Course name: **Surveying-II**

Class: **II B. Tech, II Semester**

Branch: Civil Engineering

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Unit-I

THEODOLITE

Theodolite is an instrument used for measuring the horizontal and vertical angles in survey works. It is a very important instrument in surveying and can be used in a large number of survey works like measurement of distances, leveling, prolonging a line etc.

Theodolite surveying:

The system of surveying in which the angles are measured with the help of a theodolite, is called Theodolite surveying.

Uses of theodolite:

- Measuring horizontal and vertical angles.
- Locating points on a line.
- Prolonging survey lines.
- Finding difference of level.
- Setting out grades
- Ranging curves
- Tacheometric Survey

Classification of theodolite:

Theodolites may be classified as

A)

i) Transit theodolite
ii) Non transit theodolite

B)

i) vernier theodolites
ii) micrometer theodolites

Transit Theodolite: A theodolite is called a transittheodolite when its telescope can be transited i.erevolved through a complete revolution about itshorizontal axis in the vertical plane, whereas in a-
Non-Transit type, the telescope cannot betransited. They are inferior in utility and have nowbecome *obsolete.*

Vernier Theodolite: For reading the graduatedcircle if verniers are used ,the theodolite is called as aVernier Theodolite.Whereas, if a *micrometer* is provided to readthe graduated circle the same is called as a**Micrometer Theodolite**.

Essential parts of a theodolite

Telescope:

Telescope is an integral part of the theodolite and it is mounted on a spindle known as horizontal axis or trunioun axis. The telescope can be rotated through 180^0 in the vertical plane. This telescope is internal focusing type with aperture of objective as 38mm. the length of telescope tube varies from 100mm to 175mm.

Vertcical Circle:

The vertical circle is circular graduated arc attached to the truniuon axis of the telescope. The vertical circle is secured tightly to the telescope and moves when the the telescope is rotated about the horizontal axis. The circle is either graduated continuously from 0^0 to 360^0 in clock wise direction or it is divided into four quadrants.

Vernier frame:

The vernier frame is also called is T frame or INDEX frame. The vertical leg of this T frame is called as CLIPPING arm and the horizontal arm is called as INDEX ARM. At the two extremities of the index arm fitted two verniers to read the vernier scale. The indexarm is centered on the trunion axis in front of the vertical circle and remains fixed.

Vertical clamp screw:

The vertical circle and hence the telescope can be clamped at any vertical angle by the vertical clamp screw. This prevents the rotation of the telescope about the horizontal axix in the vertical plane. But after clamping the vertical screw, small rotations of the telescope in the vertical plane can be made by means of vertical clamping screw.

Altitude Bubble:

This is the sensitive bubble tube attached at the top of the frame. The sensitivity of altitude bubble tube is 20" per 2mm.

Upper Plate:

The upper plate also called as vernier plate supports the standard at its upper surface, the upper plate is attached to the vertical spindle called as the **inner spindle** or **inner axis.** The inner spindle rotates in the outer spindle attached to the lower plate by the upper clamp screw. The upper tangent screw is used for making small movement of the upper plate after tighting the upper clamping screw. After clamping the upper plate, both upper and lower plates move together as one unit.

Lower Plate:

The lower plate is also called as the horizontal circle or the main scale plate.
It is mounted on a hollow tapered spindle also referred to as the outer spindle or the outer center. It is to be noted that the inner surface of the outer spindle acts as bearing for the inner spindle. The outer surface of the outer spindle turns in the bearing in the tribrach of the leveling head.

The lower plate is graduated from 0^0 to 360^0 with each graduations at 20'. Each fifth degree is numbered and graduations increased in the clock wise direction. The edge of the horizontal circle is beveled and silvered.

The readings of the horizontal circle are taken by verniers**A** and **B.**

The lower plate is provide with lower clamp screw. When the lower clamp is tightened, then the outer spindle is fixed to the tribatch and the lower plate gets fixed in position. Similar to the upper plate when the lower clamp is tightened, the lower plate can be rotated slightly by turning the lower tangent screw.

The diameter of the horizontal circle is between 100mm and 130mm.

Plate Level:

A level tube called as the plate level is provided on the upper plate of the theodolite.
The sensitivity of this plate level is about 35" per 2mm. In certain instruments, there are two level tubes fixed horizontally at right angles to each other.

Leveling Head:

The leveling head consists of two plates which are parallel to each other separated by three leveling screws. The upper parallel plate of the leveling head is called as the **TRIBRATCH** and the lower parallel plate is called as the **TRIVET STAGE** or **FOOT PLATE.** The tribratch supports the outer spindle with the help of tapered bearings. The tribratch consists of three arms each carrying a leveling screw.

Shifting Head:

It is a centering device placed below the lower plate but above the tribratch so as to enable the centering after the instrument has been leveled. It consists of two plates capable of movimg relative to each other.

Magnetic Compass:

A circular type of magnetic compass is generally used. It is mounted on the upper plate between the standards. When the telescope is in the normal position(face left), the letter **N** of the compass is under the objective end of the telescope and letter **S** is under the piece end. The magnetic compass indicates zero when the line of sight p[oints towards the north.
The magnetic bearing increases as the telescope turned clock wise. The working of this magnetic compass is very similar to that of surveyor's compass.

Tripod:

The theodolite is mounted on a tripod when used in the field. The legs of the are either solid or framed. Pointed steel shoes are provided at the lower ends of the tripod legs so that the tripod legs can be pushed inside the ground for fixing purposes.

DEFINITON AND TERMS

Vertical axis:
It is the axis about which the telescope or instrument can be rotated in a horizontal plane. This is the axis about which lower and upper plate rotates.

Horizontal axis:
It is also known as trunion axis. It is the axis about which the telescope can be rotated in a vertical plane.

Line of collination:
It is the imaginary line joining the intersection of the cross hairs of the diaphragm to theoptical center of the object glass and its continuation.

Axis of the telescope:
It is the line joining the optical center of the object glass to the center of the eye-piece.

Axis of the level tube:

It is the straight line tangential to the longitudinal curve of the level tube at the center of thetube. The axis of the bubble tube is horizontal when the bubble is central.

Centering:
The process of setting the theodolite exactly over the station mark is known as centering.

Transiting:
It is the process of turning the telescope in vertical plane through 180º about the trunnionaxis.

Swinging the telescope:
It means turning the telescope about its vertical axis in the horizontal plane. A swing is calledright or left according as the telescope is rotated clockwise or counter clockwise.

Face left:
If face of the vertical circle is to the left side of the observer, then the observation of the angles taken is known as face left observation.

Face right:
If the face of the vertical circle is to the right side of the observation, then the observation ofthe angles taken is known as face right observation.

Changing face:
It is an operation of bringing the face of the telescope from left to right and vice-versa.

Telescope normal:
A telescope is said to be normal or direct when the face of vertical circle is to the left and the bubble of the telescope up.

Telescope inverted:
A telescope is said to be inverted or reversed when the vertical is to the right and the bubble down.

ADJUSTMENTS:
Permanent Adjustments:

The permanent adjustments are to be done to maintain the required standard relationship between the fundamental lines (axes) of a Theodolite. The fundamental lines are as follows:

a. Vertical axis
b. Horizontal axis or trunnion axis
c. Line of collimation or line of sight
d. Axis of plate level
e. Axis of altitude level.

Required relations between the fundamental lines:

i) The axis of plate level must be perpendicular to the vertical axis.
ii) The line of collimation must be perpendicular to the horizontal axis
iii) The horizontal axis must be perpendicular to the vertical axis.
iv) The axis of the altitude level must be parallel to the line of collimation.
v) The vernier reading of vertical circle must read zero when the line of collimation is horizontal.

The permanent adjustments of a Theodolite are:

- Adjustment of plate level.
- Adjustment of line of sight
- Adjustment of horizontal axis
- Adjustment of altitude bubble and vertical index frame.

Temporary adjustments:

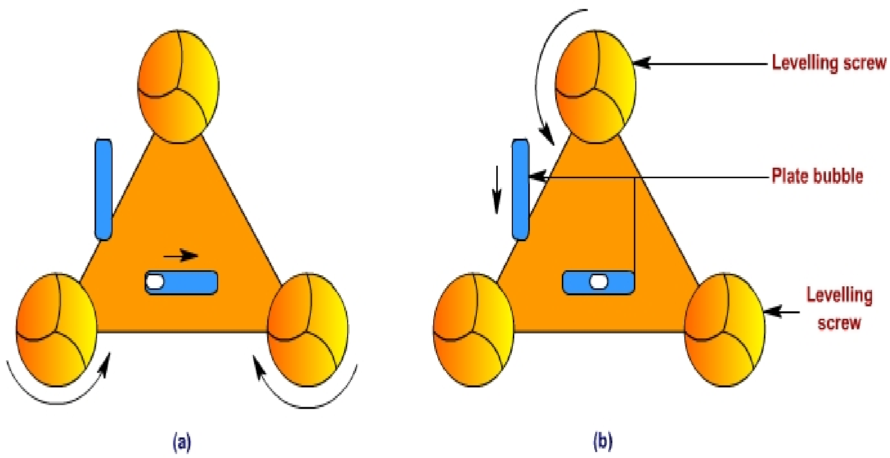
The adjustments which are carried out at every setting of the instrument before the observations are referred as temporary adjustments. There are three types of temporary adjustments as follows.

a. Setting up
b. Levelling up
c. Elimination of parallax.
a) Setting up

This adjustment includes the following two operations.
i. Centering the Theodolite over the instrument station.
ii. Approximate leveling of Theodolite with the help of the tripod legs only.

Centering
It is the operation by which the vertical axis of the theodolite represented by a plumb line is made to pass through the mark of instrument station on the ground.

Approximate levelling
The approximate leveling may be done with the reference to a small circular bubble provided on the tribrach or by eye judgements.



b) Levelling up

The operation of making the vertical axis truly vertical is known as leveling of the Theodolite. After the centering and approximate leveling an accurate leveling is to be done with the help of foot screws.

i) First the telescope is to be kept parallel to any of the two foot screws as in the figure.

ii) The bubble of plate level is to be brought to the centre of its run by turning the foot screws either inwards or outwards simultaneously.

iii) Then the telescope is to be turned through 90°, so that it lies over the third foot screw (i.e perpendicular to the first position)

iv) The bubble is to be brought to the centre of its run by turning the third foot screw either clockwise or anticlockwise.

iv) Then the telescope is brought back to its original position (position at (i)) and the position of bubble is checked whether it remains in the center or not.

v) If the bubble is not in centre the above operations are repeated till the bubble retain at centre in both the positions.

c) Elimination of parallax:

An apparent change in the position of an object caused by the change in position of the observer's eye is known as **parallax.** This can be eliminated in two steps.

i) Focusing the eye piece for distinct vision of the cross hairs.

ii) Focusing the objective to bring the image of the object in the plane of cross hairs.

i) Focusing the eye piece

The telescope is to be pointed towards the sky or a sheet of white paper is to be hold in front of the objective.

The eye piece is to be moved in or out by rotating it gradually until the appearance of cross hairs becomes sharp and distinct.

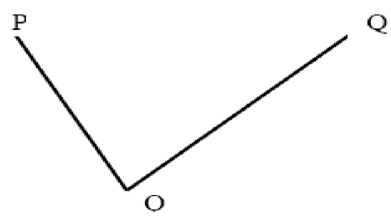
ii) Focusing the objective

Telescope is to be directed towards the object. Focusing screw is to be turned until the appearance of the object becomes sharp and clear.

Measurement of horizontal angles:

1. General procedure
2. Repetition method
3. Re iteration method

General Procedure:

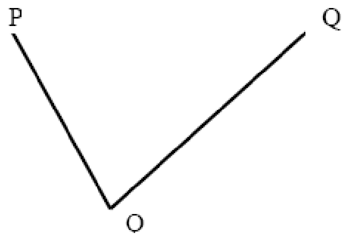


1. Set up the instrument at O and level it accurately.
2. Release the clamps. Turn the upper and lower plates in opposite direction till the zero of one of the Vernieris against the zero of the scale and the vertical circle is to the left. Clamp both the plates together by upper clamp and lower clamp and bring the two zeros into exact coincidence by turning the upper tangent screw.
3. Loose the lower clamp and turn the instrument towards the signal P. since both the plates clamped together, the instrument will rotate about the outer axis. Bisect point P accurately by using lower tangent screw. Check the readings A and B. There shoul be no change in the previous reading.
4. Unclamp the upper clamp and rotate the instrument clockwise about the inner axis to bisect point Q. clamp the Upper clamp and bisect Q accurately by using upper tangent screw.
5. Read both verniers. The reading of vernier A directly gives theangle POQ directly while the vernier B gives by deducting 180^0. While entering the reading, the full reading of vernier A should be entered, while only minutes and seconds of the vernier B are entered. The mean of the two such vernier readings gives angle with one face.
6. Change the face by transiting the telescope and repeat the whole process. The mean of two vernier readings gives the angle with one face.
7. The average horizontal angle is obtained by taking the mean of the two readings with different faces.

REPETITION METHOD:

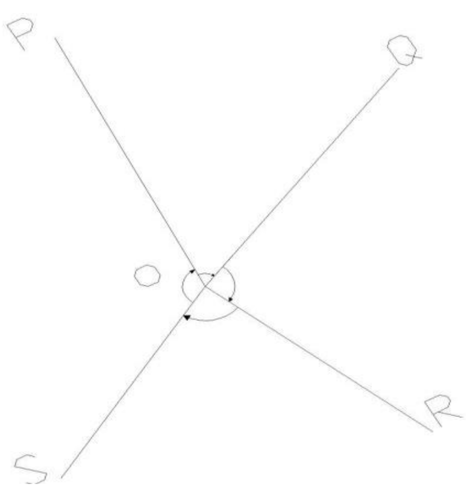
The method of repetition is used to measure a horizontal angle to a finer degree of accuracy than that obtainable with the least count of the vernier.

By this method, an angle is measured two or more times by allowing the vernier to remain clamped each time at the end of each measurement instead of setting it back to zero when sighting at the previous station. Thus an angle reading is mechanically added several tines depending upon the number of repetitions. The average horizontal angle is then obtained by dividing the final reading by the number of repititions.



1. Theodolite is set over an instrument station (O) exactly and all the temporary adjustments are done. Vertical circle is placed left to the observer (face left observation).
2. Vernier A is set to Zero with the help of upper clamp screw and tangent screws. Readings of Vernier A and B are noted.
3. Upper clamp is clamped. Lower clamp is loosened and the telescope is turned towards "P". Lower clamp is clamped and the point "P" is bisected exactly using tangent screws.
4. Both the vernier A and B are read and noted (Must be equal to 0° and 180° respectively).Upper clamp is unclamped and the telescope is turned clockwise and "Q" is bisected.
5. Upper clamp is clamped and "Q" is bisected exactly using tangent screws. Both the verniers are read. Mean of the readings provide an approximate included angle of POQ.
6. Unclamp the lower clamp and the turn the telescope clockwise about the inner axis to sight P again

RE ITERATION METHOD:



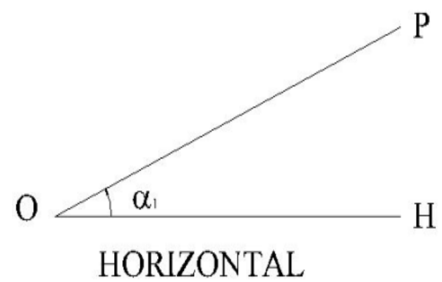
1. Theodolite is set over an instrument station (O) exactly and all the temporary adjustments are done.Vertical circle is placed left to the observer (face left observation).
2. Vernier A is set to Zero with the help of upper clamp screw and tangent screws. Readings of Vernier A and B are noted.
3. Upper clamp is clamped. Lower clamp is loosened and the telescope is turned towards "P". lower clamp is clamped and the point"P" is bisected exactly using tangent screws
4. Upper clamp is loosened and the telescope is turned clockwise to bisect R.Lower clamp is clamped and R is bisected exactly using tangent screws. Both the verniers are read and noted.
5. The same procedure is repeated for all other points.
6. The face is changed and all the above steps are repeated. (Face right observations)
7. Reading from Q is subtracted by reading R to get included angle QOR. Reading from R is subtracted by reading S to get included angle ROS.
8. The same procedure is followed to get readings of all other included angles.

