सत्यमेव जयते

FOREST SURVEY

DIRECTORATE OF FORESTS
GOVERNMENT OF WEST BENGAL

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PREFACE

Survey is the science of determining and delineating the position, form and extent of a tract of land and of the ground objects located in such land. Knowledge of principles and practice of surveying will obviously enable a forester to read forest maps correctly and to visualize location and nature of ground objects. Expertise in survey techniques will also enhance his efficiency to lay out forest coupes and plantations, and check forest boundary and areas of plantations /coupes. As part of the JICA project on 'Capacity Development for Forest Management and Training of Personnel' being implemented by the Forest Department, Govt of West Bengal, these course materials on Forest Survey have been prepared for induction training of the Foresters and Forest Guards.

The subjects covered in these materials broadly conform to syllabus laid down in the guidelines issued by the Ministry of Environment of Forests, Govt of India, vide the Ministry's No 3 -17/1999-RT dated 05.03.13. In dealing with some of the parts of the course though, some topics have been detailed or additional topics have been included to facilitate complete understanding of the subjects. The revised syllabus, with such minor modifications, is appended.

As the materials are meant for the training of frontline staff of the Department, effort has been made to present theories and practices of forest survey in a simple and comprehensive manner. Use of mathematical tools, where unavoidable, has been made in simple and elementary form. However, as knowledge of elementary Mathematics is essential to understand the subject, six lessons, covering lesson 2 to lesson 7, have been devoted to elementary Geometry and Trigonometry.

Preparation of the course materials needed study of many literature and articles including those available in internet. In particular, the contents and concepts of these study materials owe heavily to the book "Forest Surveying" by Ram Parkash. Inputs provided by Shri Amitav Mishra IFS, with regard to GPS are thankfully acknowledged. Besides, other major sources of inputs used in preparation of these materials have been cited in the respective places.

Efforts that have gone into making of this course material will be best rewarded if the frontline staff of the forest department find it useful in their day-to-day works.

Kolkata, 2015

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For IBRAD (Consultant)

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Forest Survey
Syllabus (Revised)

10. Forest Survey (28 hours and 1 day field excercise)		
1. Introduction	1-1. Need for survey 1-2. Types of survey · Chain · Chain and compass · Plane table Linear Measurement* - Chain – Testing the chain - Tapes Instruments for marking stations * Ranging out survey lines * Chaining on sloping ground*	1 hour
2. Elementary geometry and trigonometry	Elementary Geometry - Line* - Angle * - Polygon* - Types of triangles* - Types of quadrilaterals* - Perimeter - Area - Circle – radius – diameter – circumference – area - Properties of triangle* – Pythagoras Theorem Solid Geometry - Cube - Rectangular parallelepiped - Cylinder - Cone Elementary Trigonometry - Trigonometric functions - Values of trigonometric functions of specific angles - Relations among trigonometric functions - Application of trigonometric principles - angle of elevation, angle of depression	6 hours*
3. Chain survey*	3.1 Chain triangulation Equipments Survey stations Chain lines Check line – Tie line Offsets Lay out perpendiculars on chain lines. Field work of chain survey Obstacles in chaining Plotting chain survey– chain lines – offsets Traverse survey with chain Traverse by chain angles 3.2 Practical Class on chain survey*	3 hours* 3 hours

4. Angles and Bearings	Meridians Prismatic Compass - Working principles - Testing of the compass - Errors Bearings - Whole circle bearing - Reduced bearing - Fore and back bearing Local attraction - Detection - correction	1 hour
5. Prismatic compass and chain survey	5.1 Traversing with prismatic compass and chain Instruments Procedure Plotting compass traverse survey Closing error – adjustment of error Practical applications 5.2 Practical class*	1 hour 3 hours
6. Plane Table Survey*	6.1 Instruments - Alidade Procedure - Centring, Levelling,orientation Methods - Radiation, intersection Practical applications 6.2 Practical class*	1 hour 3 hours*
7.Contour and map reading	Topographical map Contour – contour interval, horizontal equivalent Contouring - Instruments - Methods – direct and indirect - Working in the field - Principles of levelling Map reading - Prerequisites - Various maps for forest management Computation of area - By division into geometrical figures - By planimeter	1 hour
8. .Basics of GPS	What is GPS Working of GPS receiver Use of GPS in the field Advantages and limitations of GPS	1 hour*
Practical class	Practice of GPS	4 hours*
Field Exercise	Application of GPS, contouring and levelling.	1 day*

* These are modifications to the MoEF-prescribed syllabus, indicating revision/addition of topics and lesson hours.

Lesson 1 — 1 hour

Lesson Plan:

Objective:

To study

- Land Survey, Need for Forest Survey
- Types Of Survey
- Secondary Classification
- Scales
- Linear Measurement, Chain, Tapes
- Instruments for Marking Station
- Ranging out Survey Lines, Ranging by eye
- Chaining on sloping ground

Backward Linkage: Nil

Forward Linkage:

- Application in subsequent lessons.

Training materials required:

- Copy of lesson 1 to be circulated beforehand
- Chain, Tape, Pegs, ranging Rods

Allocation of time:

Land Survey, Need for Forest Survey	5 mins
Types Of Survey	5 mins
Secondary Classification	5 mins
Scales	5 mins
Linear Measurement, Chain, Tapes	10 mins
Instruments for Marking Station	6 miins
Ranging out Survey Lines, Ranging by eye	5 min
Chaining on sloping ground	9 mins
Discussion/Miscellaneous	10 mins

Lesson 2 — 1 hour

Lesson Plan:

Objective:

To study

Elementary Geometry

- Straight Line, Parallel Lines, Perpendicular line
- Angle, Types of Angle
- Polygon, Sum of the angles of a Polygon
- Types of Triangle by angles
- Types of Triangle by sides
- Types of Quadrilateral

Backward Linkage: Nil

Forward Linkage:

- Application in subsequent lessons.

Training materials required:

- Copy of lesson 2 to be circulated beforehand

Allocation of time:

Straight Line, Parallel Lines, Perpendicular line	5 mins
Angle, Types of Angle	5 mins
Polygon, Sum of the angles of a Polygon	5 mins
Types of Triangle by angles	10 mins
Types of Triangle by sides	10 mins
Types of Quadrilateral	15 mins
Discussion/Miscellaneous	10 mins

Lesson 3 **1 hour**

Lesson Plan:

Objective:

To study

Elementary Geometry (Continued)

- Perimeter
- Area
- Area of some common plane figures
- Circle(Radius, Chord, Diameter, Circumference, Area)

Backward Linkage: Lesson 2

Forward Linkage:

- Application in subsequent lessons.

Training materials required:

- Copy of lesson 3 to be circulated beforehand

Allocation of time:

Perimeter	10 mins
Area	12 mins
Area of some common plane figures	14 mins
Circle(Radius, Chord, Diameter, Circumference, Area)	14 mins
Discussion/Miscellaneous	10 mins

Lesson 4 **1 hour**

Lesson Plan:

Objective:

To study

Elementary Geometry (Continued)

Exercise on perimeter and area

Backward Linkage: Lesson 3

Forward Linkage:

- Application in subsequent lessons.

Training materials required:

- Copy of lesson 4 to be circulated beforehand

Allocation of time:

- Exercise on perimeter and area 45 mins
- Discussion/Miscellaneous 15 mins

Lesson 5 1 hour

Lesson Plan:

Objective:

To study
Elementary Geometry (Continued)

- Congruent Triangles
- Similar Triangles
- Side-splitter Theorem
- Pythagoras Theorem

Backward Linkage: Lesson 2 and 3

Forward Linkage:

- Application in subsequent lessons.

Training materials required:

- Copy of lesson 5 to be circulated beforehand

Allocation of time:

Elementary Geometry (Continued)

Congruent Triangles	12 mins
Similar Triangles	15 mints
Side-splitter Theorem	12 mins
Pythagoras Theorem	15 mins
Discussion/Miscellaneous	6 mins

Lesson 6 — 1 hour

Lesson Plan:

Objective:

To study

Elementary Geometry (Continued)

Solid Geometry

- Cube
- Rectangular Parallelepiped
- Cylinder
- Cone

Backward Linkage: Previous lessons

Forward Linkage:

- Application in the field.

Training materials required:

- Copy of lesson 6 to be circulated beforehand

Allocation of time:

Elementary Geometry (Continued)

- Solid Geometry

Cube	10 mins
Rectangular Parallelepiped	12 mins
Cylinder	15 mins
Cone	15 mins

- Discussion/Miscellaneous — 8 mins

Lesson 7 **1 hour**

Lesson Plan:

Objective:

To study

Elementary Trigonometry

- Trigonometric Functions (ratios)
- Trigonometric Functions of complementary angles
- Values of functions of some specific angles
- Relations among trigonometric functions
- Application of trigonometric principles

Backward Linkage: Previous lessons

Forward Linkage:

- Application in the field.

Training materials required:

- Copy of lesson 7 to be circulated beforehand

Allocation of time:

- Trigonometric Functions (ratios) 10 mins
- Trigonometric Functions of complementary angles 10 mins
- Values of functions of some specific angles 10 mins
- Relations among trigonometric functions 10 mins
- Application of trigonometric principles 10 mins
- Discussion/Miscellaneous 10 mins

Lesson 8 **1 hour**

Lesson Plan:

Objective:

To study

Chain Survey

- Chain triangulations
- Equipments
- Survey Stations
- Chain lines
- Base line- check line –tie line
- Offsets
- Perpendiculars on chain lines

Backward Linkage: Previous lessons

Forward Linkage:

- Application in the field; Lesson 9

Training materials required:

- Copy of lesson 8 to be circulated beforehand

Allocation of time:

Chain triangulations	5 mins
Equipments	7 mins
Survey Stations	8 mins
Chain lines	5 mins
Base line- check line –tie line	10 mins
Offsets	10 mins
Perpendiculars on chain lines	10 mins
Discussion/Miscellaneous	5 mins

Lesson 9 **1 hour**

Lesson Plan:

Objective:

To study

Chain Survey (Continued)

- Field work
- Field book recording
- Obstacles in chaining

Backward Linkage: Lesson 8

Forward Linkage:

- Application in the field; Lesson 10

Training materials required:

- Copy of lesson 9 to be circulated beforehand; Survey Field book

Allocation of time:

Chain Survey (Continued)

- Field work 8 mins
- Field book recording 30 mins
- Obstacles in chaining 15 mins

- Discussion/Miscellaneous 7 mins

Lesson 10 — 1 hour

Lesson Plan:

Objective:

To study

Chain Survey (Continued)

- Plotting of chain survey
- Traverse survey with chain

Backward Linkage: Lesson 8 and 9

Forward Linkage:

- Application in the field; Lesson 11

Training materials required:

- Copy of lesson 9 to be circulated beforehand; Drawing materials, Drawing instrument

Allocation of time:

Chain Survey (Continued)

- Plotting of chain survey — 25 mins
- Traverse survey with chain — 30 mins
- Discussion/Miscellaneous — 5 mins

Lesson 11 3 hours

Lesson Plan:

Objective:

To demonstrate and apply Chain Survey Procedures in the field.

Chain Survey (Continued)

- Practical class on Chain Survey

Backward Linkage: Lesson 8, 9 and 10

Forward Linkage:

- Application in the field

Training materials required:

- Survey equipments, Drawing materials, Drawing instruments.

Allocation of time:

Chain Survey (Continued)

- Practical class

Briefing	10 mins
Field work and recording	2 hr
Drawing	50 mins

Lesson 12 — 1 hour

Lesson Plan:

Objective:

To study

Angles and Bearings

- Meridians
- Prismatic compass
  - working principle
  - testing of the compass
  - Errors
- Bearings – whole circle bearing – reduced bearing
- Local Attraction

Backward Linkage: Previous Lessons

***Forward Linkage**:*

- Application in the field; Lesson 13

Training materials required:

- Copy of lesson 12 to be circulated beforehand; Prismatic Compass

Allocation of time:

Angles and Bearings

➢ Meridians	7 mins
➢ Prismatic compass - working principle - testing of the compass - Errors	30 mins
➢ Bearings – whole circle bearing – reduced bearing	8 mins
➢ Local Attraction	10 mins
➢ Discussion/Miscellaneous	5 mins

Lesson 13 1 hour

Lesson Plan:

Objective:

To study

Prismatic Compass and Chain Survey

- Traversing with prismatic compass and chain
- Procedure
- Closing error
- Adjustment of closing error
- Practical applications

Backward Linkage: Previous Lessons

Forward Linkage:

- Application in the field; Lesson 14

Training materials required:

- Copy of lesson 13 to be circulated beforehand; Prismatic Compass

Allocation of time:

Traversing with prismatic compass and chain	7 mins
Procedure	25 mins
Closing error	5 mins
Adjustment of closing error	10 mins
Practical applications	8 mins
Discussion/Miscellaneous	5 mins

Lesson 14 3 hours

Lesson Plan:

Objective:

To demonstrate and apply Prismatic Compass Survey Procedures in the field

Prismatic Compass Survey (Continued)

- Practical class on Prismatic Compass Survey

Backward Linkage: Lesson 12 and 13

Forward Linkage:

- Application in the field

Training materials required:

- Survey equipments, Drawing materials, Drawing instruments.

Allocation of time:

Prismatic Compass Survey (Continued)

- Practical class

Briefing	10 mins
Field work and recording	2 hr
Drawing	50 mins

Lesson 15 — 1 hour

Lesson Plan:

Objective:

To study

Plane Table Survey

- Suitability
- Instruments- Alidade
- Adjustments of Plane Table – centering, leveling, orientation
- Methods – Radiation, Intersection

Backward Linkage: Previous Lessons

Forward Linkage:

- Application in the field; Lesson 16

Training materials required:

- Copy of lesson 15 to be circulated beforehand; Alidade and other instruments

Allocation of time:

Plane Table Survey

Suitability	5 mins
Instruments- Alidade	10 mins
Adjustments of Plane Table – centering, leveling, orientation	15 mins
Methods – Radiation, Intersection	25 mins
Discussion/Miscellaneous	5 mins

Lesson 16 **3 hours**

Lesson Plan:

Objective:

To demonstrate and apply Plane Table Survey Procedures in the field

Plane Table Survey (Continued)

- Practical class on Plane Table Survey

Backward Linkage: Lesson 15

Forward Linkage:

- Application in the field

Training materials required:

- Survey equipments, Drawing materials, Drawing instruments.

Allocation of time:

Plane Table Survey (Continued)

- Practical class

Briefing	10 mins
Field work and recording	2 hr
Drawing	50 mins

Lesson 17 1 hour

Lesson Plan:

Objective:

To study

Contouring and Map Reading

- Topographical map
- Contour
- Interpretation of Topographical map
- Contouring – methods- working in the field
- Principles of levelling
- Direct and indirect methods of contouring
- Map reading
- Computation of area

Backward Linkage: Previous Lessons

Forward Linkage:

- Application in the field

Training materials required:

- Copy of lesson 17 to be circulated beforehand; sample topographical map

Allocation of time:

Contouring and Map Reading

Topographical map	5 mins
Contour	5 mins
Interpretation of Topographical map	5 mins
Contouring – methods- working in the field	8 mins
Principles of levelling	10 mins
Direct and indirect methods of contouring	10 mins
Map reading	5 mins
Computation of area	7 mins
Discussion/Miscellaneous	5 mins

Lesson 18 1 hour

Lesson Plan:

Objective:

To study

Basics of GPS

- Working of GPS
- Use in survey
- Use of GPS in the field
- Advantages and limitations

Backward Linkage: Nil

Forward Linkage*:*

- Application in the field

Training materials required:

- Copy of lesson 18 to be circulated beforehand; sample GPS

Allocation of time:

Basics of GPS

Working of GPS	5 mins
Use in survey	5 mins
Use of GPS in the field	35 mins
Advantages and limitations	10 mins
Discussion/Miscellaneous	5 mins

Lesson 19 4 hours

Lesson Plan:

Objective:

To demonstrate and apply GPS in the field

- Practical class on GPS
  Application of GPS to determine locations of ground objects, and to check area of plantations / forest coupes

Backward Linkage: Lesson 18

Forward Linkage:

- Application in the field

Training materials required:

- GPS, Survey Field Book.

Allocation of time:

- Practical class
  Application of GPS to determine locations of ground objects, and to check area of plantations / forest coupes

Briefing	1 hr
Field work and recording	2 hr
Discussion/miscellaneous	1 hr

Lesson 1:

Introduction 1-6

- Land Survey
- Need for Forest Survey
- Types Of Survey
- Secondary Classification
- Scales
- Linear Measurement
- Chain
- Tapes
- Instruments for Marking Station
- Ranging out Survey Lines
- Ranging by eye
- Chaining on sloping ground

Lesson 2:

Elementary Geometry 7-12

- Straight Line
- Parallel Lines
- Perpendicular line
- Angle
- Types of Angle
- Polygon
- Sum of the angles of a Polygon
- Types of Triangle by angles
- Types of Triangle by sides
- Types of Quadrilateral

Lesson 3:

Elementary Geometry (Continued) 13-18

- Perimeter
- Area
- Area of some common plane figures
- Circle(Radius, Chord, Diameter, Circumference, Area)

Lesson 4:

Elementary Geometry (Continued) 19-20

- Exercise on perimeter and area

Lesson 5:

Elementary Geometry (Continued) 21-25

- Congruent Triangles
- Similar Triangles

- Side-splitter Theorem
- Pythagoras Theorem

Lesson 6:
Elementary Geometry (Continued) 26-30

Solid Geometry
- Cube
- Rectangular Parallelepiped
- Cylinder
- Cone

Lesson 7:

Elementary Trigonometry 31-35

- Trigonometric Functions (ratios)
- Trigonometric Functions of complementary angles
- Values of functions of some specific angles
- Relations among trigonometric functions
- Application of trigonometric principles

Lesson 8:
Chain Survey.. 36-41

- **Chain triangulations**
- **Equipments**
- **Survey Stations**
- **Chain lines**
- **Base line- check line –tie line**
- **Offsets**
- **Perpendiculars on chain lines**

Lesson 9:
Chain Survey (Continued).. 42-46

- Field work
- Field book recording
- Obstacles in chaining

Lesson 10
Chain Survey (Continued).. **47-51**

- **Plotting of chain survey**
- **Traverse survey with chain**

Lesson 11
Chain Survey (continued) 52
Practical class on Chain survey

Lesson 12
Angles and Bearings 53-60
- Meridians
- Prismatic compass
  - working principle
  - testing of the compass
  - Errors
- Bearings – whole circle bearing – reduced bearing
- Local Attraction

Lesson 13
Prismatic Compass and Chain Survey... 61-66
- Traversing with prismatic compass and chain
- Procedure
- Closing error
- Adjustment of closing error
- Practical applications

Lesson 14
Practical class on Prismatic compass survey 67

Lesson 15
Plane Table Survey 68-73
- Suitability
- Instruments- Alidade
- Adjustments of Plane Table – centering, leveling, orientation
- Methods – Radiation, Intersection

Lesson 16
Practical class on Plane Table Survey 74

Lesson 17
Contouring and Map Reading 75-84
- Topographic map
- Contour
- Interpretation of Topographical map
- Contouring – methods- working in the field
- Principles of levelling
- Direct and indirect methods of contouring
- Map reading
- Computation of area

Lesson 18
Basics of GPS.. 85-92

- Working of GPS
- Use in survey
- Use of GPS in the field
- Advantages and limitations

Lesson 19
Practical class on GPS 93
Application of GPS to determine locations of ground objects, and to check area of plantations / forest coupes

Lesson 1 **1 hour**

INTRODUCTION

LAND SURVEY

1. Surveying or land surveying is the technique, profession, and science of accurately determining the terrestrial or three-dimensional position of points and the distances and angles between them. (Source: http://en.wikipedia.org/wiki/Land_surveys)

2. To survey, as defined in Webster's Dictionary is "to determine and delineate the form, extent, position, etc of a tract of land by taking linear and /or angular measurements and by applying the principles of geometry and trigonometry". Surveying in short may be regarded as the art and science of map making. The process of surveying involves both field work of taking measurements and office work of computation and drawing. (Source: Forest Surveying by Ram Parkash)

NEED FOR FOREST SURVEY

3. Forest managers are required to undertake forest survey for various purposes that include:

(i) Demarcation and /or checking forest boundaries

(ii) Laying out felling coupes

(iii) Preparing plantation maps and stock maps

(iv) Detection and rectification of encroachments and illicit possessions

(v) Preparation of plans of areas to be cleared, or fenced or planted

(vi) Alignment of extraction roads and paths.

(vii) Mapping out fire burnt areas etc.

TYPES OF SURVEY

4. **Primary Classification –** Surveying is primarily classified into two categories, namely, (i) Plane Surveying, and (ii) Geodetic or Trigonometrical Surveying.

4.1 The basic presumption in **Plane Surveying** is that the earth's surface is plane, though in fact it is a curved surface. The error in ignoring curvature of the earth's surface is, however, negligible for survey upto 250 sq. km area (Source: Forest Surveying by Ram Parkash). In forest management we do Plane Surveying.

4.2 Geodetic survey is employed while surveying a large area of land in which corrections are made to account for the curvature of the earth. In geodetic survey, line connecting two points on earth's surface thus becomes an arc. Geodetic survey requires knowledge of spherical geometry and trigonometry, and is used when area involved is large and survey demands high accuracy.

5. Secondary Classification

Based on equipments used, forest survey may be classified into various categories like -

1. Chain Survey – major equipments required are chain and other accessories.

2. Compass Survey – major equipments are prismatic compass, chain and other accessories.

3. Plane Table Survey – major equipments are plane table, alidade and other accessories.

SCALES

6. **Scale** of a map is defined as the constant ratio of every distance on the map to the corresponding distance on the ground.

6.1 The scale may be expressed in two ways:

(i) By **statement** of the fixed proportion, e.g. scale of 1 cm=10 metres indicates that a distance of 1 cm on map would mean 10 metres on the ground.

(ii) By a **representative factor or representative fraction (R.F.).** For example a R.F of 1:1000 or 1/1000 would mean ratio of any distance on map to the corresponding distance on ground is 1:1000. In other words, distances on ground, upon being reduced by a factor 1000, have been represented on map. That is, any distance on the map should be multiplied by 1000 to arrive at the corresponding distance on ground.

[Exercise: Find the RF of (1) the 4 inches= 1 mile map, and (2) 16 inches = 1 mile map.]

Linear Measurement

7. Linear measurement means measurement of distances along lines on ground. Units of linear measurement are cm, metre, kilometre etc. in metric system and inch, foot, yard, mile etc. in British system.

8. **Chain** – A chain is a linear measure that is most frequently and commonly used in forest survey.

8.1 It consists of 100 links made of stout steel wire, of which adjoining links are connected by three oval rings. The length of a link is the distance between the centres of two consecutive middle rings (Fig 1.1). The ends of the chain are fitted with brass swivel handles. Each handle forms a part of the corresponding end link whose length includes length of the handle.

8.2 For easy reading of the chain in the field, the chain is divided into ten equal parts and the points of division are marked by brass tags, also called tallies. The tallies are notched or toothed. The number of notches or teeth in a tally represents its distance from the nearer end of the chain in terms of number of tens of links. For example, tallies at 10 links from each end will have one notch; those at 40 links from each end will have 4 notches etc (Fig 1.2).

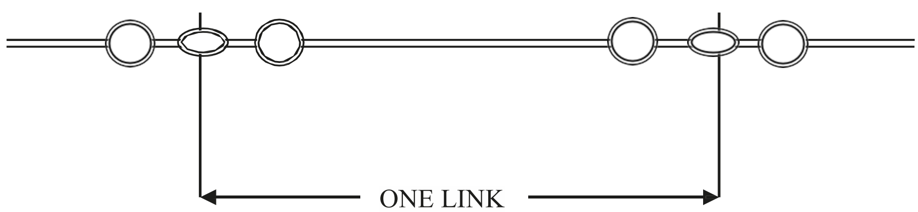


Fig. 1.1

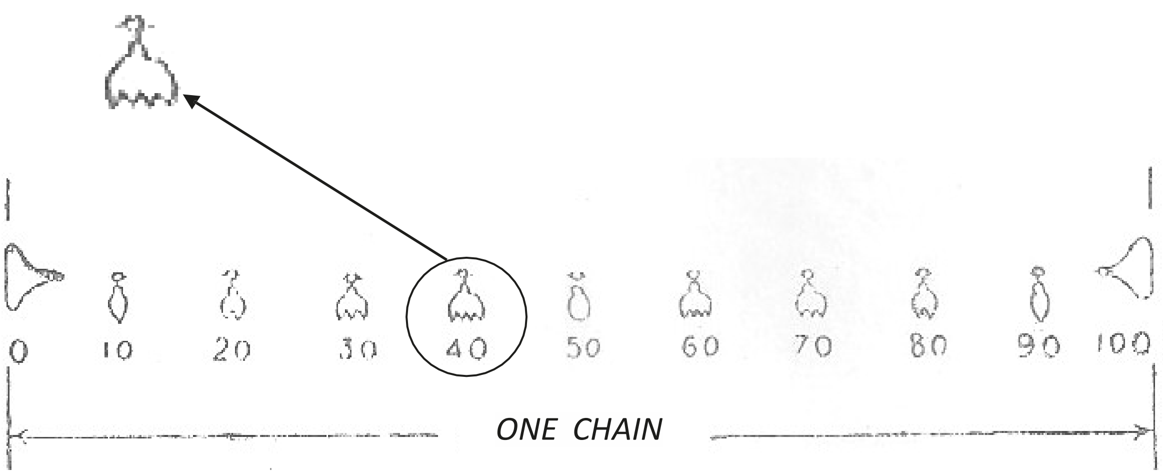


Fig. 1.2

(Source : Forest Surveying by Ram Parkash)

8.3 Gunter's or Surveyor's chain - Named after its inventor, Gunter's chain is 22 yards or 66 feet long. Thus each of its 100 links measures 0.66 foot or 7.92 inches. When British system of units are used in survey, Gunter's chain becomes convenient, as the chain length bears simple relations with units of length and area in the British system. For example, 10 chains=1 furlong; 80 chains =1 mile; 10 square chain =1 acre.

