Arbitrary Bearing***

Arbitrary bearing of a line is the horizontal angle which it makes with any arbitrary meridian passing through one of the extremities. A theodolite or sextant is used to measure it.

**3) TEMPORARY ADJUSTMENTS:**

Temporary adjustments are those adjustments which have to be made at every set up of the instrument. They comprise the following:

***Centring***

Centring is the process of keeping the instrument exactly over the station. Ordinary prismatic compass is not provided with fine centring device as is generally fitted to engineer's theodolite. The centring is invariably done by adjusting or manipulaling the legs of the tripod. A plumb-bob may be used to judge the centring and if it is not available, it may be judged by dropping a pebble from the centre of the bottom of the instrument.

***Levelling***

If the instrument is a hand instrument, it must be held in hand in such a way that graduated disc is swinging freely and appears to be level as judged from the top edge of the case. Generally, a tripod is provided with ball and socket arrangement with the help of which the top of the box can be levelled.

***Focusing the Prism***

The prism attachment is slided up or down for focussing till the readings are seen to be sharp and clear.

**4) ERRORS IN COMPASS SURVEY:**

The error may be classified as:

a) Instrumental errors
b) Personal errors
c) Errors due to natural causes

***Instrumental error***

These errors arise due to the faulty adjustments of the instruments. They may be due to the following reasons.

1) The needle not being perfectly straight.
2) Pivot being bent.
3) Sluggish needle.
4) Blunt pivot point.
5) Improper balancing weight
6) Plane of sight not being vertical

***Personal errors***

These errors arise due to the following reasons

1) Inaccurate Levelling of the compass box.
2) Inaccurate centring.
3) Inaccurate bisection of target.
4) Carelessness in reading and recording.

***Natural errors***

These errors arise due to the following reasons

1) Variation in declination.
2) Local attraction due to proximity of local attraction forces.
3) Magnetic changes in the atmosphere due to clouds and storms.
4) Irregular variations due to magnetic storms etc.

**5) Precautions:**

In every fieldwork exercise relevant precautions have to be taken to minimize the errors that are mentioned in the previous paragraphs.

**6) APPLICATIONS**

Compass surveys are mainly used for rapid filling in of detail in larger surveys and for exploratory work. It is also used for tracing of streams and plotting irregular shore lines.

# EXERCISE 4
## DISTANCE BETWEEN TWO INACCESSIBLE POINTS – COMPASS SURVEY

***Aim:***

To find the horizontal distance between two inaccessible points.

***Equipment and Accessories:***

Prismatic compass, stand, chain, tape, ranging rods, pegs, plumb bob, hammer, field-book, pencils, eraser.

***Principle:***

Prismatic compass is an instrument based on the principle that a freely_suspended or pivoted magnetic needle point in the direction of magnetic meridian. The bearings of lines are obtained in the WCB system.

***Procedure:***

It is required find the distance between two points $P$ and $Q$. Both $P$ and $Q$ are inaccessible.

1. Select two stations $A$ and $B$ on the ground such that line $AB$ is nearly parallel to line $PQ$.
2. Measure the distance $AB$.
3. Centre the prismatic compass over station $A$ and observe the bearings of lines $AP$, $AQ$ and $AB$ and record them as $\theta_1$, $\theta_2$ and $\theta_3$ Thus angles $\alpha$ and $\beta$ can be obtained.
4. Centre the prismatic compass over station $B$ and observe the bearings of lines $BA$, $BP$ and $BQ$ and record them as $\theta_4$, $\theta_5$ and $\theta_6$. Thus angles $\gamma$ and $\delta$ can be obtained.

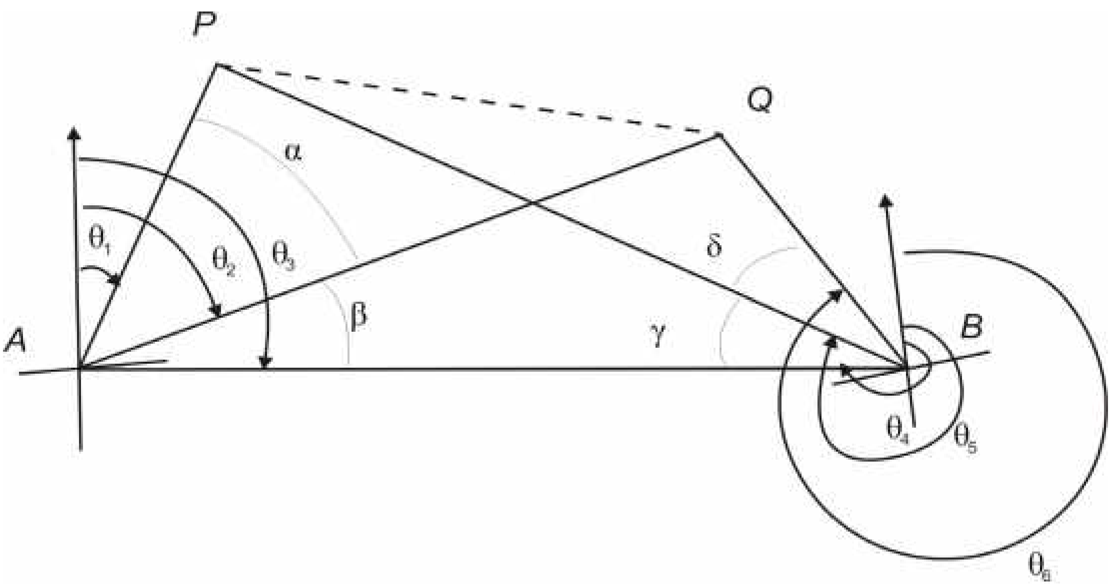



**Fig.13 Distance between two inaccessible points – compass survey**

***Observations and Calculations:***

1) $\alpha = \theta_2 - \theta_1$ ; $\beta = \theta_3 - \theta_2$ ; $\gamma = \theta_5 - \theta_4$ ; $\delta = \theta_6 - \theta_5$

2) $$PB = \frac{AB}{Sin180 - (\sim + \quad + \text{¥})} * \ Sin\,(\sim + \quad)$$

3) $$QB = \frac{AB}{Sin180 - (\quad + \text{¥} + \text{¢})} * Sin$$

4) $PQ = \quad (PB^2 + QB^2 - 2*PB*QB*Cos\ \text{¢}\ )^{1/2}$

***Result:***

Distance between inaccessible points PQ is = ________

# EXERCISE 5
## CLOSED TRAVERSE – COMPASS SURVEY

***Aim:***

To plot the plan of a given area by compass traversing.

***Equipment and Accessories:***

Prismatic compass, stand, chain, tape, ranging rods, pegs, plumb bob, hammer, field-book, pencils, eraser.

***Principle:***

Traverse is the framework of survey lines connecting the control points. A series of control points (stations), each one being intervisible with its adjacent stations are chosen. The survey lines joining the control points are called traverse lines. In this method of traversing linear measurements are taken with either chain or tape and every bearing is observed directly from the magnetic meridian established at each station by the floating needle of prismatic compass. Both fore and back bearings of lines are observed at each station. The offsets necessary to locate the details are taken along the traverse lines in the usual way and recorded in the field-book.

***Procedure:***

***Fieldwork***

1. Select the traverse stations *A*, *B*, *C*, *D* & *E* (say as shown in figure given below) along the boundary of the given area. Traverse stations must be chosen such a way that the preceding and succeeding traverse stations must be visible from any traverse station.

2. Set up the prismatic compass on a tripod over station *'A'* and level it to allow the needle to swing freely.

3. Rotate the case until the back station *E* is sighted and observe the WCB of line *AE* and record it in the table.

4. Rotate the case until the forward station *B* is sighted and observe the WCB of line *AB* and record it in the table.

5. Measure the distance *AB* and record it in the table.

6. Shift the prismatic compass to the forward station *B* and carry out similar measurements and recordings as is done in steps 3, 4 and 5.