MEASUREMENT OF VERTICAL ANGLES:

A vertical angle is the angle between the inclined line of sight and the horizontal plane through the trunnion axis of the instrument.

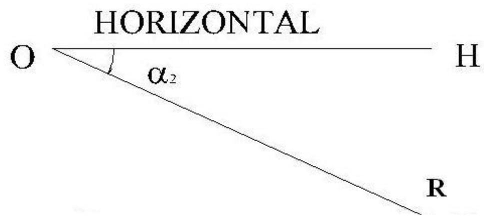
Angle of Elevation:

When the line of sight is inclined upwards from the horizontal or trunion axis, it is called as **angle of elevation.**



Angle of depression:

When the line of sight is inclined towards from the horizontal or trunion axis, it is called as **angle of depression.**



Procedure:

1. Theodolite is set up, centered and leveled with reference to the plate bubble.
2. Telescope is placed horizontally by setting the reading of 0°0’0”in the verniers of C and D.
3. Levelling process is carried out with the help of foot screws and the altitude bubble is brought in its central run.
4. Vertical circle clamp is loosened and the telescope is directed upwards to bisect P.
5. Vertical circle clamp is clamped and the point P is exactly bisected using vertical tangent screws.
6. Both the verniers of C and D are read and noted. Mean of the two verniers provide the vertical angle HOP
7. Face is changed and all the above steps are repeated to get one more vertical angle HOP.
8. Average of the vertical angles taken to get an accurate vertical angle.
9. The same procedure may be adopted to determine the angle of depression HOR by directing the telescope downwards.

TRAVERSE SURVEYING

Traverse:

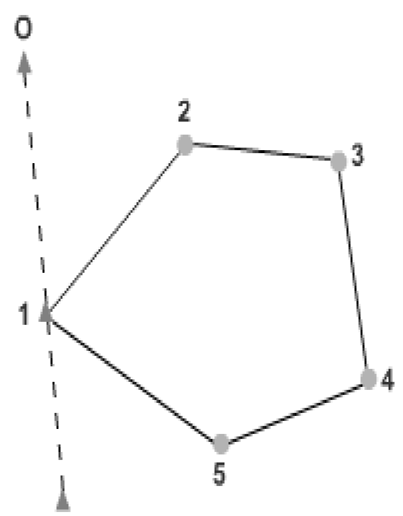
A traverse consists of a series of straight lines connected successively at established points, along the route of a survey. The points defining the ends of the traverse line are called traverse stations or traverse points. Distances between traverse stations are known as traverse side and are measured either by direct measurement using a Tape or Electronic Distance Measuring (EDM) equipment, or by indirect measurement using tacheometer. At stations where a traverse side changes its direction, relative direction are measured with a transit or theodolite.

There two types of traverses:

1. Closed traverse
2. Open traverse

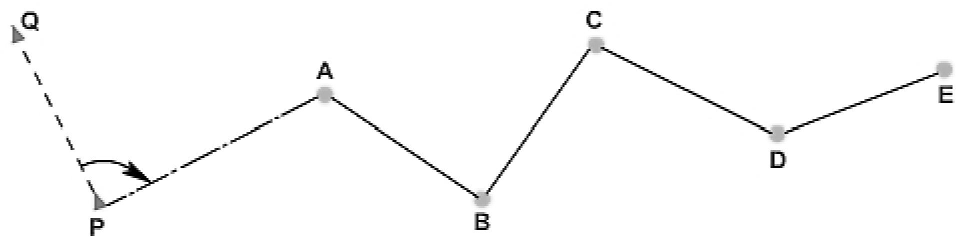
Closed Traverse:

When a traverse originates from a known position and also terminates to known position then it is called a closed traverse. (If the origin and terminating points are the same then it is called closed-loop traverse.This type of traverse permits an internal check on the accuracy of angular measurements, provides an indication of the consistency of measuring distances as well as angles. But detection of systematic errors in linear measurement or errors in the orientation of the traverse, is not possible. This type of traverse is recommended for minor projects). A closed traverse that originates from a known point and terminates to another known point.is the most reliable. This type of traverse henceforth called as open looped close traverse provides computational checks allowing detection of systematic errors in both distance and direction and, therefore, preferred to all other types of traverse.



Open Traverse:

An open traverse originates from a point whose position may be known or unknown but terminates to a point whose position is not known. In this type of traverse, computational check is not possible to detect error or blunder in distances or directions. To minimize error, repeated observations for measurements need to be taken. consider a traverse ABCDE that originates from the point A which may be unknown or may be defined with reference to known point P lying on the line PQ of known azimuth, but it terminates to an unknown point E. Thus, traverse ABCDE is an open traverse. An open traverse is generally used for exploratory purpose such as mine surveying. It should generally not be used in civil engineering works unless situation dictates. So no further discussion on this will be done.



Plotting a survey:

The accuracy of a survey depends upon the accuracy with which its control points are plotted. The traverse stations, which are the control points, can be plotted either by the angle and distance method or by the coordinate method.

1. Angle distance method;

In this method, distances between the stations are laid off to scale and angles or bearings are plotted. Thus, the traverse stations are plotted with reference to the previous station. Therefore, the accuracy of the location of each station on the plan evidently depends upon the accuracy with which previous points are plotted. Even if there is a slight error in plotting, the error gets accumulated and the position of the last station may be displaced to a considerable distance from its true position. So, this method is used for plotting of small traverse or for traverse of low accuracy.

2. Coordinate method:

The independent coordinates of horizontal control points are required in the state plane coordinate system for preparation of topographic map. So, data from field surveying are used to calculate and adjusted in the office, correct within specified limits, and made available for direct plotting by the coordinate method. This plotting can be performed with high precision, since all measurements are linear distances measured from orthogonal axes.In order to plot by the coordinate method, a series of grid lines are drawn on the base sheet for the map using a gratitude.

These grid lines are sets of X and Y axes of orthogonal coordinate systems. In the state plane coordinate system (and in most other coordinate systems), the Y grid axis is aligned toward North. These grid lines are spaced at some regular, uniform interval say, 50, 100, 200, 500 or 1000 m suitable for the scale of the map being compiled. When drawing the grid lines, extreme care must be exercised to ensure that the lines are straight and of uniform weight and that the X grid lines are perpendicular to the Y grid lines. Each X and Y grid line is labelled at the edges of the map sheet with its coordinate value. Grid lines should be drawn as quickly as possible on stable-base material under uniform temperature conditions so that all measurements are consistent. The positions of the control points are then plotted by laying off the differences between the coordinates for the point and the coordinates of a pair of intersecting grid lines close to the control point.

The grid lines are retained on the finished drawing or map or at the very least, the grid tick intersections are left. These grid lines or grid intersection points are invaluable for scaling the coordinates of points on the map. They can also be useful to evaluate dimensional changes in the map-base material and allow more realistic scaling of distances and locations from a given map sheet.

The advantages of plotting horizontal control by rectangular coordinates are as follows:

(1) adjusted coordinates are used to plot the locations so it is known that the data are correct to within the closure of the control survey network;

2) each point is plotted independently so that there is no accumulation of error;

(3) high precision and uniform accuracy can be maintained on large map sheets and when multiple map sheets are required; and

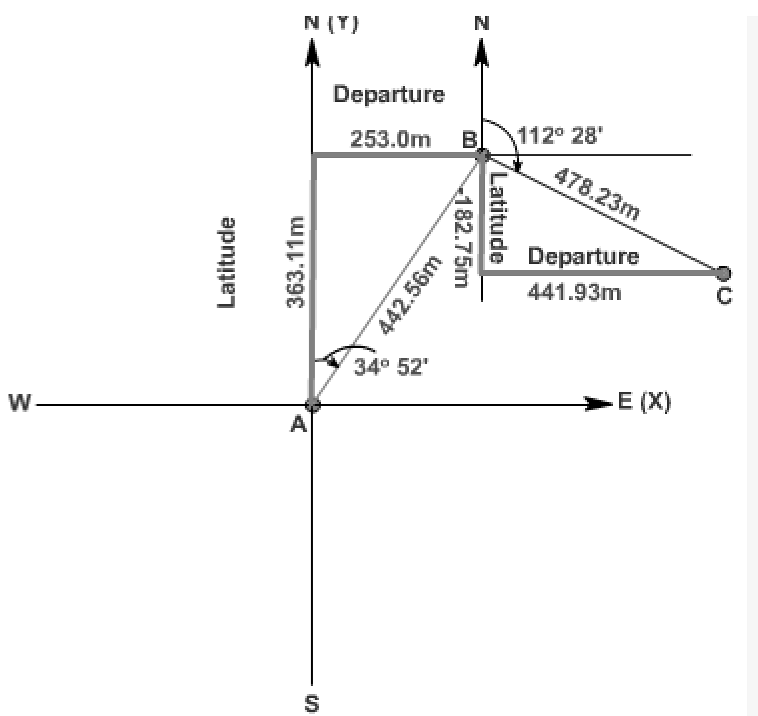
(4) the method is very adaptable to automatic plotting routines and is compatible with modern data-storage procedure.

Traverse computations:

Traverse surveying in the field yields observed angles or directions and length of the traverse sides. Thus, these parameters are used in traverse computations which are performed in a plane rectangular coordinate system. The traverse computations involve calculation of consecutive coordinates of traverse stations, checking in error of closure, determination of the amount of closing error, adjustment of traverse by balancing of consecutive coordinates, calculation of independent coordinates and determination of corrected distances and azimuth of sides.

Consecutive coordinates:

Consecutive coordinates of a station is designated by its departure and latitude from its previous station as origin. Departure of a traverse side is defined as its component perpendicular to the reference meridian and the component of the traverse side along or parallel to the reference meridian is known as latitude. Thus, if l and q are the length and azimuth of a traverse side, then departure and latitude of the side are given by l sin q and l cosine q respectively. The algebraic sign of the departure and latitude of a traverse side depends on its azimuth value thus on the sign of the trigonometric parameters associated with these. the sides AB has length and bearing as 442.56m and 34° 52' respectively. Thus, its departure and latitude are 253.0m (442.56m sine 34° 52') and 363.11m (442.56 cosine 34° 52') respectively. Similarly, the departure and latitude of the sides BC (478.23m, 112°) is 441.93m and 182.75m respectively.



Independent coordinates:

The departure and latitude of a station with reference to an origin are known as independent coordinates. The independent coorinate of at least one of the stations with reference to the considered origin is required to be known a priori. Thus, if the independent coordinates of any station, say i, is known to be **(X_i, Y_i)**, the independent coordinates of another station say j, **(X_j ,Y_j)** can be determined by using the following relations:

$$X_j = X_i + x_{ij}$$

$$Y_j = Y_i + y_{ij}$$

Where (x_{ij}, y_{ij}) are the departure and latitude of the side ij.

Adjustment of a traverse:

Traverse adjustment is required to provide a mathematically closed figure by making closure in latitudes as well as closed departures. Methods for adjustment of traverse are classified into two types: approximate methods and rigorous methods.

The approximate methods for traverse adjustment are based on the conditions prevailing in the combinations of linear and angular precision in the observations. On these basis, conditions are divided into three types.

1. Precision in angular measurement is higher than in linear measurement;
2. Precision in angular as well as in linear measurements are same;
3. Precision in linear measurement is more than that in angular measurement.

The method of least square provides the most rigorous method of traverse adjustment, which allows variation in precision in the observations, minimizes random variations in the observations, provides the best estimates for positions of all traverse stations, and yields statistics relative to the accuracies of adjusted observations and positions. This method does require more of a computational effort than the approximate adjustment. But, the results are well worth effort. However, the method is beyond the scope of discussion of this course and further discussion on adjustment of traverse are based on approximate methods.

The following are the different methods for adjusting a traverse:

1. Bowdith method
2. Transit method
3. Axis rule
4. Graphical method
5.

Transit Method:

This method is developed for balancing a traverse in which angles are measured with a higher degree of precision than the lengths of the sides. It is based on the assumption that the error in departure (or latitude) of a traverse side is proportional to its departure (or latitude). Thus, according to the transit rule, the corrections to the departure (or latitude) of a traverse side can be calculated by using

$$\delta d_{ij} = \frac{|d_{ij}|}{D} \times dD \quad \text{and}$$

$$\delta l_{ij} = -\frac{|l_{ij}|}{L} \times dL$$

where

d_{ij} = Correction in departure of a traverse side ij

l_{ij} = Correction in latitude of a traverse side ij

dD = total error in departure (or Algebric sum of the departures of all sides of the traverse)

dL = total error in latitude (or Algebric sum of the latitudes of all sides of the traverse)

d_{ij} = departure of the traverse side ij

l_{ij} = latitude of the traverse side ij

D = Arithmetic sum of the departures of all the sides of the traverse

L = Arithmetic sum of the latitudes of all the sides of the traverse

The corrections in transit rule do not take into consideration of the algebraic nature of the eparture (or latitude) of traverse sides. This made the transit rule valid when the traverse lines are parallel with the grid system used for the traverse computations. So, further discussion regarding transit rule is being restricted in this course work.

Bowditch method:

The Bowditch's method is used when both the linear and angular measurements are compatible to each other, i.e., they are of equal precision. The corrections may be applied either analytically or may be carried out graphically. This method of balancing of traverse is widely prevalent and most commonly used.

Analytical method of correction by Bowditch's rule can be applied either to its coordinates directly or to the departure (or latitude) of a traverse side.

(a) The corrections to the coordinates can be calculated by using

$$\delta X_i = \frac{L_i}{L} \times dX \quad \text{and} \quad \delta Y_i = \frac{L_i}{L} \times dY$$

where

δX_i = Correction to X_i coordinates of a station i;

δY_i = Correction to Y_i coordinates of a station i;

dX = total closure correction of the traverse in departure;

dY = total closure correction of the traverse in latitude;

L_i = distance from the initial station to the station i, measured along the sides of the traverse;

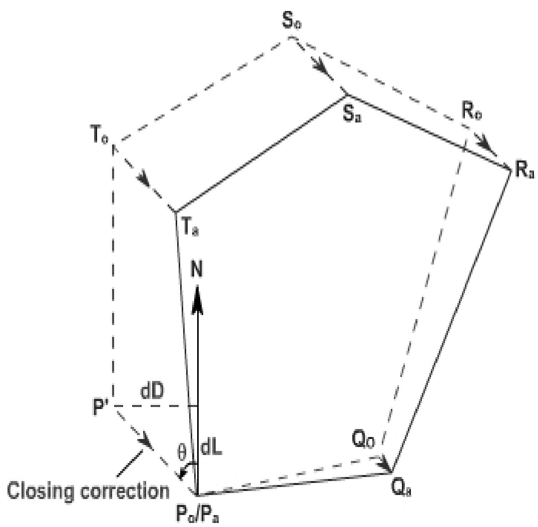
L = perimeter of the traverse

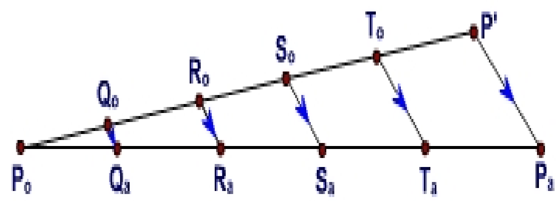
Graphical method:

For rough surveys or traverse of small area, adjustment can also be carried out graphically. In this method of balancing, the locations and thus the coordinates of the stations are adjusted directly. Thus, the amount of correction at any station is proportional to its distance from the initial station .