8.4 Metric Chain – However, in countries where metric system of units is used, the convenient chain in use is the metric chain which is 10,20, 25 and 30 metre long. The most commonly used chain is the 20 metre chain. Each link of this chain is 0.20 metre or 20 cm long, and brass tallies are attached at every 2 metres from each end.

8.5 For linear measurement in forests, chain has the advantages that it is sturdy, and suitable for rough forest terrain. It has the disadvantages also, since it is liable to suffer alteration in length due to rough use, and it is heavy and cumbersome.

8.6 Testing the Chain – On prolonged use, the length of a chain often gets changed from its standard length. Sometimes the length gets shortened due to bending of links. Again the length may get elongated due to wearing away of the links or stretching of the links. It is thus necessary that you check the chain length before you put it to use. The test is done by comparing the length of the chain with the standard length. Suppose the standard length the chain should have is 20 metres. Establish a test gauge by driving two pegs (with nails fixed on to their tops) into the ground at a distance of 20 metres apart. The distance of 20 metres between the pegs should be accurate and to be measured and checked by means of a tape or a standard chain. Now place the chain under test on this test gauge and verify if its length matches with the standard length of 20 metres.

9. Tapes -

9.1 **Cloth or Linen Tape** – It is a varnished strip of woven linen, 1 to 1.5 cm wide, that winds in a leather case. It is available in various lengths like 20 m, 30 m etc. It is graduated on one face in feet and inches, and in metre and cm on the other face. The tape is light and easy to use. However, it suffers change in length very easily. It is more handy in subsidiary measurements like offsets.

9.2 Steel Tape – Made of steel ribbon, the steel tape has width of 0.5 cm to 1 cm and is available in various lengths like 15m, 30m and 100m. It is graduated in feet-inches and cms –metres.

10. Instruments for Marking Station:

1) Pegs - These are made of any hard timber, tapering at one end; convenient size being 20-35 cm length, 2.5-4.0cm square. These are firmly driven into the ground with a hammer, with about 4 cm length projecting above the ground level. For soft ground, pegs may be 45-60 cms long and 4.0-5.0 cms square in section.

2) Ranging Rods - Ranging rods are used both for marking the stations prominently and also for ranging lines. They are made of well seasoned, straight-gained timber, generally circular in section, 2.5 to 4 cm diameter and shod with an iron shoe at the lower end. They vary from 2 to 3 metres in length, and are divided into equal parts, each 20 to 30 cm or 1 link long; and alternately painted red and white, or black and white for easy visibility from a distance.

(Source: Forest Surveying by Ram Parkash)

[Chain, tape, and other instruments may be shown in the class.]

11 **Ranging out Survey Lines –** It means alignment of survey line along which chain is to be laid for linear measurement of distances of objects from the chain on both sides. Given two end stations identified and fixed on the ground, the chain is to be laid on ground along a straight line that passes through the end stations. If the survey line is short, that is the end stations are not far off from each other and inter-visible, then the chain line can be aligned easily. One surveyor stationed in one station and holding one end of the chain can guide the direction of other man moving with the other end of chain. However, if the line is long and the end station is not clearly visible, it would be necessary to fix intermediate points on the line of alignment with the help of ranging rods. The process of interpolating rods in between and in line with the end stations is called ranging.

11.1 Ranging by eye – Normally ranging is done by eye or ocularly. Standing in one station the Surveyor sends his assistant with a ranging rod towards the forward station. The assistant positions himself roughly on the line of alignment and faces the surveyor seeking instruction. The surveyor places his eye along the line intersecting the two stations, and signals asking the assistant to move right or left until the rod he is carrying is in line with the end stations. The assistant is then signaled to fix the rod on ground and thus establish an intermediate station. The surveyor can now take the position of the first intermediate station and guide the assistant to move forward to fix further intermediate stations as necessary.

12 **Chaining on sloping ground –** A plan or a map is the horizontal projection, that is projection on a horizontal plane, of the ground it represents. Thus while chaining on a sloping ground, if measurements are made along a slope, the said measurements should be reduced to equivalent horizontal distances for the purpose of plotting. In the diagram below showing section of a slope between two stations A and B, the distance between A and B to be plotted is not AB, the measurement along the slope, but AC, that is projection of AB on the horizontal plane.

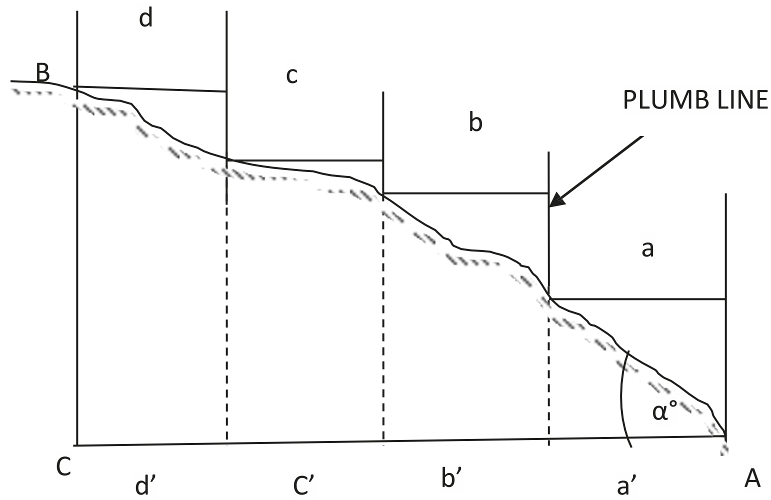


Fig.1.3

In the field, AC can be measured as sum of a, b, c, d, that is, AC = a+b+c+d. The horizontal segments a, b, c and d can be measured by stepping method. The forward man moving up the slope from A with chain takes a few steps, and the follower raises his end of the chain until it is stretched horizontally. As the follower guides the leader into alignment of survey line, the leader marks the point of the chain on the ground with an arrow and takes the measurement of a. The process is repeated until the leader reaches the point B and in the process the measurements of a, b, c and d are taken to find AC. Another method is to apply the principle of trigonometry and find AC from the measurement of AB from the equation AC = AB cosα. The trigonometric ratios have been described in subsequent lessons.

Elementary Geometry

Lesson 2 **1 hour**

1. **Straight Line:** A straight line is the path of shortest distance between two points.

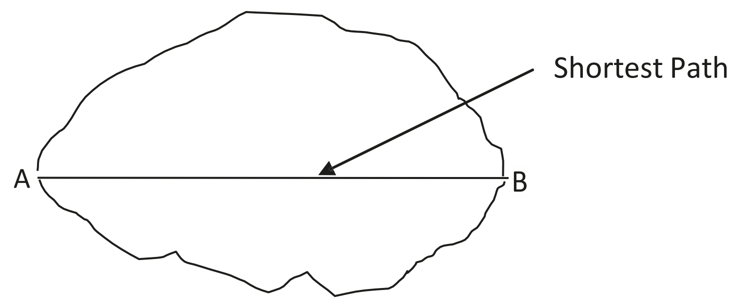


Fig.2.1

Fig 2.1 shows two points A and B. There are innumerable paths by which one can go from A to B. It is, however, clear from the diagram that the shortest path is the straight line or line AB.

2. **Parallel Lines:** Two lines in the same plane are said to be parallel if they, no matter how far they extend, do not intersect with each other. Parallel lines are the same distance apart at any given point.

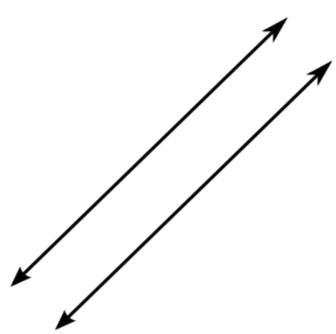
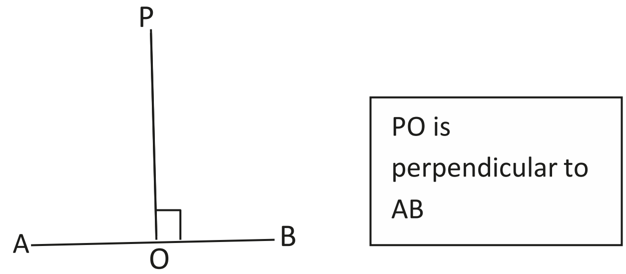


Fig. 2.2

3. **Perpendicular line:** A line is perpendicular to another if it meets or crosses it at right angles (90°).



(Fig. 2.3)

4. **Angle – An angle measures the amount of turn.**

5. **Types of Angle –**

   5.1 Acute Angle – It is an angle that is less than 90°.
   5.2 Right Angle – It is an angle that is exactly 90°.
   5.3 Obtuse Angle – It is an angle that is greater than 90° but less than 180°.
   5.4 Straight Angle – It is an angle that is exactly 180°.
   5.5 Reflex Angle – It is an angle that is greater than 180° but less than 360°.

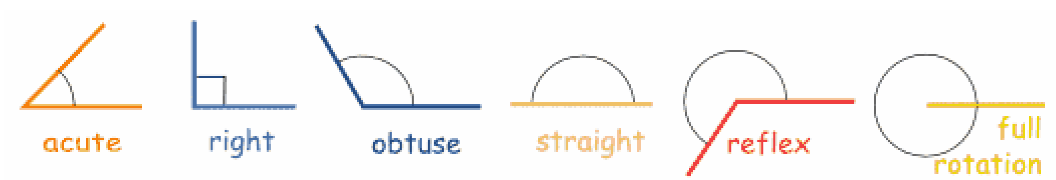
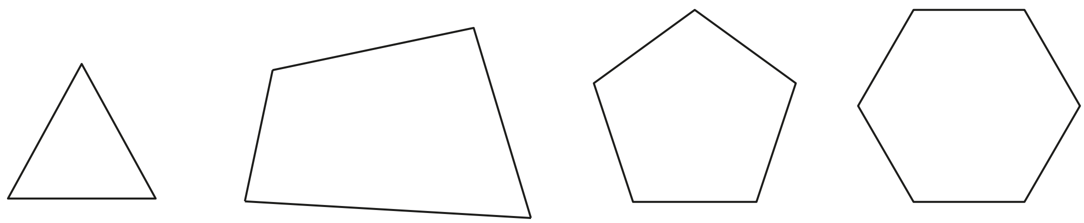


Fig.2.4 (Source: mathsisfun.com)

6. **Polygon –** A closed figure formed by line segments (straight sides) is called a polygon. Some common polygons are shown below.



Triangle: 3 sides, 3 angles

Quadrilateral: 4 sides, 4 angles

Pentagon: 5 sides, 5 angles

Hexagon: 6 sides, 6 angles

Fig. 2.5

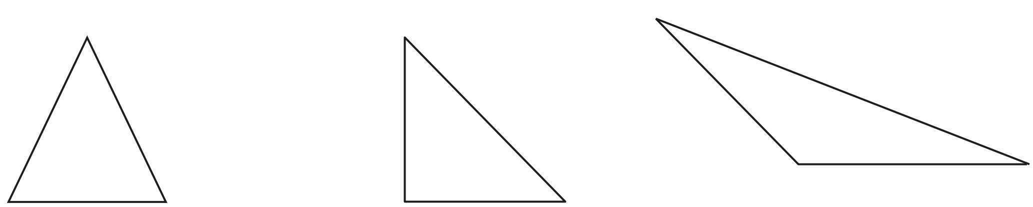
7. **Sum of the angles of a Polygon –** If n is the number of sides of a polygon, then sum of the angles of the said polygon is (n – 2) x 180°.

Sum of the angles = (n – 2) x 180°

It follows from the above formula that sum of the various polygons will be as given below.

Polygon	No of sides (n)	Sum of angles [(n – 2) x 180°]
Triangle	3	180°
Quadrilateral	4	360°
Pentagon	5	540°
Hexagon	6	720°

8. **Types of Triangle by angles –**



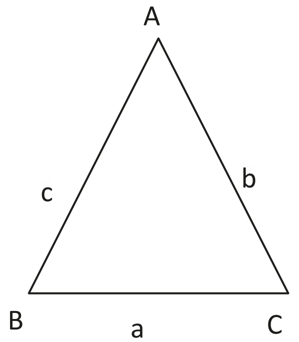
Acute Triangle
All angles are acute

Right Triangle; One angle is a right angle

Obtuse Triangle; one angle is an obtuse angle

Fig. 2.6

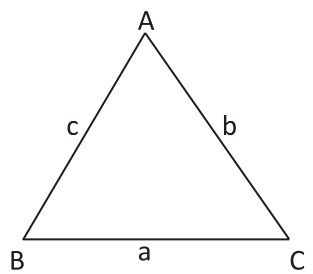
9. Types of Triangle by sides –



Isosceles Triangle (Fig. 2.7)

If only two sides of a triangle are equal, the triangle is isosceles triangle. Angles opposite to equal sides are equal.

$\angle B = \angle C$; $b = c$

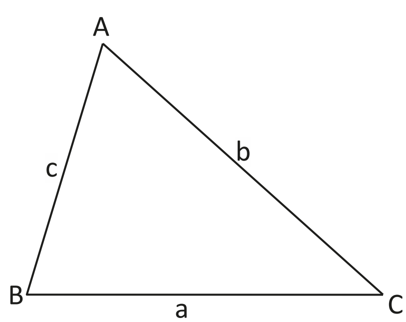


Equilateral Triangle (Fig. 2.8)

If all three sides are equal, the triangle is called equilateral triangle. Angles of equilateral triangle are equal and each equal to 60°.

$a = b = c$.

$\angle A = \angle B = \angle C = 60^\circ$.



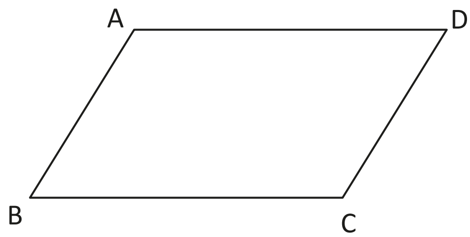
Scalene Triangle (Fig. 2.9)

If all the three sides of a triangle are of different length, the triangle is called a scalene triangle.

$a \neq b \neq c$

10. Types of Quadrilateral (Polygon formed by four line segments)

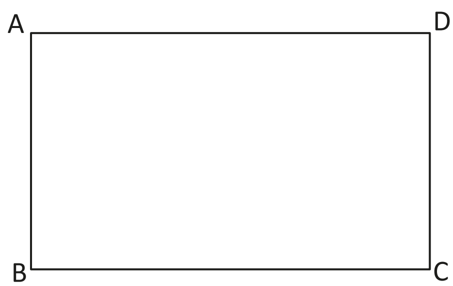
Parallelogram – A quadrilateral in which the opposite sides are parallel is called a parallelogram.



Parallelogram (Fig. 2.10)

> **In a parallelogram, opposite sides are parallel and equal. Opposite angles are also equal.**
> AD || BC; AB || CD
> AD = BC;   AB = CD
> $\angle A = \angle C$; $\angle B = \angle D$

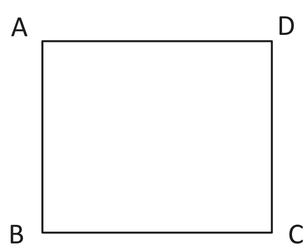
Rectangle – A rectangle is a parallelogram in which all angles are right angles.



Rectangle (Fig. 2.11)

> In a rectangle, **opposite sides are parallel and equal; all the four angles are right angles.**
> AD = BC;   AB = CD
> $\angle A = \angle B = \angle C = \angle D = 90^\circ$

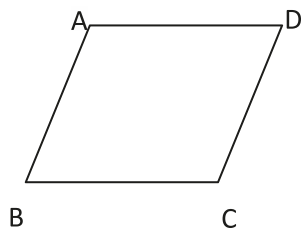
Square – A square is a parallelogram in which all angles are right angles and all sides have the same length.



Square (Fig. 2.12)

> In a square, **all the four sides are equal and all the four angles are right angles.**
> AB = BC = CD = DA
> $\angle A = \angle B = \angle C = \angle D = 90^\circ$

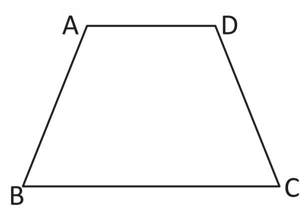
Rhombus – A rhombus is a parallelogram in which all four sides have the same length.



Rhombus (Fig. 2.13)

In a rhombus, all the four sides are equal; opposite angles (not all angles) are equal; none of the angles is right angle.
AB = BC = CD = DA;
$\angle A = \angle C$, $\angle B = \angle D$

Trapezium – It is a quadrilateral with one pair of parallel sides, while the other two sides are not parallel.



Trapezium (Fig. 2.14)

In a trapezium two sides **(AD and BC) are parallel, and the other two sides (AB and CD) are not**.

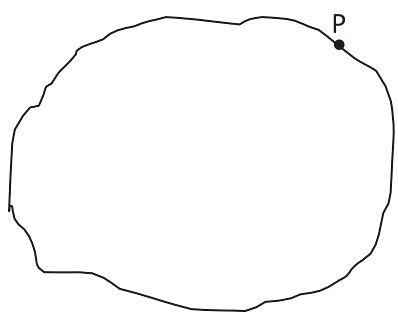
The above definition of trapezium is the British version of trapezium. According to US version, a trapezium is a quadrilateral which has no parallel sides, and the quadrilateral with one pair of parallel sides is a trapezoid. However, according to British version, a trapezoid is a quadrilateral with no parallel sides. Thus the British and US definitions of the terms Trapezium and Trapezoid are just opposite.

Elementary Geometry (Continued)

Lesson 3 **1 hour**

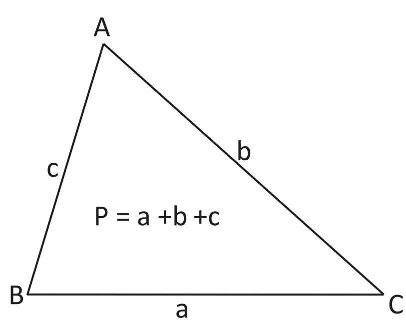
1. **Perimeter –** It is defined as the distance around a plane figure or the length of the boundary of a plane figure. For example, perimeter of a polygon is the sum of the lengths of the sides of a polygon. For circles and ellipses, it is called the circumference.

1.1 Please consider the figure given in the diagram below. From a point **(P)** on the boundary if you walk along the boundary and come back to the starting point P, then the total distance that you travel is the length of the boundary. The said distance or length will be the perimeter of the figure.



Perimeter is the length of the boundary (Fig, 3.1)

1.2 From a map or plan, calculation of perimeter becomes easy if the plane figure in question is of regular geometrical shape. Illustrations with some known geometrical figures are given below.



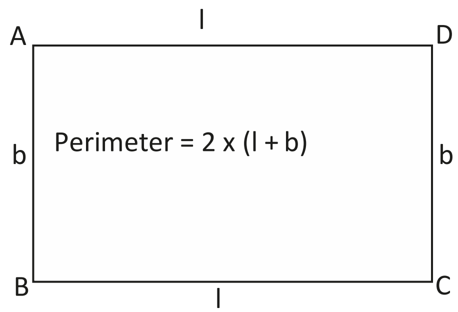
Perimeter of Δ ABC = AB + BC + CA

= a + b + c ;

Perimeter of equilateral Δ of side a

= a + a + a = 3a

Perimeter of Triangle (Fig. 3.2)



Length of the rectangle ABCD is BC = DA = l

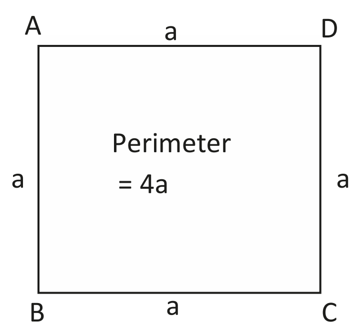
Breadth = AB = CD = b

Perimeter = AB +BC + CD + DA

= 2xl +2xb = 2x (l +b)

= 2 x (length + breadth)

Perimeter of Rectangle (Fig. 3.3)



Length of each side of square ABCD = a

Perimeter = AB +BC + CD + DA

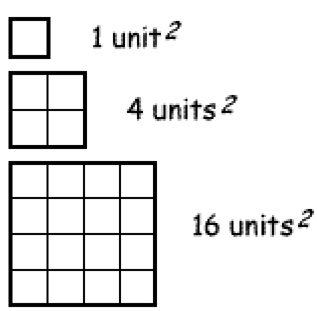
= a + a + a + a

= 4a

= 4 x length of any side

Perimeter of Square (Fig. 3.4)

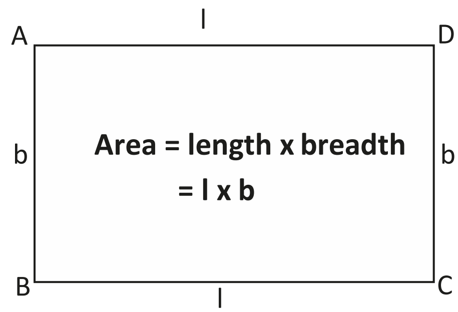
2. **Area -**(Please also see Forest Mensuration Lesson 1) Area is the extent of a two dimensional surface or shape. In other words, area of



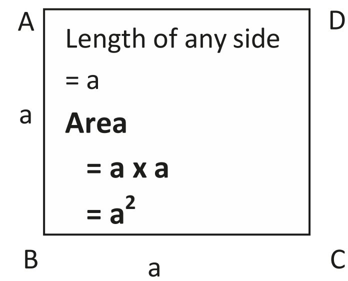
Area of a plane figure (Fig. 3.5)

a plane figure means the number of square units the figure covers. In the above diagram, given the extent of one square unit, the second figure (square) contains 4 squares, and the third figure (square) contains 16 squares. Therefore, areas of the second and the third square are 4sq. unit and 16 sq. unit respectively.

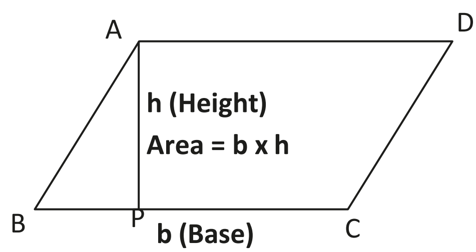
2.1 Area of some common plane figures



Area of Rectangle (Fig.3.6)



Area of Square (Fig. 3.7)



Area of Parallelogram (Fig. 3.8)

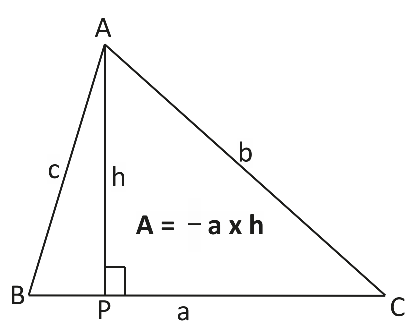
Base of parallelogram = BC = AD = b;

AP is perpendicular dropped from A to base BC.

Length of perpendicular = AP = h.

Area = Base x Height

= b x h.



Area of triangle (Fig. 3.9)

BC is base of the triangle ABC. AP is perpendicular dropped from vertex A to opposite side BC, i.e. base.

Length AP = h = height or altitude

Length BC = a = length of base

Area = $\frac{1}{2}$ **base x height**

= $\frac{1}{2}$ **a x h**

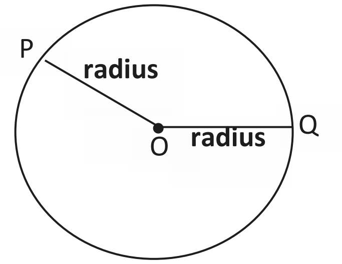
Similarly, AB or CA can be taken as base and in that case height (for calculation of area) should be length of perpendiculars dropped on AB or CA from C or B respectively.

Area of a triangle by measuring off its sides – When the three sides of a triangle are known, its area can be calculated from the following formula:

> **Area (A) =** $\sqrt{s(s-a)(s-b)(s-c)}$ **, where**
> **a, b and c are the lengths of the three sides, and**
> **s=** $\frac{a+b+c}{2}$ **= semi-perimeter of the triangle**

3. Circle

A circle is a closed curve in a plane, all points on which (curve) are at a constant distance (radius) from a fixed point called centre of the circle.