7. Similarly complete the work on remaining stations *C, D* and *E*.

## *Graphical Plot*

1. Using the observations recorded in the table obtain the corrected bearings in order to eliminate the local attraction.
2. Draw a line up the drawing sheet to represent the reference direction of the magnetic meridian and mark the starting point *A*.
3. Place the circular protractor with its centre at *A* and zero lined up with the reference direction. Mark on the paper against the protractor edge the corrected bearing of line *AB*.
4. Remove the protractor, draw the direction of the line *AB*, scale the distance and plot the position of *B*.
5. The direction of *BC* is plotted by placing the centre of the protractor at *B* and orienting it by rotating it until its zero direction is parallel to the reference direction as before. This is achieved when the line *BA* cuts the protractor at the corrected bearing of *BA*.
6. Mark the bearing *BC* and plot *C* in the same way as *B* was plotted before.
7. Continue the process for all remaining stations. And thus obtain the figure *ABCDEA′*.
8. The figure *ABCDEA′* as now plotted does not truly represent the actual figure on the ground because the plotted figure gives two positions for *A*, where as only on exist on the ground. This apparent displacement of *A* is due to the build-up of error in surveying and plotting around the traverse. The total error in the figure indicated by the line *AA′* may be distributed back around the figure graphically in the following way:
   a) *A′* should be at a and must be moved the distance *AA′* in the direction shown. The effect of this movement will be to move the plotted position of the other points proportionally alon the parallel directions.
   b) Draw lines parallel to the direction of the closing error through the other plotted points.
   c) Draw a straight line and scale off the lengths of the traverse legs along it. The scale of this construction need not be the same as for the original traverse plot and is more conveniently drawn to a smaller scale.
   d) Erect perpendiculars at each point along the line. Pick off the length of the closing error on the plot with a pair of dividers and mark it on the perpendicular erected at *A*'. Join *aA*
   e) The intersection of *aA* with the perpendiculars indicates the extent of adjustment needed for each station, illustrating also the proportional build-up or error from nothing at *A* to the maximum amount of *A′*.
   f) The amount of error at *E*, being *eE*, is picked off the diagram and transferred to the line drawn through *E* on the plot parallel to the closing error, giving the adjusted position *e*. The other errors at each station are transferred to the plot in the same way.
   g) Join up the positions of the adjusted points giving the figure *AbcdeA*, which now forms the graphically adjusted traverse. This figure represents more closely the actual layout on the ground than the original plot did prior to adjustment.

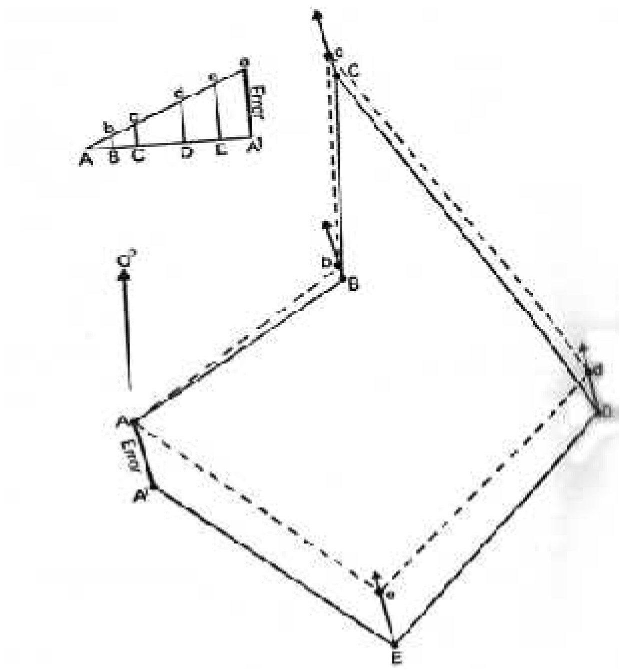



**Fig.14 Closed traverse – compass survey**

***Observations and Calculations:***

***TABLE***

| S. No | Station | Line | Length (m) | Observed WCB | Correction | Corrected WCB |
|---|---|---|---|---|---|---|
| 1 | *A* | *AE* | --- | | | |
| | | *AB* | | | | |
| 2 | *B* | *BA* | --- | | | |
| | | *BC* | | | | |
| 3 | *C* | *CB* | --- | | | |
| | | *CD* | | | | |
| 4 | *D* | *DC* | --- | | | |
| | | *DE* | | | | |
| 5 | *E* | *ED* | --- | | | |
| | | *EA* | | | | |

***Result:***

Plan of the given area is shown on the drawing sheet.

# PLANE TABLE SURVEY

# INTRODUCTION

In plane table surveying, a plane table is used for taking the measurements and for plotting the plan in the field. A plane table consists of a drawing board mounted on a tripod. Plane table surveying is a method in which the field observations and plotting of the plan proceed simultaneously. Thus the plan is plotted as the survey progresses. It is unlike other methods of surveying, such as compass surveying and chain surveying, in which the plan is plotted in the office after taking the measurements in the field.

The main feature of plane table surveying is that the plotting is done in the field where all the stations and other features are in the view of the surveyor, and he can compare the plan and plotted details with actual features on the ground. Thus, the mistakes are easily detected.

## 1) EQUIPMENT AND ACCESSORIES:

- The following instruments are used in plane table survey
- The plane table with levelling head having arrangements for *(a)* levelling, *(b)* rotation about vertical axis, and *(c)* clamping in any required position.
- Alidade for sighting
- Plumbing fork and plumb bob.
- Spirit level.
- Compass.
- Drawing paper with a rainproof cover.

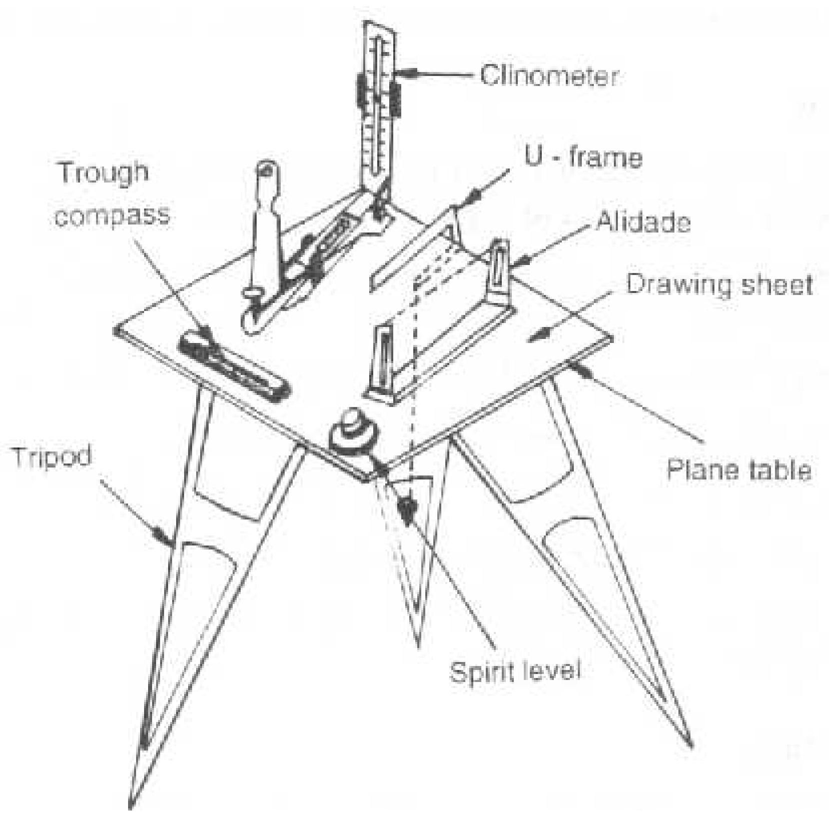



**Fig.15 Plane table and its accessories**

## ***The Plane Table***

Three distinct types of tables (board and tripod) having devices for levelling the plane table and controlling its orientation are in common use

*(i)* the *Traverse* Table, *(ii)* the *Johnson* Table and *(iii)* the *Coast Survey* Table.

*The Traverse Table* : The traverse table consists of a small drawing board mounted on a light tripod in such a way that the board can be rotated about the vertical axis and can be clamped in any position. The table is levelled by adjusting tripod legs, usually by eye-estimation.

*Johnson Table* : This consists of a drawing board usually 45 x 60 cm or 60 x 75 cm. The head consists of a ball-and-socket joint and a vertical spindle with two thumb screws on the underside. The ball-and-socket joint is operated by the upper thumb screw. When the upper screw is free, the table may be tilted about the ball-and-socket for levelling. The clamp is then tightened to fix the board in a horizontal position. When the lower screw is loosened, the table may be rotated about the vertical axis and can thus be oriented.

*The Coast Survey Table* : This table is superior to the above, two types, and is generally used for work of high precision. The levelling of the table is done very accurately with the help of the three foot screws. The table can be turned about the vertical axis and can be fixed in any direction very accurately with the help of a clamp and tangent screw.

### ***Alidade***

A plane table alidade is a straight edge with some form of sighting device. Two types are used :

(i) Plain alidade and (ii) telescopic alidade.

*Plain Alidade:* It is generally consist of a metal or wooden rule with two vanes at the ends. The two vanes or sights are hinged to fold down on the rule when the alidade is not in use. One of the vanes is provided with a narrow slit while the other is open and carries a hair or thin wire. Both the slits thus provide a definite line of sight which can be made to pass through the object to be sighted. The alidade can be rotated about the point representing the instrument station on the sheet so that the line of sight passes through the object to be sighted. A line is then drawn against the working edge (known as the *fiducial edge)* of the alidade.

*Telescopic Alidade:* The telescopic alidade is used when it is required to take inclined sights. Also the accuracy and range of sights are increased by its use. It essentially consists of a small telescope with a level tube and graduated arc mounted on horizontal axis.