Let P_o Q_o R_o S_o T_o P' is the graphical plot of a closed-loop traverse PQRSTP. The observed length and direction of traverse sides are such that it fails to get balanced and is depicted in its graphical presentation by an amount P_o P'. Thus, the closing error of the traverse is P_o P' The error P_o P' is to be distributed to all the sides of the traverse in such a way that the traverse gets closed i.e., P' gets coincides with P_o in its plot. This is carried out by shifting the positions of the station graphically. In order to obtain the length and direction of shifting of the plotted position of stations, first a straight line is required to be drawn, at some scale, representing the perimeter of the plotted traverse. In this case, a horizontal line P_oP' is drawn Mark the traverse stations on this line such as Q_o, R_o, S_o and T_o in such a way that distance between them represent the length of the traverse sides at the chosen scale. At the terminating end of the line i.e., at P', a line P' P a is drawn parallel to the correction for closure and length equal to the amount of error as depicted in the plot of traverse. Now, join P_o to P_a and draw lines parallel to P' P_a at points Q_o, R_o, S_o and T_o. The length and direction of Q_o Q_a, R_o R_a, S_o S_a and T_o T_a represent the length and direction of errors at Q_o, R_o, S_o and T_o respectively. So, shifting equal to Q_o Q_a , R_o R_a, S_o S_a and T_o T_a and in the same direction are applied as correction to the positions of stations Q_o, R_o, S_o and $T_o$respectively. These shifting provide the corrected positions of the stations as to Q_a, R_a,

S_a,T_a and P_a. Joining these corrected positions of the stations provide the adjusted traverse P_a Q_a R_a, S_a T_a .





Omitted measurements:

If the length and/or bearing of any side of a closed traverse gets omitted, that can be computed analytically by applying.

S departures = (X_n - X_1)

S latitudes = (Y_n - Y_1)

where (X_1 ,Y_1) and (X_n ,Y_n) are the independent coordinates of initial and terminating control stations. Thus, in any traverse, maximum two omitted parameters can be computed from two available equations. However, no check on the accuracy of the field work can be done nor can the traverse be balanced as errors, if any, present in the survey work get propagated into the computed values of the omitted quantities. So, computation of omitted measurement, if any, is done for during computation of traverses of lower order.

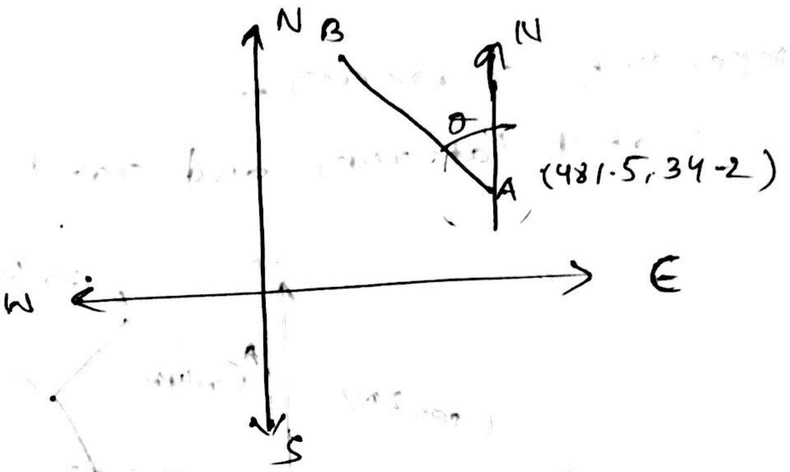
Types of Omitted Measurements:

The number of omitted measurement may be one i.e., the length or bearing of any side of a traverse.

1. Length and bearing of one side omitted
2. Length of one side and bearing of adjacent side omitted.
3. Lengths of two adjacent sides are omitted
4. Bearings of two adjacent sides are omitted.
5. Length or bearings of two sides or omitted(which are not adjacent to each other)

The coordinates of two points A and B are as follows. Find the length and bearing.

Point	Coordinates (m) N	E
A	481.5	324.2
B	607.6	75.4



Length of AB $= \sqrt{(607.6 - 481.5)^2 + (324.2 - 75.4)^2}$

$= 278.93\,m$

$\tan\theta = \frac{324.2 - 75.4}{607.6 - 481.5}$

$\theta = 63^\circ 7' 21.41''$

W.C.B Bearing $= 296^\circ 52' 38.59''$

R.B $=$ N $63^\circ 7' 21.41''$ W

Two points A and B as following coordinates. Find the length and bearing of AB.

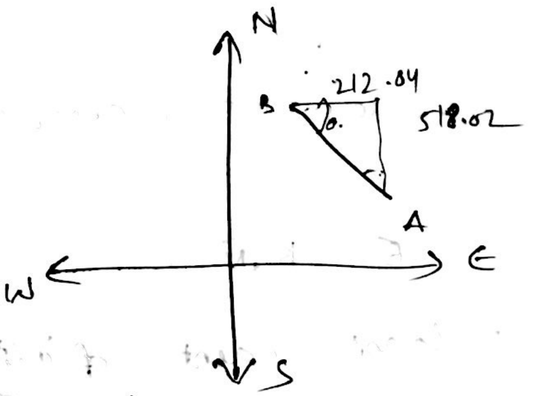
Point	N	E
A	788.35	630.45
B	1306.37	418.41 m

Length of AB = $\sqrt{(788.35 - 630.45)^2 + (1306.37 - 418.41)^2}$

= 901.89 m.

$\tan\theta = \dfrac{788.35 - 630.45}{1306.37 - 418.41}$

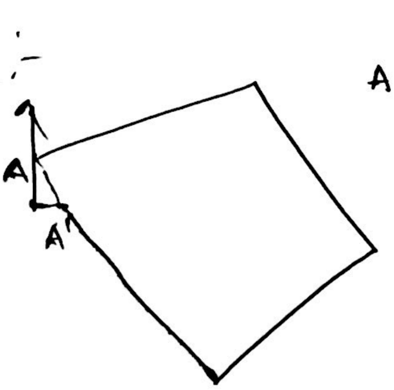
$\theta = 39^\circ 13' 37.26''$



$\theta = 67^\circ 44' 2''$

In a traverse

Closing error :-



$AA' = \sqrt{\Sigma L^2 + \Sigma D^2}$

$\Sigma(D)$

$\tan\theta = \dfrac{\Sigma D}{\Sigma L}$

In a traverse Lattitudes and departures are observed to be $\Sigma L = 1.45$ m $\Sigma D = -2.16$ m. what ale the length and bearing of a closing Error.

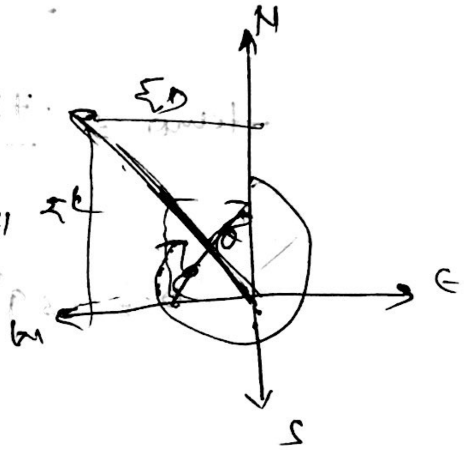
Length of closing error $= \sqrt{\Sigma L^2 + \Sigma D^2}$

$= \sqrt{1.45^2 + (-2.16)^2}$

$= 2.601$

$\theta = 56^\circ 7' 36.06''$

bearing $= 203^\circ 52' 23.94''$

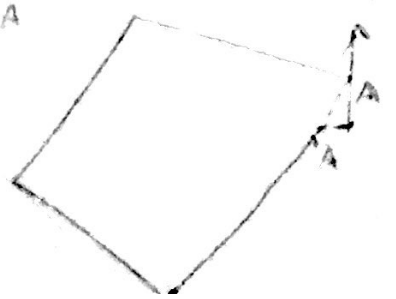


Permissible closing error of a traverse

$E = K\sqrt{N}$

K = least count of instrument

N = No. of Sides of a traverse



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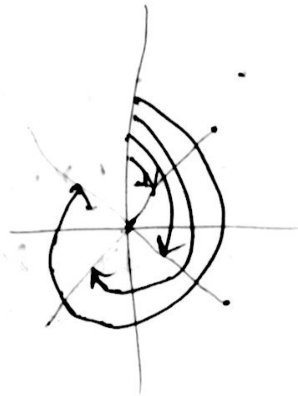
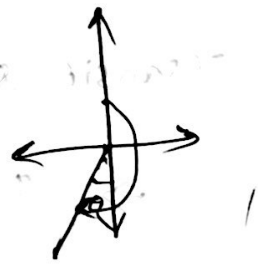
A traverse survey was conducted and the data obtained was given below. Find the magnitude and direction of closing error if ending.

Line	Length	Bearing
AB	156.5	78° 40'
BC	178.2	152° 32'
CD	234.8	251° 18'
DA	202.6	356° 15'



Latitude	Departure
30.75	153.44
−158.11	82.29
−75.27	−222.83
202.16	−13.25
−0.470	+0.06

Length of closing error



$$= \sqrt{(0.47)^2 + (0.06)^2}$$

$$= 0.473\,m$$

$$\tan\theta = \frac{0.06}{0.47}$$

$$\theta = \tan^{-1}\left(\frac{+0.06}{-0.47}\right) = 7^\circ 16' 30''$$

$$\text{bearing} = 7^\circ 16' 30'' + 180^\circ$$

$$= 187^\circ 16' 30''$$

Scanned by CamScanner

Balancing a traverse :-

(1) Arbitary method.
(2) Graphical method.
(3) Bowditch rule → Compass rule.
(4) Transit rule
(5) Axis rule

Bowditch rule

Both angular and linear measurements are made with equal precision.

Correction to lattitude/ departure = Algebraic Sum of lattitude/ Departure X. $\frac{\text{Length of that line}}{\text{Perimeter of that traverse}}$

While making the adjustment with bowditch rule lengths are changed less and bearings are changed more.

Transit rule :-

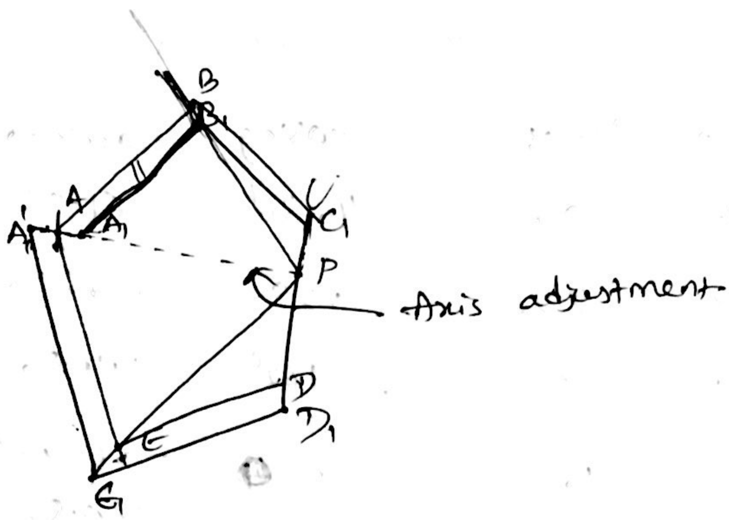
→ In Transit rule Angular measurements are made with more precise than linear measurements.

→ Correction to lattitude/departure ⇒ Algebraic Sum of lattitude/Departure × $\frac{\text{Lattitude/Departure of that line}}{\text{Arithmetic Sum of L/D}}$

⇒ Angles are changed less, and lengths are changed more.

Axis Rule :-

Corrections applied to only linear measurements.



Correction to length of a line =

$$\Rightarrow \frac{\text{one half of closing error}}{\text{Length of axis}} \times \text{Length of that line}$$

Correction to length of line AB

$= AB - A_1B_1$

From similar triangles ΔABP & ΔA_1B_1P.

$$\frac{AB}{A_1B_1} = \frac{AP}{A_1P} \Rightarrow AB = A_1B_1 \times \frac{AP}{A_1P}$$

$$C.L \Rightarrow AB = A_1B_1 \times \frac{AP}{A_1P} - A_1B_1$$

$$= A_1B_1 \left(\frac{AP - A_1P}{A_1P}\right) = A_1B_1 \times \frac{AA_1}{A_1P}$$

Scanned by CamScanner

Using bowditch method and transit method correct the traverse Calculate Corrected lattitude and departure of a closing traverse and also Calculate the length and bearing of a line

Line	length	bearing	Lattitude	Departure
AB	90	46°30'	61.95	65.28
BC	220	72°	67.98	209.23
CD	152	162°	-144.56	46.97
DE	160	238	-102.84	-122.567
				-200.57
EA	234	301°	120.52	-197.148
			118.845	
	ΣL = 856		Σ = 3.04	Σ = -1.65

Correction lattitude for AB :-

$AB = 3.04 \times \frac{90}{856} = -0.319$

B.C = -0.781

CD = -0.539

DE = -0.568

EA = -0.831

Departure

0.173

0.424

0.292

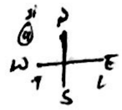
0.308

0.451

Corrected lattitude	Corrected departure
61.631	65.453
67.199	209.654
-145.099	47.262
-103.408	-122.259
119.689	-200.119
0	0

Corrected length	Corrected bearing
89.89	46°43'20''
220.156	~~17°46'19''~~ 72°13'41.28''
152.602	18°2'30''
160.12	49°46'30.33''
233.180	59°7'1''

* A Traverse was run with a prismatic compass And the length and Bearings of lines are observe given below. check weather or Not the traverse closes if not balance using Bowditch rule And Transit rule.



Left side departure Negitive

Arithmetic - + (only)

Line	length	Bearing
AB	105.8	N40°45'W
BC	142.5	N51°30'E
CD	188.8	S46°15'E
DA	188.9	S76°45'W

Line	Length	Bearing	Lattitude	Departure
AB	105.8	319°15'	80.150	-69.06
BC	142.5	51°30'	88.708	111.522
CD	188.8	131°45'	-125.718	140.856
DA	188.9	256°45'	-43.29	-183.871
	626		-0.156	-0.554

Correction on Lattitude

$AB = -0.156 \times \frac{105.8}{626} = +0.026$

BC = +0.355

CD = +0.0470

DA = +0.04707

Correction on departure

0.094

0.126

0.168

DA = 0.167

Length of closing end

$= \sqrt{0.156^2 + 0.554^2}$

$= 0.577$

$\tan\theta = \frac{0.554}{0.156}$

$= 74°78'W$

Corrected Lattitude

Ommitted measurements

* missing measurements

(1) when length, bearing(θ), both values of lines are missing.

(2) lengths of two adjecent sides are missing.

(3) Bearings of two adjecent sides are missing.

(4) length of one side bearing of adjecent sides are missing.

* the following table gives the lengths and Bearings of the four lines of a closed traverse ABCDE. determine the length and Bearing of EA.

Line	length	Bearing	lattitude	Departure
AB	194.1	85°30'	15.119	193.502
BC	201.2	15°0'	194.344	52.074
CD	165.4	285°30'	44.201	-159.384
DE	172.6	195°30'	-166.323	-46.125
EA	l ?	? θ	$l\cos\theta$	$L\sin\theta$

Σ lattitudes = 0

$l\cos\theta = -87.451$

Σ Departure = 0

$L\sin\theta = -40.067$

$l^2\sin^2\theta + l^2\cos^2\theta = 0$

$l^2 = 9252.882$

$l = 96.192m.$

$\frac{l\sin\theta}{l\cos\theta} = \frac{40.065}{87.451}$

$\theta = 24°36'53''$

Bearing of EA $= 204°36'53''$

(2)

Line	Length	Bearing	Latitude	Departure
AB	100	314°30'	70.091	-71.325
BC	605	0°30'	602.974	57.986 / 8.2779
CD	95	88°20'	2.76	94.95
DA	-	-	$l\cos\theta$	$l\sin\theta$

$\Sigma L = 0$

$l\cos\theta = -677.065 \rightarrow (1)$

$\Sigma D = 0$

$l\sin\theta = -81.620 \rightarrow (2)$

$l^2\sin^2\theta + l^2\cos^2\theta = 0$

$l^2 = 462367.82$

$l = 679.970m.$

$\frac{l\sin\theta}{l\cos\theta} = \frac{-81.620}{-675.065}$

$\theta = 6°53'46''$

Bearing of DA = 186°53'46".