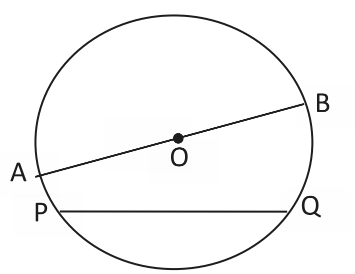


O is the centre. All points on the circle are equidistant from O; OP = OQ = radius = r

Fig 3.10

3.1 Radius -The **radius** of a circle is the distance from the center of a circle to any point on the circle.

3.2 Chord - A **chord** is a line segment joining two endpoints that lie on a circle.



PQ is a chord; AB is a diameter

Fig 3.11

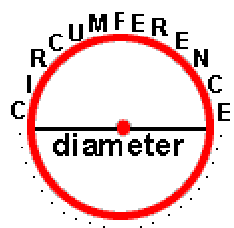
3.3 Diameter - Diameter of a circle is the longest chord of that circle that passes through the centre of the circle. If you place two radii end-to-end in a circle, you would have the same length as one diameter. Thus, the diameter of a circle is twice as long as the radius.

Diameter = 2 x radius

3.4 Circumference – Perimeter of a circle, that is, the distance around a circle is called the **circumference**. The circumference (C) bears a constant ratio to diameter (d). The ratio is known as **π.** Value of is approximately taken as $\frac{22}{7}$ or, 3.1416. Thus the relationship of circumference and diameter of a circle can be expressed as:

$$\frac{C}{d} = \pi$$

where C is circumference and d is diameter.



(Fig. 3.12 – Source: http://www.mathgoodies.com/)

Thus if the diameter of a circle is known, its circumference can be calculated by means of the formula:

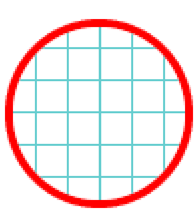
C = π.d

Or, if the circumference is known, the diameter can be calculated from the formula:

$$\boldsymbol{d} = \frac{C}{\pi}$$

3.4 Area

The area of a circle is the number of square units that get accommodated inside that circle.



(Fig. 3.13 – Source: http://www.mathgoodies.com/)

Area is determined by using the following formula.

$$A = \pi . r^2 \quad \text{or} \quad A = \pi . r . r$$

where A is the area, and r is the radius.

Thus if radius of a circle is known, the area covered by the circle can be calculated with the help of the formula given above.

ELEMENTARY GEOMETRY (CONTINUED)

Lesson 4 **Time 1 hour**

Exercise on perimeter and area

1. In a forest blank you are required to lay out a plantation area of 64 ha. The area should be rectangular in shape.
    a) If the length of plantation area is designed to be 1 km, what should be the breadth of the area?
    [Hint: Area of rectangle = length x breadth]
    b) Draw the rectangular area on a sheet of paper on a scale 1cm = 100 m
    c) If the plantation area were designed to be square in shape, what should be the length of each side of the square?
    [Hint: Area of a square = (length of any side)^2]
    d) Draw the square on a sheet of paper on a scale 1cm = 100 m.
    e) You are required to fence the area with 5 strands of barbed wire. Calculate the length of barbed wire required to fence the (i) rectangular plot and (ii) the square plot. Note the difference in requirement of barbed wire, and identify the plot – rectangular or square - in which the requirement is less.
    [Hint: Perimeter of rectangle = 2 x (length + breadth)
    Perimeter of square = 4 x any side]
    f) Two plots – one rectangular and one square – have the same area. Do they have same perimeter? Which plot has less perimeter?
    g) If the plantation area of 64 ha is to be designed in the shape of a parallelogram having length (or base) of 1 km, what would be the height of the parallelogram?
    [Hint: Area of a parallelogram = base x height]

2. A sample plot, triangular in shape, has three sides measuring 70 metres, 60 metres and 50 metres.
    a) Draw the sample plot on a sheet of paper on a scale 1 cm = 10 m
    b) It is required to dig continuous boundary trench around the plot. What will be the total length of the trench? [Hint: Perimeter= sum of the lengths of the sides]
    c) Calculate the area of the sample plot. [Hint: Area (A) = $\sqrt{s(s-a)(s-b)(s-c)}$]
    d) Taking the 70 m side as the base of the triangle, calculate its height.

    [Hint: Area = $\frac{1}{2}$ base x height]

3. You are required to lay out a circular plot of area 2500 sq.metre.

a) What will be the radius of the circular plot? [Hint: $A = \pi \cdot r^2$; take **π** =3.14]
b) Calculate the circumference of the circular plot.
c) Draw a square (on a scale 1 cm = 10m) having the same area as the circular plot, and compare the circumference of the circular plot with the perimeter of the square.

Elementary Geometry (Continued)

Properties of Triangle

Lesson 5 **1 hour**

1. **Introduction –** Preliminary description of triangles and the types have been dealt with in lesson 3. A triangle is a 3-sided polygon and sum of the three angles is 180 degree. The underlying principle of triangulation is frequently used in ground survey. The tract of land under survey is divided into a frame-work of triangles whose sides form the chain or survey lines. Once the sides of a triangle on ground are measured, that is known, the triangle is uniquely determined. Its vertices, the sides and their relative positions get uniquely fixed. Thus by measuring the sides of triangles, the entire frame-work can be plotted on survey sheet on a suitable scale. Positions of ground features measured with respect to vertices and the sides of triangles, that is, stations and chain lines, thus become uniquely determined and can be conveniently plotted on survey sheet.
2. It is therefore necessary to be conversant with some basic properties and theorems relating to triangles.
3. **Congruent Triangles**

   Congruent means equal in all respect. Triangles are said to be congruent when all corresponding sides and interior angles are equal. Congruent triangles will have the same shape and size.

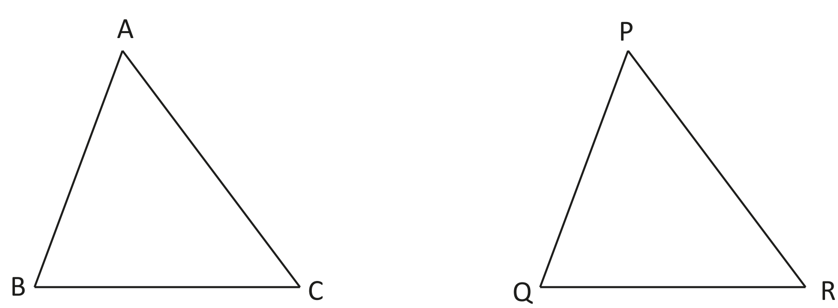


Fig.5.1 (Congruent Triangles)

3.1 Please see Fig. 5.1. The two triangles ABC and PQR are congruent, since

- Corresponding sides have the same length, that is, AB = PQ, BC = QR and CA = RP
- Corresponding angles have equal measure, that is, ∠ A = ∠P, ∠B = ∠ Q and ∠C = ∠R

3.2 How to tell if two triangles are congruent (Source: www.mathopenref.com)

Any triangle is defined by six measures (three sides, three angles). But you do not need to know all of them to show that two triangles are congruent. Any of the following groups of three will do. **Two triangles are congruent if:**

1. **SSS** (side side side)
   If all three corresponding sides are equal in length.
2. **SAS** (side angle side)
   A pair of corresponding sides and the included angle are equal.
   [**For example, with reference to Fig.5.1, if you can show AB = PQ, BC = QR and included ∠B = included ∠Q, then the two Δs will be proved to be congruent.**]
3. **ASA** (angle side angle)
   A pair of corresponding angles and the included side are equal.
   [For example, with reference to Fig.5.1, if you can show ∠B = ∠Q, ∠C = ∠R, and the included side BC = included side QR, then the two Δs will be proved to be congruent].
4. **AAS** (angle angle side)
   A pair of corresponding angles and a non-included side are equal.
   [For example, with reference to Fig.5.1, if you can show ∠B = ∠Q, ∠C = ∠R, and non-included side CA = non-included side RP, then the two Δs will be proved to be congruent] Here non-included side means a side opposite either one of the angles.
5. Two right triangles are congruent if the hypotenuse and one leg are equal. Here leg means any of the two sides other than the hypotenuse.

[Two congruent right triangles: Hypotenuse CA = Hypotenuse RP, Leg BC = Leg QR]

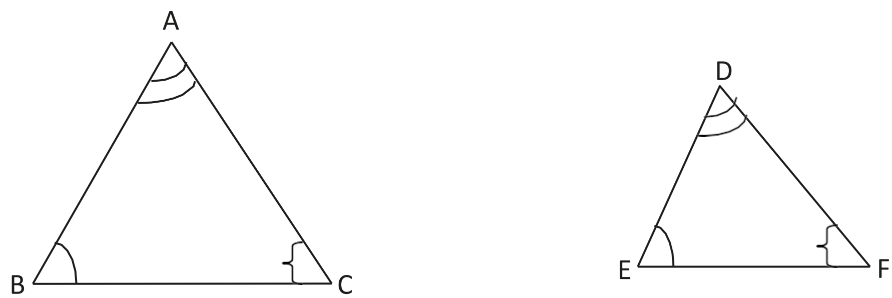
Fig. 5.2

4. Similar Triangles

When you draw a map to scale, you are actually creating a new geometric object that has the "same shape" as the old one, but has all of its parts reduced or enlarged in size – or "scaled" – by the same ratio. In geometry, two figures that have the same shape but not necessarily the same size are said to be similar to each other.

4.1 Two triangles are said to be similar, if their corresponding angles are equal.

4.2 Please see the Fig. 5.3. In the two triangles ABC and DEF, $\angle A = \angle D$, $\angle B = \angle E$, and $\angle C = \angle F$, and thus the Δ ABC and Δ DEF are similar.



Similar Triangles (Fig. 5.3)

4.3 It may be noticed that in order to know whether two triangles are similar, it is only necessary to check if two of the corresponding angles are equal. Since the sum of three angles of a triangle is 180 degree, if two pairs of the corresponding angles are equal, the third pair of the corresponding angles will also be equal. In other words, if we know $\angle A = \angle D$, and $\angle B = \angle E$, then automatically, $\angle C$ will be equal to $\angle F$, and the Δs will be similar.

4.4 Corresponding sides of two similar triangles are in the same ratio or proportion.

Thus with reference to Fig.5.3, $\frac{AB}{DE} = \frac{BC}{EF} = \frac{CA}{FD}$

4.5 Side-splitter Theorem – A line drawn parallel to a side of a triangle cuts off proportional segments from the other two sides. In other words, a line drawn parallel to a side of a triangle divides the other two sides in the same ratio or proportion.

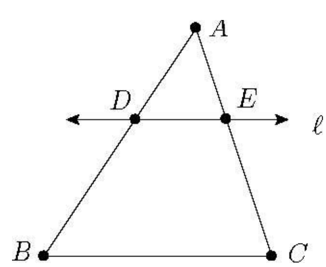


Fig. 5.4

Please see Fig. 5.4. The line l is drawn parallel to BC to intersect AB and AC at D and E respectively. It is apparent from the diagram that Δs ADE and ABC are similar. Therefore, it follows that

$$\frac{AD}{AB} = \frac{AE}{AC}$$ (Segments AD and AE bear the same ratio to AB and AC respectively)

The above equation may also be written as

$$\frac{AD}{DB} = \frac{AE}{EC}$$ (Sides AB and AC are divided in the same ratio)

5. **Pythagoras Theorem**

In a right triangle the square of the hypotenuse is equal to the sum of the squares of the other two sides.

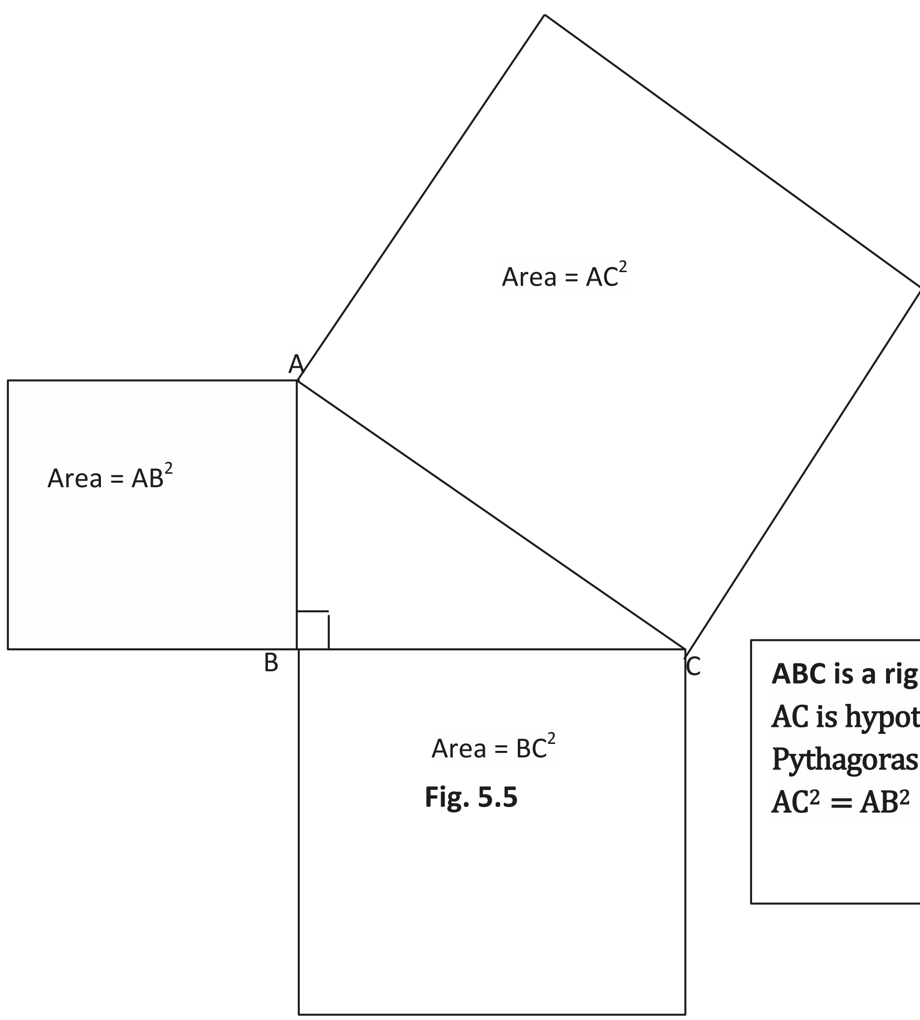


Fig. 5.5

ABC is a right Δ; ∠B is right angle;
AC is hypotenuse.
Pythagoras Theorem states
$AC^2 = AB^2 + BC^2$

- If you construct three squares, as shown in Fig. 5.5, taking AC, AB and BC as base respectively, then according to Pythagoras Theorem,
  Area of square on AC = Area of square on AB + Area of square on BC.

Elementary Geometry (Continued)

Solid Geometry

Lesson 6 **1 hour**

Solid Objects

1. **Cube – I**t is a 3-dimensional, six sided solid figure with the same length, breadth, and height. The image given below explains what is a cube.

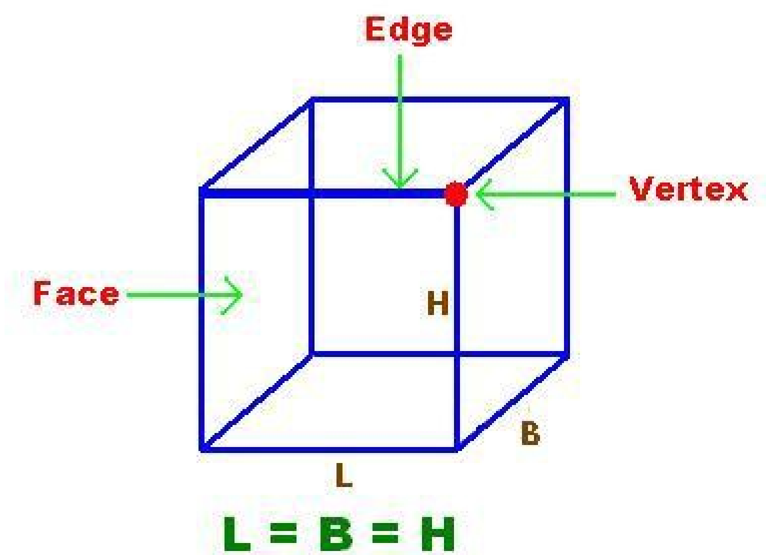


Fig. 6.1 (Source: http://www.mathcaptain.com/geometry/cube.html#**)**

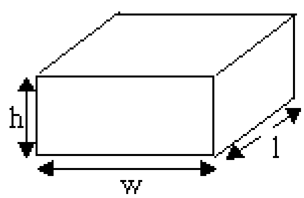
Volume of a cube = amount of space occupied by the object

= a x a x a (as length = breadth = height = say, a)

= a^3 cubic units

Total surface area of a cube = $6a^2$ square units

2. **Rectangular Parallelepiped -** A box shape in three dimensional space for which all faces are rectangles.



Rectangular parallelepiped having length l units, width w units and height h units
Its volume = (l x w x h) $unit^3$.
If l = 4 units, w = 3 units and h = 2 units, then volume = 4 x3 x 2 = 24 $unit^3$. That is, 24 unit cubes can be accommodated within the parallelepiped.

Fig. 6.2

3. **Cylinder** (Source:http://www.mathopenref.com/)

A cylinder is a closed solid that has two parallel (usually circular) bases connected by a curved surface.

Base and side

A cylinder is a geometric solid that is very common in everyday life. It has two ends, called bases that are usually circular. The bases are always congruent (equal in all respect) and parallel to each other. The side which is a curved surface, when laid flat, is actually a rectangle.

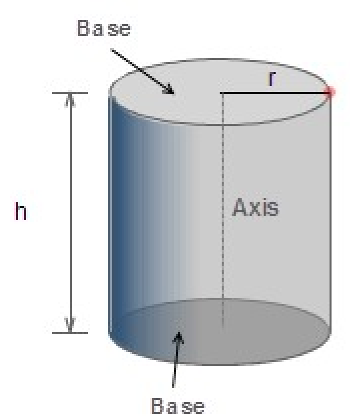


Fig. 6.3

Height or Altitude

The height ***h*** is the perpendicular distance between the bases.

Radius

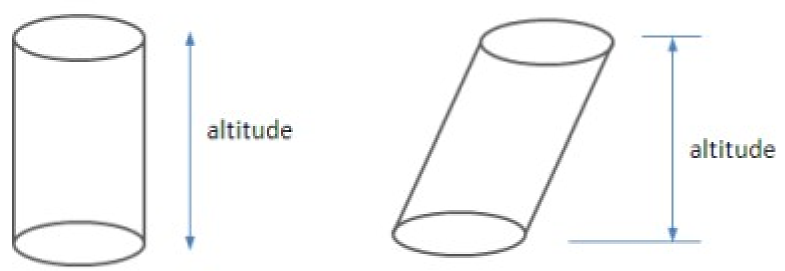
The radius ***r*** of a cylinder is the radius of a base. If diameter is given, it is to be halved to find radius.

Axis

A line joining the center of each base.

Right and oblique cylinders

When the two bases are exactly over each other and the axis is at right angles to the base, this is a called a 'right cylinder'. If one base is displaced sideways, the axis is not at right angles to the bases and the result is called an oblique cylinder. The bases, although not directly over each other, are still parallel.



Right Cylinder Oblique Cylinder

Fig. 6.4

Volume and surface area of cylinder

Volume $= \pi . r^2 . h$

Surface Area = Area of bases + Area of curved surface

$= 2 \pi r^2 + 2 \pi r.h$

$= 2 \pi r (r + h)$

4. Cone (Source:http://www.mathopenref.com/)

A cone is a solid that has a circular base and a single vertex. If the vertex is over the center of the base, it is called a right cone. If it is not, it is called an oblique cone. An object that is shaped like a cone is said to be 'conical'..

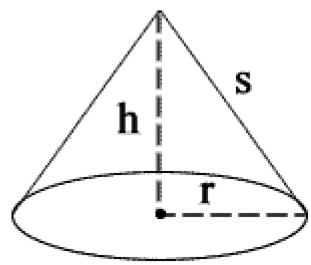


Fig. 6.5

The volume of a cone is given by the formula

$$Volume = \frac{1}{3}\pi r^2 h$$

where *r* is the radius of the circular base, and ***h*** is the height - the perpendicular distance from the base to the vertex.

The surface area of a cone is given by the formula

$$area = \pi r s + \pi r^2$$

Where r is the radius of the circular base, and ***s*** is the slant height (the distance from the top of the cone down the side to a point on the edge of the base) of the cone.

Exercise:

1. Volume of a cube is 27 cu.cm. What is the length of a side of the cube?
2. A short trench in the shape of a rectangular parallelepiped measures 3 m in length, 60 cm in width and 30cm in depth. What is the volume of earth excavated?

3. A wooden log of shape approximately of a cylinder has length of 3.60 metre, and its diameter measures 60 cm. Calculate the volume of the log in cubic metre.
4. Consider that a tree is conical in shape. Height of the tree measures 12 metres. Circumference (girth) of the tree at the base is 180 cm. Calculate the volume of the tree.

Elementary Trigonometry

Lesson 7 **I hour**

1. Trigonometric Functions (ratios)

There are six functions that form the core of trigonometry. Of these six functions, following there are primary:

- Sine (sin)
- Cosine (cos)
- Tangent (tan)

The other three which can be derived from the three primary functions are:

- Secant (sec)
- Cosecant (cosec)
- Cotangent (cot)

The abbreviated names of the functions are shown in parentheses above.

2. How the trigonometric functions are defined - Let us take a right △ ABC as shown. ∠B is a right angle and ∠A is an acute angle.

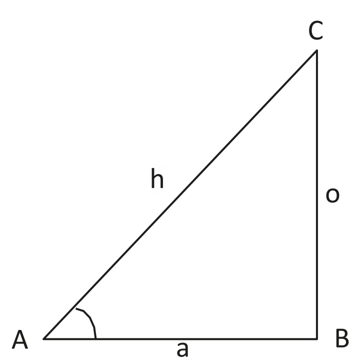


Fig. 7.1

Let

h = length **of hypotenuse** AC;

a = length of side AB **adjacent** to ∠A;

o = length of side BC **opposite** to ∠A

The trigonometric functions of ∠A are defined as follows:

Primary Functions-

$$\sin A = \frac{BC}{AC} = \frac{o}{h}$$

$$\cos A = \frac{AB}{AC} = \frac{a}{h}$$

$$\tan A = \frac{BC}{AB} = \frac{o}{a}$$

Sine A = $\frac{opposite\ side}{hypotenuse}$,

Cosine A = $\frac{adjacent\ side}{hypotenuse}$

Tangent A = $\frac{opposite\ side}{adjacent\ side}$

Other three functions –

$$\text{cosec A} = \frac{AC}{BC} = \frac{h}{o}$$

$$\text{sec A} = \frac{AC}{AB} = \frac{h}{a}$$

$$\text{cot A} = \frac{AB}{BC} = \frac{a}{o}$$

Please note

$$\text{cosec A} = \frac{\textit{hypotenuse}}{\textit{opposite side}} = \frac{1}{\sin A},$$

$$\text{sec A} = \frac{\textit{hypotenuse}}{\textit{adjacent side}} = \frac{1}{\cos A}$$

$$\text{cot A} = \frac{\textit{adjacent side}}{\textit{opposite side}} = \frac{1}{\tan A}$$

3. Functions are independent of size of triangle

As the functions are a *ratio* of two side lengths, they always produce the same result for a given angle, regardless of the size of the triangle. In other words, values of the functions do not vary with the lengths of the sides.

4. Trigonometric Functions of Complementary Angles.

In the right $\triangle ABC$ (Fig.7.1) the two acute angles A and C are complementary, as $\angle A + \angle C = 90^0$. Trigonometric functions of ∠C can be defined in the same manner as has been done for ∠A. **As we define trigonometric functions of ∠C, please note how they are related to those of ∠A.**

Thus –

$$\text{Sin C} = \frac{\textit{opposite side}}{\textit{hypotenuse}} = \frac{AB}{AC} = \text{cos A}, \quad \text{Cos C} = \frac{\textit{adjacent side}}{\textit{hypotenuse}} = \frac{BC}{AC} = \text{sin A}$$

$$\text{tan C} = \frac{\textit{opposite side}}{\textit{adjacent side}} = \frac{AB}{BC} = \text{cot A}, \quad \text{cot C} = \frac{\textit{adjacent side}}{\textit{opposite side}} = \frac{BC}{AB} = \text{tan A}$$

$$\text{sec C} = \frac{\textit{hypotenuse}}{\textit{adjacent side}} = \frac{AC}{BC} = \text{cosec A}, \quad \text{cosec C} = \frac{\textit{hypotenuse}}{\textit{opposite side}} = \frac{AC}{AB} = \text{sec A}$$

Therefore we may state –

sin (90^0 - A) = cos A , **cos (90^0 - A) = sin A**

tan (90^0 - A) = cot A , **cot (90^0 - A) = tan A**

sec (90^0 - A) = cosec A, **cosec (90^0 - A) = sec A**

5. Values of trigonometric functions of some specific angles

$\angle A$	0^0	30^0	45^0	60^0	90^0
sin A	0	$\frac{1}{2}$	$\frac{1}{\sqrt{2}}$	$\frac{\sqrt{3}}{2}$	1
cos A	1	$\frac{\sqrt{3}}{2}$	$\frac{1}{\sqrt{2}}$	$\frac{1}{2}$	0
tan A	0	$\frac{1}{\sqrt{3}}$	1	$\sqrt{3}$	Not defined
cosec A	Not defined	2	$\sqrt{2}$	$\frac{2}{\sqrt{3}}$	1
sec A	1	$\frac{2}{\sqrt{3}}$	$\sqrt{2}$	2	Not defined
cot A	Not defined	$\sqrt{3}$	1	$\frac{1}{\sqrt{3}}$	0

6. Relations among trigonometric functions

If the value of one trigonometric function of an angle is known, then values of other functions of the said angle can be calculated from the relations that exist between the functions.