### ***Plumbing Fork***

The plumbing fork, used in large scale work, is meant for centring the table over the point or station occupied by the plane table when the plotted position of that point is already known on the sheet. Also, in the beginning of the work, it is meant for transferring the ground point on to the sheet so that the plotted point and the ground station are in the same vertical line.

The fork consists of a hair pin-shaped light metal frame having arms of equal length, in which a plumb-bob is suspended from the end of the lower-arm. The fitting can be placed with the upper arm lying on the top of the table and the lower arm below it, the table being centred when the plumb-bob hangs freely over the ground mark and the pointed end of the upper arm coincides with the equivalent point on the plan.

***Spirit Level***

A small spirit level may be used for ascertaining if the table is properly level. The level may be either of the tubular variety or of the circular type, essentially with a flat base so that it can be laid on. the table and is truly level when the bubble is central. The table is levelled by placing the level on the board in two positions at right angles and getting the bubble central in both positions.

***Compass***

The compass is used for orienting the plane table to magnetic north. The compass used with a plane table is a trough compass in which the longer sides of the trough are parallel and flat so that either side can be used as a ruler or laid down to coincide with a straight line drawn on the paper.

*Drawing Paper*: The drawing paper used for plane tabling must be of superior quality so that it may have minimum effect of changes in the humidity of the atmosphere. The changes in the humidity of the atmosphere produces expansion and contraction in different directions and thus alter the scale and distort the map. To overcome this difficulty, sometimes two sheets are mounted with their grains at right angles and with a sheet of muslin between them. Single sheet must be seasoned previous of the use by exposing it alternatively to a damp and a dry atmosphere. For work of high precision, fibre glass sheets or paper backed with sheet aluminium are often used.

The other equipment and accessories used are chain, tape, ranging rods, pegs and hammer.

## 2) TERMINOLOGY:

***Radiation***

In this method the instrument is setup at a station and rays are drawn to various stations which are to be plotted. The distances are cut to a suitable scale after actual linear measurements on the ground are taken.

***Traversing***

In this method the table is set at each of the stations in succession. A foresight is taken to the next station and the distance is cut to a suitably chosen scale.

***Intersection***

In this method two stations are so selected that all the other stations to be plotted are visible from these. The line joining these two stations is called *base line*. The length of this line is measured very accurately. Rays are drawn from these stations to the stations to be plotted. The intersection of the rays from the two stations gives the positions of the stations to be plotted on the drawing sheet. Sometimes, this method is also termed as *graphical triangulation*.

***Resection***

It is a method of orientation employed when the table occupies a position not yet located on the drawing sheet. Therefore, it can be defined as the process of locating the instrument station occupied by the plane table by drawing rays from the stations whose positions have already been plotted on the drawing sheet. The resection of two rays will be the point representing the station to be located, provided the orientation at the station to be plotted is correct, which is seldom achieved. The problem can be solved by any of the methods such as resection after orientation by back ray, by two points, or by three points.

## 3) TEMPORARY ADUSTMENTS:

Three *operations* are needed

### *Fixing*

Fixing the table to the tripod.

### *Setting*

(i) Levelling the table *(ii)* Centring *(iii)* Orientation.

### *Levelling*

For small-scale work, levelling is done by estimation. For work of accuracy, an ordinary spirit level may be used. The table is levelled by placing the level on the board in two positions at right angles and getting the bubble central in both directions. For more precise work, a Johnson Table or Coast Survey Table may be used.

### *Centring*

The table should be so placed over the station on the ground that the point plotted on the sheet corresponding to the station occupied should be exactly over the station on the ground. The operation is known as *centring* the plane table. As already described this is done by using a plumbing fork.

### *Orientation*

Orientation is the process of putting the, plane-table into some fixed direction so that line representing a certain direction on the plan is parallel to that direction on the ground. *This is essential, condition to be fulfilled when more than one instrument station is to be used.* If orientation is not done, the table will not be parallel to itself at different positions resulting in an overall distortion of the map. The processes of centring and orientaion are dependent on each other. For orientation, the table will have to be rotated about its vertical axis, thus disturbing the centring. If precise work requires that the plotted point should be exactly over the ground point, repeated orientation and shifting of the whole table are necessary.

There are two main methods of orienting the plane table :

*(i)* Orientation by means of trough compass.
(ii) Orientaiton by means of backsighting.

### *Sighting the points*

Points are sighted using alidade

## 4) ERRORS IN PLANE TABLING:

The degree of precision to be attained in plane tabling depends upon the character of the survey, the quality of the instrument, the system adopted and upon the degree to which accuracy is deliberately sacrificed for speed. The various sources of errors may be classified as:

1. Instrumental Errors: Errors due to bad quality of the instrument.
2. Errors due to manipulation and sighting: These include
   a) Non-horizontality of board: The effect of non-horizontality of board is more severe when the difference in elevation between the points sighted is more.
   b) Defective sighting: The accuracy of plane table mapping depends largely upon the precision with which points are sighted. The plain alidade with open sight is much inferior to the telescopic alidade in the definition of the line of sight.
   c) Defective orientation: Orientation done with compass is unreliable, as there is every possibility of local attraction. Erroneous orientation contribute towards distortion of the survey. This orientation should be checked at as many stations as possible by sighting distant prominent objects already plotted.
   d) Movement of board between sights: Due to carelessness of the observer, the table may be disturbed between any two sights resulting in the disturbance of orientation. To reduce the possibility of such movement the clamp should be firmly applied. It is always advisable to check the orientation at the end of the observation from a station.
   e) It is very essential to have a proper conception of the extent of error introduced by inaccurate centring, as it avoids unnecessary waste of time in setting up the table by repeated trials.

## 5) PRECAUTIONS:

In every fieldwork exercise relevant precautions have to be taken to minimize the errors that are mentioned in the previous paragraphs.

## 6) APPLICATIONS:

Maps can be produced directly with the plane table with complete networks of control points fixed with it and the whole of the detail filled in. This method can be used for the filling in of detail or the revision of plans when the control points have already been fixed by traversing or triangulation. This method can also be used for location of contour-lines.

# EXERCISE 6
## RADIATION METHOD – PLANE TABLE

***Aim:***

To draw the position in plan of the given points by radiation method.

***Equipment and Accessories:***

Plane table and its accessories (tripod, alidate, trough compass, plumbing fork, spirit level, drawing sheet, cello- tape, pencil, eraser and dusting cloth), chain, tape, ranging rods, pegs, hammer and field-book.

***Principle:***

Plane table is a surveying instrument that can be used to prepare a map or plan of an area directly in the field without the direct measurement of any angles. Radiation is one of the methods employed in plane table survey. This method is generally employed for locating the details.

In this method, a ray is drawn from the instrument station towards the point. The distance is measured between the instrument station and the point. The point is located by plotting to some scale the distance so measured. This method is more suitable for small distances. One instrument station can cover several points to be detailed.

***Procedure*:**

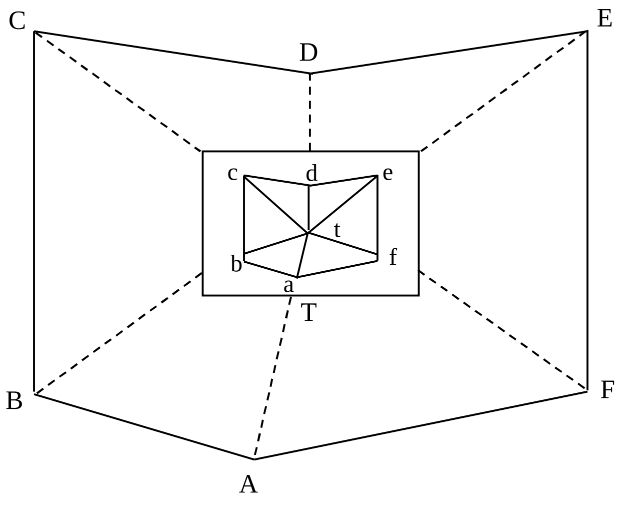



**Fig.16 Radiation method – plane table**

1) Select a point *'T'* on the ground so that all points to be located are visible from it.
2) Set up the table at *'T'*, level it, and do centering.

3) Transfer the point *‘T’* on to the drawing sheet by means of plumbing fork so that it is exactly over station *‘T’* on the ground and name it *‘t’*.
4) Mark the direction of the magnetic meridian on the drawing sheet by means of trough compass.
5) Centering the alidade on *‘t’* BISECT the points *A, B, C, D, E* and *F* one after the other and draw the rays along the fiducial edge.
6) Measure the distances *TA, TB, TC, TD, TE* and *TF* on the ground and plot their distances to some scale along the corresponding rays and thus get the position of points *a, b, c, d, e,* and *f* on the drawing sheet. (upper case letters are used to represent stations on ground and lower case letters are used to represent stations on drawing sheet)
7) Join *a,b,c,d,e* and *f* on the drawing sheet.

***Observations and Calculations:***

1. Measure the distance *AB, BC, CD, DE, EF* and *FA* on the ground.
2. Scale the distance *ab, bc, cd, de, ef* and *fa* on the drawing sheet.