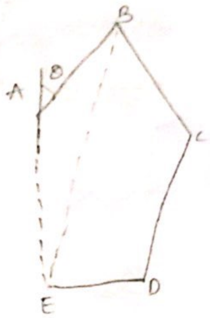
* A traverse made data given below contains the lengths and interior angles of a traverse PQRSTP. the bearing of the line was observed and recorded as S36°12'30" E. check the traverse and closing error if any. find the latitude and departure by Transit method and Bowditch rule.

Line	Length	Station	Included angle
		P	131°14'30"
PQ	102.6		
QR	98.4	Q	84°19'25"
RS	110.8	R	116°35'25"
ST	82.8	S	119°58'05"
TP	113.29	T	87°54'05"
			540°1'30"

correction angles	Corrected Included angles	Bearing
$-0°0'18''$	$131°14'12''$	$143°47'30''$
$-0°0'18''$	$84°19'7''$	~~321°54'18''~~ $48°6'37''$
$-0°0'18''$	$116°35'7''$	$344°41'44''$
$-0°0'18''$	$119°57'47''$	$284°39'31''$
$-0°0'18''$	$87°53'47''$.	$192°33'18''$

Lattitude	Departure
-82.785	60.608
~~9.741~~	~~97.916~~
65.701	73.25
106.8706	-29.245
20.95330	-80.104
-110.5809	-24.62661

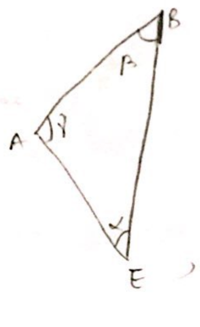
① when length ~~and~~ Bearing both are of the same line is missing



$$l_{AB} + L_{BC} + l_{DC} + l\cos\theta = 0$$

$$D_{AB} + D_{BC} + D_{CD} + l\sin\theta = 0.$$

when length of one side and bearing of adjecent side are missing.



$$\frac{AB}{\sin\alpha} = \frac{BE}{\sin\gamma} = \frac{AE}{\sin\beta}$$

$$\sin\gamma = \frac{\sin\alpha \times BE}{AB}$$

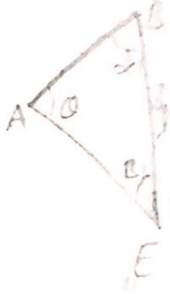
(iii) lengths of two adjecent sides are missing.

$$\frac{BE}{\sin\theta} = \frac{AE}{\sin\alpha} = \frac{AB}{\sin B}.$$

$$AB = \frac{BE}{\sin A} \times \sin E$$

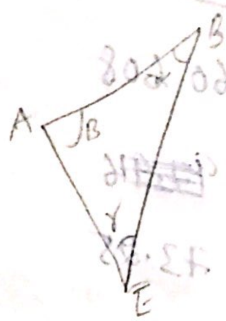
$$AF = \frac{BE}{\sin A} \times \sin B$$

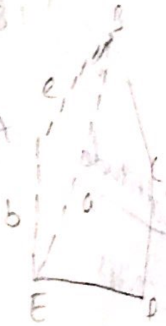
from $\triangle ABE$



(iv) Bearings are two adjecent sides missing.

$$\frac{AE}{\sin\alpha} = \frac{BE}{\sin A} = \frac{AB}{\sin\theta}$$

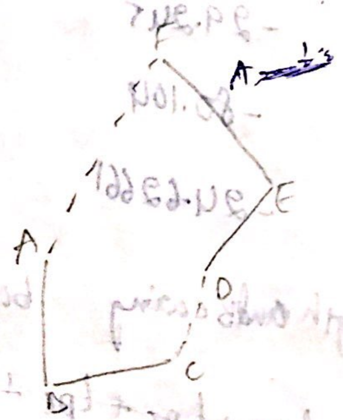




from $\triangle ABE$

$$\Delta = \sqrt{s(s-a)(s-b)(s-c)}$$

$$s = \frac{a+b+c}{2},$$



$A = \frac{1}{2}ab\sin c$

$\frac{1}{2}$

UNIT-II
TACHEOMETRY

Generally, horizontal distances are measured by direct methods, i.e. laying of chains or tapes on ground. These methods are not always convenient if the ground is undulating, rough, difficult and inaccessible. Under these circumstances, indirect methods are used to obtain distances. One such method is "Tacheometry". Using tacheometric methods, elevations can also be determined. It is in fact a branch of angular surveying in which both the horizontal and vertical positions of points are determined from the instrumental observations, the chain surveys being entirely eliminated.

Advantages of Tacheometry:

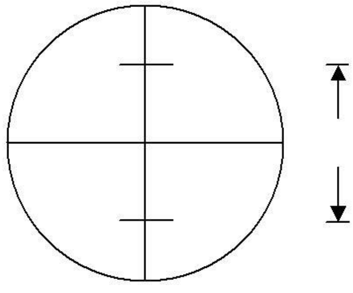
Since both the quantities viz., horizontal distances and the difference of elevations are determined indirectly in tacheometric surveying, it has a number of advantages over the direct methods of measurement of these quantities.

In terrain where direct methods are not convenient, tachometric methods can be used. Tacheometric methods are convenient for reconnaissance surveys of routes, for hydrographic surveying and for filling in details in a traverse. There is considerable saving in time and money with the use of tacheometric methods.

Tacheometer:

A tacheometer is similar to an ordinary transit theodolite, generally a vernier theodolite itself, fitted with two stadia wires in addition to the central cross-hair. The stadia diaphragm has three horizontal hairs viz., a central horizontal hair and upper and lower stadia hairs. The upper and lower stadia hairs are equidistant from the central horizontal hair. Stadia hairs are sometimes called stadia lines.

For the purpose of tacheometry, even though an ordinary transit can be employed, accuracy and speed are increased if the instrument is specially designed for the work. The magnification of the telescope in tacheometer should be at least 20 to 30 diameters, with an aperture of at least 40 mm for a sufficiently bright image. The magnifying power of the eyepiece is also greater than for an ordinary transit to produce a clearer image of a staff held far away. Further, the altitude bubble is made more sensitive, since vertical angles form an important part of the data for calculation of elevation differences. Figure 2.1 shows a more commonly used pattern of stadia diaphragm.



Stadia Diaphragm

Stadia Rods

For short sights of about 100 m or less, an ordinary levelling staff may be used. For long sights, special staff called stadia rod is generally used. The graduations are in bold type (face about 50 mm to 150 mm wide and 15 mm to 60 mm thick) and the stadia rod is 3 m to 5 m long. To keep the staff or stadia rod vertical, a small circular spirit level is fitted on its backside. It is hinged to fold up.

Systems of Tacheometric Measurements

The underlying principle common to various systems of tacheometry is that the horizontal distance between an instrument station *P* and a point *Q*, as well as the elevation of *Q* relative to the instrument, can be deduced from

(a) the angle at *P* subtended by a known small distance at *Q*, and

(b) the vertical angle from *P* to *Q*.

This basic principle is applied in different ways in different tacheometric methods. There are basically three systems of tacheometric measurements such as stadia system, tangential system, and substense bar system.

Stadia System

This is the more extensively used system of tacheometry particularly for detailed work, such as those required in engineering surveys. In this system, a tacheometer is first set up at a station, say *P*, and a staff is held at station *Q*. The difference of upper hair reading and lower hair reading is called staff intercept *s*. All the three hairs including central cross hair are read, and *s* is determined. Vertical angle, θ, corresponding to the central hair is also measured. These measurements enable determination of horizontal distance between *P* and *Q* and their difference in elevation. There are two different types of systems in stadia method. These are as follows :

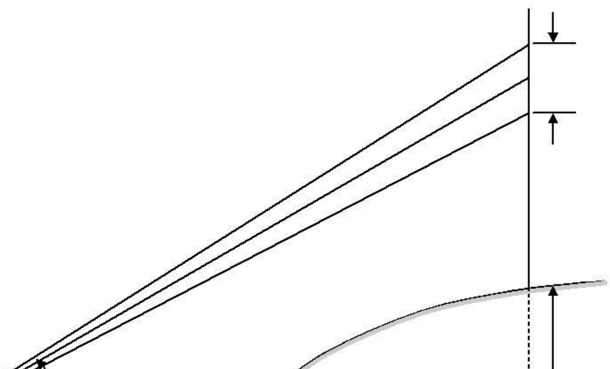
Fixed Hair Method:

In this method, the distance between the upper hair and lower hair, i.e. stadia interval *i*, on the diaphragm of the lens system is fixed. The staff intercept *s*, therefore, changes according to the distance *D* and vertical angle θ.

Movable Hair Method:

In this method, the stadia interval '*i*' can be changed. The stadia hairs can be moved vertically up and down by using micro meter screws. The staff intercept *s*, in this case, is kept fixed. Two vanes (targets) are fixed on the staff at a fixed interval of 2 m or 3 m.

The fixed hair method is the one which is commonly used and, unless otherwise mentioned, stadia method means fixed hair method. Movable hair method is not in common use due to difficulties in determining the value of *i* accurately.



s

Q

θ

h

P D

The Stadia System

Tangential System

In this system, observations are not taken on stadia hairs. Instead vertical angles θ1 and θ2 to the two targets fixed on a staff are recorded (Figure 2.3). The targets are at a fixed distance s. Vertical angles θ1, θ2 and staff intercept s enable horizontal distance D and the difference of elevations to be determined. Advanced Survey In Figure 2.3, both the vertical angles θ1 and θ2 are the angles of elevations. There may be two more cases where either both the angles may be angles of depression or one of the angles is angle of elevation and another is angle of depression.

Subtense Bar System:

Subtense bar is a bar of fixed length generally 2 m fitted with two targets at the ends. The targets are at equal distance apart from the centre. The subtense bar can be fixed on a tripod stand and is kept horizontal. angle α subtended by the two targets at station P is measured by a theodolite. The distance s between the targets and the angle α enable the distance D between station P and Q to be determined.

Basic Principle of Stadia Method:

We will derive distance and elevation formulae for fixed hair method assuming line of sight as horizontal and considering an external focusing type telescope. O is the optical centre of the object glass. The three stadia hairs are a,
b and *c* and the corresponding readings on staff are *A*, *B* and *C*. Length of image of *AB* is *ab*. The other terms used in this figure are

f = focal length of the object glass,

i = stadia hair interval = *ab*,

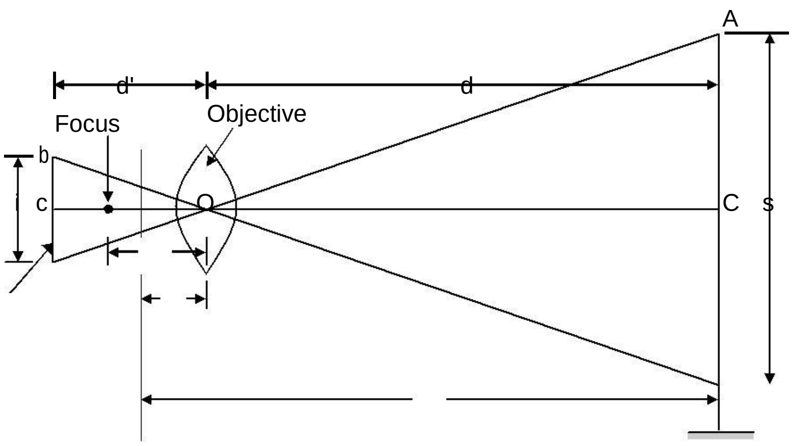
s = staff intercept = *AB*,

c = distance from *O* to the vertical axis of the instrument,

d = distance from *O* to the staff,

d' = distance from *O* to the plane of the diaphragm, and *D* = horizontal

distance from the vertical axis to the staff.



From similar triangles AOB and aob, we get

$$d/s=d/i$$

And from lens formula,

$$\frac{1}{f} = \frac{1}{d'} + \frac{1}{d}$$

Combining the two equations, we get

$$d = \frac{fs}{i} + f$$

Adding c to both the sides

$$D = \frac{fs}{i} + (f + c)$$

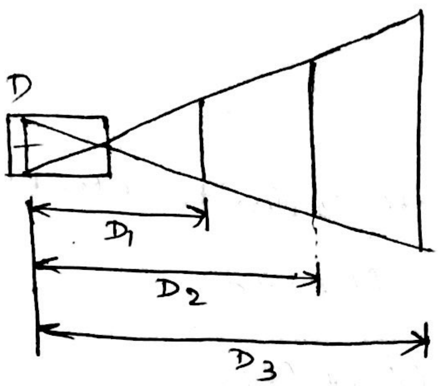
or $$D = Ks + C,$$

Where K is called as multiplying constant, and is generally kept as 100.
C is called as addiitive constant.

TACHEOMETRY

30/01/17

(i) principle of stadia tacheometry :-

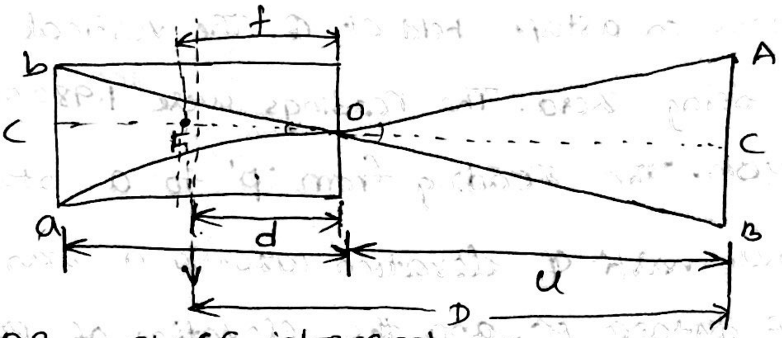


Staff intercept is proportional to distance beteween staff and Instrument.

$D \alpha S$ α

$D = KS + C$.

measurement of horizontal distance when line of sight is horizontal hence staff held vertical.



AB = staff intercept = s

ab = stadia interval.

u = distance from optical centre of object piece to staff.

v = distance from optical centre of object piece to diaphragram.

f = distance b/w focus to optical centre of objective

$\angle aob = \angle AOB$ $\Rightarrow \frac{ba}{BA} = \frac{v}{u}$

$\Delta abob \simeq \Delta AOB$

$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$$

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v} \quad \text{—(i)}$$

multiplying eq(i) with 'uf'

$$u = f + \frac{uf}{v}$$

$$u = f + \left(\frac{BA}{ba}\right) f$$

$$u = f + \left(\frac{s}{i}\right) f$$

D = Distance from staff station to instrument centre.

$$D = u + d = f + f\left(\frac{s}{i}\right) + d$$

$$= s\left(\frac{f}{i}\right) + (f + d)$$

$$\boxed{D = KS + C}$$

$$\boxed{K = \frac{f}{i}, \quad C = f + d}$$

1) A tacheometer was setup at station 'p' and observation were taken on a staff held at Q. The vertical circle reading being zero. The readings were 1.980 m, 1.660 m and 1.340 m. The reading from 'p' to a staff held at Bench mark of elevation 1020.50 m was 2.85 m. Find the distance PQ and the elevation of point 'Q'. The instrument constants were 100 & 0.5.