6.1 Given below are some trigonometric identities which hold good for any value of the angle. These can be established easily with reference to right triangle ABC (Fig.7.1).

$$\tan A = \frac{BC}{AB} = \frac{BC/AC}{AB/AC} = \frac{\sin A}{\cos A}$$

$$\cot A = \frac{AB}{BC} = \frac{AB/AC}{BC/AC} = \frac{\cos A}{\sin A}$$

$$\sin^2 A + \cos^2 A = \left(\frac{BC}{AC}\right)^2 + \left(\frac{AB}{AC}\right)^2 = \frac{BC^2+AB^2}{AC^2} = \frac{AC^2}{AC^2} = 1$$

[applying Pythagoras theorem $BC^2 + AB^2 = AC^2$]

$$1 + \tan^2 A = 1 + \frac{\sin^2 A}{\cos^2 A} = \frac{\sin^2 A + \cos^2 A}{\cos^2 A} = \frac{1}{\cos^2 A} = \sec^2 A$$

$$1 + \cot^2 A = 1 + \frac{\cos^2 A}{\sin^2 A} = \frac{\sin^2 A + \cos^2 A}{\sin^2 A} = \frac{1}{\sin^2 A} = \text{cosec}^2 A$$

7. Application of trigonometric principles

7.1 Trigonometric principles have useful applications in measurement of heights, distances and angles. Please refer to lesson on measurement of tree height in Forest mensuration. In making application of trigonometric principles, often reference is made to the terms, namely, line of sight, angle of elevation and angle of depression. Let us understand what is meant by these terms.

7.2 Line of sight is the line drawn from the eye of the observer to the point in the object viewed by the observer. Please refer to Fig.7.2. E is the eye of the observer; T is the top of the tree BT being viewed. Then ET is the line of sight.

7.3 Angle of Elevation – It is the angle ($\angle E$) formed by the line of sight with the horizontal (line EB) when the point being viewed is above the horizontal level.

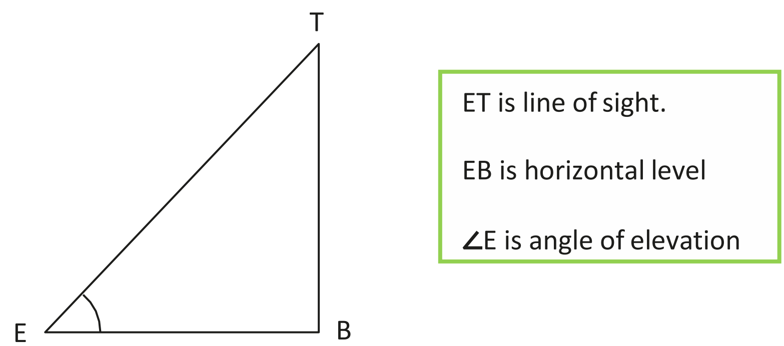
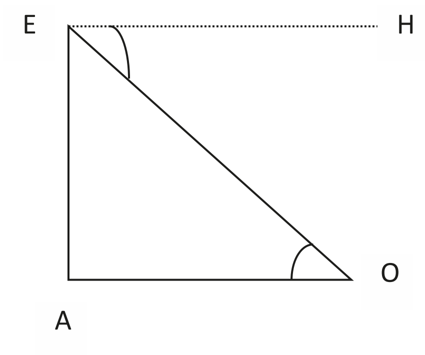


Fig. 7.2

If the angle of elevation $\angle E$ and the horizontal distance EB are measured, then the height BT of the tree can be calculated from the following relation.

$$BT = EB \tan \angle E$$

7.4 Angle of Depression – It is the angle formed by the line of sight with the horizontal when the point in the object being viewed is below the horizontal level. Please see Fig. 7.3. Suppose the observer is positioned on the top of a tower AE. E is the position of his eye. EH is horizontal level with reference to the observer. He views an object O below on the ground. EO is line of sight, which makes an angle HEO with the horizontal. Thus $\angle HEO$ is the angle of depression of the point O.



E is observer's eye. O is the point of object being viewed.
EO is line of sight.
∠HEO is angle of depression.
Please note ∠HEO =∠EOA

Fig.7.3

In this case, if the angle of depression ∠ HEO and the horizontal distance AO are measured, then the height of the tower AE can be calculated from the following formula.

$$AE = AO. \tan \angle EOA = AO. \tan \angle HEO$$

CHAIN SURVEY

Lesson 8 **1 hour**

Chain Triangulation or Chain Survey

1. In this method the ground to be surveyed is divided into a frame-work of triangles whose sides or arms serve as survey lines or chain lines and features of the ground are located with reference to these chain lines. The underlying principle of chain triangulation is that a triangle is uniquely defined in shape and size when lengths of its three sides are known. Thus if survey stations are made the vertices of triangles, then by measuring off the distances between stations (or sides of the triangles) the location and disposition of the stations are uniquely determined and can be plotted on a drawing sheet. Number and positions of the stations to be established will depend on the configuration of the ground, presence of natural obstacles and nature of details to be plotted.
2. The method is suitable for small areas and open ground with simple details. This method of survey involves only linear measurements.
3. **Equipments required for Chain Survey**

(i) A chain (20 metres) and 10 arrows

(ii) A tape

(iii) An offset rod

(iv) A cross staff*

(v) A plumb bob

(vi) Ranging rods

(vii) Survey field book

(viii) A pencil and a pen knife

[* **Cross Staff –** It is a simple equipment that allows two lines of sight mutually at right angles to each other. A wooden cross staff is described below.

It consists of a wooden block, square or round shaped, about 4 cm thick. On the upper surface two fine saw cuts about 1 cm deep are made in such a way that the cuts intersect each other at right angles. The bottom surface is provided with a hole so that the block can be mounted on a staff about 1 to 1.5 metre long. The saw cuts or grooves are the lines of sight. Sometimes the ends of the grooves are provided with vertical slits to facilitate sighting.

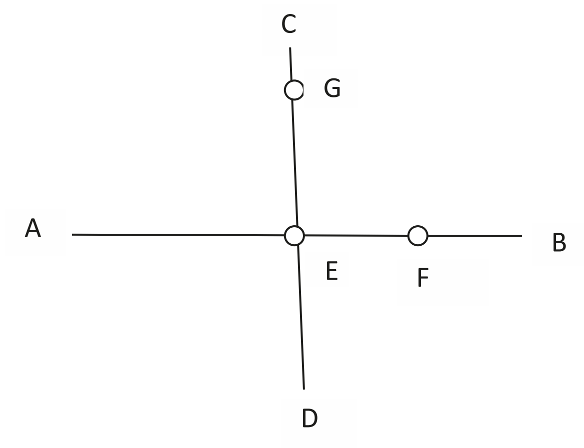


Fig.8.1

Cross staff is used to set out a right angle. Suppose the survey party is proceeding along the chain line AB, and it is required to move at right angle at E. It means the survey party will have to align a chain line CD which is at right angle to AB. The cross staff is set up at E, and a ranging rod is fixed at F on the chain line. The cross staff located at E is turned until the ranging rod at F is sighted through one of the grooves. At this position of the cross staff, sighting is done through other groove or line of sight and position of the other ranging rod is adjusted until it is viewed, that is, until it comes on the line of sight. The position of the second ranging rod G is marked and the rod is fixed at this point. The line EG gives the desired chain line CD which is perpendicular to AB.]

4. Survey Station

A survey station is a point where main, base or any other chain or tie line begins or terminates. There are two kinds of stations, viz., main stations and subsidiary or tie stations. Main stations are the principal corners of the main lines which command the boundaries of the survey. (Source: Forest Surveying by Ram Parkash). Subsidiary stations are established on the main survey lines in order to locate interior details when such details are far off the main lines. On the survey sheet stations are indicated by small circles. Main stations are denoted by capital letters and tie stations by small letters. In the following diagram, A, B, C and D are main stations, and p, q and r tie stations.

5. **Station Lines or Chain Lines** are those lines which connect station points. They are called **main or survey lines** when they join main stations, and they are referred to as subsidiary or tie lines when they join subsidiary stations. In the following diagram, AB, BC and CD are main or survey lines, and pq and Ar are subsidiary lines.

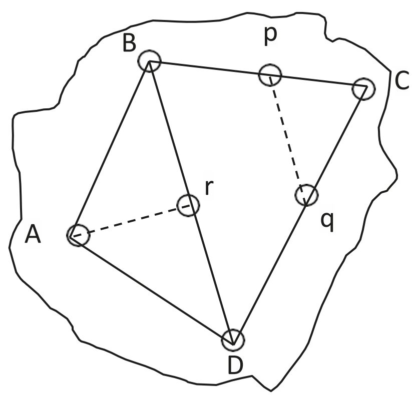


Fig. 8.2

6. **Base Line**: A base line is usually the longest and the most important of all chain lines, running through the centre and length of the area to be surveyed (Source: Forest Surveying by Ram Parkash). In the above diagram BD is the base line. The base line should be measured accurately and the measurement should be checked.
7. **Check or proof line:** In order to check the accuracy of measurements and plotting, check or proof lines are drawn on the sheet and their lengths on the plan are checked with the corresponding distances in the field. In ideal cases, the measured length of a check or proof line in the field should tally with the length scaled on the map. In the above diagram, suppose r is a fixed point on the ground, which is easily identifiable. Then the line Ar may serve as a check or proof line. Similarly, the line pq joining two fixed points on the ground may be a check or proof line.
8. **Tie line:** A tie line has dual function. When joining two fixed identifiable points on the ground, it may serve as check or proof line to check the accuracy of the frame- work. Again when it joins two subsidiary stations, chaining along this line will enable the surveyor to capture interior details which otherwise cannot be picked up from main survey lines.
9. **Offsets:** Offsets are lateral distances from the chain line of objects lying on either side of the chain line. Once the frame-work of triangles is established and measured, the surveyor moves along the chain lines and takes measurements of offsets which give location of the objects with reference to recorded points of chain line. Thus offsets enable the surveyor to locate the objects on plan.

9.1 Offset, that is lateral distances, is normally taken at right angles to chain line. Every offset involves two recordings. Firstly, the points (D, F) of the chain at which offset is taken are recorded, and secondly, the lengths (CD, EF) of the offset, that is, the perpendicular distances of the object from the chain are measured and recorded.

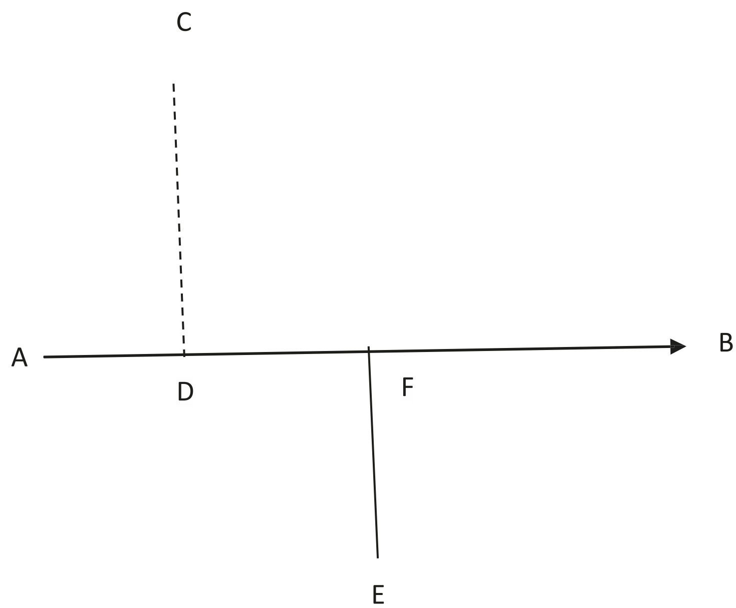


Fig.8.3

Please see the above diagram. Line AB shows the direction of chain line. C and E are two objects on the left and right side of the surveyor. Perpendiculars are dropped from C and E to meet the chain line at D and F respectively. Positions of D and F are noted. For example, their positions are 180 links (D) and 230 links(F). That means starting from the last station, their distances along the chain line are 180 links (36 m) and 230 links (46m) respectively. These readings uniquely determine the positions of D and F and they can be plotted on the sheet. Now the offsets CD and EF are measured, which are perpendicular distances of C and E from the chain line AB. Suppose these offsets are found to be 12 m (CD) and 8m (EF). These offsets are recorded. The surveyor then plots these points by taking perpendicular distances (12m and 8 m as per scale) from D and F which are already plotted.

10. To drop perpendicular on chain line from a point outside

It is clear from above that to measure offsets and plot the objects, it is necessary to locate the points D and F. These are the points where the perpendiculars drawn from the objects C and E meet the chain line. Thus to know the location of D and F, we need to know how to drop perpendiculars on to chain line from an external point. Please see the following diagram. AB is the chain line. C is an object. With C as centre, a circular arc

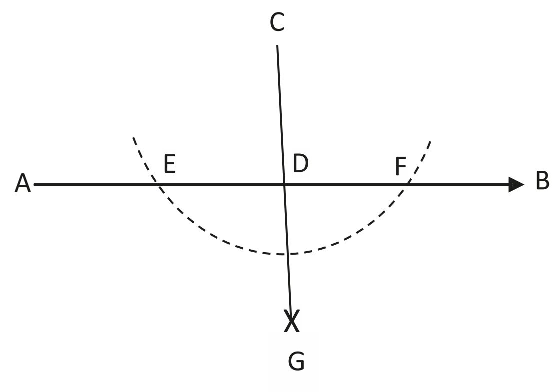


Fig.8.4

Is drawn which intersects AB at E and F. Now with centre at E and F, two circular arcs with same radius, being more than half of EF, are drawn, which meet each other at G. CG is joined to meet AB at D. Thus CD is the line perpendicular to AB and position of D is known.

11. **Swinging method to know foot of offset**

An easy method to locate the foot (D) of the perpendicular CD is by way of swinging the tape. The underlying principle of this method is that the shortest distance of a point (say C) from a line (say AB) is the perpendicular distance (CD), that is, length of the perpendicular dropped from the point C to line AB. In the field, one member of the survey party holds the zero end of the tape at C, and another member, carrying the tape, swings it slowly along the chain line. As he swings the tape, he notices the reading of the point at which the tape meets the chain. He can easily find the point D which is the point of minimum reading for the length of the offset.

12. **To erect a perpendicular to chain from a point on it**

The diagram below explains how to erect a perpendicular from a point on the chain. ABC is the chain line, and it is required to erect a perpendicular at B. With B as center a circular arc of any radius is drawn to intersect ABC at D and E. Thus D and E are equidistant from B. Now with D and E as centers, circular arcs with radius more than half of DE are drawn on both sides of the chain line. One pair of arcs intersect at F above the chain line, and the other pair intersect at F’ below the chain line. Join F and F’. BF and BF’ will be perpendiculars to line AC at B.

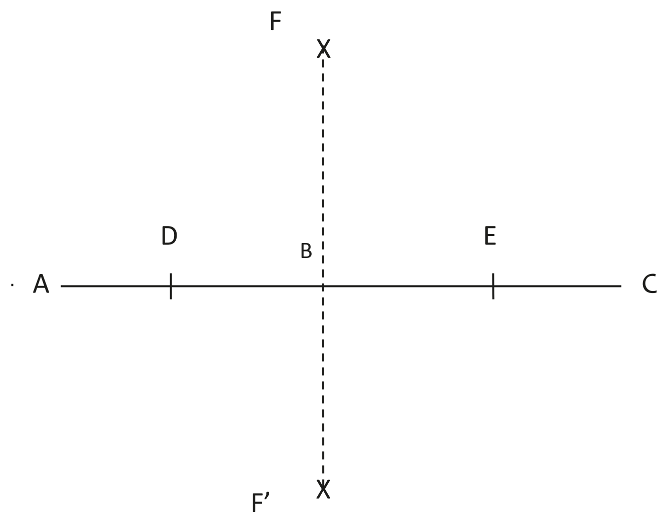


Fig.8.5

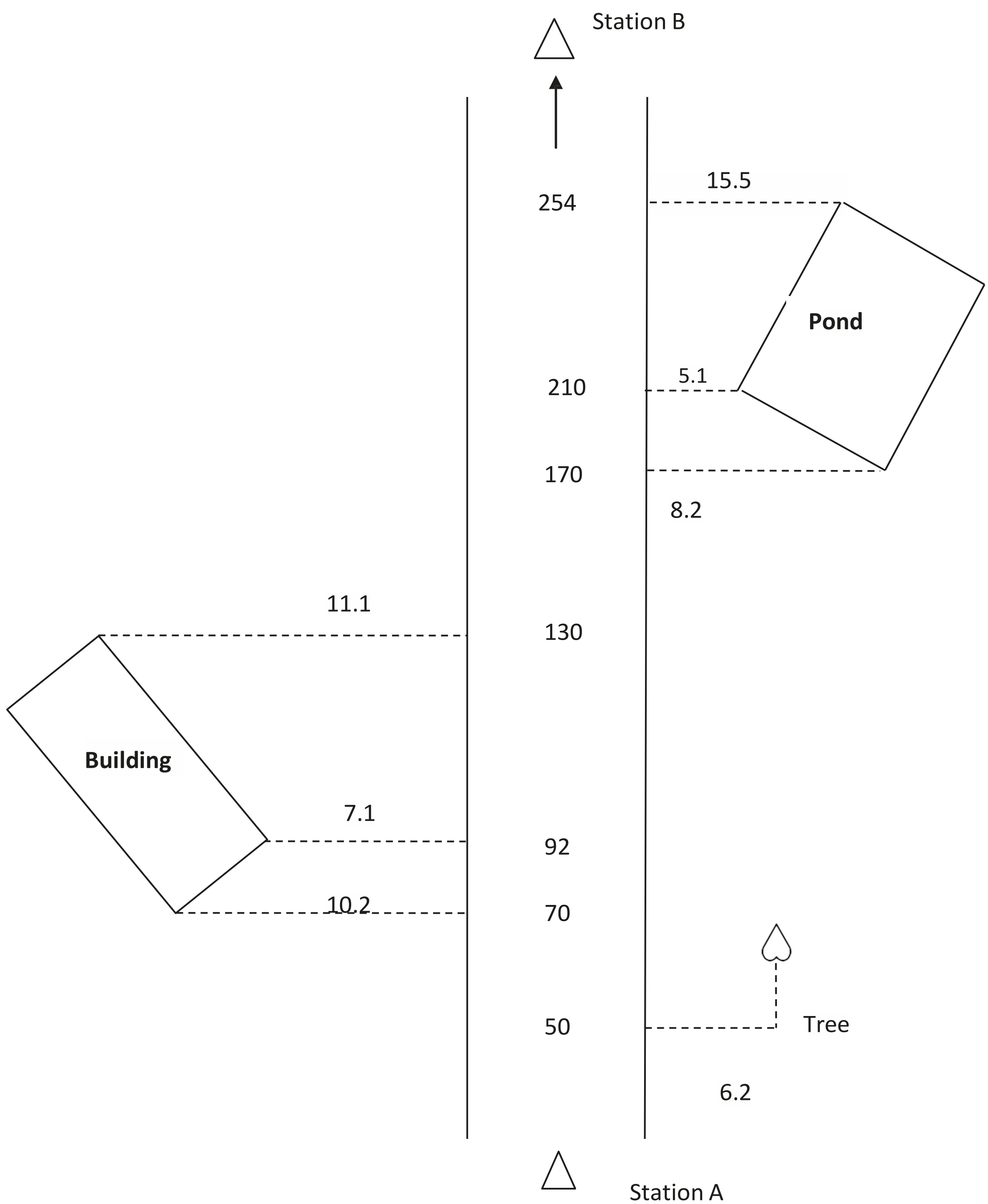
CHAIN SURVEY (CONTINUED)

LESSON 9 **1 hour**

Field Work of Chain Survey

1. **Procedure –** The procedure conssists of the following steps, namely, (1) Preliminary reconnaissance or recce, (2) Marking Stations, (3) Chaining and offsetting and (4) Field Book Recording.
2. **Preliminary reconnaissance or recce** – The purpose is to make and record a rough and approximate idea of (i) the area to be surveyed, and (ii) the physical features to be plotted, and mark survey stations.
   2.1 Steps to follow:
   - Walk through the entire area, and mark field boundaries and features to be plotted, e.g buildings, roads, hedge, trees, gate etc.
   - Select locations of survey stations in such a manner (a) that the stations are, as far as possible, inter- visible (can be tested by ranging rods), (b) that the survey lines face minimum obstacles, and (c) that the triangles formed by the survey lines are well conditioned, that is their angles are neither very acute nor very obtuse.
   - Draw a rough sketch on the first page of the field book indicating the area and its details that you have noted during recce. Indicate the survey stations by capital letters like A, B, C etc. , survey lines by numbers 1, 2, 3 etc. and the direction in which each line is to be chained.
3. **Marking Stations** – Locations of the stations are selected during recce. Now mark those stations on the ground by wooden pegs or in case of hard ground by nails or spikes. To be certain of their locations, the distances of the stations from two or three permanent identifiable points on the ground, located nearby, may be measured and recorded.
4. **Chaining and Offsetting** – After marking the stations, start the chaining operation, preferably from base line, in a prefixed direction, moving counter clockwise or clockwise. As you move from one station to the next, you make note of offset measurements of objects that lie within reasonable distances (preferably within 15 to 20 metres) on both sides of the chain, and the corresponding chainages, that is, points along the chain at which offset measurements are taken. Record the chainage and offsets of objects along with sketches of objects in the field book. Normally, the chainage is measured and recorded in links (which gives distance of the point in links from the beginning of chain line) and offset measured and recorded in metres. Continue chaining and offsetting till the end of chain line. Repeat the same procedure for each chain line.
5. **Field Book Recording –** Field book is a special kind of note book where measurement of chainage and offset is recorded. It is about 20cm x 10 cm in size and opens length wise. The pages are machine numbered and two faces from bottom to top are treated as one page. The pages are blank except that two parallel lines about 1.5cm apart run centrally along the length. These lines represent the chain line. Record the distances along the chain, that is, the chainages in the space between the parallel lines. Record the offsets

opposite the points of chainage on the right or left depending on whether objects come on the right or left and make indicative sketches of the objects. Please see the diagram below.



Chaining along AB from Station A to Station B.
Chainage is in Links and offsets in metres.
Fig 9.1

5.1 Please note the following in the above diagram.

- Fixing zero of a tape at the object points, the corresponding chainage points – feet of perpendiculars from the objects – may be determined by swinging of tape and finding the points of minimum reading.
- For the object tree on the right, chainage is 50 links, and offset is 6.2 metres.
- For the object building on the left, rectangular in shape, offsets of three corner points are necessary to plot the object. The chainages and the offsets are (70 links, 10.2 metres), (92 links, 7.1 metres) and (130 links, 11.1 metres).
- Similarly for the pond on the right, offsets of three corner points are necessary.

5.2 Please note the following norms for field book recording

- Make a table of contents on the first page, giving page reference of chain lines
- Draw in the next page a rough sketch of the area after recce.
- Each survey line commences from a station and start recording from the bottom of a page.
- The main stations may be indicated by symbols like Δ A, Δ B etc, the tie stations by circles O X , O Y etc. The chainage figures of the stations should be indicated beside their symbols.
- The name and /or number of survey lines should be indicated.
- Each survey line starts on a new page, and it may continue over pages.
- The chainage figure in links starts from zero at the beginning of each survey line and increases progressively along the chain line over pages till the survey line ends.
- Entries made in pencil during field works are inked at the end of day's work.

6. **Obstacles in Chaining –** When one is faced with obstacles that obstruct chaining or ranging along survey lines, methods based on simple geometry or trigonometry are adopted to measure distance along those obstacles. Some such cases are described below.

6.1 Intervening Hills or elevated ground – chaining free but vision or ranging obstructed

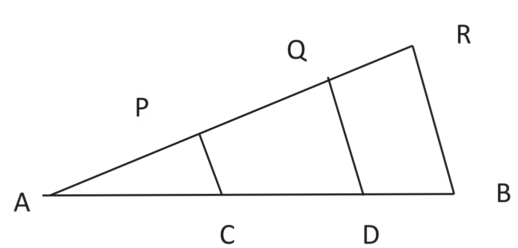


Fig.9.2

- AB is the chain line, chaining is possible but station A and B are not inter-visible.
- Take a line AR as close as possible to AB so that B is visible from R.
- Drop perpendicular BR from B to the line AR so that ∠ARB is right angle.
- To find the distance AB, apply Pythagoras Theorem : AB= $\sqrt{AR^2 + RB^2}$
- Intermediate stations C and D, if necessary, may be located by applying the property of similar triangles as follows.

  PC = RB.($\frac{AP}{AR}$) and QD = RB.($\frac{AQ}{AR}$)

  Lay out perpendiculars PC and QD at P and Q respectively and measure off lengths PC and QD as obtained from the above relations. C and D so determined will be intermediate stations along the survey line AB.