***Result:***

Compare the ground and plan distances between the stations *A, B, C, D, E* and *F*.

# EXERCISE 7
## INTERSECTION METHOD – PLANE TABLE

***Aim:***

To draw the position in plan of the given points by intersection method.

***Equipment and Accessories:***

Plane table and its accessories (tripod, alidate, trough compass, plumbing fork, spirit level, drawing sheet, cello- tape, pencil, eraser and dusting cloth), chain, tape, ranging rods, pegs, hammer and field-book.

***Principle:***

Plane table is a surveying instrument that can be used to prepare a map or plan of an area directly in the field without the direct measurement of any angles. Intersection is one of the methods employed in plane table survey. This method is generally employed for locating the details.

In this method the location of an object is determined by sighting at the object from two plane table stations and drawing the rays. The intersection of these rays will give the position of the object. Therefore in this method it is essential to have at least two plane table stations. The distance between the two plane table stations is measured and plotted on the sheet to some scale. The line joining the two plane table stations is known as the base line. No linear measurement other than that of the base line is made in this method of surveying.

This method is preferred when the distance between the point and the plane table station is either too large or cannot be measured accurately due to some field conditions.

***Procedure:***

It is required to plot the position of ground points *PQRS* (shown in figure given below) on the drawing sheet. The line *AB* is a base line measured on the ground. It is represented by the line *ab* on the board drawn to scale. The position of the base line *AB* is chosen such that it is in the middle of the boundary formed by *PQRS*.

1. Set up the plane table over *A* and orient the plane table by laying the alidade along the drawn line *ab* and rotate the board until *B* is sighted from *A* through the alidade (Now the line *ab* is aligned with line *AB* on the ground).
2. Pivot the alidade at '*a*' and sight to the points *P*, *Q*, *R & S* and draw the rays. These rays represent the lines of sight to these features.
3. Shift the table to *B*. Plumb point *b* on the board over *B* on the ground.
4. By laying the alidade along the drawn line *ba* rotate the board until *A* is sighted and clamp the board (Now the line *ab* is aligned with line *AB* on the ground)
5. Mark the direction of the magnetic meridian on the drawing sheet by means of trough compass.

6. Pivot the alidade at *'b'* and sight to the points *P, Q, R & S* and draw the rays (The rays from *B* will intersect those drawn from *A*, thus establishing the positions *p, q, r* and *s* on the board).
7. Join the points *p, q, r & s* on the drawing sheet.

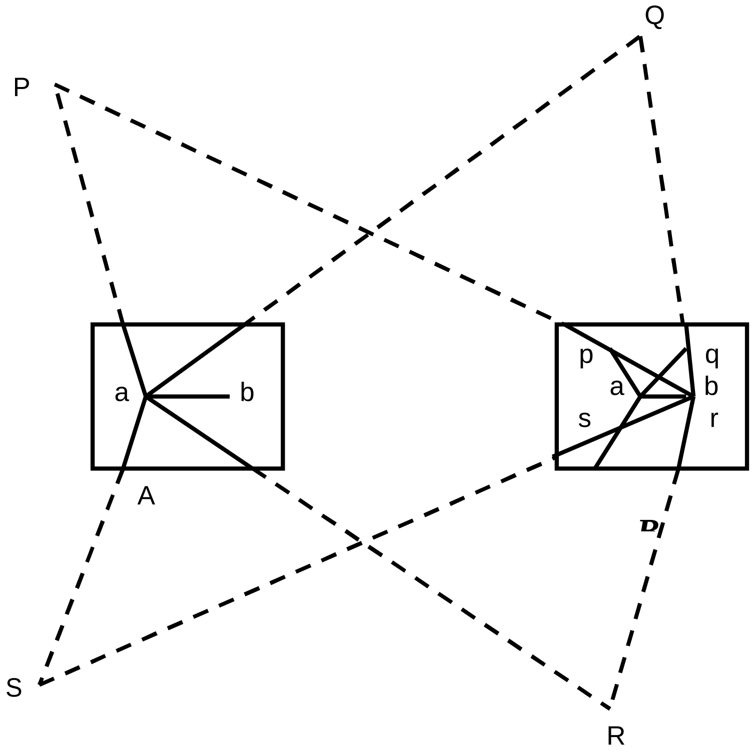



**Fig.17 Intersection method – plane table**

***Observations and Calculations:***

1. Measure the distance *PQ, QR, RS* and *SP* on the ground.
2. Scale the distance *pq, qr, rs* and *sp* on the drawing sheet.

***Result:***

Compare the ground and plan distances between the stations *P, Q, R* and *S*.

# EXERCISE 8
## TWO-POINT PROBLEM – PLANE TABLE

***Aim:***

To Locate the position on the plan, of the station occupied by the plane table by means of observations to two well defined points whose positions have been previously plotted on the plan.

***Equipment and Accessories:***

Plane table and its accessories (tripod, alidate, trough compass, plumbing fork, spirit level, drawing sheet, cello- tape, pencil, eraser and dusting cloth), chain, tape, ranging rods, pegs, hammer and field-book.

***Principle:***

Plane table is a surveying instrument that can be used to prepare a map or plan of an area directly in the field without the direct measurement of any angles. In the process sometimes a technique called 'resection' is employed.

Resection is the process of determining the plotted position of the station occupied by the plane table, by means of sights taken towards known points, location of which have been plotted.

In two-point problem the position of occupied station on the drawing sheet is obtained by means of observations to two well defined points whose positions have been previously plotted on the plan.

***Procedure:***

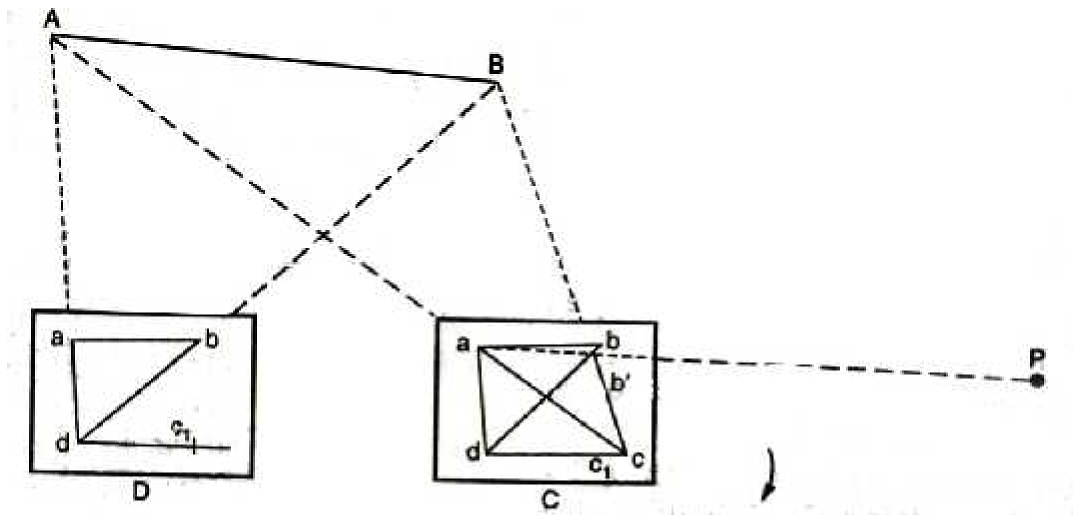



**Fig.18 Two-point problem – plane table**

Let us take two points *A* and *B*, the plotted positions of which are known (*a*, *b*). Let *C* be the point to be plotted. Therefore the whole problem is to orient the table at *C*.

1. Choose an auxiliary point *D* near *C*. While choosing *D* take care that angle *CAD* and angle *CBD* are not very acute.

2. Place the table at *D*. By eye judgment orient the table at *D* such that ab is nearly parallel to *AB*. Clamp the table.

3. Keep the alidade at *a* and sight *A* and draw back a resector. Similarly keep the alidade at *b* and sight *B* and draw back a resector. The two rays resect at *d1*. *(Here we are not naming it as d because it is not exactly d, since the orientation is by eye judgment and therefore not a correct orientation).*

4. Transfer the point *d1* to the ground and drive a peg.

5. Keep the alidade at *d1* and sight *C*. Draw the ray. Mark a point *c1* on the ray by estimation to represent the distance *DC*.

6. Shift the table to *C*, orient it by taking backsight to *D* and centre it with reference to *c1*. *(Thus the orientation is same as it was at D).*

7. Keep the alidade pivoted at *a* and sight it to *A*. Draw the ray to intersect with the previously drawn *d1c1* in *c2*. *(Thus c2 is the point representing the station C with reference to the approximate orientation made at D).*

8. Pivot the alidade about *c2* and sight *B*. Draw the ray to intersect with the ray *d1b* in *b1*. *(Thus b1 is the approximate representation of B with reference to the approximate orientation made at D)*

9. The angle between *ab* and *ab1* is the error in orientation and must be corrected for. Keep the alidade along *ab1* and fix a pole at *P* on the ground in line with *ab1* at a great distance.