Given, $K = 100$, $C = 0.5$

Upper cross hair reading ⇒ 1.340 m

Lower cross hair reading ⇒ 1.980 m

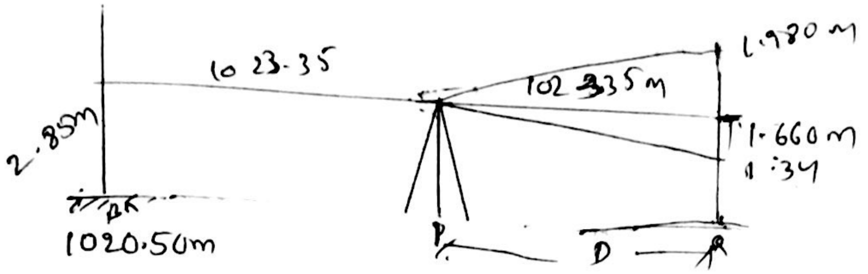
Staff intercept ⇒ 1.980 − 1.340

⇒ 0.640 m

$$D = KS + C$$

$$= 100 \times 0.640 + 0.5$$

$$= 64.5 \text{ m}$$



$HI = 1020.50 + 2.85 = 1023.35$

$R.L = 1023.35 - 1.660 = 1021.69$

(2) The stadia reading with sight horizontal taken on a vertical staff 60m away from the tacheometer were 1.280 m and 1.785m. The focal length of objective lens was 30cm and differen distance between objective lense and vertical axis of tacheometer was 20cm. Find the stadia intercept.

$D = 60m$, upper cross hair reading $= 1.280m$

Lower cross hair reading $= 1.785m$

Focal length, $f = 30cm$.

$D = Ks + C \Rightarrow 60 = K(0.505) + (0.3 + 0.2)$ $(\because C = f + d)$

$\Rightarrow K(0.505) = 59.5$

$K = \frac{59.5}{0.505} = 117.82$

$K = \frac{f}{i} = 117.82 \Rightarrow i = \frac{0.3}{117.82} = 0.0025\ m$

$= 0.3\ cm$

(3) Find the stadia constants K and C from the following data.

Inst. at	observation	Distance	staff Readings
P	Q	50m	1.354, 1.603, 1.852
	R	100m	1.15, 1.65, 2.149

$S_1 = 1.852 - 1.354 = 0.498$ m.

$S_2 = 2.149 - 1.15 = 0.999$ m

$D_1 = KS_1 + C$

$\Rightarrow 50 = K(0.498) + C \quad -(i)$

$D_2 = KS_2 + C$

$100 = K(0.999) + C \quad -(ii)$

$K(0.498) + C - 50 = 0$

$K(0.999) + C - 100 = 0$

(−) (−) (+)

$K = +99.80, \; C = +0.299$

Determine the tacheometeric constants from the following readings.

Distance of Staff from Vertical Axis.	Stadia readings. Lower	Upper.
50 m	1.115	1.350
135 m	1.215	2.315.

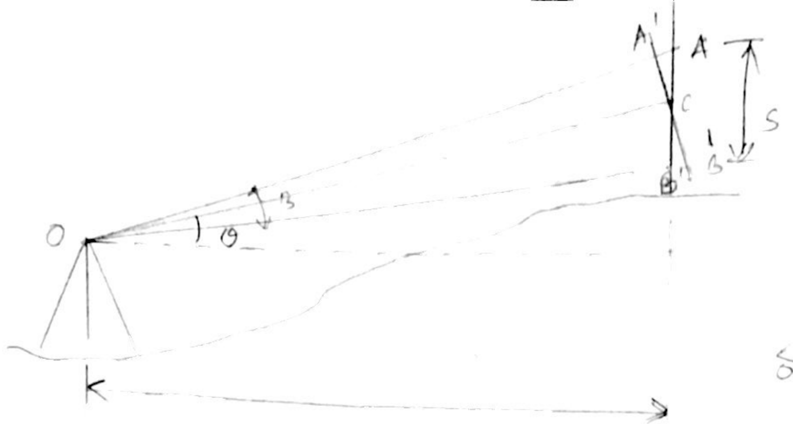
$S_1 = 0.235, \; S_2 = 1.1$

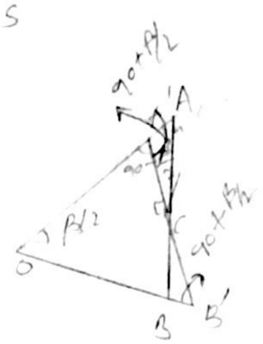
$D_1 = KS_1 + C \Rightarrow 50 = K(0.235) + C \quad -(i)$

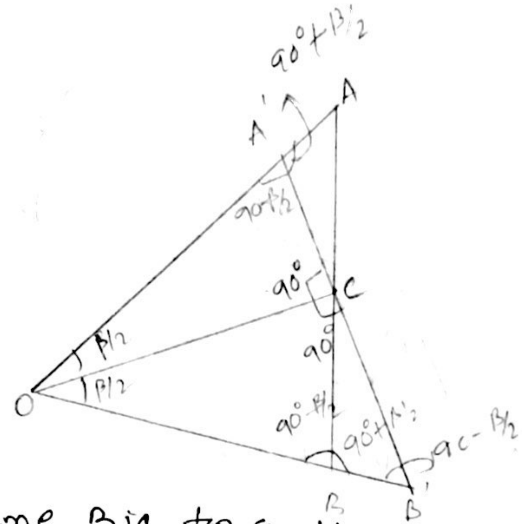
$D_2 = KS_2 + C \Rightarrow 135 = K(1.1) + C \quad -(ii)$

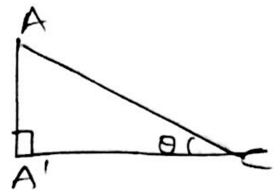
By solving (i) & (ii)

$K = 98.265 \quad C = 26.907$









Assume B is too small,

$\frac{B}{2}$ is negligible

From $\triangle$le. $AA'C$, $\angle AA'C = 90^\circ$ $\cos\theta = \frac{AC}{CA'}$

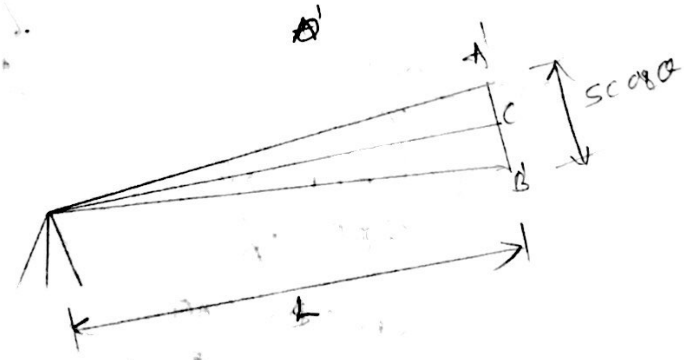
$\cos\theta = \frac{A'C}{CA}$ $CA' = \frac{AC}{\cos\theta}$

$A'C = AC\cos\theta$. , $B'C = AC\cos\theta$. , $A'C + B'C = 2AC\cos\theta$

$B'C = AC\cos\theta$. $\Rightarrow$ $A'B' = 2AC\cos\theta$

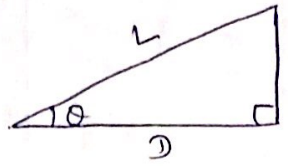
$\Rightarrow$ $A'B' = AB\cos\theta$

$= S\cos\theta$.



$L = ks + c$

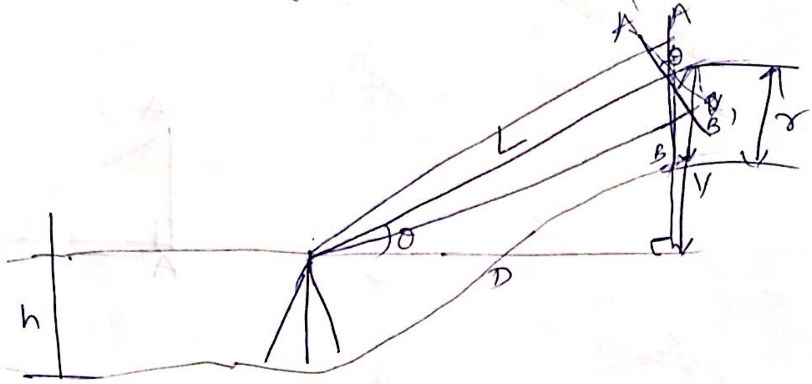
$L = ks' + c$; $L = ks\cos\theta + c$



$\cos\theta = \frac{D}{L}$ $D = L\cos\theta$

$= (KS\cos\theta + C)\cos\theta$

$= KS\cos^2\theta + C\cos\theta.$

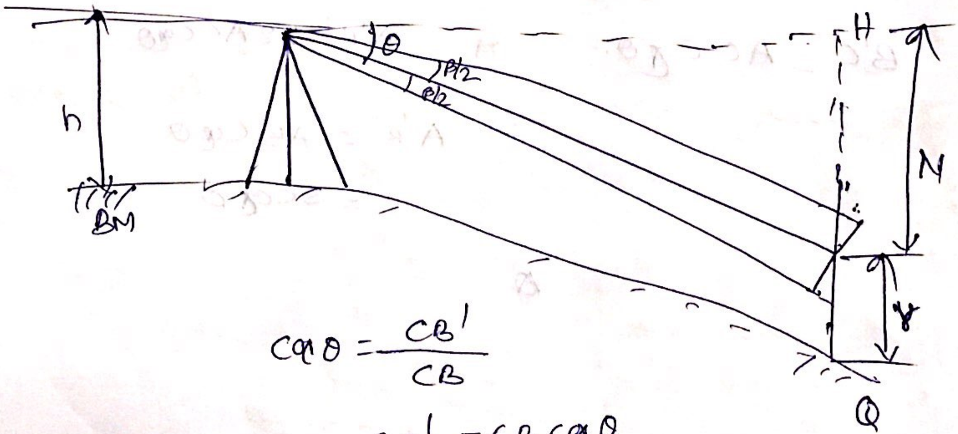


$\sin\theta = \frac{V}{L} \Rightarrow$ $V = L\sin\theta$

$L = KS' + C$

$L = KS\cos\theta + C$

RL of Q = BM + h + V − r.



$\cos\theta = \frac{CB'}{CB}$

$CB' = CB\cos\theta$

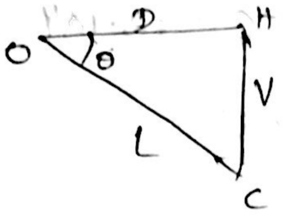
$\cos\theta = \frac{CA'}{AC}$

$CA' = AC\cos\theta$

$A'B' = A'C + B'C$

$= AC\cos\theta + BC\cos\theta.$

$= AB\cos\theta$



$\triangle$le OCH,

$\cos\theta = \frac{D}{L}$

$D = L\cos\theta$

$D = KS\cos^2\theta + C\cos\theta$

$\sin\theta = \frac{V}{L}$

$V = K \cdot S\cos\theta \cdot \sin\theta + C\sin\theta.$

R.L of Q = BM + h − V − r.

(11) A Levelling staff is held vertical at a distance of 104 m and 307 m from the tacheometer axis and staff intercepts for horizontal sights are 0.850 m, and 2.750 m respectively find the instrument constants. when instrument was setup at 'p' and staff at Q. The telescope was depressed at an angle of 8.5 degrees with the horizontal and the staff readings were 2.780 m, 1.845 m and 0.955 m. Find the R.L of Q and it's horizontal distance from 'p'. The height of instrument at 'p' is 1.25 m and RL of 'p' is 435 m.

$D_1 = 104\,m$, $D_2 = 307\,m$

$D = KS + C.$

$S_1 = 0.85\,m$, $S_2 = 2.75\,m$

$D_1 = KS_1 + C \Rightarrow 104 = K(0.850) + C$

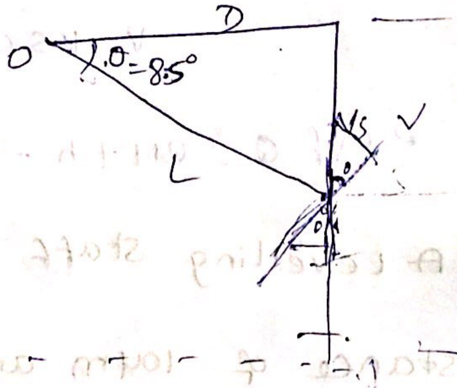
$D_2 = KS_2 + C \Rightarrow 307 = K(2.75) + C$

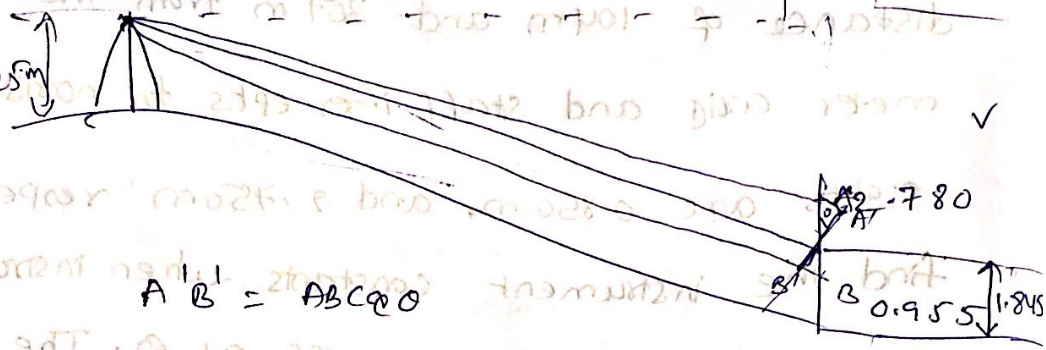
K = 106.842 , C = 13.184

Staff is held vertical

h = 1.25 m

BM = 435 m





$A'B' = AB\cos\theta$

$= S\cos\theta$

$= (2.780 - 0.955)\cos(8.5°)$

$A'B' = 1.804$ m

$L = KS_1 + C$

$= KS\cos\theta + C$

$= 106.842 \times 1.804 \times \cos(8.5) + 13.184$

$L = 203.929$ m

$D = L\cos\theta = 205.929\cos(8.5°)$

$= 203.667$ m.

$V = l\sin\theta = 30.438$ m

R.L of Q = BM + h − V − r

$425 + 1.25 - 30.438 - 1.845 = 4$[illegible]

07/02/17

(1) points A and B are in opposite sides of a river about 100 m wide. A tacheometer is set up on point 'B' on the line BA produced. and staff readings are taken at A and B. The instrument is then shifted to a point 'Q' on the line AB produced. and again staff readings are taken.

Instrument at	Staff at	Readings.
P	A	1.560, 1.420, 1.280
	B	1.000, 0.400, below ground
Q	A	3.240, 2.600, 1.960
	B.	1.600, 1.440, 1.280.

(a) what is the true difference in levels of A and B. (b) what is the collimation error.

Take K = 100, C = 0 neglect error due to curvature and refraction

Sol)

$D = KS + C$

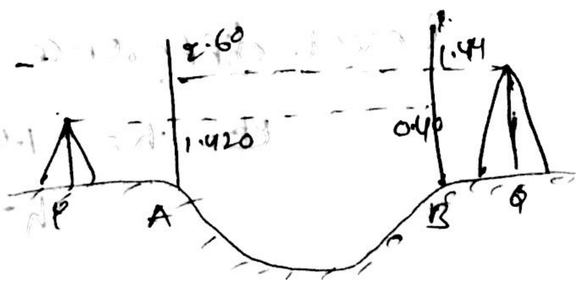
$S = 1.560 - 1.280 = 0.28.$

$D_A = 100 \times 0.28 + 0$

$D_A = 28 \text{ m}$

$D_B = 100$

(1) ←



$P_B = 100(1-(-0.20))$

$= 120$ m.

$Q_A S = 3.24 - 1.96$

$= 1.28$

$Q_A = 100 \times 1.28 + 0$

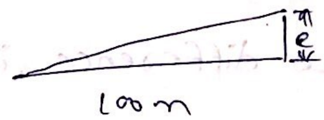
$Q_A = 128$ m

$Q_B \Rightarrow \quad S = 1.6 - 1.28 = 0.32$ m

$Q_B = 100 \times 0.32 + 0 \Rightarrow 32$ m.