6.2 A stream or a canal – chaining obstructed but ranging free.

Please see the figure below.

- The survey line AB is obstructed by the canal.
- The point C is ranged in line with AB on the other side of the canal.

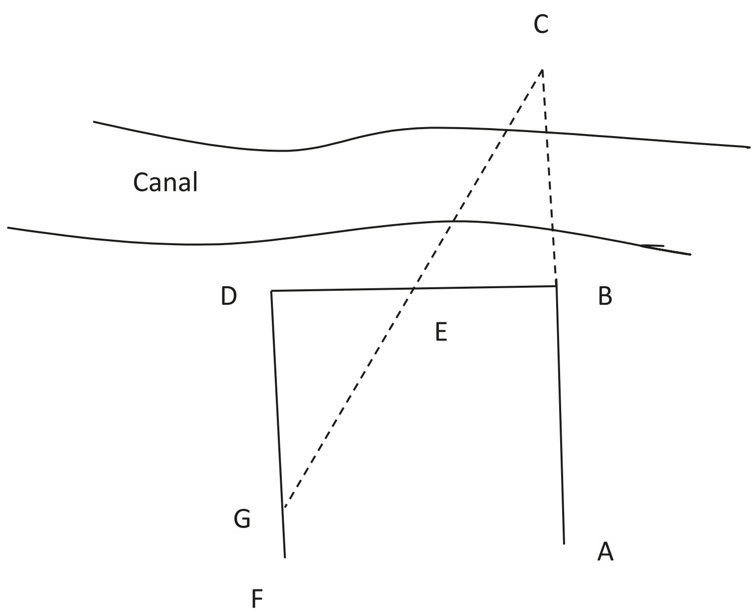


Fig. 9.3

- The task is to know the distance BC and continue chaining along ABC.
- Lay out a perpendicular BD at B on AB.
- Bisect BD at E
- Fix ranging rods at C and E
- Lay out perpendicular DF at D on BD.
- Your friend may move along DF with a ranging rod and locate the point G so that G, E and C are ranged in a line.
- Since ∆s EDG and EBC are congruent, that is, equal in all respects, BC = DG.

6.3 A building – both chaining and ranging are obstructed.

Please see the figure below.

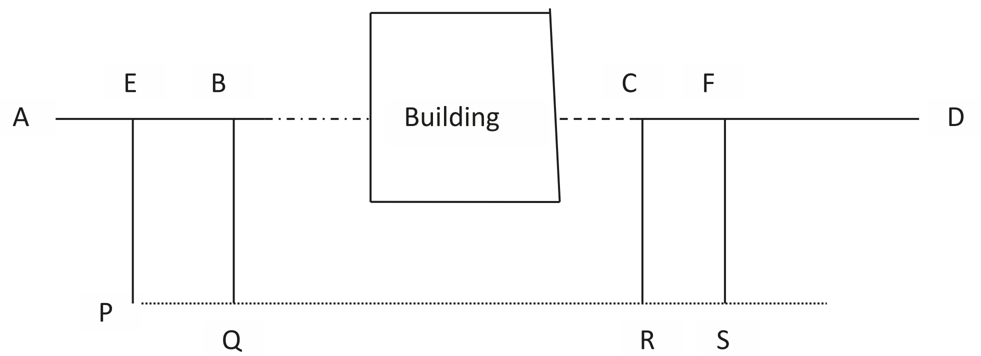


Fig.9.4

- **The survey line AB is obstructed by the building.**
- **Choose two points E and B about a chain apart and lay out perpendiculars EP and BQ at E and B on the line AB**
- **Measure off equal lengths EP and BQ so that P and Q stay clear off the obstacle (building).**
- **Range a line PQRS so that RS remains clear of the building.**
- **Drop perpendiculars RC and SF on the line CD.**
- **Please note that EP = BQ = CR = FS.**
- **Range the line CFD, which will be continuation of the original survey line AB.**

CHAIN SURVEY (CONTINUED)

Lesson 10 **1 hour**

Plotting

1. The end product of survey is the drawing sheet which should correctly present the ground situations of the area that has been surveyed. From the survey sheet one should know the boundaries of the area, distances of any two points on the ground, locations and orientation of important features on the ground, areas of selected plots and many other information. These will be possible only when field data are correctly plotted on the drawing sheet.

2. Drawing Materials required are Drawing paper, Drawing pins & clamps, Pencils, Rubber or Eraser, Ink, Colours and brushes.

3. Drawing Instruments required are

a) Drawing table to support the drawing board at a suitable height.
b) Drawing Board to lay drawing paper.
c) Set squares – one pair of 45^0 and 60^0 for drawing parallel and perpendicular lines.
d) Tee(T)-square for drawing lines parallel to length of the board and support set squares.
e) Protractor. – semi circular or circular to draw chosen angles.
f) Instrument Box containing divider and compass. With divider one can measure off and mark any chosen length. The compass with pencil or pen point can draw circles or arcs of circle.
g) Set of French Curves for drawing irregular and curved figures.
h) Set of scales – 30 cm long graduated to read lengths on varying scales like 1cm = 1 m or 2m, or 3m etc. Each scale has its corresponding offset scale (5 cm long) graduated exactly in the same way as the long scale.
i) Beam compass for drawing arcs of large radius.

4. Plotting chain lines-

- Draw a border line on the sheet leaving a margin of 2 -3 cm on all sides.
- Choose a scale of drawing so that survey plan and its features are accommodated well on the sheet.
- First draw the base line being the longest on the chosen scale. Placement of the baseline should be so chosen that the final framework of triangles is well balanced and centred on the sheet.
- As far as possible, try to make north of the plan towards the top direction.

- On this base line the triangles are drawn with the help of compass or beam compass. Check the accuracy of triangles by tie or proof lines. Chain lines are thus plotted. Number the lines.
- Mark the station points on the chain lines, name and/ or number them.

5. Plotting offsets- After plotting the frame- work and checking its accuracy, the offsets are plotted. There are two methods of plotting the offsets.

(1) With an ordinary scale

- Mark chainages of points at which offsets were taken on the chain line, draw perpendiculars at these points and scale off lengths of the offsets.

(2) With an offset scale, which is a quick and convenient method.

- Place the long or the plotting scale of the ratio (or scale) chosen along the chain line with its zero coinciding with the beginning of the line.
- Hold the plotting scale in that position by placing weights on two ends.
- Hold the offset scale (of the corresponding ratio, as of plotting scale) at right angle to the plotting scale and move along to the required chainages, and, at each chainage, read the offset length on the offset scale to locate the object. Mark the objects at the required chainages.

6. Inking in

- After filling in and checking all the details, ink in the pencil work of the plan.
- Station lines, check and tie lines may be inked in thin light red lines, or with dot-and-dash in black.

7. Colouring

- Before colouring, clean the drawing sheet thoroughly with a soft rubber.
- Use light colours;

8. Scale-

- Indicate the Scale of drawing on the sheet.

9. Title or Heading

- A title or heading, suitably worded, is written with letters distinct and well spaced and is normally placed at the centre.

10. North Point

- Indicate on the top of the sheet the direction of north.

11. Table of references or Legend

- Provide a table at the left or right hand bottom of the sheet showing symbol and colours used to indicate the various features on the plan.

Traverse Survey with Chain

12. The most common method of chain survey is by triangulation, which has been described earlier. The other method is by traversing.

13. Traverse – A series of straight lines joining a series of established points (stations) is described as a traverse. A survey may be closed or open depending on where the traverse ends. A closed traverse is one which ends at the point it has started from – it is a closed polygon. An open traverse does not return to the beginning station – it is an open figure.

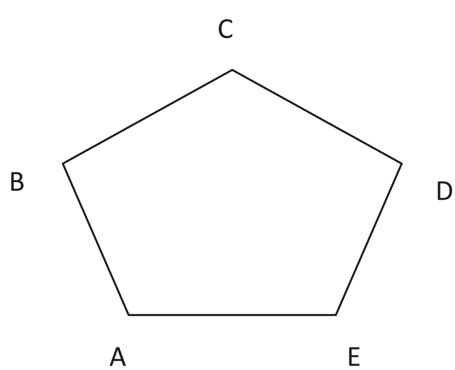


Fig.10.1 Closed Traverse

(Closed Traverse AB→BC →CD→DE→EA; traverse reaches back the starting point A)

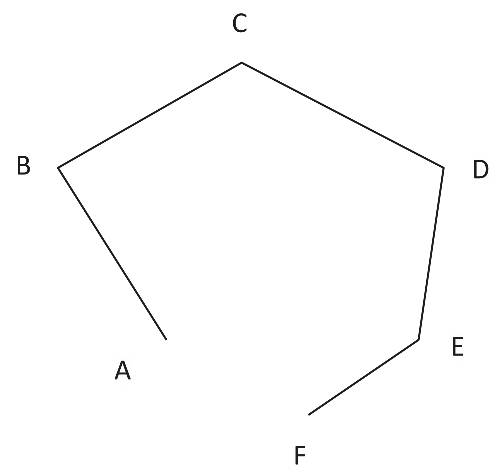


Fig.10.2 Open Traverse

(Open Traverse AB→BC→CD→DE→EF; traverse does not come back to starting point A)

Traverse by Chain Angles

14. When you need to survey a pond or a wooded land, that is, lay chain lines around the boundary of such pond or wooded land, triangulation is obviously not possible. Ranging of lines in such cases is normally done by an angle measuring instrument. But if you are left with only chain and accessories and no angle measuring instrument, survey lines could still be laid by chain angles. Angles between adjacent survey lines (thereby orientation of chain lines) are fixed by measurement of tie lines between the survey lines. The angles so determined by linear measurement are called chain angles.

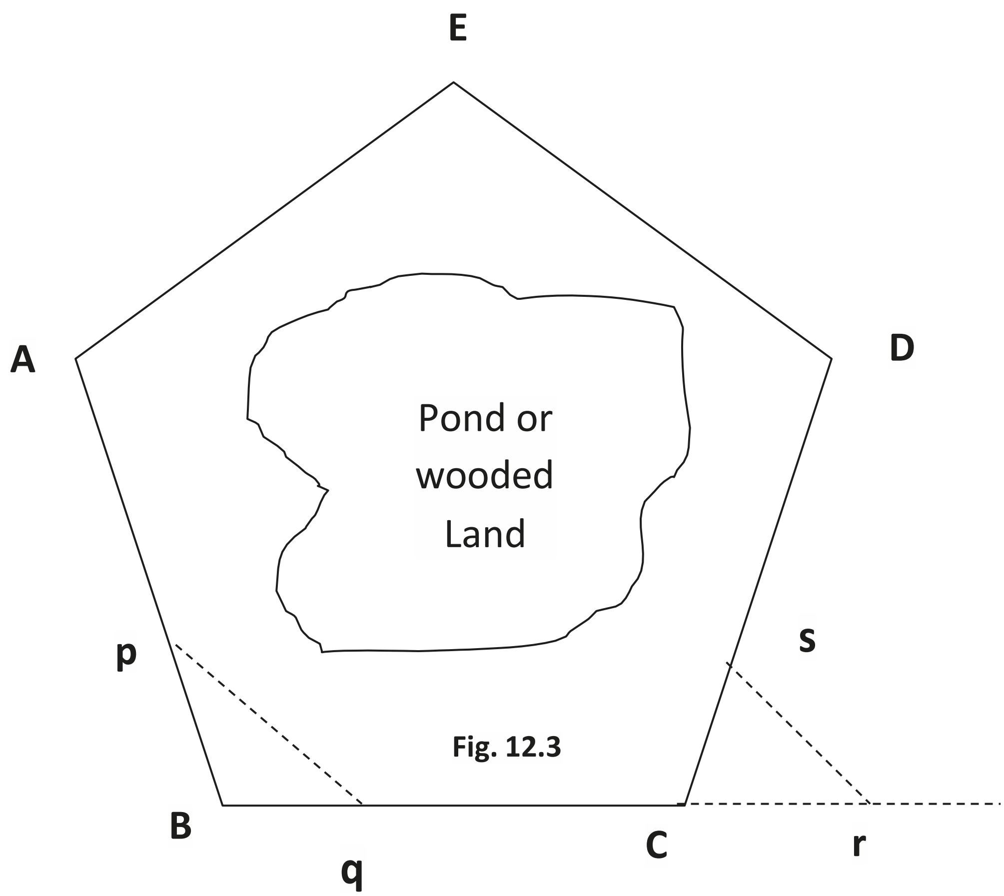


Fig.10.3

15. Please see the diagram above. After laying and measuring the line AB, the surveyor is faced with the problem of fixing line BC. He can lay and measure BC on ground, but in absence of knowledge about angle ABC or angle B, he cannot orient the line BC on drawing plan.

16. In order to know the direction of BC,

- Identify and mark two suitable points p and q on the ground on line AB and BC respectively.
- Measure Bp. Bq and the tie line pq.
- Once you know the measurements Bp, Bq and pq, the triangle Bpq is uniquely defined and fixed. As a result the direction Bq or BC is fixed.

Similarly to fix the angle C or direction of CD,

- Identify suitable points r (on extension of BC) and s (on CD).
- Measure Cr, Cs and the tie line rs. These measurements will fix the triangle Crs and thus the direction of CD.

Proceed in this manner to fix DE and EA.

17. Please note that in the example given above since triangulation comprising with the survey lines is not possible, therefore small triangles are formed at the corners (stations) with tie lines.

CHAIN SURVEY

Lesson 11 **3 hours**

Practical class on chain survey –

Demonstration and application of Chain Survey procedures as described in Lesson 8, 9 and 10.

ANGLES AND BEARINGS

Lesson 12 **1 hour**

Why measurement of angles or bearings is necessary –

1. In order to plot a survey line we need to know magnitude of its length as well as direction. While magnitude of length is determined by linear measurement of the line in the field with the help of chain or tape, direction is known by measuring included angles between adjacent survey lines or by measuring the bearing of the line - the angle the line makes with a fixed line of reference called meridian.

Meridians

2. Three meridians are in use and they are defined differently. **True or Geographical Meridian (GM)** at a point is the line in which earth's surface is intersected by a plane through geographical north/south poles and the given point. Thus true or geographical meridian (GM) at a point indicates the true or geographic N-S direction at that point. GM can also be defined as a great circle terminated by geographical north and south poles and passing through the zenith of the observer. Similarly, **Magnetic Meridian (MM)** is the great circle passing through magnetic north and south poles and the zenith of the observer. It can be taken as earth's magnetic force lines along the surface of the earth. Therefore a free compass needle at a point will align itself parallel to the magnetic meridian passing through that point.

2.1 Since geographical and magnetic poles are not identical, the GM and MM are not same at a point. The angle between the magnetic and true meridian is the magnetic **declination at** a point.

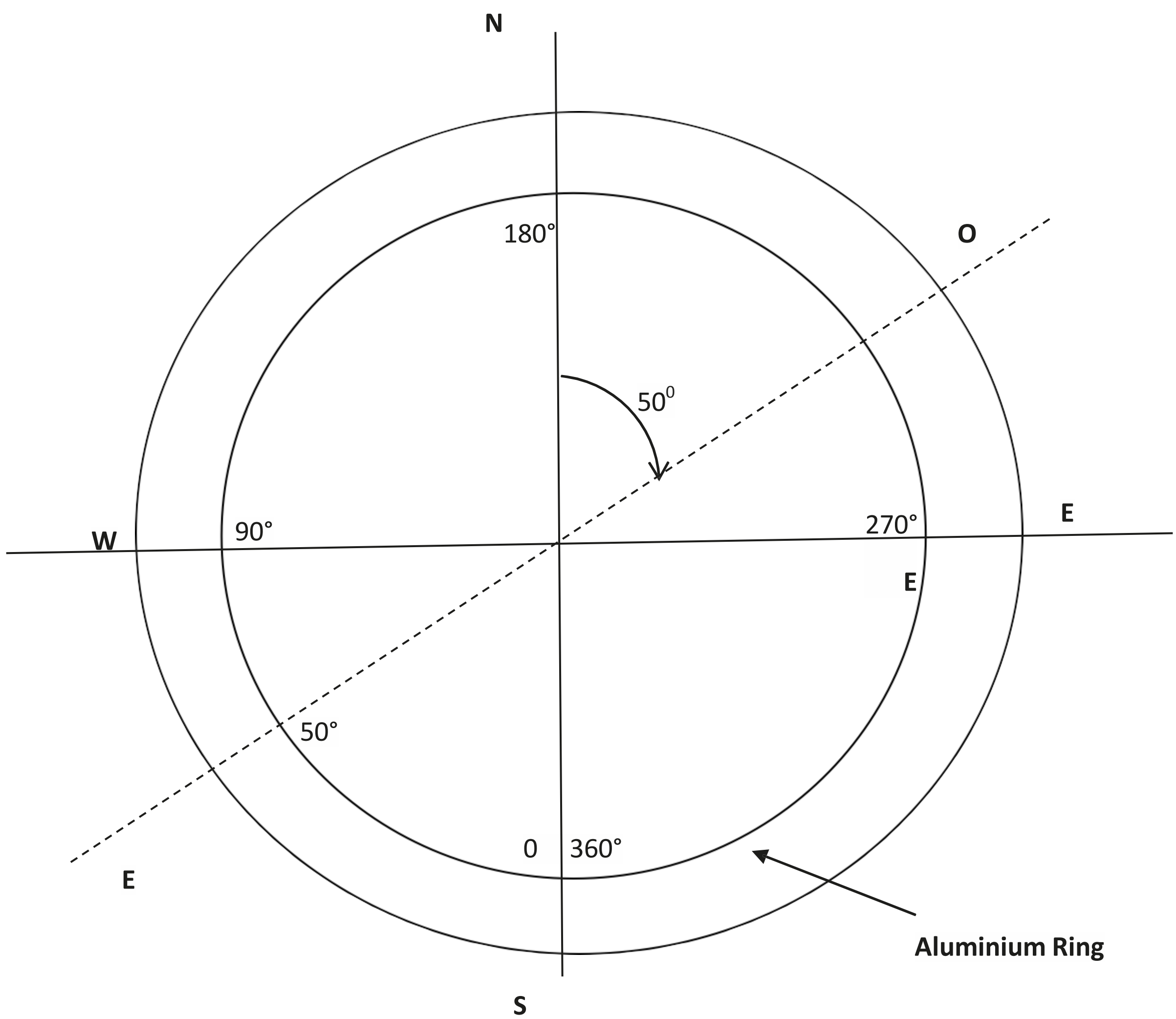
2.2 For the purpose of measurement of bearing, some convenient or arbitrary direction may be taken as the line of reference, which is then called **Arbitrary or Assumed Meridian.**

Instruments

3. Box sextant – Theodolite – These instruments are used to measure the included angles between adjacent survey lines.

4. Prismatic Compass – An instrument common in forest survey, prismatic compass is used to measure the bearing of a survey line. It is a circular box (diameter 8-18 cm and depth about 1.5 cm) with a steel pointed pivot at the centre. Upon the pivot rests an agate cap that supports a magnetic needle. The needle is attached with an aluminum ring (diameter 6-15cm). The ring is graduated in degrees increasing in the clockwise direction with $0/360^0$ coinciding with south. Please see the Fig.12.1.

4.1 The prismatic compass is provided with two vanes – object vane or sight vane and eye-vane or eyepiece, fixed on to compass box at diametrically opposite ends. The object vane has a vertical fine wire which is made to coincide with an object when sighting the said object. The eyepiece carries a right angled prism which can move up and down and can be focused on aluminium ring. The prism reflects the ring calibration producing a vertical image of the ring graduations in which the position of the vertical wire (object) can be read.



Reading in a Prismatic Compass
Fig.12.1

4.2 Working Principle

- The prismatic compass is mounted on a tripod stand and centred vertically over the observation station.
- The instrument is then leveled, that is, made horizontal by rolling a round pencil.
- The needle being free to rotate on the pivot will orient itself in the magnetic meridian. Therefore the north and south ends of the ring attached to the needle will be in N-S direction.
- The prism is focused to read the graduations of the circular ring.
- The line of sight is defined by the objective vane and the eye slit, both attached to the compass box.
- When an object is sighted, the sight vanes will rotate with respect to the N-S end of ring through an angle which the line makes with the magnetic meridian. In the Fig.12.1, the line of sight OE is shown to make an angle 50 degree with magnetic meridian NS. Thus the bearing of line OE is 50 degree.

- The bearing is directly read from the ring in the quadrant opposite to that of the object. In the fig. above the object O is in NE quadrant. Reading of bearing 50 degree (that is of the angle OE makes with NS) is taken in the opposite quadrant SW. It may be noted that the aluminium ring is so graduated that the bearing of line of sight can be directly read in the quadrant diametrically opposite to that of the object.

4.3 Testing of the compass – Please check the following to ascertain if the compass has instrumental errors.

1) Sluggishness of the needle – When a magnetic needle does not orient itself quickly along magnetic meridian, it is called sluggish. Sluggishness can be tested easily. After you take a bearing, bring a magnetic object near the needle for a moment to disturb its position. After you withdraw the magnetic object, see if the needle settles back to the same reading. Sluggishness is more often due to dullness of the pivot. The pivot point should be sharpened if sluggishness is detected.
2) Straightness of needle and position of pivot – The needle should be straight and the pivot should be at the centre. Whether these conditions are satisfied can be tested easily. See the readings of the two ends of the needle. They should differ by 180 degree ideally.
3) Line of sight with respect to pivot – Line of sight should pass over the pivot. This can be tested by stretching a thread through middle of the slits and checking if the thread passes over pivot.
4) Sights to be vertical and diametrically opposite to each other – To test this, level the instrument and suspend a plumb bob at a distance. Ideally, the plumb line, object vane hair and the eye vane should be in the same line and parallel.
5) Needle to be horizontal when the compass is leveled.
6) Magnetic strength of the needle – The needle should be re-magnetised, if it shows sluggishness due to loss of magnetism.

4.4 Errors in working with Prismatic Compass –

While working with prismatic compass one should be careful of the following likely errors.

1) Instrumental errors - These have been explained in the previous paragraph.
2) Personal errors - They may be due to the following reasons:
   - Inaccurate leveling of the compass box.
   - Inaccurate centering.
   - Inaccurate intersection of objects or ranging rods.
   - Carelessness in reading and recording.
3) Errors due to external influences - They may be due to following reasons:
   - Variation in declination
   - Local attraction due to proximity of local attraction forces.
   - Magnetic changes in the atmosphere due to clouds and storms.
   - Irregular variations due to magnetic storms etc.

4.5 Precautions - Following precautions may be taken in the use of prismatic compass.

1) Set up and level the instrument properly
2) Tap the box after the needle comes to rest to make sure that the needle is capable of rotating freely without hindrance.

3) Take both fore and back bearings of important lines
4) Magnetic objects like keys, knife, arrows etc. should be kept away from the compass.
5) The needle may be lifted off from the pivot, when not in use, by folding down the sight vanes.
6) Eliminate or minimize the instrumental and personal errors.

5. Bearings

Bearing of a line – the angle the line makes with a fixed line of reference called meridian – will be called true or magnetic or arbitrary according as the line of reference taken is geographical meridian, magnetic meridian or an arbitrary meridian.

5.1 As magnetic declination is the angle between magnetic north and true north, the difference between magnetic and true bearing will also be equal to the magnetic declination. Please see Fig. 12.2 and 12.3 below.

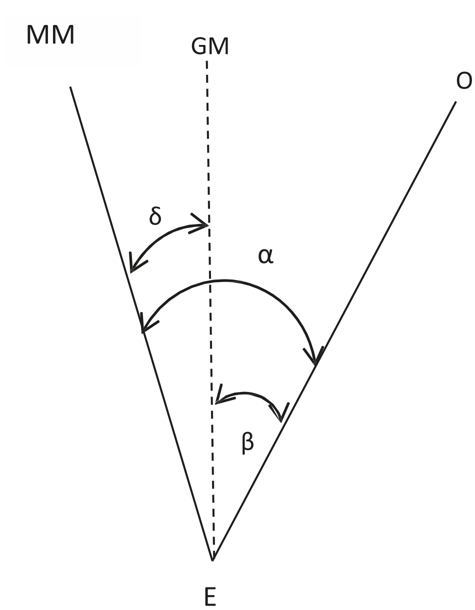


Fig. 12.2

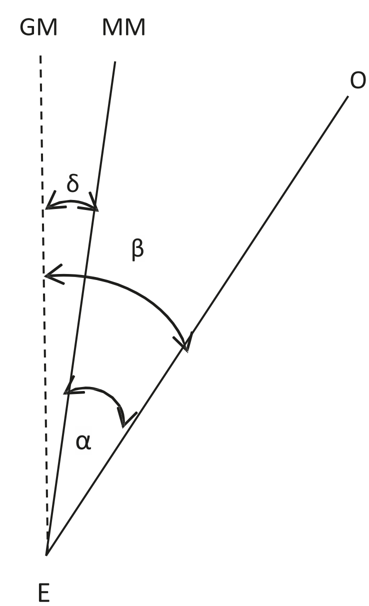


Fig.12.3

True and Magnetic Bearing

M.M= Magnetic Merridian

G.M=Geographical or True Merridian

δ = Declination, α = Magnetic Bearing, β = True Bearing

In Fig. 12.2, declination = δ^0 west, and $\beta = \alpha - \delta$,

In Fig.12.3, declination = δ^0 east, and $\beta = \alpha + \delta$

5.2 Whole Circle Bearing (WCB) and Quadrantal Bearing (QB) or Reduced Bearing (R.B)

To express bearing of a line, two systems are commonly used.