10. Keep the alidade along *ab*, rotate the table till *P* is bisected. Clamp the table. The table is thus correctly oriented.

11. Draw a resector from a to *A* and another from *b* to *B*, the intersection of which will give the position *C* occupied by the table. Thus name the point as *c*.

***Observations and Calculations:***

1. Measure the distance *CA* and *CB* on the ground.
2. Scale the distance *ca* and *cb* on the drawing sheet.

***Result:***

Compare the ground distances *CA* and *CB* with corresponding plan distances *ca* and *cb*.

# EXERCISE 9
## THREE POINT PROBLEM – PLANE TABLE

***Aim:***

To Locate the position on the plan, of the station occupied by the plane table by means of observations to three well defined points whose positions have been previously plotted on the plan.

***Equipment and Accessories****:*

Plane table and its accessories (tripod, alidate, trough compass, plumbing fork, spirit level, drawing sheet, cello- tape, pencil, eraser and dusting cloth), chain, tape, ranging rods, pegs, hammer and field-book.

***Principle:***

Plane table is a surveying instrument that can be used to prepare a map or plan of an area directly in the field without the direct measurement of any angles. In the process sometimes a technique called ‘resection’ is employed.

Resection is the process of determining the plotted position of the station occupied by the plane table, by means of sights taken towards known points, location of which have been plotted.

In three-point problem the position of occupied station on the drawing sheet is obtained by means of observations to three well defined points whose positions have been previously plotted on the plan.

***Procedure:***

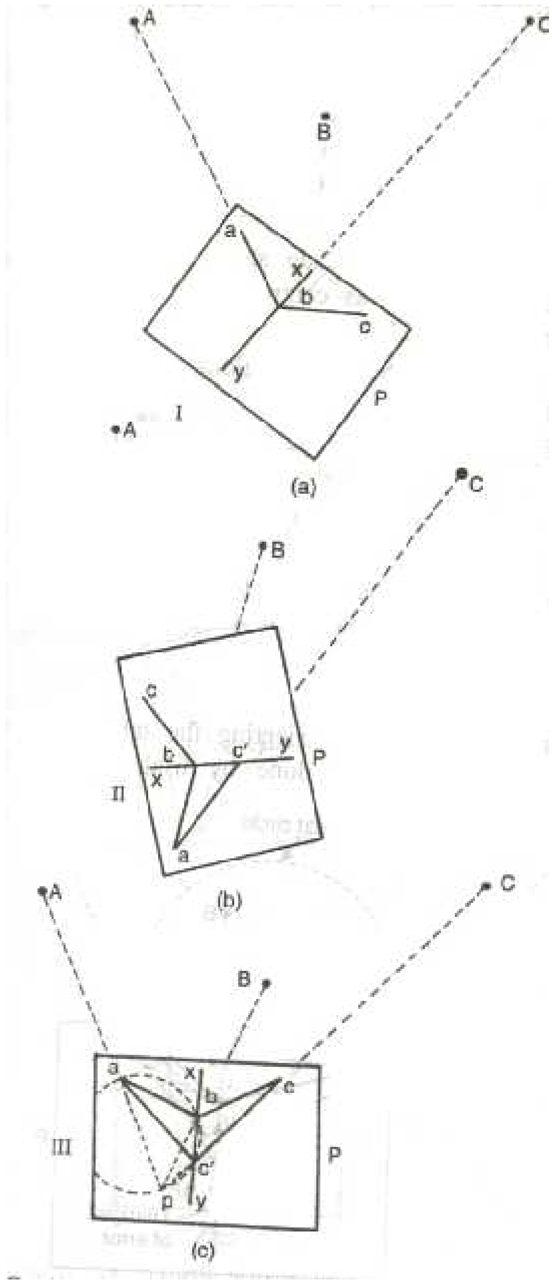



**Fig.19 Three-point problem – plane table**

Let us take three points *A* , *B* and *C* the plotted positions of which are known (*a*, *b* and *c*). Let *P* be the point to be plotted. Therefore the whole problem is to orient the table at *P*.

1) After having set the table at station *P*, keep the alidade on ba and rotate the table so that *A* is bisected. Clamp the table.

2) Pivot the alidade about *b*, sight to *C* and draw the ray *x y* along the edge of the alidade.

3) Keep the alidade along *ab* and rotate the table till *B* is bisected. Clamp the table.

4) Pivot the alidade about *a*, sight to *C*. Draw the ray along the edge of the alidade to intersect the ray *x y* in *c′*. Join *c c′*.

5) Keep the alidade along *c'c* and rotate the table till *C* is bisected. Clamp the table. Now the table is correctly oriented.

6) Pivot the alidade about *b*, sight to *B*. Draw the ray to intersect *c c'* in *p*. Similarly, if alidade is pivoted about *a* and *A* is sighted, the ray will pass through *p* if the work is accurate.

***Note***: The points *a, b, c'* and *p* form a quadrilateral and all the four points lie along the circumference of a circle. Hence this method is known as “ Bessel’s Method of Inscribed Quadrilateral”.

***Observations and Calculations:***

1. Measure the distance *PA, PB* and *PC* on the ground.
2. Scale the distance *pa, pb* and *pc* on the drawing sheet.

***Result:***

Compare the ground distances *PA, PB* and *PC* with corresponding plan distances *pa pb* and *pc*.

# EXERCISE 10
## TRAVERSING – PLANE TABLE

***Aim:***

To survey a small piece of land by closed traverse technique using plane table.

***Equipment and Accessories:***

Plane table and its accessories (tripod, alidate, trough compass, plumbing fork, spirit level, drawing sheet, cello- tape, pencil, eraser and dusting cloth), chain, tape, ranging rods, pegs, hammer and field-book.

***Principle:***

Traversing is that of survey in which a number of connected survey lines form a framework. The directions and lengths of the survey lines are measured with the help of an angle (or direction) measuring instrument and a tape respectively. If the framework formed by the lines closes at the starting station, that is, if they form a closed polygon, it is called closed traverse.

In plane table traversing, at each successive station the table is set, a foresight is taken to the following station and its location is plotted by measuring the distance between the two stations as in the radiation method.

***Procedure:***

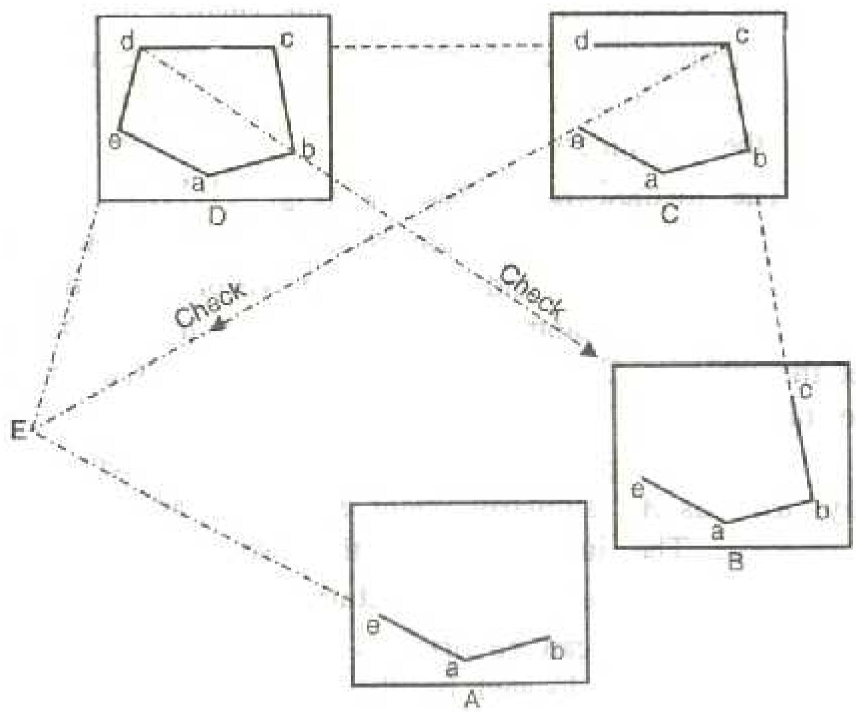



**Fig.20 Traversing – plane table**

1) Select the traverse stations *A*,*B*,*C*,*D* and *E* on the ground.
2) Set the table at *A*. Use plumbing fork and transfer *A* on to the sheet and name it *'a'*. On the top right corner of the sheet mark the direction of magnetic north with the help of trough compass.
3) With the alidade pivoted about a, sight it to *B* and draw the ray. Measure *AB* and scale of ab to a suitable scale. Similarly draw a ray towards *E*, measure *AE* and mark *'e'*.
4) Shift the table to *B* and set it. Orient the table accurately by back sighting *A*. Clamp the table.
5) Pivoting the alidade about *b*, sight to *C***.** Measure *BC* and plot it on the drawn ray to the same scale. Similarly, the table can be set at other stations and the traverse is completed.