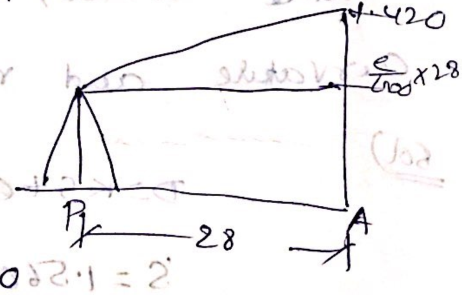
Let us assume collimation error

'e' is for 100 m. Assume collimation error is inclined upwards.



When instrument at 'P', correct staff reading at A

$= 1.420 - \frac{e}{100} \times 28 = 1.420 - 0.28e$



When instrument at P

correct staff reading B.

$= 0.400 - \frac{e}{100} \times 120$

$= 0.4 - 1.2e.$

Level difference between A & B

$h = 1.42 - 0.28e - (0.4 - 1.2e)$

$h = 1.82 + 0.92e. \rightarrow (1)$

When instrument at Q, correct staff reading

at A ⇒ $Q = 2.600 - \frac{e}{100} \times 128$

$= 2.600 - 1.28e$

When instrument at Q, correct staff reading

at B $= 1.44 - \frac{e}{100} \times 32$

$= 1.44 - 0.32e.$

Level difference between A & B.

$h = 2.600 - 1.28e - (1.44 - 0.32e)$

~~h = 2.600~~, $h = 1.16 - 0.96e \rightarrow (2)$

Solving (1) & (2).

, $h = 1.82 + 0.92e \Rightarrow 0.92e - h + 1.82 = 0$

$h = 1.16 - 0.96e. \Rightarrow -0.96e - h + 1.16 = 0$

~~2h~~

$h = 1.08m.$

$e = 0.074m.$

$\tan\alpha = \frac{0.074}{100} = 0°2'32''$ upwards

(2). A tacheometer is setup at an intermediate point on a traverse PQ and the following observations.

Staff station.	Vertical angle	Staff intercept.	Axial hair readings.
P	$+9°30'$	2.250	2.105
Q	$+6°00''$	2.055	1.875

Scanned by CamScanner

The instrument is fitted with analytic lens and constant is 100. Compute the length PQ and the reduced level of Q. RL of P is 350.50 m

A $K = 100$, $C = 0$.

$D_1 = KS\cos^2\theta + C\cos\theta$

$= 100 \times 2.25 \cos^2(9°30') + 0 (\cos(9°30'))$

$D_1 = 218.870$ m.

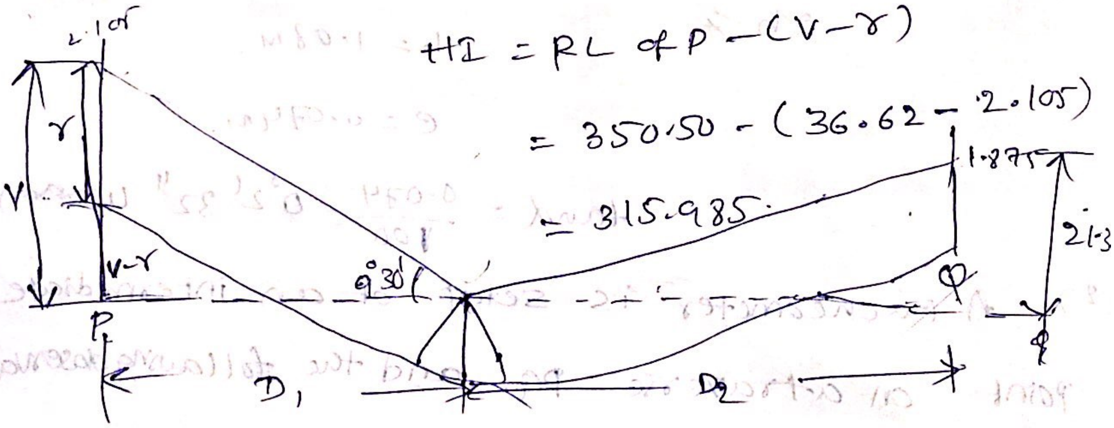
$D_2 = 100 \times 2.055 \cos^2(6°0'0'') + 0$

$D_2 = 203.254$ m.

$V_1 = KS \cos\theta \cdot \sin\theta$

$= 100 \times 2.25 \times \cos(9°30') \sin(9°30')$

$V_1 = 36.62$ m.



HI = RL of P − (V − r)

$= 350.50 - (36.62 - 2.105)$

$= 315.985$

$V_2 = KS \cos\theta \sin\theta$

$V_2 = 100 \times 2.055 \cos 6°, \sin 6°$

$V_2 = 21.36$ m

~~HI~~ RL of Q = H.I + V − r

= 315.985 + 21.36 − 1.875

08/02/17

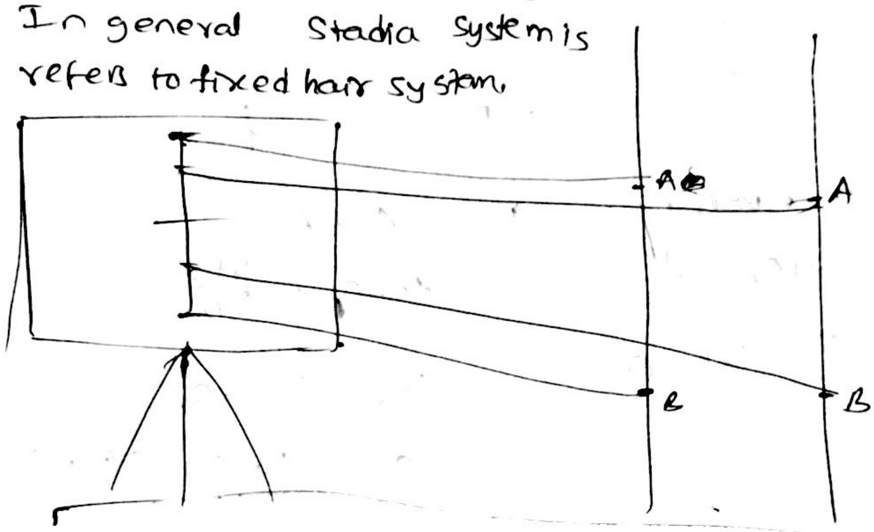
= 335.470m.

Movable Hair System:-

⇒ Stadia interval

⇒ Staff intercept is fixed

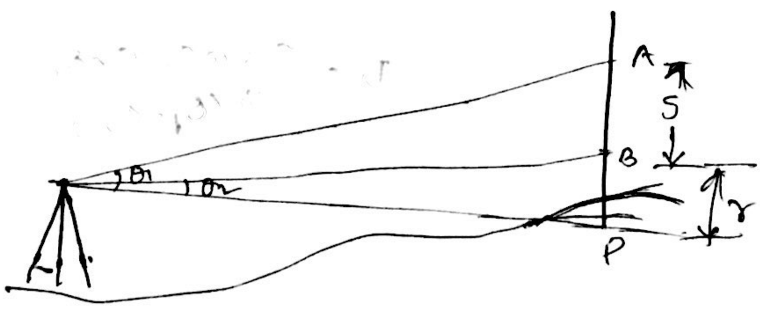
⇒ In general Stadia System is refers to fixed hair system.



Tangential System:-

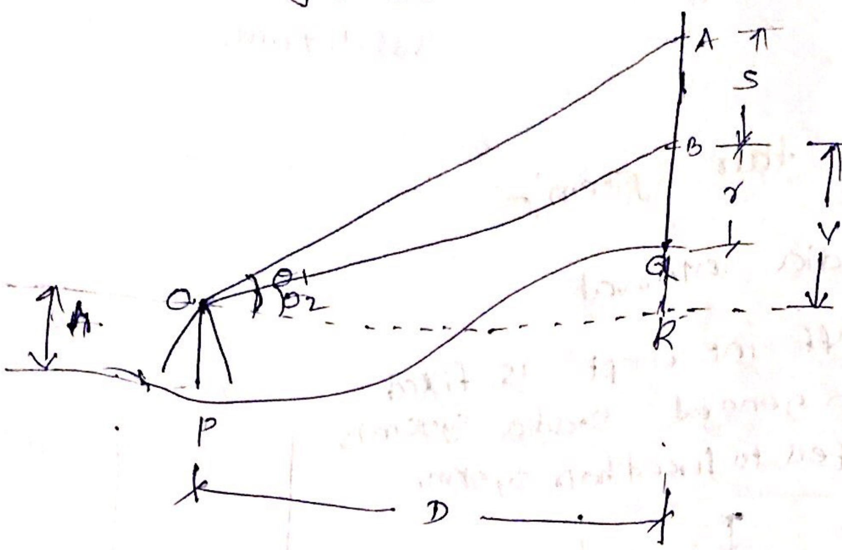
⇒ Telescope does not consists Stadia diaphragram

⇒ The staff consists of two targets which are fixed for all the measurements.



This system is used when the staff is too far away from the instrument.

(i) Both the angles are in elevation



From ΔORB,

$$\tan\theta_2 = \frac{V}{D}$$

$$V = D\tan\theta_2$$

From ΔORA.

$$\tan\theta_1 = \frac{S+V}{D}$$

$$S+V = D\tan\theta_1$$

$$S = D\tan\theta_1 - D\tan\theta_2$$

$$D = \frac{S}{\tan\theta_1 - \tan\theta_2}$$

$$D = \frac{S}{\frac{\sin\theta_1}{\cos\theta_1} - \frac{\sin\theta_2}{\cos\theta_2}}$$

$$D = \frac{S}{\frac{\sin\theta_1 \cdot \cos\theta_2 - \sin\theta_2 \cdot \cos\theta_1}{\cos\theta_1 \cdot \cos\theta_2}}$$

$$D = \frac{S\cos\theta_1 \cdot \cos\theta_2}{\sin\theta_1 \cos\theta_2 - \cos\theta_1 \sin\theta_2}$$

$$D = \frac{S\cos\theta_1 \cdot \cos\theta_2}{\sin(\theta_1 - \theta_2)}$$

$H.I = RL \text{ of } BM + h$

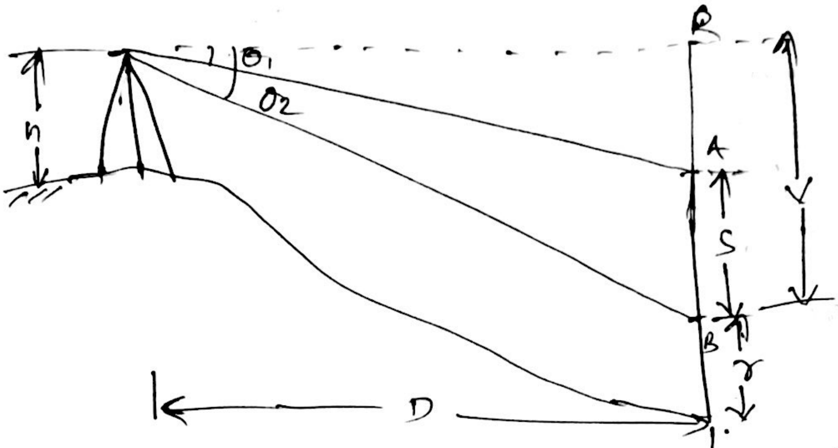
$RL \text{ of } Q = RL \text{ of } BM + h + V - r$

$V = D\tan\theta_2$

$$D = \frac{S\cos\theta_1 \cos\theta_2}{\sin(\theta_1-\theta_2)}$$

$$V = \frac{S\cos\theta_1 \cdot \cos\theta_2}{\sin(\theta_1-\theta_2)} \times \frac{\sin\theta_2}{\cos\theta_2}$$

$$V = \frac{S\cos\theta_1 \cdot \sin\theta_2}{\sin(\theta_1-\theta_2)}$$



From AORA;

$$\tan\theta_1 = \frac{V-S}{D}$$

$V - S = D\tan\theta_1$

From Δ ORB,

$$\tan\theta_2 = \frac{V}{D}$$

$V = D\tan\theta_2$

$D\tan\theta_2 - S = D\tan\theta_1$

$S = D\tan\theta_2 - D\tan\theta_1$

$$D = \frac{S}{\tan\theta_2 - \tan\theta_1}$$

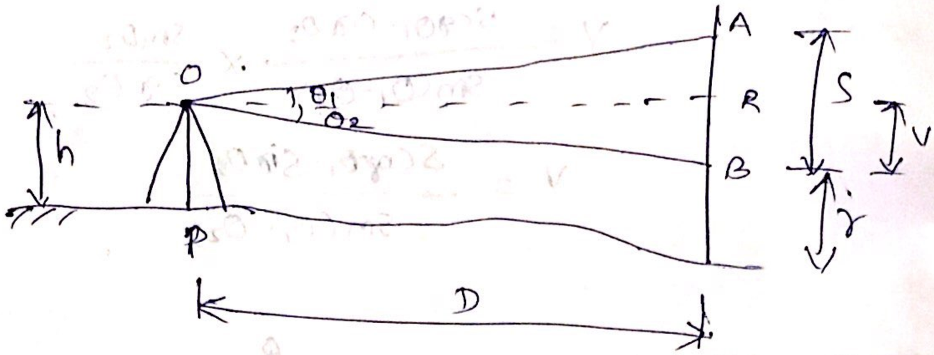
$$D = \frac{S\cos\theta_1 \cdot \cos\theta_2}{\sin(\theta_2-\theta_1)}$$

$RL \text{ of } Q = RL \text{ of } BM + h - V - r$

$V = D\tan\theta_2$

$$V = \frac{S\cos\theta_1 \cdot \sin\theta_2}{\sin(\theta_2-\theta_1)}$$

one target is inelevation and other is in depression :-



From ΔORA,

$$\tan\theta_1 = \frac{S-V}{D}$$

$$S-V = D\tan\theta_1$$

From ΔOAB.

$$\tan\theta_2 = \frac{V}{D}$$

$$V = D\tan\theta_2$$

$$S = D\tan\theta_1 + D\tan\theta_2$$

$$D = \frac{S}{\tan\theta_1 + \tan\theta_2}.$$

$$D = \frac{S\cos\theta_1 \cdot \cos\theta_2}{\sin(\theta_1+\theta_2)}$$

RL of Q = RL of BM + h − V − r.

$$V = D\tan\theta_2$$

$$V = \frac{S\cos\theta_1 \cdot \sin\theta_2}{\sin(\theta_1+\theta_2)}$$

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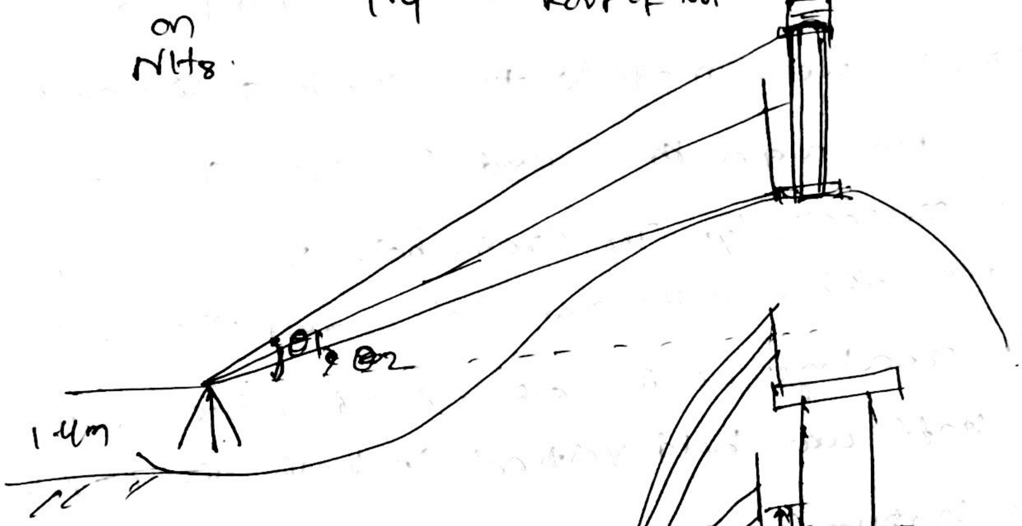
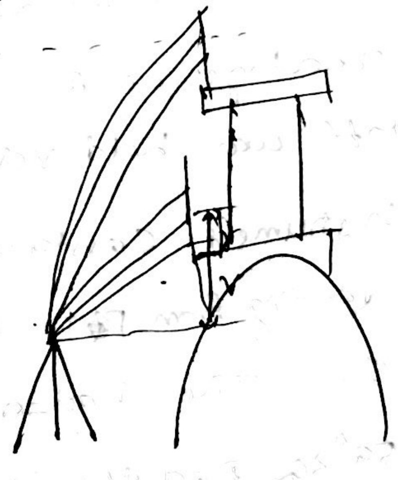
(1) There is fort on a hill in jaipur. Adjascent to the hill Delhi - Jaipur NH8 is passing through in order to determine the height of fort roof from it's plinth and also to determine the distance of fort from road, Calculate

K=100, C=0

the tacheometric constants were taken with instrument constants of

Instrument station	H.I	Staff Station	V.A.	Staff readings
		plinth of fort	+12°47'	3.250, 3.525, 3.80
A point on NH8	1.4	Roof of fort	+18°35'	2.180, 2.630, 3.080





D =

$D = KS\cos^2\theta + C\cos\theta$

$= 52.30\ m \quad V_1 = 11.86\ m.$

RL of plinth level = 1.4 + V − r = 9.735

$V_2 = KS_2 \cos\theta_2 \sin\theta_2$

$= 100 \times 0.9 \cos 18°35' \sin 18°35'$

$V_2 = 27.186m$

RL of top of roof.