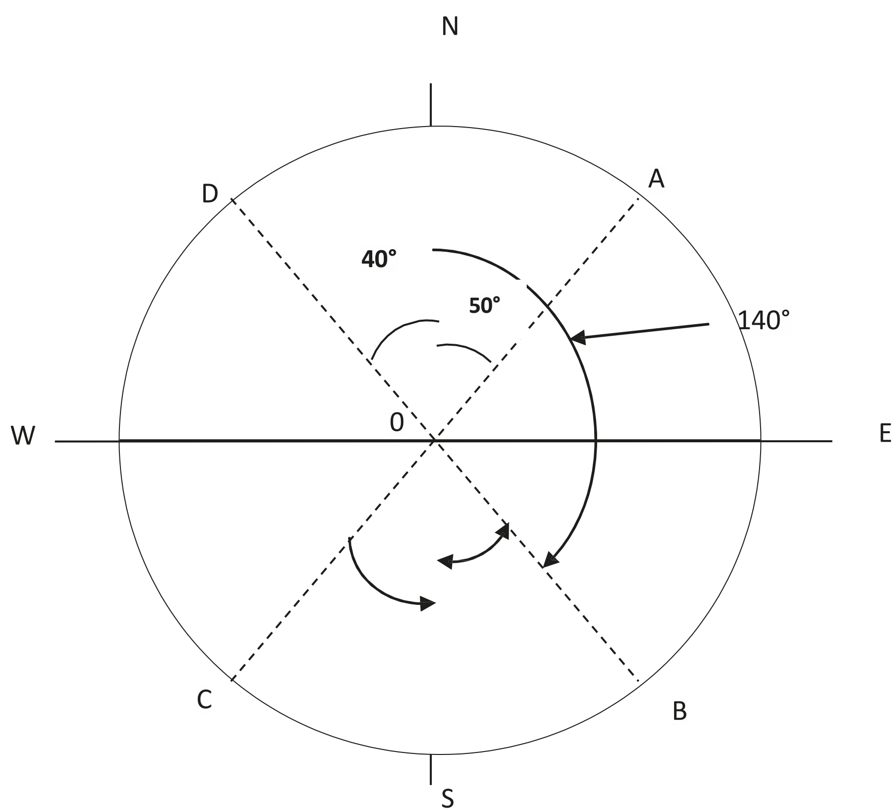
- **WHOLE CIRCLE BEARING (WCB):**

  In this system the bearing of a line is measured with the magnetic or true north in clockwise direction. The value of bearing thus varies from 0^o to_360^o. Prismatic compass gives readings of WCB**.**

- **QUADRANTAL BEARING (QB) OR REDUCED BEARING (R.B)**

  In this system the bearing of a line is measured eastward or westward from north or south whichever is nearer. The directions can be either clock wise or anti clockwise depending upon the position of the line.

5.2.1 Please see the Fig.12.4 where the two systems of bearing and their relations have been illustrated.



Line OA- WCB=50°; RB=N 50°E; Line OB- WCB=140°; RB=S 40°E

Line OC- WCB=230°; RB=S 50°W; Line OD- WCB=320°; RB=N 40°W

Fig.12.4

5.2.2 Relation between WCB and RB

The relations between WCB and RB may be seen from the following table.

Quadrant	WCB between	RB
NE	0^0 and 90^0	= WCB
SE	90^0 and 180^0	= 180^0 -WCB
SW	180^0 and 270^0	= WCB -180^0
NW	270^0 and 360^0	= 360^0 - WCB

5.3 Fore and Back Bearings

- Every line has two bearings one observed at each end of the line.
- The bearing of the line in the direction of progress of the survey is called Fore Bearing (FB), while the bearing in the opposite direction is called Back Bearing (BB).
- Therefore BB of a line differs from FB by exactly 180^o.

Please see the Fig.12.5 1nd 12.6 where fore and back bearings have been illustrated.

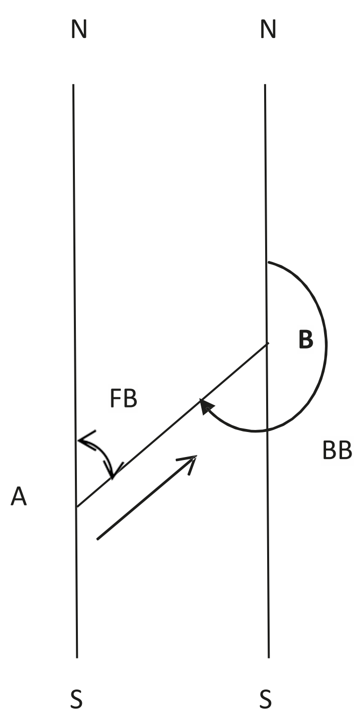


Fig.12.5

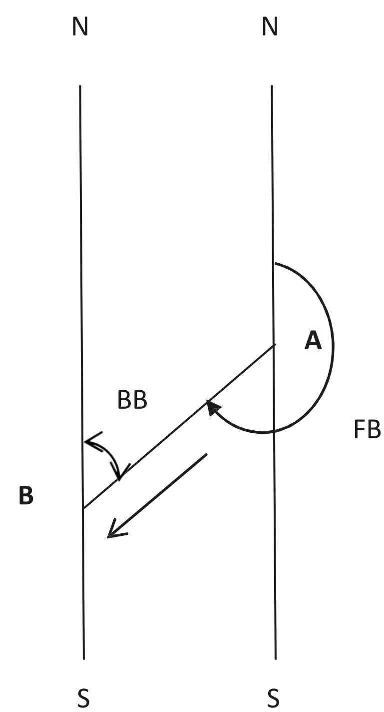


Fig.12.6

BB = FB±180°

5.3.1 The bearing of the line AB taken at A to B (Fig.12.5) and bearing from B to A are fore bearing and back bearing of the line AB. It is obvious from the diagram that in this case (where FB is less than 180^0) BB = FB + 180^0

5.3.2 if the location of A and B were as shown in Fig. 12.6, and the progress of survey is from A to B, the FB and BB of line AB would have been as shown in Fig.12.6. In this case FB is more than 180^0, and BB = FB – 180^0.

6 Local Attraction – Working of prismatic compass is based on the premise that earth's magnetic field is the only magnetic force that is acting on the magnetic needle of the instrument. Presence of any other magnetic field acting on the needle of compass will vitiate the above condition and will produce a disturbing influence known as local attraction. Presence of magnetic objects like keys, pen-knife, watch chains (which a surveyor may inadvertently carry), or iron fence, lamp post, rails, telegraph wires in the vicinity or axe, arrows lying close, will produce such local attraction. Obviously, readings of the compass needle under the influence of local attraction will be faulty.

6.1 Detection of Local Attraction –

- Take fore and back bearing of a line AB on ground. A and B are the two end stations of line AB.
- Ensure there is no personal or instrumental error, and check the readings a number of times.
- If you find the difference of fore bearing and back bearing differs from 180 degree by more than 15 minute (least count of the compass), and such difference continues to remain even on repeated observations, then existence of local attraction at A or B or at both the stations is confirmed.

6.2 Correction of error due to Local Attraction -

1) **When the difference between fore and back bearing of a line is nearly 180^0**
   - Take the mean of the observed and calculated bearings.
     (Example: Observed FB = 85^0 15'. observed BB = 265^0 25'.
     Given the said BB, calculated FB = 265^0 25' - 180^0 = 85^0 25'
   - Therefore, corrected FB = mean of observed and calculated FB
     = (85^0 15' + 85^0 25')/2 = 85^0 20', and corrected BB = 265^0 20';
     (Source: Forest Surveying by Ram Parkash)

2) **Correction with reference to unaffected line**
   - This is the most common method where the line with unaffected bearing (meaning line for which FB-BB = 180^0) is identified.
   - It is presumed that the end points of an unaffected line are free from local attraction.

- Considering bearings taken from the end points of unaffected line as correct bearings, other bearings are corrected. This is illustrated below.

Line	Observed Bearings		Correction	Corrected Bearings		Remarks
	F.B	B.B		F.B	B.B	
AB	89^0 30'	271^0 30'	+2^0 10' at B; +4^0 10' at A	93^0 40'	273^0 40'	Station A and B affected
BC	110^0 20'	290^0 30	+2^0 0' at C; +2^0 10' at B	112^0 30'	292^0 30'	Station B and C affected
CD	188^0 30	8^0 15	+2^0 15' at D; +2^0 0' at C	190^0 30'	10^0 30'	Station C and D affected
DE	91^0 15	273^0 30	+2^0 15' at D	93^0 30	273^0 30	Station D affected
EF	95^0 15	275^0 15		95^0 15	275^0 15	Station E and F unaffected

(Source: Forest Surveying by Ram Parkash)

Please note that

- For EF, BB – FB = 180^0; therefore stations E and F are unaffected, meaning thereby bearings taken at E and F may be taken as correct.
- So, observed BB of DE (bearing observed at E) is correct. Now work backward. Therefore FB of DE should be BB – 180^0 = 93^0 30'.
- The above reasoning indicates correction to be applied to bearings observed at D = corrected FB (of DE) – observed FB (of DE) = 93^0 30' – 91^0 15'= 2^0 15'.
- Apply the correction 2^0 15' to BB of CD, find the corrected FB of CD, get the correction of 2^0 0' to be applied at C as the difference of corrected FB (of CD) and observed FB (of CD).

Thus you can work backward and find the corrections to be applied to bearings observed at stations B and A as illustrated in the table above.

PRISMATIC COMPASS AND CHAIN SURVEY

Lesson 13 **1 hour**

Traversing with prismatic Compass and chain

1. Traversing is the method of survey where position of each survey station of a series is fixed by the distance from the previous station and the angle which the last line chained makes with the previous line. In the prismatic compass and chain survey, the distance between stations or magnitude of survey lines is measured by chain and the direction of survey lines (that is, angles between successive chain lines) is determined by taking magnetic bearings at each corner with the help of prismatic compass.

Comparison with Chain Survey

2. In compass and chain survey, chaining of survey lines and locating objects by offsets are done in the same manner as chain survey. The difference lies in the fact that while in chain survey direction of survey lines is fixed by triangulation, the same job in compass and chain survey is done by taking bearings (that is measurement of angles) of the survey lines with prismatic survey.

2.1 While chain survey is suitable for small areas, compass and chain survey is useful where large areas are involved and chaining becomes difficult.

Instruments Required

3. The various instruments used in the compass survey are :

- Prismatic compass
- Chain
- Tape
- Ranging rods-flags
- Tripod
- Pegs
- Arrows

Procedure

4. In order to carry out traverse of a plot with the help of prismatic compass and chain, follow the steps mentioned below. Let us suppose the traverse is a polygon ABCDA and AB is the starting survey line, A being the starting station (please see the Fig.13.1).

- Fix pegs and flags at the stations.
- Centre the compass vertically over the station point A. This may be tested by dropping a stone from underneath the compass and ensuring that it drops on the peg.

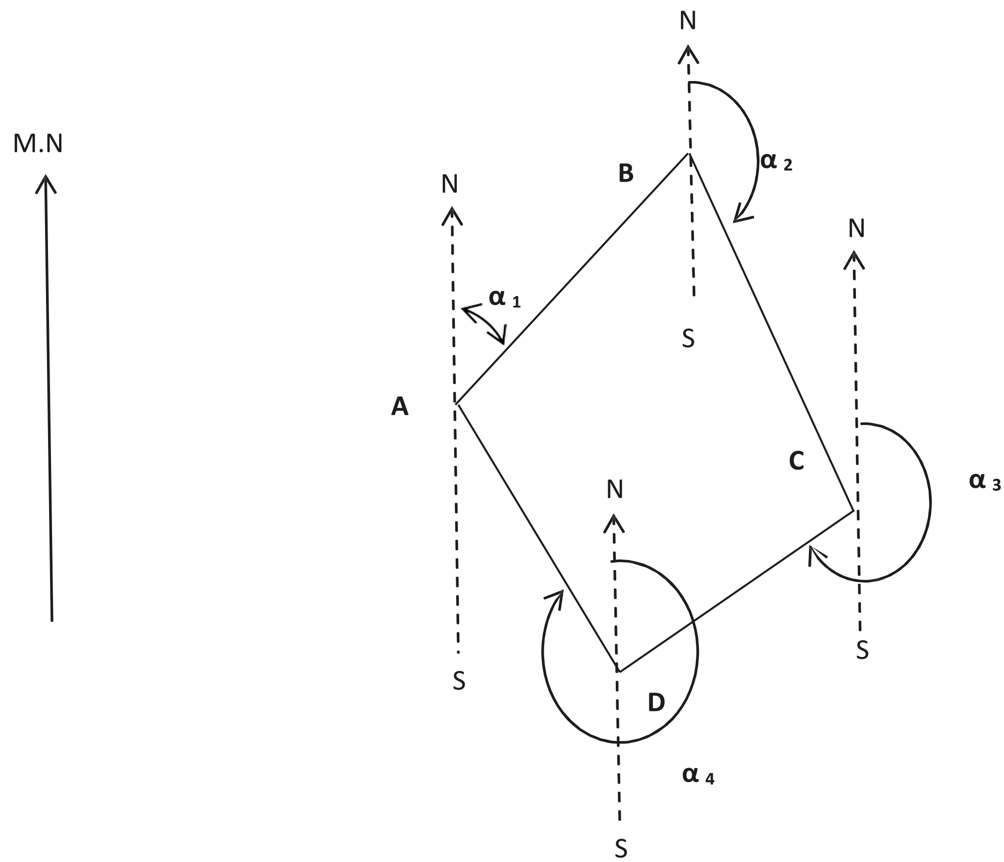


Fig. 13.1

- By means of ball and socket arrangement of the stand, level the Compass so that the graduated ring swings quite freely. It may be tested by rolling a round pencil on the compass box.
- Move the prism attachment up or down till graduations of the ring are in sharp focus.
- Turn the compass box until the ranging rod at the station B is bisected by hair when looked through the slit in eye-vane and the vertical hair in the sight vane. Note the reading which the hair line appears to cut on the graduated ring, and thus obtain fore bearing (FB) to station B. Similarly, obtain back bearing (BB) to station D.
- Chain the survey line AB and take offsets on both sides.
- Record the bearings, chainage and offsets in the field book.
- Now placing the compass at station B, take FB to station C and BB to station A, carry out chaining and offsets along BC.
- Repeat the steps until you end the traverse.
- During the process, take bearings of conspicuous objects from stations or known points on the chain line. Bearings of an object from two known stations will enable you to locate the object.

5. Why FB and BB are both measured

- BB provides a check on the accuracy of observation of FB. (Remember their difference should be 180 degree)
- Permissible error of reading is 15 minute. When the difference between FB and BB exceeds or falls short of 180 degree by more than 15 minute, then bearings to be taken afresh.
- If the error persists at a level more than the permissible error, there could be reasons to believe that the compass needle is being affected by local attraction (disturbing influence of magnetic objects).

Plotting Compass Traverse Survey

6. There are a number of methods for plotting compass traverse. One of the common methods is described below.

6.1 By parallel meridians

- Draw magnetic meridian NS at the top of the sheet. If magnetic declination is known, draw geographical or true meridian also.
- Decide a suitable position for station A on the paper so that the traverse and the plan get placed centrally.
- Draw a line through A parallel to meridian line NS. The line NS through A would represent meridian at A (Please see Fig.13.1).
- Plot the FB α_1 with reference to NS (at A) with a protractor and draw the line AB.
- Measure off length AB (obtained by chaining) to locate B.
- Draw a parallel meridian line NS through B. Plot FB α_2 to find the direction BC and measure off BC.
- Repeat the process and C and D and complete the traverse. Ideally, the line DA should terminate at A, as the case illustrated here is of a closed traverse.
- Once the traverse is plotted, plot the objects by offsets as one does in chain survey.

Closing Error

7. We refer to the closed traverse ABCDA (Please see the Fig. 13.2). It is always advisable to work on a closed traverse (rather than open) as it facilitates to exercise a check on the accuracy of observation and plotting.

8. It has been stated before that ideally, the traverse ABCDA, when plotted on the basis of field readings, should give a closed traverse. However, it is impossible to be cent per cent correct in chaining and taking bearings and thus faulty measurements lead to what is known as closing error. It means that the last station measured to does not coincide with the starting station.

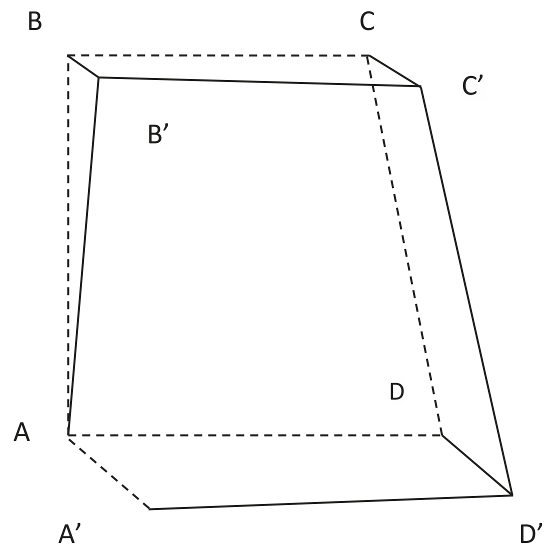


Fig.13.2

Based on field readings when you plot the traverse you may end up in an open polygon AB'C'D'A', where as A' should have been coincided with A and it should have been a closed traverse. The length of the line AA' joining the first and the last point of a plotted traverse is the measure of the closing error.

Adjustment of Closing Error

9. If the closing error is small (upto 1 in 200), the same can be adjusted by a little modification in plotting the traverse.

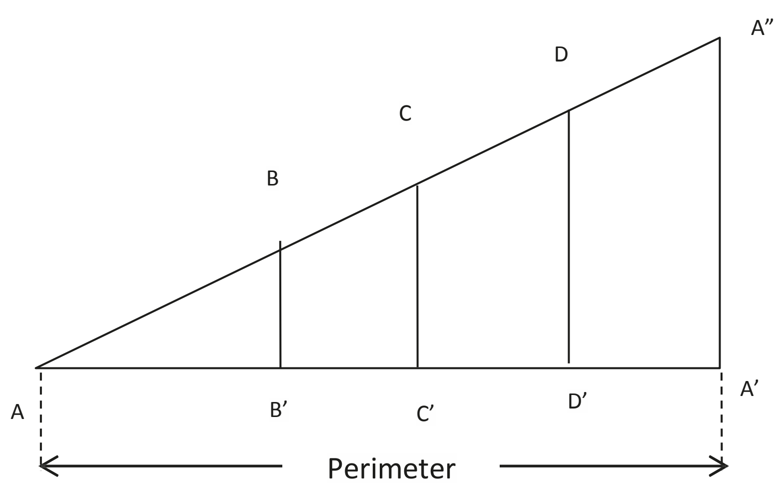


Fig.13.3

We discuss here graphical method of adjustment. It is based on the premise (1) that the closing error is the result of accumulation of errors that have taken place from the start; and (2) that error at each station is proportional to its distance from the starting station and parallel to the line of closing error.

- Draw a horizontal line AA' (please see Fig. 13.3) equal in length to the perimeter (AB'+B'C'+C'D'+D'A') of the plotted traverse of Fig.13.2 on the same scale as of traverse.
- Measure off on line AA' lengths AB', B'C', C'D' and D'A' equal to lengths of traverse arms (please see Fig.13.2 and 13.3).
- Erect perpendicular A'A" on line AA' at A' of length equal to the closing error AA' of Fig.13.2.
- Join AA" and on points B', C' and D' draw lines B'B, C'C and D'D parallel to A'A", intersecting AA" at B, C and D. Intercepts B'B, C'C and D'D of Fig.13.3 represent the magnitudes of corrections to be adjusted at B', C' and D' of Fig.13.2.
- Draw lines (see Fig.13.2) equal to B'B, C'C and D'D (intercepts of Fig.13.3) at B', C' and D' of Fig.13.2 parallel to and in the same direction as AA'. Thus in the survey sheet (Fig.13.2) you get A, B, C and D being the shifted and adjusted locations of the stations. ABCDA of Fig13.2 becomes the adjusted traverse with reference to which plotting of offsets can be done.

Some Practical Applications in Forest Survey

10.1 Locating one's place on survey plan or map –

a) **By prismatic compass alone**
   - **You have to have at least two prominent features (say, A and B) like boundary pillars which are plotted on the map.**
   - **From the Observer's station (O), take bearings to A and B . These are fore bearings (FB) of OA and OB.**
   - **Calculate the back bearings (BB) of OA an OB.**
   - **Now from A and B protract these back bearings on the map.**
   - **Intersection O of these bearings will give the observer's position.**

b) **By compass and chain**
   - **You have to have one prominent feature (say A) like a boundary pillar which is plotted on the map.**
   - **From the observer's position O, take bearing of OA. Calculate the back bearing of OA.**
   - **Measure of the distance OA by means of the chain.**

- **Protract the calculated back bearing at A and scale off the distance AO on it. The point you reach is the observer's position O.**

10.2 Laying out a forest coupe on the ground

- **The coupe map is available.**
- **Suppose ABCD is the coupe boundary shown on the map, and you have to lay the coupe on ground (Please see Fig.13.4).**
- **Identify a ground feature P (shown on the map).**
- **Measure the bearing and distance of A from P on the map.**
- **The distance PA on map can be converted to distance PA on ground, as scale of the map is known.**
- **Now from the feature P on ground you can reach A, since distance PA and bearing of A from P are known.**
- **In the same manner points B, C & D of the traverse can be located by knowing successive bearings of AB, BC and CD from the map and calculating distances (AB, BC and CD) on the ground from the corresponding distances on the map.**

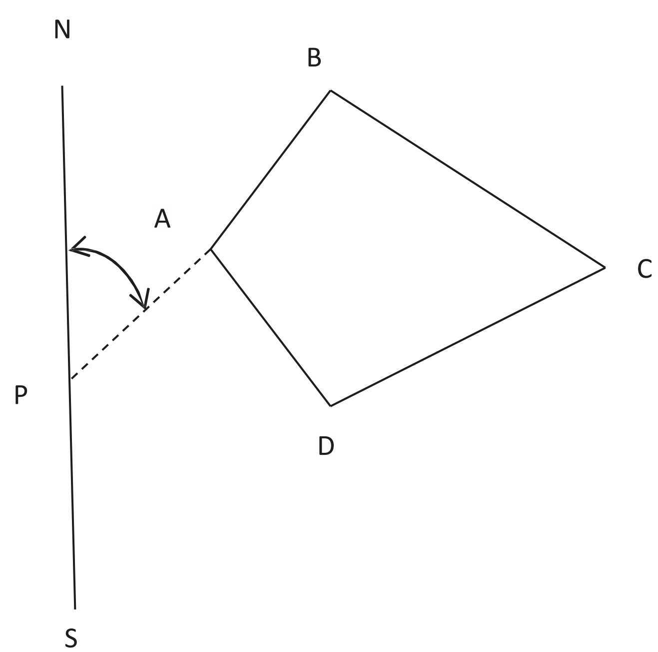


Fig.13.4

PRISMATIC COMPASS SURVEY

Lesson 14 **3hours**

Practical class

Demonstration and application of Prismatic Compass Survey as described in Lesson 12 and 13.

PLANE TABLE SURVEY

Lesson 15 **1 hour**

Plane Table Survey

1. Plane Table Survey is a method of Surveying in which field work and the office work are done simultaneously. It is also known as the graphical method of Surveying. The principle is similar to prismatic compass survey, save that in place of taking bearings of survey lines or rays and plotting them later in office, the rays are drawn on the plane table sheet in the field itself.

Suitability of Plane Table Survey

2. Plane table Survey is very suitable in

- Filling in details in a closed traverse which has been traversed by prismatic compass or triangulation.
- Preparing plan on a small scale.

3. List of Instruments required in Surveying

(1) Plane Table

(2) Alidade

(3) Plumbing fork and Plumb bob

(4) Spirit Level

(5) Chain and Tape

(6) Rain proof cover for the plane table

(7) Trough Compass

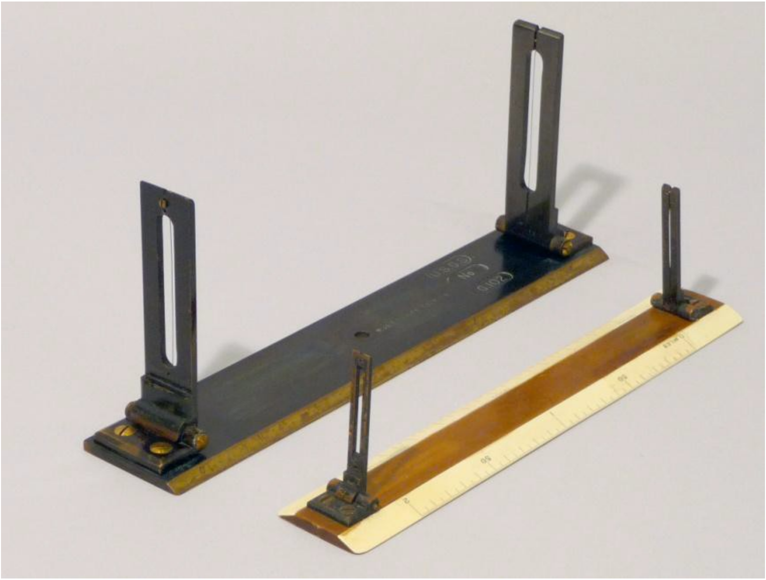
(8) Ranging Rods

(9) Drawing Sheets

(10) Drawing equipment.