***Note:*** *While being at each station, take measurements by radiation to any details that are to be included in the plan.*

***Observations and Calculations:***

1) Measure the distance *DB* and *EC* on the ground.
2) Scale the distance *db* and *ec* on the drawing sheet.

***Result:***

Compare the ground distances *DB* and *EC* with corresponding plan distances *db* and *ec*.

# LEVELLING

# INTRODUCTION

Levelling is a method of surveying used for determination of the difference of elevations or levels of various points on the surface of the earth. The elevation of a point is its' vertical distance above or below a reference level, called datum. The most commonly used datum is the mean sea level (M.S.L.). The levelling deals with distances in a vertical plane.

Levelling is an important method of surveying for many engineering works and construction projects. Levelling is required to determine the undulations of the earth's surface for topographic mapping. Levelling is needed for the design of highways, railways, canals, sewers, etc., and for locating the gradient lines. Levelling is essential for the layout of construction projects, for locating the excavation levels, and for the control of various elevations in buildings, bridges, dams, etc.

The drainage characteristics of the area can be obtained by levelling, The results of the levelling can be used to determine the catchment area, volume of the reservoir and the area submerged by a reservoir. The results of levelling can also be used to determine the volume of earthwork for roads, railways, etc.

Levelling is required in almost all engineering work of importance in one form or the other.

## 1) EQUIPMENT AND ACCESSORIES:

The instrument used in levelling is level. Its basic purpose is to establish a horizontal line of sight.

It consists essentially of the following parts:

- a telescope which provides a line of sight.
- a level tube for making the line of sight horizontal.
- a levelling head for bringing the bubble of the level tube at the centre of its run.
- a tripod for providing support to the level.

Of the various types of levels the following are the most common:

1) Dumpy level
2) Tilting level
3) Automatic level

Now a days automatic level is the most widely used Levelling instrument.

### *Dumpy level*

The dumpy level shown in figure consists of a telescope, generally the internal focussing type, fixed on a vertical spindle. The telescope tube and the vertical spindle are cast as one piece. The spindle revolves in the socket of the levelling head. The levelling head consists of two parallel plates held apart by three (or four) levelling screws. The upper plate is called tribrach and the lower one is called trivet stage. The telescope can be rotated in the horizontal plane about its vertical axis.

A sensitive level tube is fitted on the top of the telescope or on its side. An inclined mirror is attached to the level tube to enable the observer to view the bubble from the eye end of the telescope without moving round the instrument. The cross hairs of the diaphragm normally have a vertical line and a horizontal line. When instrument is in adjustment, the line of sight of the instrument is perpendicular to the vertical and parallel to the bubble tube axis as shown in figure.

The modern dumpy levels are provided with a clamp for clamping the telescope to the tribrach in any desired position. Also a graduated horizontal circle is provided to determine the direction of the telescope. The dumpy level is simple in construction and requires fewer permanent adjustments.

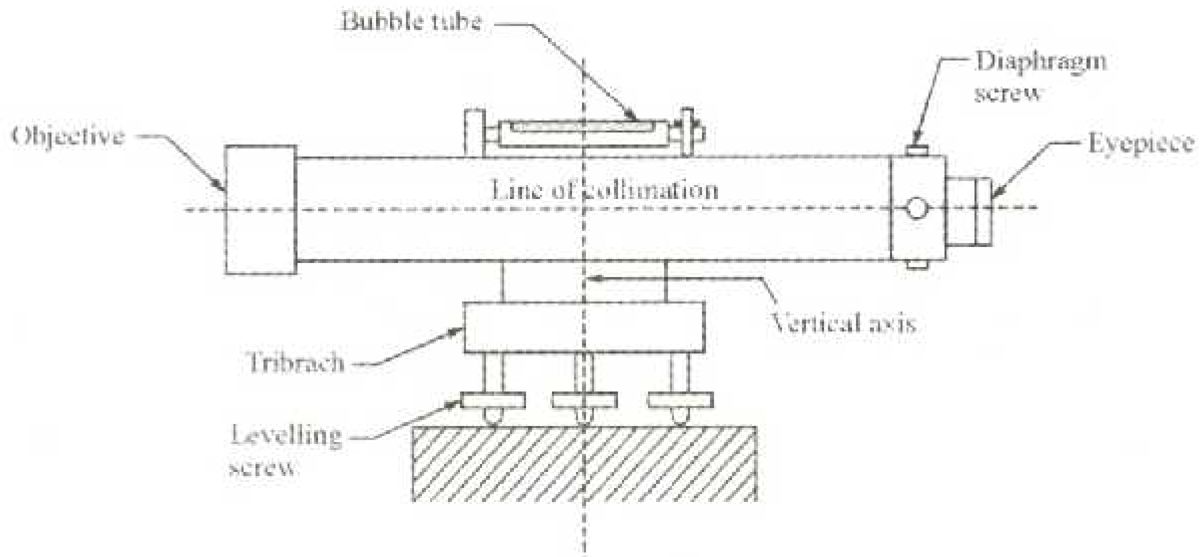



**Fig.21 Dumpy level**

***Tilting level***

The telescope of a tilting level is not rigidly fixed to the vertical spindle as in the case of dumpy level. The telescope can be tilted on a pivot about a horizontal axis in the vertical plane upwards or downward through a small angle by means of a tilting screw as shown in figure.

The bull's eye or circular level is fixed to the upper plate of levelling head for approximate levelling by foot screws. The exact levelling of the instrument is done using the tilting screw before taking every reading. The tilting screw is usually graduated to set out gradient lines.

Tilting levels are more robust, compact and accurate than dumpy levels. These have shorter telescope and are lighter. The tilting arrangement saves time required for temporary adjustments. A tilting level is most useful when only a few readings are to be taken from one setting of the instrument.

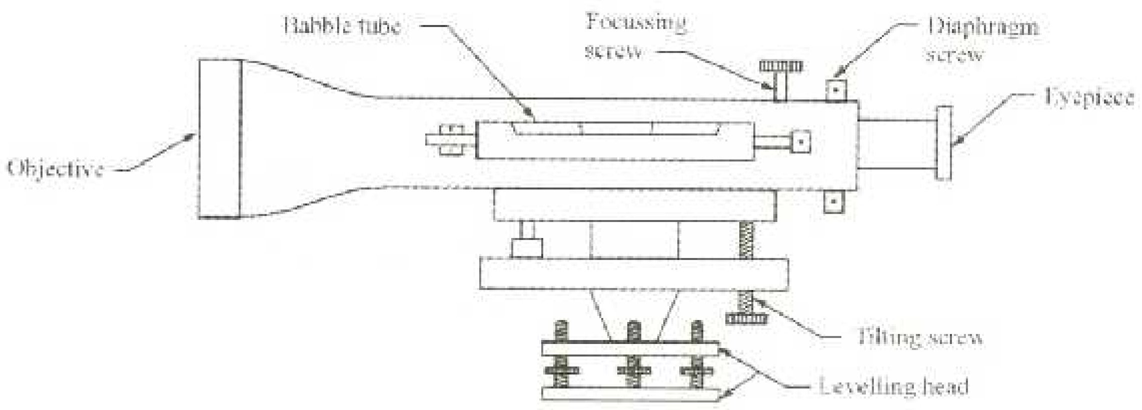



**Fig.22 Tilting level**

### *Automatic level*

The automatic level employs a gravity referenced prism or mirror compensator to automatically orient the line of sight (line of collimation). The instrument is quickly levelled when a circular spirit level is used. When the bubble has been centered or nearly so, the compensator takes over and maintains the horizontal line of sight, even if the telescope is slightly tilted.

Automatic levels are extremely popular in present-day surveying operations. They are quick to set up, easy to use, and can be obtained for use at almost any required precision.