$= 1.4 + 27.186 - 2.630$

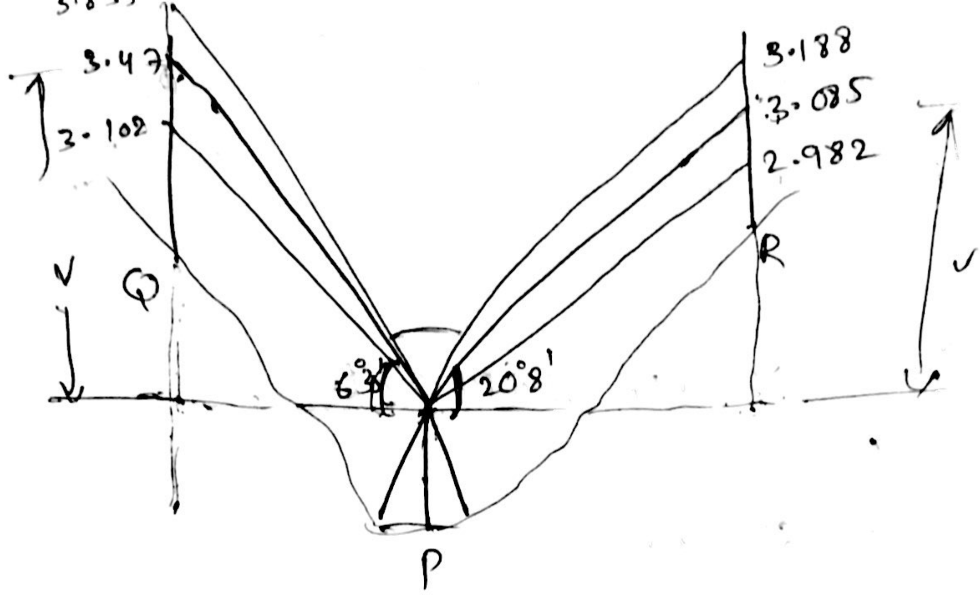
$= 25.92 m$

Height of building $= 25.92 - 9.735$

$= 16.185m.$

14/02/17

(1) A tacheometer was set up at station 'P' and observation were made to two stations Q and R. The vertical angles ~~to~~ Q and R were 6°30' and 20°8' respectively. The cross hair readings at Q are 3.102, 3.470 and 3.835 and the cross hair readings at R are 2.982, 3.085, 3.188. The staff was held vertical in both the cases. The instrument constants were 100 and 0.15. The reading from P to BM of RL = 275.35 was 3.255. The horizontal angle QPR measured was 59°30'. Find the distance Q to R, the gradient from Q to R and RL's of Q and R.



When instrument at P staff at Q.

$D = KS\cos^2\theta + C\cos\theta$.

$D = 100(3.835 - 3.102)\cos^2(6°30') + 0.15\cos(6°30')$

$D = 72.50$ m.

Given H.I = 3.255

$V = KS\cos\theta\sin\theta + C\sin\theta$

$= 8.26$ m

RL of Q = RL of BM + H.I + V − r

$= 275.35 + 3.255 + 8.26 - 3.47$

$= 283.395$ m.

When instrument at P staff at R,

$D = KS\cos^2\theta + C\cos\theta$ S = 0.206

$D = 18.300$ m.

$V = KS\cos\theta\sin\theta + C\sin\theta$

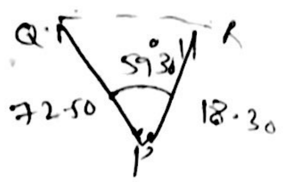
$V = 6.7$ m.

RL of R = RL of BM + H.I + V − r

= 282.19 m.

$PQ = 72.50\,m$ $\angle QPR = 59^\circ 30'$

$PR = 18.30\,m$



$$QR = \sqrt{PQ^2 + PR^2 - 2PQ \cdot PR \cdot \cos(QPR)}$$

$QR = 65.14\,m$

$$\text{Gradient} = \frac{283.395 - 282.19}{65.14}$$

$$= \frac{1}{0.018} \Rightarrow 1 \text{ in } 55.$$

(2) Following observations were taken with a tacheometer fitted with an analytic lens.

Inst. at	Staff station.	R.B.	V.A.	staff readings
O	P	N 37° W	+4°12'	0.910, 1.510, 2.11
	Q	N 23° E	+5°42'	1.855, 2.705, 3.5

Calculate the horizontal distance PQ and Level difference of PQ, Gradient of PQ.

$K = 100$, $C = 0$

Inst. at 'O' staff at 'P'

$s = 1.2\,m$

$D = KS\cos^2\theta + C\cos\theta.$

$D = 100(1.2)\cos^2(4^\circ 12') + 0(\cos 4^\circ 12')$

~~D = 99.46 m~~ $D = 119.35\,m$

$V = KS\cos\theta\sin\theta + C\cos\theta$

$V = 100(1.2)\cos(4^\circ 12')\sin(4^\circ 12') + (0)\cos(4^\circ 12')$

$V = 8.76\,m$

RL of P = RL of BM + H.I + V − r = x + 7.254.

(x)

staff at Q, $S = 1.7$

$D = 100(1.7)\cos^2(5^\circ 42')$

$D = 168.32\,m$.

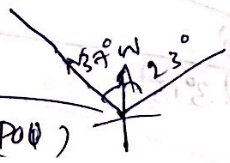
$V = 100(1.7)\cos(5^\circ 42')\sin(5^\circ 42')$

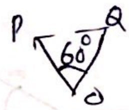
$V = 16.8\,m$

$RL\ of\ Q = x + V - r = x + 16.8 - 2.705$

$= x + 14.095$.

Distance between P and Q.





$PQ = \sqrt{OP^2 + OQ^2 - 2\,OP\,OQ\cos(POQ)}$

$PQ = 149.86\,m$.

Level difference between P and Q.

$= x + 7.254 - (x + 14.095)$

$= -6.841\,m$

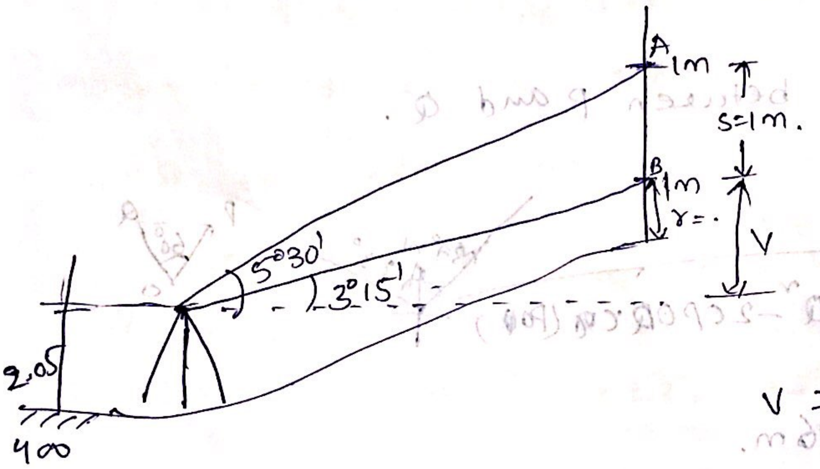
Q is higher

$Gradient = \dfrac{149.86}{6.841} \Rightarrow 1\ in\ 21.9.$

=o=

15/02/17

(1) In the tangential method of tacheometry two vanes (or) targets are fixed at an interval of 1m on a 3m staff with the bottom vane at an interval 1m. The staff was held vertical at station A. and vertical angles measured for the two vanes were 5°30' and 3°15' respectively. Find the RL of A and horizontal distance between Bench Mark station to A., if the RL of BM was 400 m. Height of the instrument i.e. BS = 2.05 m.



$V = D\tan\theta_2$

$= 25.313 \tan(3°15')$

$V = 1.437m$

$$D = \frac{S \cdot \tan\theta_1 \tan\theta_2}{\tan\theta_1 - \tan\theta_2}$$

$$D = \frac{1 \times \tan(5°30')\tan(3°15')}{\tan(5°30') - \tan(3°15')}$$

$D = 0.138 m$

$$D = \frac{S}{\tan\theta_1 - \tan\theta_2} = 25.3$$

$$V = \frac{S \cos\theta_1 \sin\theta_2}{\sin(\theta_1 - \theta_2)} = 1.437m$$

RL of A = BM + h + V ∓ r

= 400 + 2.05 + 1.437 ∓ 1

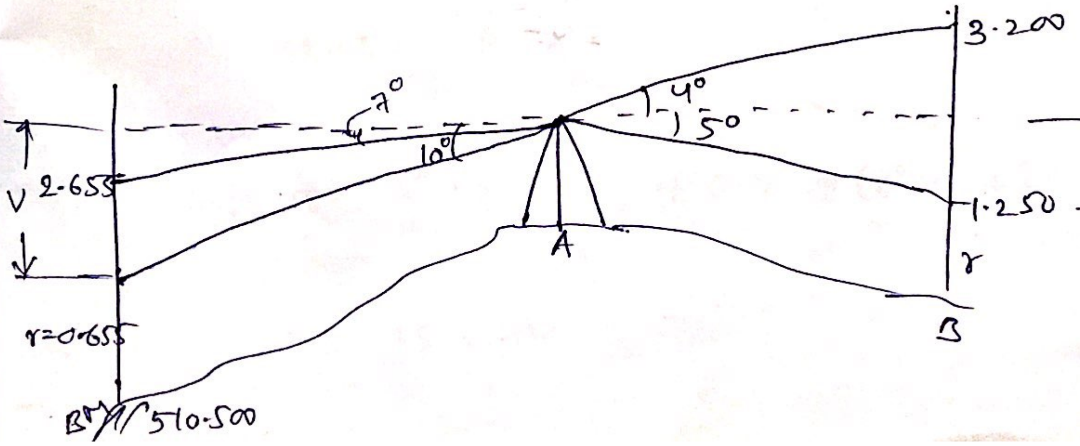
= 402.487 m

(2) Two observations are taken by a a theodolite from Station A. one to the benchmark and other to the Station B. The records are as follows.

Inst. Station	Staff station.	Target	V.A.	staff reading	Remarks
A	BM	lower	$-10°0'$	0.655	RL of BM =510.500
		upper	$-7°0'$	2.655	
A	B	lower	$-5°0'$	1.250	
		upper	$+4°0'$	3.200	

Find the distance between BM and B.

Find RL of B.



$V = D \tan 10^\circ$

$$D = \frac{S}{\tan\theta_2 - \tan\theta_1} = \frac{2}{\tan(10^\circ) - \tan(7^\circ)} = 37.35 \text{ m.}$$

$$V = 37.35 \tan 10^\circ = 6.586 \text{ m.}$$

$$RL \text{ of } H.I = RL \text{ of } BM + r + V$$

$$= 510.500 + 0.655 + 6.586$$

$$= 517.741 \text{ m.}$$

$$D = \frac{S}{\tan\theta_1 + \tan\theta_2} = \frac{1.95}{\tan(4^\circ) + \tan(5^\circ)}$$

$$= 12.387 \text{ m.}$$

$$V = D\tan\theta_2 = 12.387 \tan(5^\circ)$$

$$= 1.083 \text{ m.}$$

$$RL \text{ of } B = H.I - V - r$$

$$= 517.741 - 1.083 - 1.25$$

$$= 515.408 \text{ m}$$

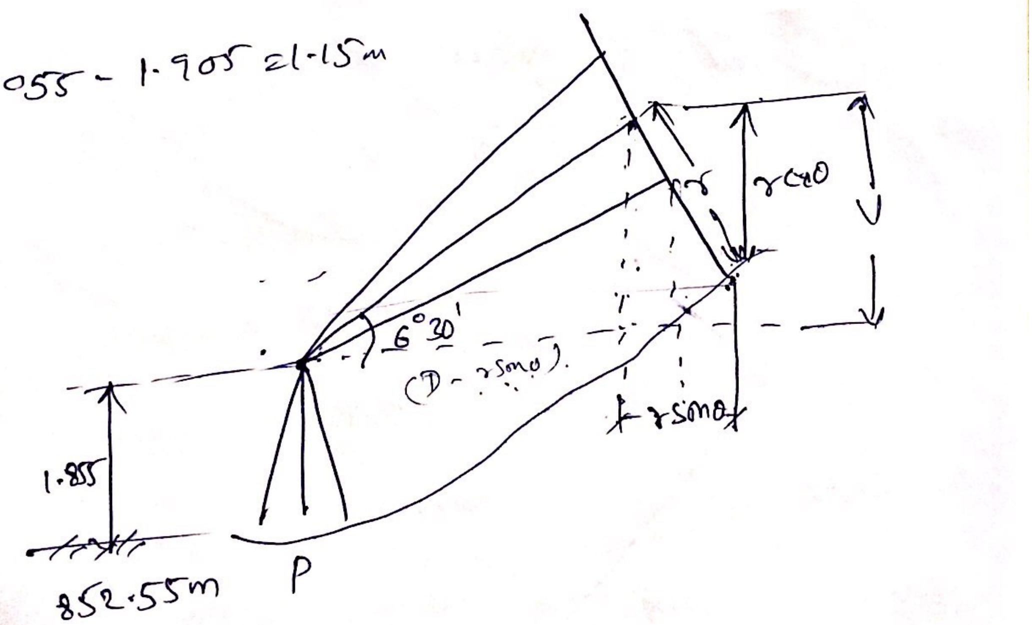
Distance between BM and B $= 37.35 + 12.38$

$= 49.737$ m.

(3) A tacheometer was set up at station p and the observations were made to a staff held normal to the line of sight over point 'Q'. The vertical angle measured was $6^\circ 30'$. The three cross hair readings were 1.905, 2.480, and 3.055m respectively. The reading from P with the line of sight to Bench mark of RL. = 852.55m was 1.855m. If the instrument constants are 100 & 0.5 Find the elevation of station Q and horizontal distance between staff station and instrument station.