4. Alidade – Of the various instruments mentioned above, the alidade is an important plane table accessory which is described below.

4.1 Alidade is a combined sight and straight edge ruler. With its help one can view an object and draw a line on the plane table sheet in the direction of the object. The simplest alidade consists of a wooden or metal ruler, 40 to 60 cm long and about 4 cm wide. It is provided with two vertical sight vanes, each about 15 cm long, one at either end. One of the vanes has a narrow slit and the other carries a hair or wire. One of the edges of the alidade being sloping edge is used to draw rays, though the line of sight is along the centre of alidade. The resulting error is, however, insignificant.



Alidade
(Source: Wikipedia)
Fig.15.1

Procedure:

5. Temporary adjustments of plane table:

At each survey station, following three operations have to be carried out for temporary adjustments of a plane table.

(1) Centering
(2) Leveling
(3) Orientation

5.1 Centering

- Spread and adjust the tripod legs to have a convenient height for working on the board.
- Place the pointed end of the plumbing fork on point on paper and fix a plumb bob at the other end. Shift the table or board bodily till the plumb bob hangs exactly over the peg of the station. Thus centering is done which ensures that the point on paper represents

the station point on ground.

5.2 Leveling

Level the board with the help of spirit level by tilting the board or by ball and socket arrangement or by adjusting the legs of tripod.

5.3 Orientation

It is the process by which one ensures that the positions occupied by the board at various survey stations are kept parallel. Thus, when a plane table is properly oriented, the lines on the board are parallel to the lined on ground which they represent.

5.3.1 Methods of orientation

(i) ***Orientation by magnetic needle:***

- Draw the line of the magnetic north with the help of trough compass on paper at a particular station.
- At the next station, place the trough compass along the line of magnetic north and then turn the table until the ends of magnetic needle are opposite to the zeros of the scale. Clamp the board in that position. The board is thus oriented. Orientation by this method is liable to be faulty if there is local attraction.

(ii) ***Orientation by back sighting:***

- In this method, the orientation is carried out by the back sighting of a particular line. Suppose the board is set up at station A, and point **a** on paper represents station A on ground.
- Take a ray to station **B** and draw to scale the line **ab** on paper. It means **b** on paper represents station **B** on ground.
- Next when the board is set up at **B**, orientation of the table would mean that line **ba** on paper is brought over line **BA** on ground. To do this, place the alidade along the line **ba**. Turn the table till the line of sight bisects the ranging rod at A. Clamp the board in this position. The table thus gets oriented. This method of orientation by back sighting is more accurate and reliable.

Methods of plane table survey:

6. Following are the four methods by which an object might be located on paper by plane table:

(1) Radiation , (2) Intersection, (3) Traversing and (4) Resection.

The first two methods are described here.

6.1 Radiation

This is the simplest method and it is useful only when the whole traverse can be commanded from a single station. The procedure is as follows. Please see Fig. 15.2. Stations on the ground are denoted by capital letters. Corresponding plotted points on drawing sheet are indicated by corresponding letters in lower case. The size of the board is upscaled for the sake of illustration.

- Select a point P so that all points (A, B, C, D) to be surveyed are visible from this point. The stations are A, B, C and D form the corners of the traverse ABCD.
- Set up the table (by centering and leveling) at P. Select a point p on the drawing sheet suitably to represent the station position P. Mark the north line on paper.
- Place the alidade on point P and draw the line of sight for station A. Measure the distance PA on ground. Reduce this distance to a suitable scale on paper to represent line pa which will give point a.
- Similarly, obtain points b, c and d on paper by drawing lines of sight for stations B, C and D, measuring the distances PB, PC and PD on ground respectively, and scaling them off on paper.
- Join points a, b, c and d on paper, as shown in figure.
- For checking the accuracy of work, measure the distances AB, BC, CD and DA on ground and compare them with the lengths ab, bc, cd and da respectively on paper.

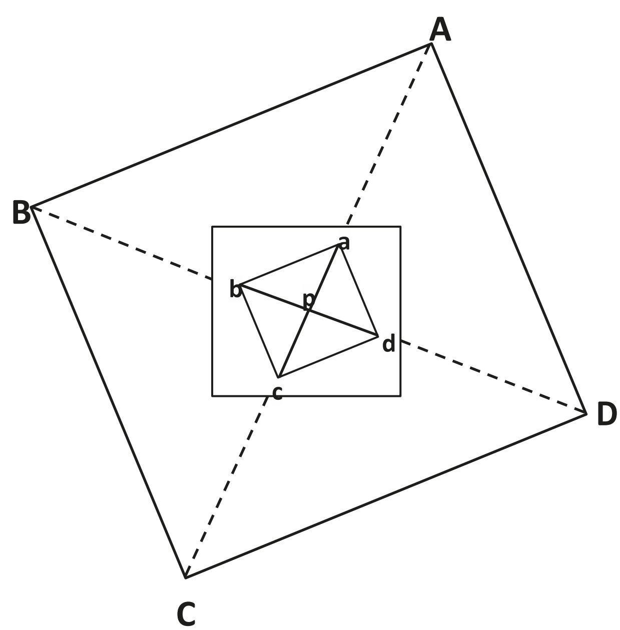


Fig. 15.2 Radiation method

(Source:www:tnau.ac.in)

Intersection

6.2 . This method is useful where it is not possible to measure the distances on ground as in case of a mountainous country. Hence, this method is employed for locating inaccessible points, the broken boundaries, rivers, fixing survey stations, etc. In this method objects or stations are plotted by intersection of rays drawn from two instrument stations. Obviously, the objects have to be visible from both these stations. The procedure is as follows. Please see Fig.15.3. Stations on the ground are denoted by capital letters. Corresponding plotted points on drawing sheet are indicated by corresponding letters in lower case. The size of the board is upscaled for the sake of illustration.

- Select two instrument stations P and Q so that the points to be located on paper are easily seen from them.
- The line PQ joining the two instrument stations is known as base line. Measure the length PQ on ground, and plot the corresponding line pq on the paper to scale.
- Set up the table at P, centre it with point p vertically above P. Orient the table by placing the alidade along pq, turning the table so that line of sight cuts Q and clamping the table in that position.
- Having oriented the table at P as described above, and with alidade pivoted on point p, sight various objects A, B etc, and draw corresponding rays pa, pb etc.
- Shift the table to station Q, centre and level the table and orient the table by back-sight on P. With alidade touching q, sight the same objects and draw rays qa, qb etc in alignment with QA, QB etc.
- The intersection of rays from stations P (pa, pb etc.) with the corresponding rays (qa, qb etc.) from station Q will give locations a, b etc. on paper of the stations A and B, as shown in figure.
- For checking the accuracy of work, measure the distance AB on ground and compare it with its corresponding length ab on paper.

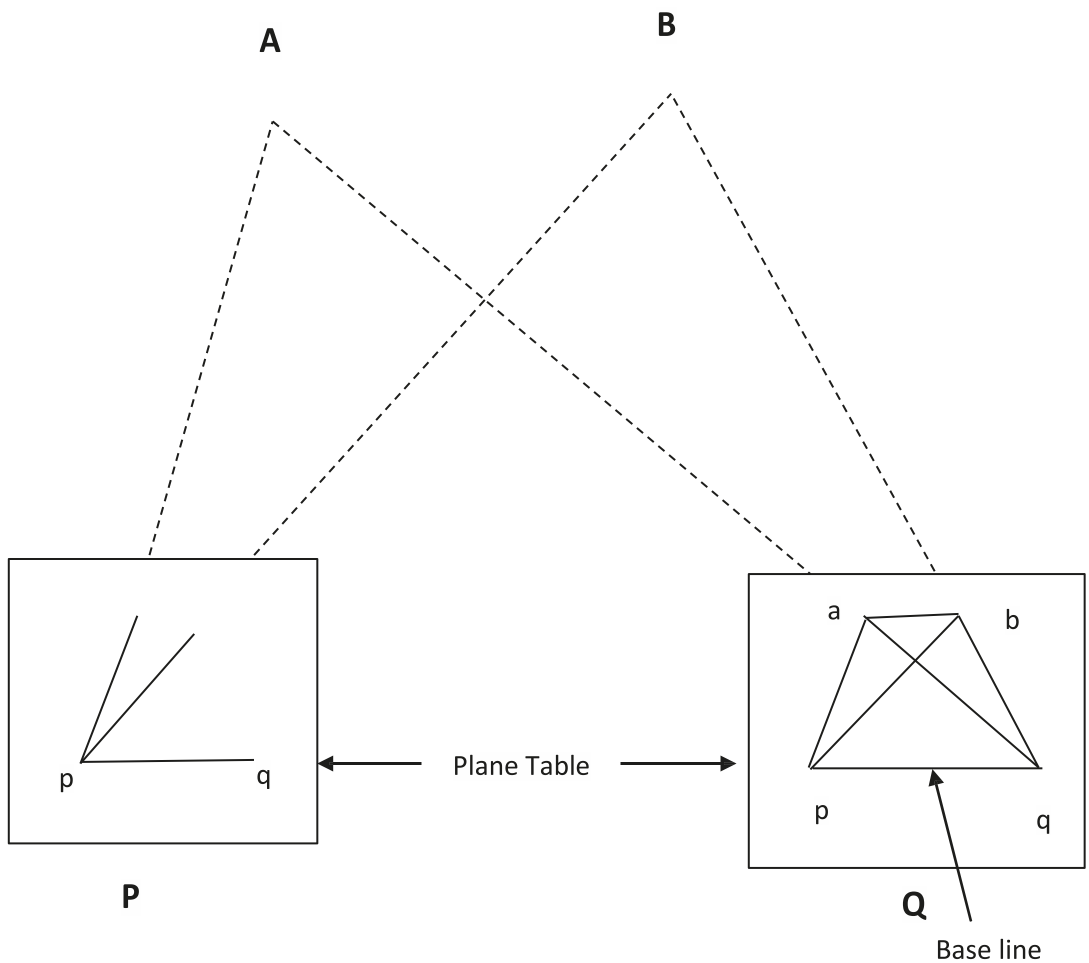


Fig 15.3
Intersection method

7. Some practical applications of plane-cabling in Forest Survey

- Locating observer's position on the map.
- Laying out fire-line, compartment boundary etc.
- Laying out a Forest Coupe on the ground.
- Checking of forest boundary.

PLANE TABLE SURVEY

Lesson 16 **3 hours**

Practical class

Demonstration and application of Plane Table Survey as described in Lesson 15.

CONTOUR AND MAP READING

Lesson 17 **1hour**

1. **Topographical Map –** It shows by suitable symbols configuration of earth's surface called physical relief. Physical relief includes features like hills and valleys, ridges, spurs, slopes etc. Thus while a map shows relative positions of objects on a plane, a topographical map additionally indicates the relative altitudes of surface features.
2. **Contour –** Of the various symbols by which relief is represented on a topographical map, contour lines are the most widely used as contour lines give elevations directly and quantitatively.
   - **2.1 Contour Line** - A contour line may be defined as a thin imaginary line drawn on the map, joining up points of equal height above the mean sea level (M.S.L). In other words, a contour line is a line connecting points of equal elevation on the earth's surface. Each contour line is thus characterized by a constant altitude or elevation.
   - **2.2 Contour Interval (C.I) or Vertical Interval (V.I) –** The difference in elevation or the vertical distance between two consecutive contour lines on a map is known as contour interval or vertical interval. While preparing a topographic map, the choice of C.I is decided by various considerations like, slope of terrain, purpose of survey, time and cost involved, and scale of the map. In a given terrain C.I should vary inversely as the scale chosen. That is, lower the scale, there is freedom to work on higher C.I.
   - **2.3 Horizontal Equivalent (H.E) –** Horizontal distance between two consecutive contour lines is called Horizontal Equivalent (H.E). H.E is measured as the projection on a horizontal plane of the line connecting the two contour lines. For two given contour lines, that is, for a given C.I or V.I, the corresponding H.E will depend on the slope of the line connecting the contours. Steeper the slope of connector, shorter the H.E. Please see the Fig. 17.1.

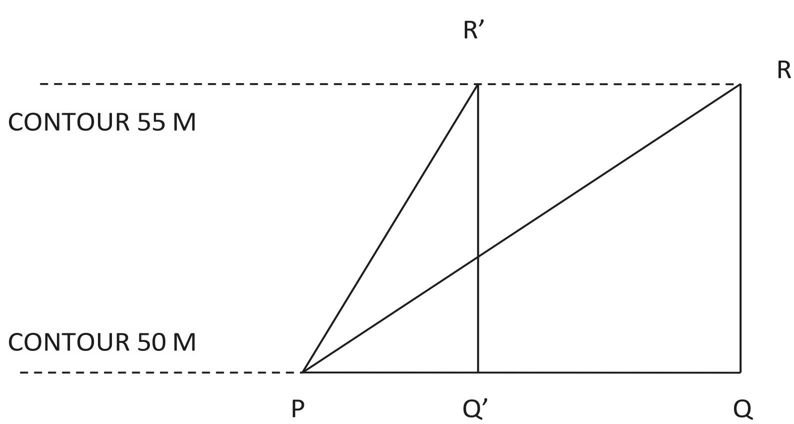
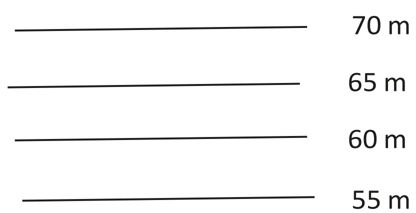


Fig. 17.1

Fig. 17.1 depicts two consecutive contour lines having C.I or V.I equal to 5 m. When the connector PR joins the contour lines, the horizontal projection of the connector is PQ, which will be the H.E. However, if the lines had been joined by PR' having steeper slope, the horizontal projection of the connector PR' would have been PQ'. The H.E would have been PQ', which is less than PQ, the H.E in the earlier case. Thus it is clear that steeper the slope of the connector, shorter would be the H.E of the same V.I.

3. Interpretation of Topographical Map

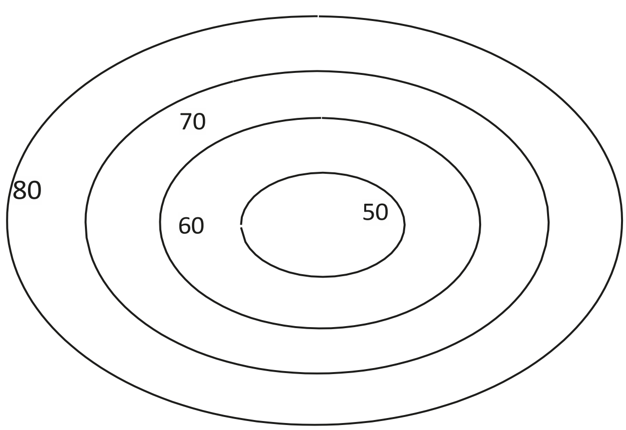
- Direction of steepest slope is the direction of shortest distance between contours.
- Straight, parallel and uniformly spaced contours represent **a plane surface**. Please see Fig. 17.2.



Plane Surface

Fig. 17.2

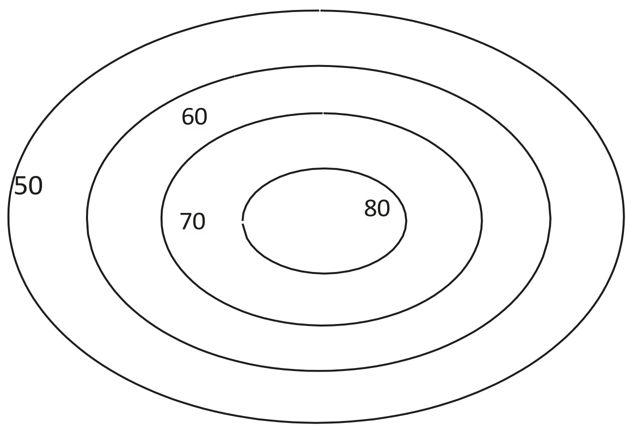
- Series of closed contours with contour elevation decreasing inward represent a depression or hollow without outlet. Please see Fig. 17.3.



Depression or Hollow

Fig. 17.3

- If series of closed contours have their elevation increasing inward, it would represent hill top or a peak. Please see Fig 17.4.



Hill Top or a Peak

Fig.17.4

4. Contouring

The process of determining a series of contours (level lines) on the ground at equal vertical interval apart and plotting the same on a map is known as contouring.

4.1 Methods of Contouring

The field work for contouring involves two operations, namely (i) Locating points on Contour, i.e. finding points on ground having equal elevation or altitude; and (ii) surveying these points on Contours. The first operation requires levelling or vertical measurement, and the second operation means finding locations of contour points on a horizontal plane by measurements along ground.

4.2 Instruments used

a) For vertical measurements, a telescopic level, or a clinometer or any levelling instrument is used.

   Level **is an instrument used to determine the relative heights of different points on the earth surface. It is advised to demonstrate working of levelling instruments like Abney Level, Dumpy Level etc.**

b) For Surveying of points on Contours, instruments required for typical ground survey are used – for example chain or tape, prismatic compass or plane-table.

4.3 Working in the field

Broadly there are two methods of contouring, namely (i) Direct, and (ii) Indirect. Before we proceed to describe the methods of contouring, it is necessary to understand the principle of levelling, and some terms used in that connection.

Levelling – It is the branch of survey that involves measurements in the vertical plane and determines relative heights of objects.

Level – It is an instrument used for establishing a horizontal line of sight at a given point and determining relative heights of different points.

Level Surface – It is a surface which is normal to the direction of gravity (lines of gravitational force). Considering the spherical shape of earth and the fact that gravitational force is directed to centre of earth, level surface would be a curved surface.

Level Line – It is a line lying on a level surface. Thus a level line will be perpendicular to plumb line (line of gravity) at all points.

Datum surface or Line – It is an assumed surface or line with reference to which heights or altitudes of various points are measured and expressed. The mean sea level (MSL) is the most conventional datum.

Line of collimation or Principal Line of sight – It is the imaginary line joining the intersection of cross-wire of diaphragm with the optical centre of the objective (of the levelling instrument) and its continuation forward.

Reduced Level (R.L)– It is the vertical distance of a point with reference to datum.

Height of Instrument (H.I) – It is the elevation (or R.L) of the line of collimation (or principal line of sight) of the instrument, correctly levelled, with reference to assumed datum.

Bench Mark – It is a fixed point of reference whose elevation with respect to datum is known.

Levelling staff – It is a graduated wooden rod, usually 3 to 5 metres (10 to 16 feet) long, the reading of which gives the vertical distance between the horizontal collimation line (line of sight) and the points below the line of sight at which the staff is held.

Back-sight – It is the first reading, after the level is set up and levelled at a position, on the staff held at a point of known elevation. Back-sight provides the height of instrument (H.I).

Fore-sight – It is the reading on a staff held on a forward station to know latter's elevation.

Principle of levelling –

- The instrument is set up and levelled at a commanding point providing good visibility all around. Thus a line of collimation or level line of sight is established. Please see Fig. 17.5
- Back-sight of Bench Mark (or a point of known elevation) is taken with the staff held at B.M. If the B.M's elevation (known) is 98 m and back sight

reading is 2.5 m, then H.I = 98m + 2.5m = 100.5m. Thus H.I at the position where the instrument has been set up is determined.

- Being fixed and levelled at that position the instrument can revolve on a horizontal plane with H.I unaltered.
- Now the staff can be held at various points below the line of sight within a zone of reasonable visibility and fore-sight readings may be taken.
- The H.I reduced by fore-sight of a point will give the elevation of the corresponding point. If fore-sight reading of station A is 3 m, the elevation of A is calculated as H.I – fore-sight = 100.5m - 3m = 97.5m.
- When the stations are spread over a large area, or difference of level is large, or visibility is impaired, then levelling is done at stages, that is, by setting up the level at different points.

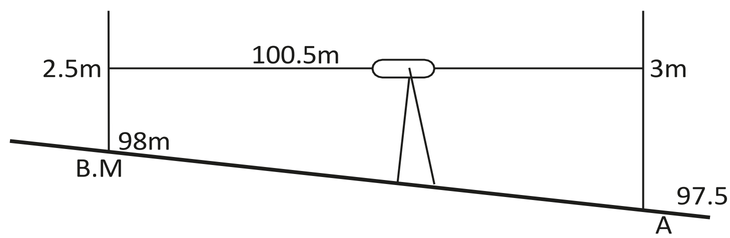


Fig. 17.5

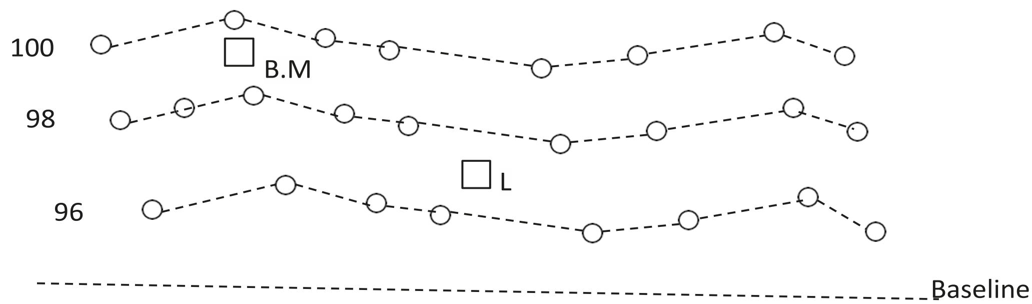
4.4 Direct Methods

In these methods a series of points on each contour are located on the ground by means of a levelling instrument. These points are surveyed and plotted on a drawing sheet. Lines joining these points form Contours on the sheet. Please see Fig17.6.

- Set up the Level at a commanding position L, and level the Instrument.
- Take a back-sight on the benchmark (B.M). The bench mark may be a permanent one or one established temporarily. The altitude or elevation of B.M is known, say, 98 m, as illustrated above.
- Determine the height or altitude of the Instrument (H.I), as explained, from B.M height and back-sight reading. Suppose back-sight on B.M is equal to 2.5 m, then height of the Instrument (H.I) = 98 +2.5 = 100.5m
- Suppose Contours are to be determined at 2 m interval, say 100m, 98m, 96m etc.
- In this example, where H.I is 100.5m, reduced level (= H.I – fore-sight) becomes 100m if fore-sight is 0.5m. Therefore, all those points at which fore-sight reading on staff is 0.5m will lie on 100m contour. Thus the job of locating points on 100m contour is reduced to finding points on ground at which fore-sight is 0.5m. This can be done by first guiding the staff-man to

approximate locations by ocular estimation and then finally zeroing on accurate locations after checking the staff readings to be 0.5m. A series of points on contour 100m can thus be located. Peg these points and label their heights with tags.

- In the same manner you can locate and peg points of contour 98m, 96m etc. by way of finding points on ground at which staff readings for fore-sight will be 2.5m and 4.5m respectively..
- Survey these pegged contour points, plot them on drawing sheet, and sketch the contour lines by joining the points on a contour.



Direct Contouring

Fig 17.6

4.5 Indirect Methods

Direct contouring involves lot of time and is expenses. It is suitable for small areas and where higher accuracy is demanded. Indirect methods provide faster and less expensive means of contouring. The procedure of indirect methods, in brief, is as follows.

- Lay squares lines (say one chain by one chain) on ground. Peg the corner points of the squares.
- Measure the elevations of the corner points of the squares by a level instrument.
- Survey and plot the corner points and the squares on the drawing sheet.
- Mark the elevations of the corner points on the map.
- Draw the contours by interpolations which presumes that slope between two points is uniform.

5. Map Reading

A map is a representation of the whole or part of the earth surface on a chosen sale. All objects on the map are exactly in the same relative positions as on the ground. In other words, distances between points on the ground are truly reflected, on a reduced scale, on the map, and angles between lines on the ground are exactly reflected by equal angles between the corresponding lines on map.

6. **Object of Map Reading**

The object of map reading is to get an accurate picture of ground features. It requires correct interpretation of the scale, signs, legends and symbols used in the map.

7. **Prerequisites for Map Reading**

- **Scale of the map** - Scale is the fixed ratio which any distance on map bears to corresponding horizontal distance on the ground. You should know scale of a map accurately to get the idea of ground distance from the corresponding distance on the map.
- **Signs and symbols** - Various objects on the ground are indicated on the map by distinct signs and legends. The signs or legends used in a map are indicated on the body of a map. Please go through the signs / symbols to know the nature of ground features.
- **Orientation (setting up) of the map**- When north direction of a map coincides with the actual geographical north, the map is said to be properly oriented or set up. When correctly oriented, any line connecting two points on the map indicates the actual direction of the line connecting the corresponding points on the ground .A map has to be oriented before ascertaining the location/direction of the ground features. Orientation is commonly done with the help of a compass. The map is turned until its true or magnetic north line coincides with the north indicated by the compass. In absence of a compass, a map may be oriented with the help of a plain table. Given two points located on the map and identifiable on the ground, the table is set up on one of the points. Placing the alidade along the line joining the two points, the table along with the map may be turned until the line of sight through alidade intersects the other point. The table may be clamped and thus the map gets oriented or set up in this position.
- **Knowing one's position on the map**- This can be done with the help of a prismatic compass or with a plain table.