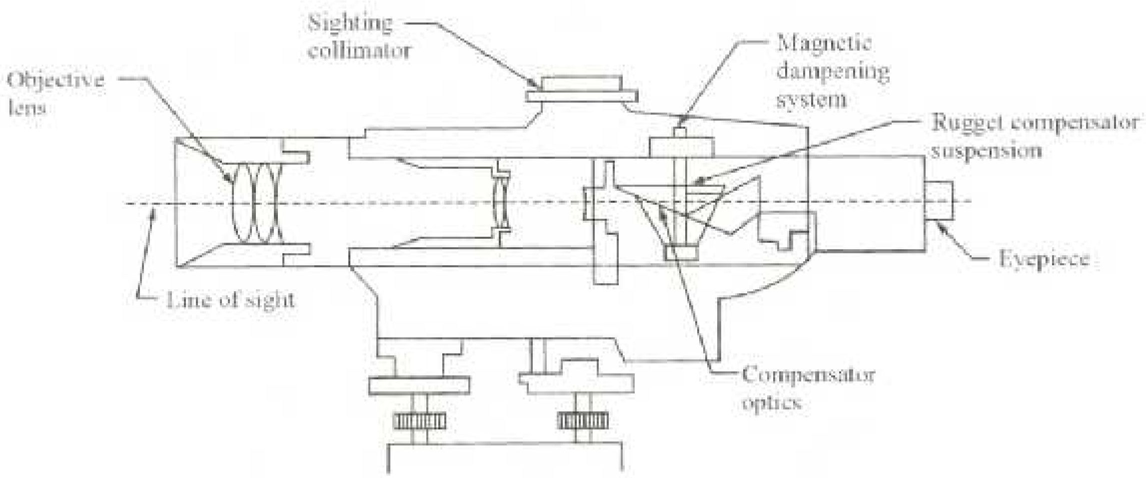



**Fig.23 Section through automatic level**


**Fig.24 Automatic level**

### *Levelling Staff*

Staffs used for levelling work are sectional and are assembled either telescopically or by slotting onto one another vertically. Most modern designs are manufactured in an aluminium alloy. Staff lengths are either 3m, 4 m or 5 m on extension. The graduations are 10 mm deep spaced at 10 mm intervals, the lower three graduations in each 100 mm interval being connected by a vertical band to form an E shape, natural or reversed. The 50 mm or 100 mm intervals are therefore located by these shapes. The graduations of the first metre length are coloured black on a white background, with the next metre length showing red graduations and so on alternately.

## 2) TERMINOLOGY:

### *Level Surface*

A surface parallel to the mean spheroidal surface of the earth is called level surface, e.g., a still lake. A level surface is a curved surface, every point on which is equidistant from the centre of the earth. It is normal to the plumb line at all the points.

### *Vertical line*

It is a line from any point on the earth's surface to the centre of the earth. It is commonly considered to be the line defined by a plumb line.

### *Levelline*

It is a line lying on a level surface. It is normal to the plumb line at all the points.

### *Horizontal plane*

It is a plane tangential to the level surface at the point under consideration. It is perpendicular to the plumb line.

***Horizontal line***

It is a line lying in the horizontal plane. It is a straight line tangential to the level line.

***Axis of telescope***

It is a line joining the optical centre of the objective to the centre of the eyepiece.

***Line of collimation***

It is a line joining the intersection of the cross-hairs to the optical centre of the objective and its continuation. It is also called the line of sight.

***Axis of level tube or bubble tube***

It is an imaginary line tangential to the longitudinal curve of the tube at its mid-point.

***Height of instrument (H.I.)***

It is the elevation of the plane of collimation when the instrument is leveled. It should be noted that the height of instrument does not mean the height of the centre of the telescope above the ground, where the level is set up.

***Back sight (B.S.)***

It is a staff reading taken on a point of known elevation, e.g., a sight on a bench mark or on a change point. It is the first staff reading taken after the level is set up. It is also called plus sight.

***Fore sight (F.S.)***

It is a staff reading taken on a point whose elevation is to be determined, e.g., a sight on a change point. It is also cal!ed a minus sight. It is the last staff reading and denotes the shifting of the instrument.

***Intermediate sight (I.S)***

It is a staff reading taken on a point of unknown elevation between backsight and foresight.

***Change point (C.P.) or turning point (T.P.)***

It is a point, denoting the shifting of the level. Both F.S. and B.S. are taken on this point.

***Station***

A point, whose elevation is to be determined is called station.

***Parallax***

It is the apparent movement of the image relative to the cross-hairs when the image formed by the objective does not fall in the plane of the diaphragm.

***Bench Mark***

It is a fixed reference point of known elevation. Depending upon the permanency and precision, bench marks may be of the following types:

*Great trigonometric survey (G. T.S.) bench marks (B.M.)*

These are established by the Survey of India at an interval of about of 100 km all over the country with respect to the mean sea level at Karachi as datum. Their elevations are shown on a G.T.S. map.

*Permanent bench marks*

These are established between the G.T.S. bench marks by the government agencies like P.W.D. on clearly defined and permanent points such as the top of a parapet wall of a bridge or culvert, kilometre stone, railway platform etc.

*Arbitrary bench marks*

These are reference points whose elevations are arbitrarily assumed for small levelling operations. Their elevations do not refer to any fixed datum.

*Temporary bench marks*

These are the reference points on which a day's work is closed and from where levelling is continued the next day. Such a B.M. is carefully established on permanent objects like km stones, parapets, etc.

## 3) TEMPORARY ADJUSTMENTS:

These consist of setting up, levelling, and elimination of parallax.

***Setting Up***

Since the level is not to be set at any fixed point. the setting up of a level is much simple as compared to other instruments. While locating the level the ground point should be so chosen that

(a) the instrument is not too low or too high to facilitate reading on a bench mark

(b) the length of the backsight should preferably not be more than 98.0 m

(c) the backsight distance and foresight distance should be equal, and the foresight should be so located that it advances the line of levels. Setting up includes fixing the instrument and approximate levelling by leg adjustment.

*Fixing the instrument over tripod*

The clamp screw of the instrument is released. The level is held in the right hand. It is fixed on the tripod by turning round the lower part with the left hand and is firmly screwed over the tripod.

*Leg adjustment*

The instrument is placed at a convenient height with the tripod legs spread well apart and so adjusted that the tripod head is as nearly horizontal as can be judged by the eye.

***Levelling Up***

1. The telescope is held parallel to two foot screws, the two foot screws are turned uniformly towards each other or away from each other until the circular bubble is central.

2. Turn the telescope through 90° and bring the circular bubble in centre by turning the third foot screw.
3. Now the circular bubble should be central for any orientation of telescope.

***Elimination of Parallax***

*Focussing the eyepiece*

This operation is done to make the cross-hairs appear distinct and clearly visible. The following steps are involved:

1. The telescope is directed skywards or a sheet of white paper is held in front of the objective.
2. The eyepiece is moved in or out till the cross-hairs appear distinct.

*Focussing the objective*

This operation is done to bring the image of the object in the plane of the cross-hairs. The following steps are involved:

1. The telescope is directed towards the staff.
2. The focussing screw is turned until the image appears clear and sharp.

**4) ERRORS IN LEVELLING:**

There are five sources of error in ordinary Levelling.

a) Instrumental errors
b) Errors in handling the instruments
c) Errors due to displacement of equipment
d) Errors in reading and booking
e) Errors due to natural clauses

***Instrumental errors***

1) The line of sight should be horizontal. If it is not the error is proportional to the length of the line of sight.
2) The bubble may be unstable.
3) The level must be stable. Examine the tripod for any looseness in the joints or damage to the screw threads caused by over tightening.
4) Staff graduations may be in error or the staff may not be properly extended.

***Errors in handling the instruments***

1) Ensure the  bubble is always centred.
2) The staff should be held vertically or readings will be too great.

***Errors due to displacement of the equipment***

1) Set up the instrument on stable ground. On soft ground the instrument may settle and alter the height of line of collimation.
2) Change points must be choosen so that when turning the staff round or when replacing it after removal no alteration of height take place.
3) Never move the staff until a backsight has been taken. Never move the level until a foresight has been taken.

***Errors in reading and booking***

1) Reading against a stadia hair instead of the horizontal cross hair.
2) Concentrating on the decimal reading and noting the metres wrongly.
3) Omitting a zero for example recording 3.09 instead of 3.009
4) Entering a reading in the wrong column.
5) Forgetting to book an entry.
6) Noting a reading with the numbers interchanged for example 1.501 instead of 1.105.
7) Noting a wrong distance or point description in the remarks column.

***Errors due to natural causes***

1) Errors arise due to curvature of the earth’s surface and atmospheric refraction. For sights up to 272.5 m this error is 0.005 m which is the usual least count of the staff being used. Therefore, sights longer than 272.5 m should be avoided. However for precise work sights longer than 98 m are not permitted. The error can be eliminated by equalizing B.S and F.S distances.
2) The wind causes vibration of the level, tripod and the staff and can make accurate sighting impossible.
3) The sun can cause an apparent vibration of the staff owing to irregular refraction. Sighting is difficult when sun shines into object glass.

## 5) PRECAUTIONS:

In every fieldwork exercise relevant precautions have to be taken to minimize the errors that are mentioned in the previous paragraphs.

## 6) APPLICATIONS

Apart from the general problem of determining the difference in level between two points, the main application of Levelling are: taking longitudinal sections, cross-sections, contouring and setting out levels.

# EXERCISE 11
## FLY LEVELLING

***Aim:***

To find the reduced levels of the given stations by differential levelling.

***Equipment and Accessories:***

Automatic Level, levelling staff, Levelling book, pencil and eraser.

***Principle:***

In order to find difference of level between two points on the ground, it is necessary to establish a level surface above the two points and measure the vertical distance from it to the points. The difference between these measurements will give the difference in level between the points. It is possible to get a horizontal surface from the line of sight of a telescope adjusted into the horizontal position. This is done by any Levelling instrument.