8. **Various maps for forest management**

- Working plan maps- These maps are prepared generally on 1:50,000 scale (i.e. 2cm=1Km). In addition to topographic features, these maps indicate working circles, felling series, annual coupes, sample plots etc.
- Stock maps- These are normally prepared on 1:15,000 scales. These maps provide information on distribution of forest patches, major forest species,crop density, non forest areas etc.
- Control maps- These maps are prepared normally on 1: 15,000 scales. These maps show progress of forestry operations to exercise checks and control.
- Beat maps- These maps are produced normally on 1:15,000 scales and provided to the beat officers. These maps indicate forest compartments, working circles, roads, buildings, besides topographic features, as required for beat management.

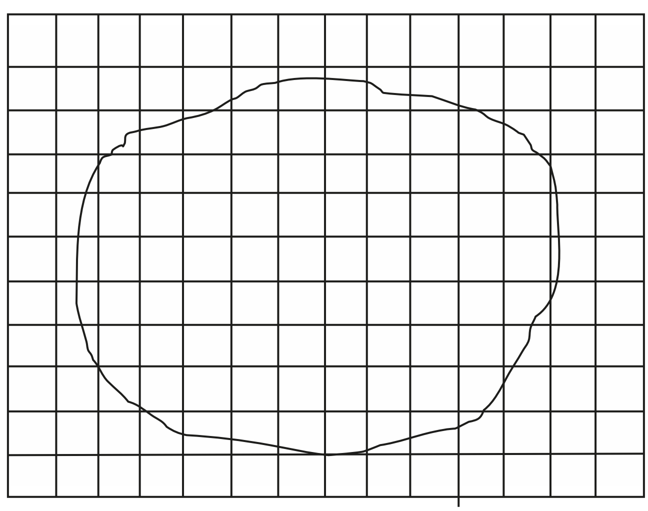
9. **Computation of Area**

Survey of a tract of land enables us to compute the area of the tract surveyed. **Please note that the area to be determined from a survey plan is the area of the land projected on a horizontal plane and not the actual area in case the land is a sloping ground.**

9.1 Area computation by division into geometrical figures

- Take a piece of tracing paper or cloth ruled into squares each of which represents a definite area on ground.

  Preparation of these area squares may be planned suitably. Suppose the scale of plan is 1:10000, that is 1cm = 100m. Then 1 cm square on plan would mean an area of 100m x 100m or 10000 sq.m or 1 ha on ground.
- Place the tracing paper over the given plan. The boundary of the closed tract seen through the tracing paper will look like as shown in Fig. 17.7. The closed area will consist of a number of full squares and a number of partial squares.
- Count the number of complete squares (N) within the boundary and calculate the equivalent area in ha. If the scale is 1:10000, and ruled squares are each 1cm square (as mentioned above), and suppose number of complete squares counted is 10, then area represented by complete squares is 10 x 1 ha = 10 ha.
- Add to this area of complete squares the area represented by partial squares. Area represented by partial squares can be estimated. One way of doing this is to count each ½ or more square as one complete square and ignore each less than ½ square.
- Sum of the area of complete squares (calculated exactly) and partial squares (estimated as above) will give the area of the tract.



Area Computation by method of squares

Fig. 17.7

Illustration of computation (from Fig.17.7):

Row	Number of		Total Number
	Complete square	½ or more partial square	
2	0	3	3
3	5	3	8
4	8	2	10
5	10	0	10
6	10	1	11
7	9	1	10
8	9	0	9
9	7	2	9
10	0	6	6
Total count of squares = 76; if area of square is 1 ha on the given scale, area of tract = (total count of square x area of each square) = 76x1 = 76 ha.			

9.2 Computing area by Planimeter

It is evident that measurement of area by method of squares is an approximate method to find area and should be used for an estimation of the tract area or where high accuracy is not required. The error comes in mainly in estimation of area represented by partial squares. Computing area by instrument like planimeter is a better option to determine area of tract having irregular boundary.

A planimeter is a table-top instrument for measuring areas, usually the areas of irregular regions on a map or photograph. They were once common, but have now largely been replaced by digital tools.

The following picture gives some idea of the setup. The **pole arm** rotates freely around the **pole**, which is fixed on the table. The **tracer arm** rotates around the **pivot**, which is where it joins the polar arm. You trace a curve in the clockwise direction with the **tracer**, and as you do so the **measuring wheel** rolls along, and the total distance it rolls is accumulated on the **dial**. The **support wheel** keeps the thing from flopping over. At the end, you read off a number from the dial, and after multiplication by a factor depending only on the particular configuration of the planimeter, you get the area inside the curve.

(Source: www.ams.org; Mathematics of Surveying Part II; American Mathematical Society)

- Working of Planimeter may be demonstrated in the class.

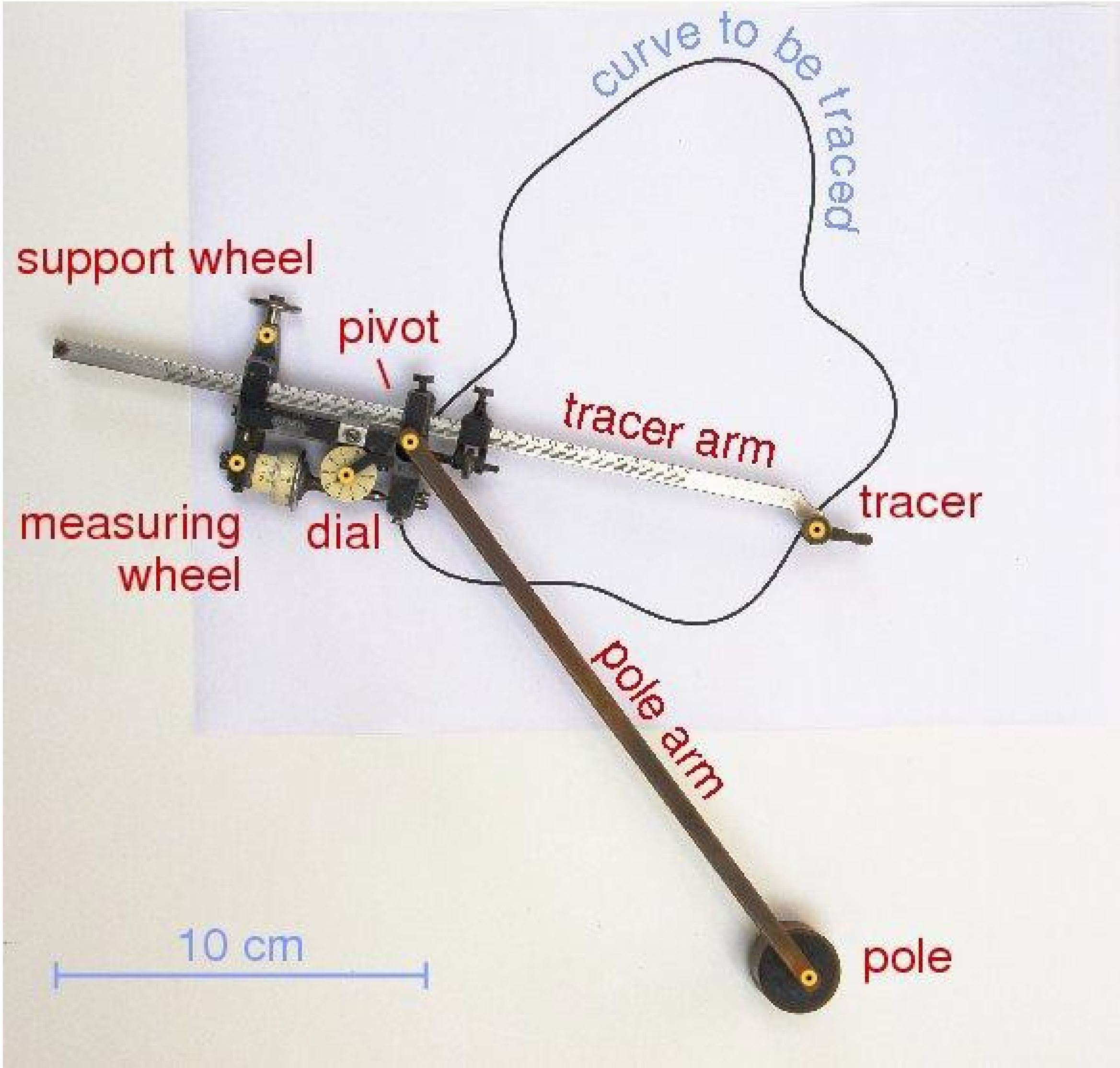


Fig. 17.8 (Source: www.ams.org; Mathematics of Surveying Part II; American Mathematical Society)

BASICS OF GPS

Lesson 18 **1hour**

1. What is GPS?

GPS stands for Global Positioning System. It is a fairly accurate navigation system using signals from a group of satellites to determine a location on the Earth's surface, irrespective of weather conditions.

2. How it works

GPS satellites circle the earth twice a day in a very precise orbit and continually transmit messages that include

- the time the message was transmitted
- satellite position at time of message transmission

The GPS receiver uses the messages it receives to determine the transit time of each message and computes the distance to each satellite using the speed of light. These distances and satellites' locations are used to compute the location of the receiver using the navigation equations. This location is then displayed on the unit's electronic map.

2.1 Any ground-based receiver which receives signals from four or more GPS satellites can use navigation equations to calculate its location on the Earth's surface. Constant signaling can then update speed and direction information for moving receivers.

2.2 Originally developed for military use, GPS has been open since 1990s for civilian use. It now finds application in surveying and mapping, mobile phones and car navigation system.

3. Use in Survey

Since it provides a latitude and longitude position directly without the need to measure angles and distances between points, GPS has been found to be a convenient tool for survey. However, it has not entirely replaced the conventional survey methods and instruments.

3.1 Though known by various names, GPS survey techniques are by nature of two categories – static and dynamic. A static survey utilizes two or more receivers which collect data over different survey points for sufficient amount of common time. Each receiver maintains separate file for each occupation and no data is collected while moving between survey points. Dynamic techniques require the use of moving or trajectory data. In the method known as Real Time

Kinematic (RTK) observations, one receiver remains in one position over a known point -the Base Station - and another receiver moves between positions - the Rover Station.

(Source: Wikipedia, www.garmin.com, Jurovichsurveying.com)

4. Use of GPS in the field

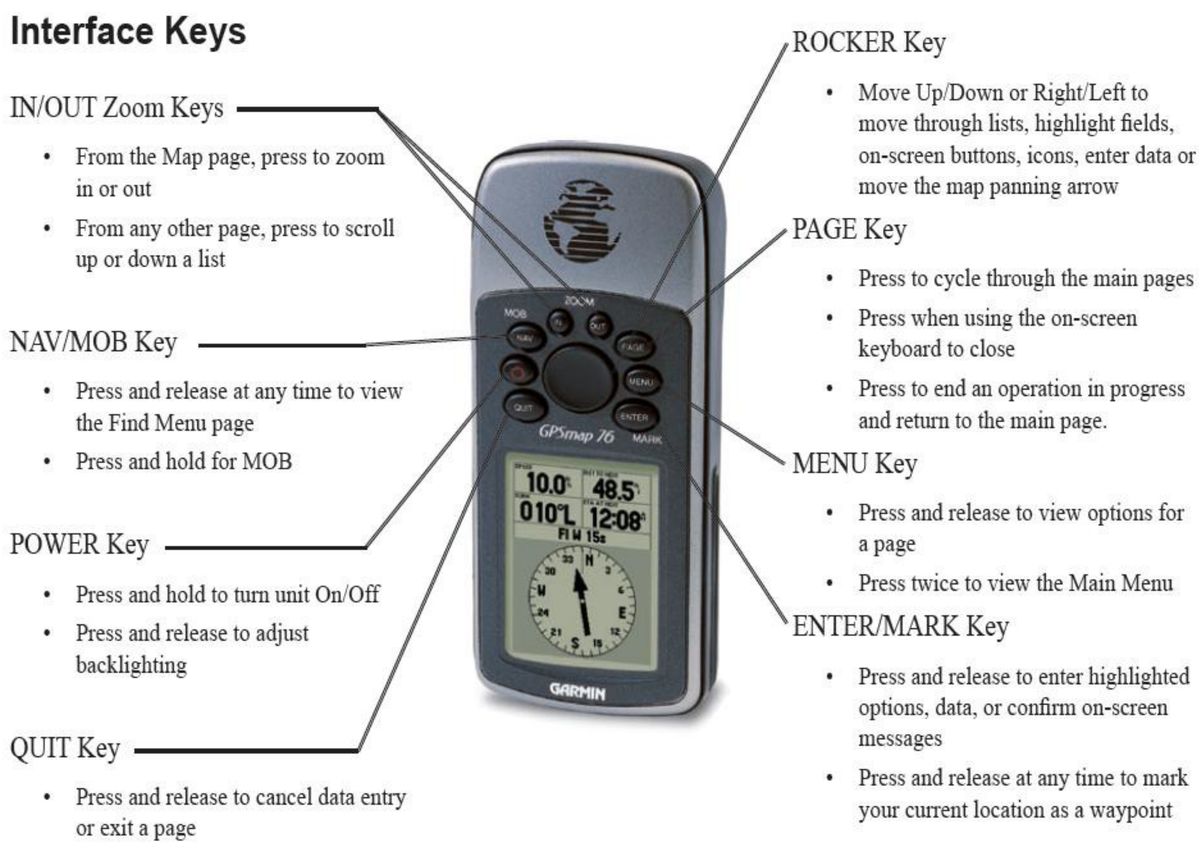
(Source: Note provided by Shri Amitav Mishra IFS,)

Demonstration of GPS receiver is necessary to understand its use.

4.1 Some Basic Terms used in GPS

- Almanac Data: Satellite Constellation (including location and signals of satellites) that is transmitted to your receiver from every GPS Satellite. Almanac data must be acquired before GPS Navigation can begin.
- Bearing (BRG): The compass direction from your position to a destination.
- GRID: Coordinate System that projects the earth on a flat surface, using square zones for position measurements. UTM/UPS and Maidenhead formats are grid system.
- LATITUDE: The north/south measurement of position perpendicular to the earth's polar axis
- LONGITUDE: An east/west measurement of position in relation to the Prime Meridian, an imaginary circle that passes through the north and south poles.
- NAVIGATION: The process of traveling from one place to another and knowing where you are in relation to your desired course.
- POSITION: An exact, unique location based on a geographic coordinate system.
- TRACK(TRK): The direction of movement relative to a ground position.
- WAYPOINT: A specific location saved in the receiver's memory.

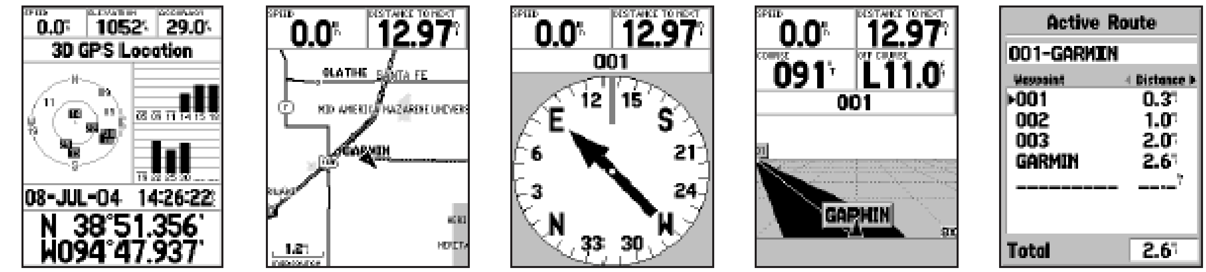
4.2 Basic Keys of GPS



4.3 Main Page

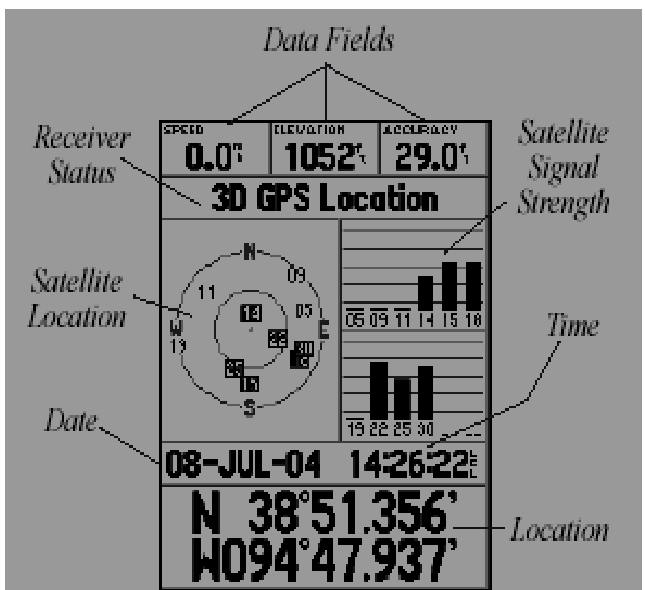
There are five main display pages:

1. GPS Information page
2. Map page
3. Pointer page
4. Highway page
5. Active Route page.



GPS Information Page | Map Page | Pointer Page | Highway Page | Active Route Page

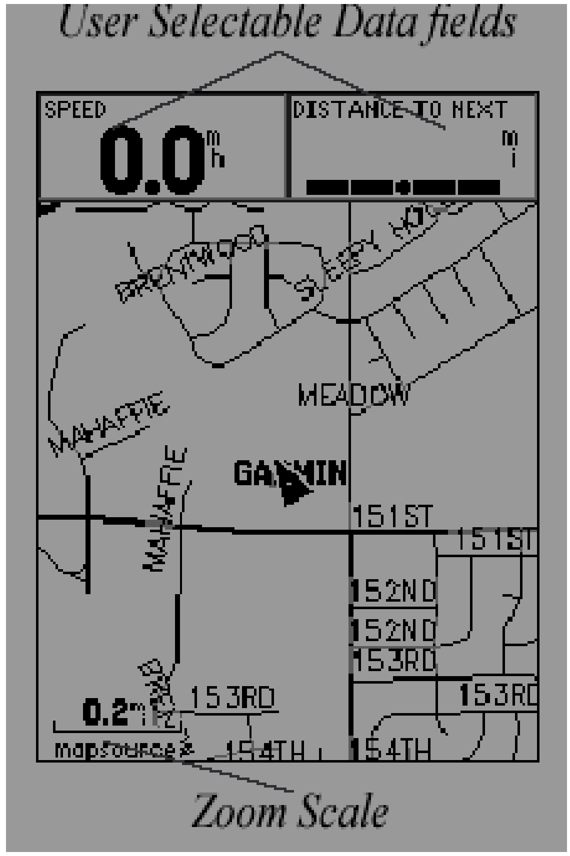
4.3.1 **GPS Information page** : It displays your speed, estimated accuracy, receiver status, satellite locations, satellite signal strength, date, time and the receiver's current location when the unit receives signals from at least three satellites. The unit must receive at least four satellite signals to report elevation.



GPS Information Page

4.3.2 Map Page

The GPSMAP76 comes with a built-in base map that includes a database of Cities, Interstate, State and County Highways, Exit Information, Lake and River outlines, and Railway Lines.

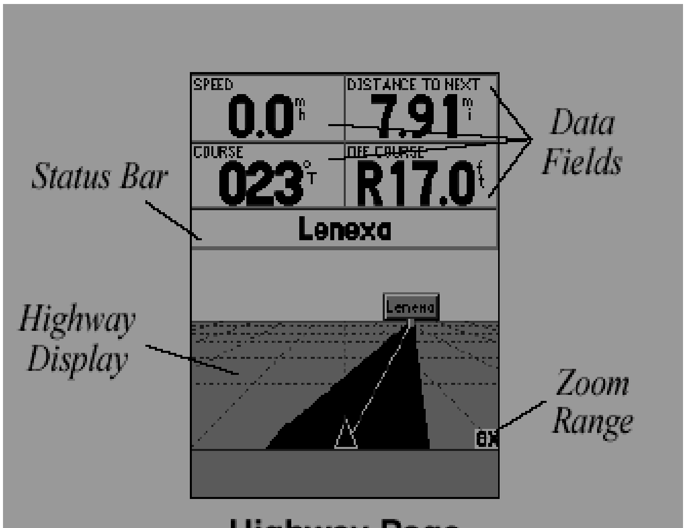


4.3.2.1 Using Additional Map Data in Map Page - With optional Map Source CD-ROMs, listing of nearby restaurant, lodging, shopping Centre etc. and even retrieve addresses and phone numbers for any listed location can be viewed.

4.3.2.2 Changing the zoom range - Zoom Range in the Map Page can be changed for either viewing a smaller area in greater detail or a larger area with less detail by pressing IN and OUT.

4.3.3 Pointer Page - The Pointer Page is best used for navigation when a straight line course cannot be followed. Regardless of direction, the pointer always point toward the active way point. The Pointer is aligned with the vertical line in the Compass Ring when going directly towards the active waypoint. Arriving at Destination is displayed when the selected way point is reached. It is important to note that the Compass Ring does not act as a true compass. Pointer will correctly point towards destination.

4.3.4 Highway Page - The Highway Page is best used for navigation when a straight line course can be followed. To navigate using the Highway Page, just follow the road. If the highway moves to the right, turn right until the triangle is aligned with the white line in the middle of the highway and the highway is pointed towards the top of the display.



Highway Page

4.4 Main Menu

The Main Menu contains settings and features that are not contained in the Main Pages and submenus. The Main Menu is accessed from any of the Main Pages by pressing MENU twice. To select an item on the Main Menu, highlight the menu item and press ENTER.

Main Menu Page

4.4 New, Mark and Waypoint Position

The New Waypoint page has a secondary menu containing three options : Average Location, Project Location, and Append to Route. Access this menu by pressing the MENU key when the New, Mark or Waypoint page is displayed.

- Average Location: collects and averages location readings. The location, Estimated Accuracy, and Elevation Measurement count are displayed on the Average Location Page. When waypoint are ready to be saved, highlight the Save button and press Enter.
- Project Location: Projects a Waypoint from a specified location.
- Append to Route: Shows the available route or a New Route selection is displayed. If an existing route is selected, the waypoint is added to the end of the route. If a New Route is selected, a new route is created and that waypoint is added to route.

4.5 Calculation of Area and viewing the map

The area of a track is reflected immediately as you save the track after its completion. The track may be seen by pressing the map icon when you open a saved track record.

4.6 Storing the GPSMAP 76

Do not store the GPSMAP 76 where prolonged exposure to temperature extremes may occur (such as in the trunk of a car) as permanent damage may result. User information, such as waypoint and routes are retained in the unit’s memory without the need for external power. It is always a good practice to back up important user data by manually recording it or downloading it to a PC.

4.7 Advantages and Limitations of GPS

4.7.1 Advantage of GPS surveys

- Three Dimensional
- Site Intervisibility Not Needed
- Weather Independent
- Day or Night Operation
- Common Reference System
- Rapid Data Processing with Quality Control
- High Precision
- Less Labor Intensive/Cost Effective
- Very Few Skilled Personnel Needed

(Source: Surveying with GPS - Michigan Technological University
http://www.tech.mtu.edu/courses)

4.7.2 Limitations

GPS is proven to be a very valuable tool for the purposes of Surveying and Navigation. However its users must be aware of its characteristics and cautious of its limitations.

Common Factors affecting the accuracy of GPS:

- GPS Technique employed
- Surrounding conditions (satellite visibility and multipath)
- Number of satellites in view
- Satellite Geometry
- Distance from Reference Receiver(s) (non-autonomous GPS ie: WADGPS, DGPS, RTK)
- Ionospheric conditions
- Quality of GPS receiver

Ideal condition for GPS Surveying or Navigation demands a clear view of the sky with no obstruction from about 5 degrees elevation and up.

Any obstruction in the area of the GPS antenna can cause a very significant reduction in accuracy. Examples of interfering obstructions include: buildings, trees, fences, cables etc. Obstructions may have the following effects thereby reducing accuracy:

- Reduced number of satellites seen by the receiver
- Reduced strength of satellite geometry (Dilution of Precision (DOP) values)
- Satellite signal multipath
- Corruption of GPS measurements

Multipath is caused by GPS signals being reflected from surfaces near the GPS antenna that can either interfere with or be mistaken for the signal that follows the straight line path from the satellite. In order to get an accurate measurement from a GPS satellite, it is necessary that the signal from the GPS satellite travels directly from the satellite to the GPS antenna. If the signal has been reflected off of another surface prior to being received at the antenna, its length will be greater than was anticipated and will result in positioning error. Multipath is difficult to detect and sometimes hard to avoid.

Thus it is apparent that GPS navigation and surveying techniques have limitations that may not permit desired accuracies in a given environment. The cause for poor accuracy is not always obvious but is usually attributable to one or more of the sources of error described above. These errors can lead to position errors as large as several of meters or more.

(Source: http://earthmeasurement.com/GPS_accuracy.html)

GPS

Lesson 19 **4 hours**

Practical Class

Application of GPS to determine locations of ground objects, and to check area of plantations / forest coupes.