Therefore by setting up a Levelling instrument at a suitable location on the ground it is possible to obtain difference between levels of two points. Automatic level is a very convenient Levelling instrument. When the difference in level between two points cannot be obtained by one set-up of Levelling instrument, it is necessary to repeat the process. This process of using a series of several set-ups of Levelling instrument to find the level difference between two distantly placed points is called fly Levelling.

***Procedure:***

1. Set-up the automatic level at point ‘P’ near to the Bench Mark (BM) (the R.L of BM is 100.000 m) as shown in figure and level the instrument.
2. Focus the telescope towards BM and bisect the staff correctly and take the back sight (BS) on it and record the reading in the Levelling book.
3. Keep the levelling staff at a convenient intermediate point(s) and take the intermediate sight (IS) and enter the reading.
4. Before shifting the instrument to the next station enter the last staff reading in the FS column.
5. Shift the instrument to the next station ‘Q’ and follow the steps from 3 to 4.
6. Calculate the Reduced levels by Height of Instrument Method and also by Rise and Fall Method which can be shown in Table 6 & 7 respectively.

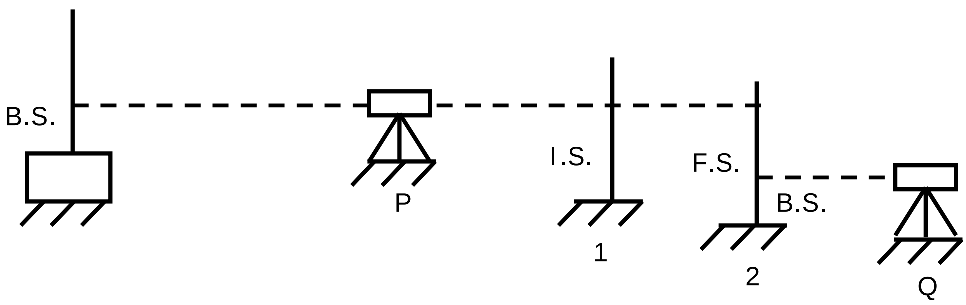


**Fig.25 Fly levelling**

***Observations and Calculations:***

***TABLE - Height of Instrument Method***

| S. No. | Station | Sight to | B.S. (m) | I.S. (m) | F.S. (m) | H.I. (m) | R.L. (m) | Remarks |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |

***TABLE - Rise and Fall Method :***

| S. No. | Station | Sight to | B.S. (m) | I.S. (m) | F.S. (m) | Rise (m) | Fall (m) | R.L. (m) | Remarks |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |

**a) Height of Instrument Method:**

| | | |
|---|---|---|
| Height of Instrument (H.I.) | = | R.L. of A.B.M. + B.S. |
| R.L. of a station | = | H.I. – I.S. or F.S. |
| Height of Instrument at C.P. (H.I.) | = | R.L. of C.P. + B.S. |
| R.L. of a station | = | R.L. of C.P. – I.S. or F.S. |
| **CHECK** : Sum of B.S. – Sum of F.S. | = | First R.L. – Last R.L. |

**b) Rise and Fall Method:**

If the difference of successive observations is +ve, it indicates fall, otherwise it indicate rise.

| | | |
|---|---|---|
| R.L. of a station | = | R.L. of B.M. + Rise or ( – Fall) |
| **CHECK** : Sum of B.S. – Sum of F.S. | = | Sum of Rise – Sum of Fall |
| | = | First R.L. – Last R.L. |

# EXERCISE 12
## LONGITUDINAL AND CROSS SECTIONING

***Aim:***

To plot the longitudinal section and cross section along a proposed alignment of a highway.

***Equipment and Accessories:***

Automatic Level, tripod, Levelling staff, chain, tape, cross staff, arrows, ranging rods, pegs, hammer, Levelling book, pencil and eraser.

***Principle:***

Profile Levelling is an operation to determine elevations of points spaced apart at known distances along a given line. The purpose of profile Levelling is to provide data from which a vertical section of the ground surface along a surveyed line can be plotted. Longitudinal sectioning and cross sectioning are examples of profile Levelling.

a) Longitudinal sectioning: to find out the elevations of the points on the ground at fixed intervals along the centre line of proposed sewer lines, pipelines, highways, railways, canals, etc.
b) Cross sectioning: to find out the elevations of the points on the ground at fixed intervals on either side and perpendicular to centre line of proposed highways, canals, etc.

***Procedure:***

1. Establish points on the ground at fixed interval say 5 m along the proposed centre line of the highway by direct ranging and fix arrows as shown in figure given below.
2. Establish perpendicular lines on either side of the proposed centre line of the highway using cross staff as shown in figure given below.
3. Along the perpendicular lines that are established in the previous step fix arrows on the ground at a fixed interval say 2 m as shown in figure given below.
4. Carry out differential Levelling to find the R.Ls of every arrow point and enter the readings in table.
5. Calculate the R.Ls of all the points.
6. Draw the longitudinal section along the centre line of the proposed highway to a suitable scale.
7. Draw cross section in the transverse direction at each chainage point along the centre line of the proposed highway to a suitable scale.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **6** | õ | õ | õ | õ | õ | õ | õ | õ |
| **4** | õ | õ | õ | õ | õ | õ | õ | õ |
| **2** | õ | õ | õ | õ | õ | õ | õ | õ |
| | õ | õ | õ | õ | õ | õ | õ | õ |
| | **0** | **5** | **10** | **15** | **20** | **25** | **30** | **35** |
| **2** | õ | õ | õ | õ | õ | õ | õ | õ |
| **4** | õ | õ | õ | õ | õ | õ | õ | õ |
| **6** | õ | õ | õ | õ | õ | õ | õ | õ |

**Fig.26 Longitudinal and cross sectioning**

***Observations and Calculations:***

***TABLE***

| S. No. | Chainage of centre line | Chainage Left C.S. | Chainage Right C.S. | B.S. (m) | I.S. (m) | F.S. (m) | H.I. (m) | R.L. (m) | Remarks |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |

Height of Instrument = R.L. of B.M. + B.S.

R.L. of each arrow point = H.I. – I.S. or F.S.

***Result:***

Profile of the centre line of the proposed highway and various cross sections along the centre line of the proposed highway are shown on the drawing sheet.

# EXERCISE 13
## CONTOURING

***Aim:***

To plot the contours of an area by method of squares (or gridding).

***Equipment and Accessories:***

Automatic Level, tripod, Levelling staff, chain, tape, cross staff, arrows, ranging rods, pegs, hammer, Levelling book, pencil and eraser.

***Principle:***

The method of squares is also called *coordinated method* or *gridding* of locating contours. The entire area is divided into squares or rectangles forming a grid. The reduced levels of the corners are then determined by differential Levelling. The reduced levels are then plotted on the plan showing the same grid drawn to a suitable scale. After choosing suitable elevation values for contours to be drawn, the required contours are plotted by means of interpolation.

***Procedure:***

1. On the parcel of the ground for which contour map has to be made establish a square grid of points at a suitable interval ( anywhere between 3m to 20m) by means of direct ranging and fix arrows as shown in figure given below.
2. Carry out differential Levelling to find the R.L.'s of every arrow point and enter the readings in table.
3. Draw the same grid that is established on the ground on the drawing sheet to a suitable scale.
4. Indicate on the drawn grid the reduced levels of each grid point.
5. Choose suitable values for elevations of contour lines.
6. Draw contour lines on the grid by interpolation.

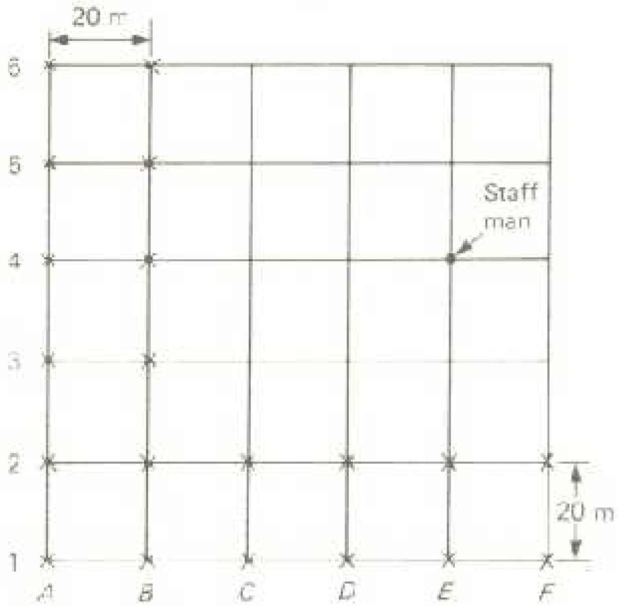


**Fig.27 Contouring**

***Observations & Calculations:***

***TABLE :***

| S. No. | Grid point | B.S. (m) | I.S. (m) | F.S. (m) | H.I. (m) | R.L. (m) | Remarks |
|---|---|---|---|---|---|---|---|
| | | | | | | | |

***Result:***

Contours of the given area are plotted.