$D = KS\cos\theta + C\cos\theta + r\sin\theta$

$S = 3.055 - 1.905 = 1.15m$



$D = 100 \times 1.15\cos(6^\circ 30') + 0.5\cos(6^\circ 30') + 2.480 \times \sin(6^\circ 30')$

$D = 115.038m$

$V = (D - r\sin\theta)\tan\theta$

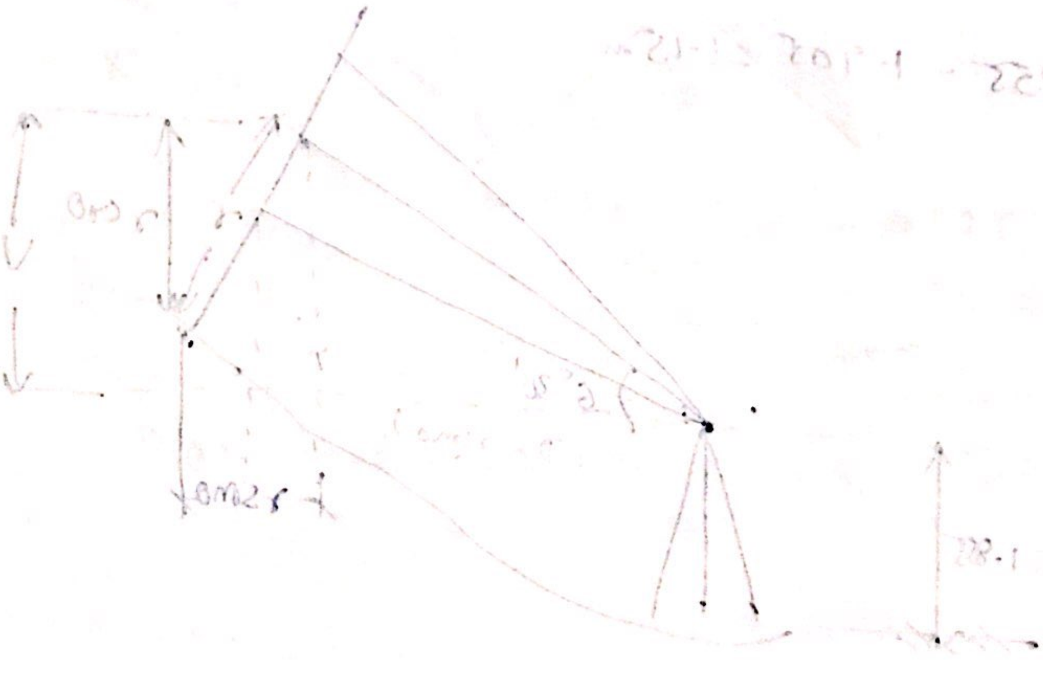
$V = (115.038 - 2.480\sin(6°30'))\cdot\tan(6°30')$

$V = 13.074m$

RL of Q = RL of BM + H.I + V − r.

$= 852.55 + 1.855 + 13.074 - 2.480\cos 6°$

$= +865.05m$

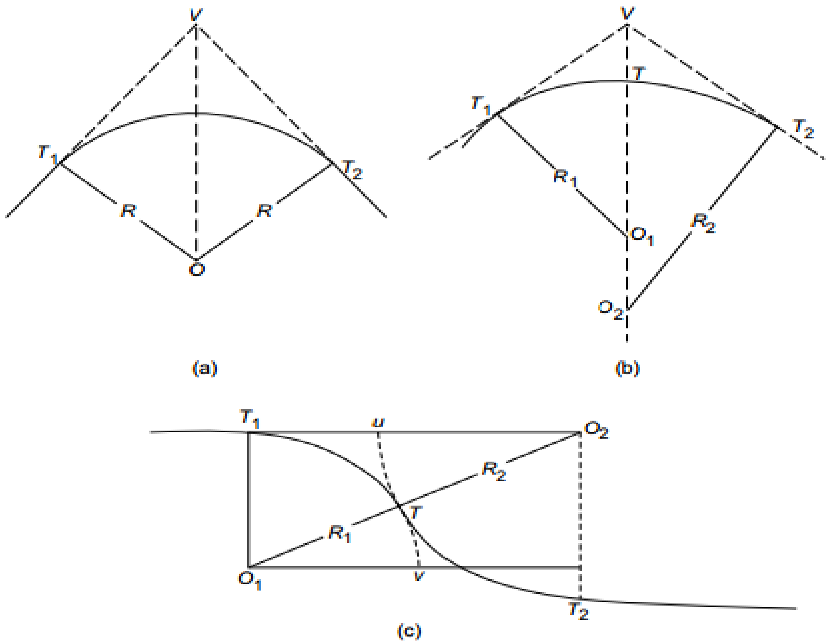


UNIT-III

CURVES

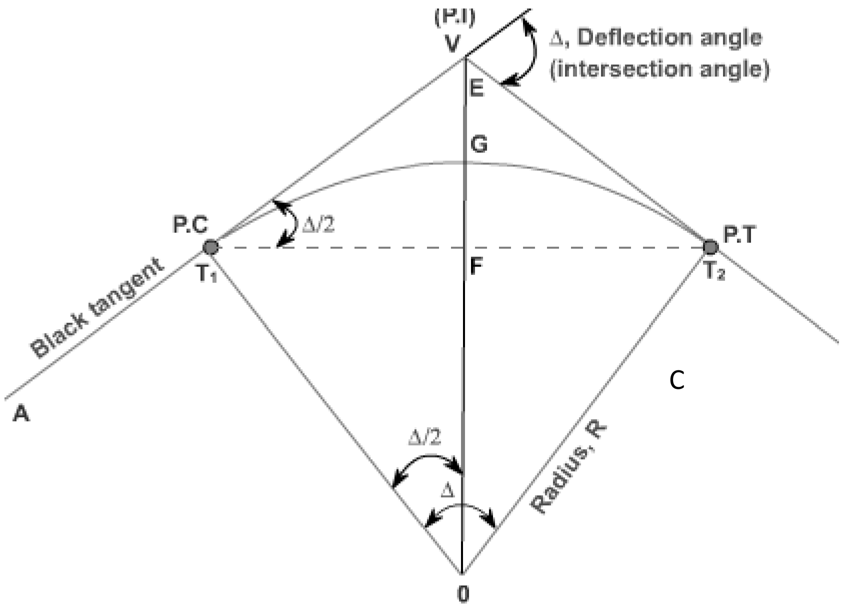
Whenever the direction of a road or railway line is to be changed, curves are provided between the intersecting straights. This is necessary for smooth and safe movement of the vehicles and for the comfort of passengers. When two straights are intersecting at each other, then the curve is provided in between them which is tangential to the two straights. The curves required may be in the horizontal planes or in the vertical planes. Accordingly the curves are classified as horizontal curves and vertical curves. Horizontal curves are further classified into

1. Simple circular curve
2. Compound curve
3. Transition curve
4. Serpentine curve or S- curve



Elements of simple curve:

once the alignment of a route is finalized, such as AVC, the change in direction is achieved through provision of circular curves. To change the direction from AV to VC, a circular curve T1 GT2 is provided. The straight alignments, between which a curve is provided, are tangential to the curve. Thus, AT1 V and VT2C are tangential to T1 GT2 . The tangent line before the beginning of the curve is called the Back tangent or the rear tangent. The tangent line after the end of the curve is called the Forward tangent . The line AT1 is the back tangent and the line T2C is the forward tangent for the curve T1GT2. The distinction of the back tangent from the forward tangent depends on the direction of the route surveying. The point at which extension of the back tangent and the forward tangent meet is known as the Vertex (V) or point of intersection (P.I.). The exterior angle at the vertex or point of intersection is known as the Intersection angle (I). It is also known as Deflection angle (D) as it represents the deflection angle between the back tangent and the forward tangent. Thus, angle between the line AV produced beyond the vertex V and the line VC represents I (or D). The point on the back tangent where the curve begins is known as the Point of Curvature (P.C.). At this point, the alignment of the route changes from a straight line to a curve. This is represented by T1 in Figure 37.1. The point on the forward tangent where the curve ends is known as the Point of tangency (P.T.). At this point, the alignment of the route changes from a curve to a straight line. It is represented by T2 in Figure 37.1. The distance between the point of curvature (T1) to the point of intersection (V) along the extension of back tangent is known as Tangent distance (T). It is also equal to the distance between the point of tangency (T2) to the point of intersection along the extension of forward tangent. The distance between the point of intersection (V) and the middle point of the curve is called as External distance (E). The longest possible chord of the circular curve is known as Long chord (L). It is the line joining the point of curvature (T1) and the point of tangency (T2). The distance between the middle point of the curve and the middle point of the long chord is Mid-ordinate (M). The length of the alignment along the curve between the point of curvature (T1) and the point of tangency (T2) is known as the Length of curve (l). During the progress of the route, if the direction of deflection is to the right then it is called Right-hand curve (T1GT2) .



let T1GT2 be the circular curve that has been provided between the tangents AV and VC. The deflection angle, D between the tangents is measured in the field. The radius of curvature is the design value as per requirement of the route operation and field topography. The line joining O and V bisects the internal angles at V and at O, the chord T1T2 and arc T1GT2 . It is perpendicular to the chord T1T2 at F.,RT1 O T2 = D and

$$\angle T_1OV = \angle VOT_2 = \angle VT_1T_2 = \angle VT_2T_1 = \frac{\Delta}{2}$$

To compute the elements of a circular curve, consider the radius of the curve OT1 = OT2 = R. Further, it is known that the RVT1 O = RVT2 O = 90° (since the tangent to a circle is perpendicular to the radius at the point of tangency). The elements of a circular curve required to lay it out in the field with reference to Figure 37.1 are as follows :

Length of Curve,

l = T1 GT2

$$= \left(\frac{2\pi R}{360^\circ} \right) \times \Delta$$

$$= \frac{\pi R \Delta}{180^\circ}$$

Tangent Length,

T = length T1 V = length T2 V

$$= O\,T_1 \tan \frac{\Delta}{2} \quad = R \tan \frac{\Delta}{2}$$

Chainages of tangent point : The chainage of the point of intersection (V) is generally known. Thus,

Chainageof T1 = Chainage of V - tangent length (T)

Chainage of T2 = Chainage of T1 + length of curve (l)

Length of the long chord (L) : Length of the long chord,

L = length T1 FT2

$$= 2 \times R \sin \frac{\Delta}{2}$$

External distance (E) :

E = length VG

= VO - GO

$$= R \sec \frac{\Delta}{2} - R$$

$$= R\,[\sec \frac{\Delta}{2} - 1]$$

Mid-ordinate (M) :

M = length GF = OG-OF

$$= R - R\cos\frac{\Delta}{2}$$

$$= R\left(1 - \cos\frac{\Delta}{2}\right)$$

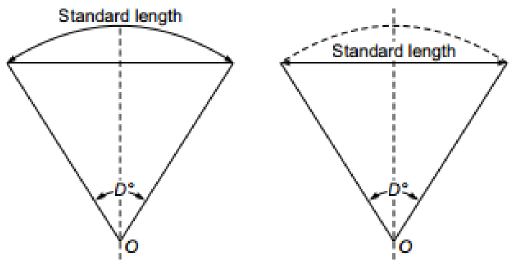
Designation of a Curve:

A curve is designated either in terms of its degree (D) or by its radius (R).

In Great Britain the sharpness of the curve is designated by the radius of the curve while in India and many countries it is designated by the degree of curvature. There are two different definitions of degree of curvature:

(i) Arc Definition
(ii) (ii) Chord Definition.

According to arc definition degree of curvature is defined as angle in degrees subtended by an arc of standard length This definition is generally used in highway practice. The length of standard arc used in FPS was 100 ft. In SI it is taken as 30 m. Some people take it as 20 m also.

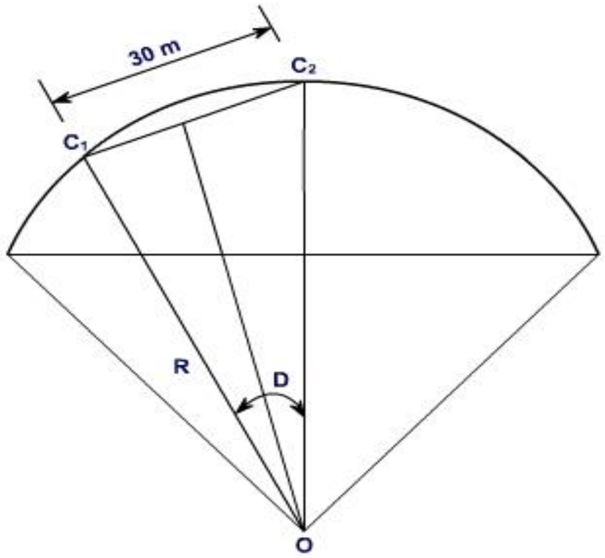


(a) Arc Definition (b) Chord Definition

According to chord definition degree of curvature is defined as angle in degrees subtended by a chord of standard length. This definition is commonly used in railways. Earlier standard chord length used was 100 ft. Now in SI 30 m or 20 m is used as standard chord length.

Chord definition:

the degree of a curve is defined as the angle subtended at the centre of the curve by a chord of 30 m length.



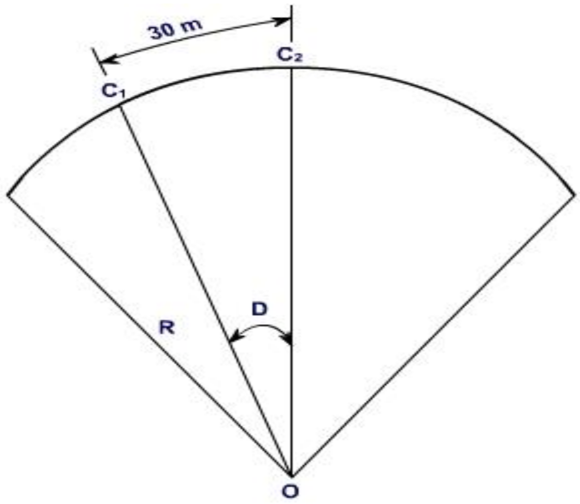
Let D be the degree of a curve i.e., it is the angle subtended at its centre O by a chord C_1C_2 of 30 m lengt. Thus

$$\sin\frac{D^\circ}{2} = \frac{(30/2)}{R}, \text{where R is the radius of the circular curve}$$

$$\therefore R = \frac{15}{\sin\left(\frac{D^\circ}{2}\right)}$$

Arc Definition:

The degree of a curve is defined as the angle subtended at its centre of the curve by an arc of 30 m length.



From

$$\frac{D^\circ}{30} = \frac{360^\circ}{2\pi R}$$

$$\text{Or, } D^\circ = \frac{1718.9}{R} \text{ degrees}$$

Setting out a Simple Curve:

There are different methods for laying out a circular curve based on the types of instruments used for the purpose. Of these two methods

1. Linear methods
2. Angular methods

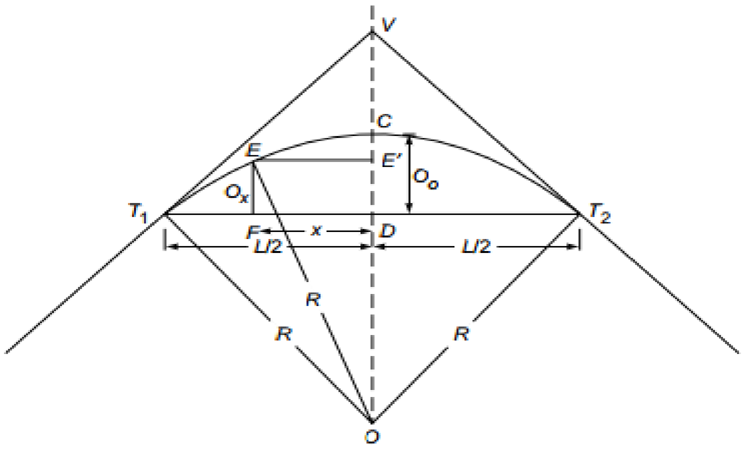
Linear methods of setting out a simple curve:

The following are some of the linear methods used for setting out simple circular curves:

(i) Offsets from long chord
(ii) Successive bisection of chord
(iii) Offsets from the tangents–perpendicular or radial
(iv) Offsets from the chords produced.

I. Offsets from long chord method:

In this method, long chord is divided into an even number of equal parts. Taking centre of long chord as origin, for various values of x, the perpendicular offsets are calculated to the curve and the curve is set in the field by driving pegs at those offsets.



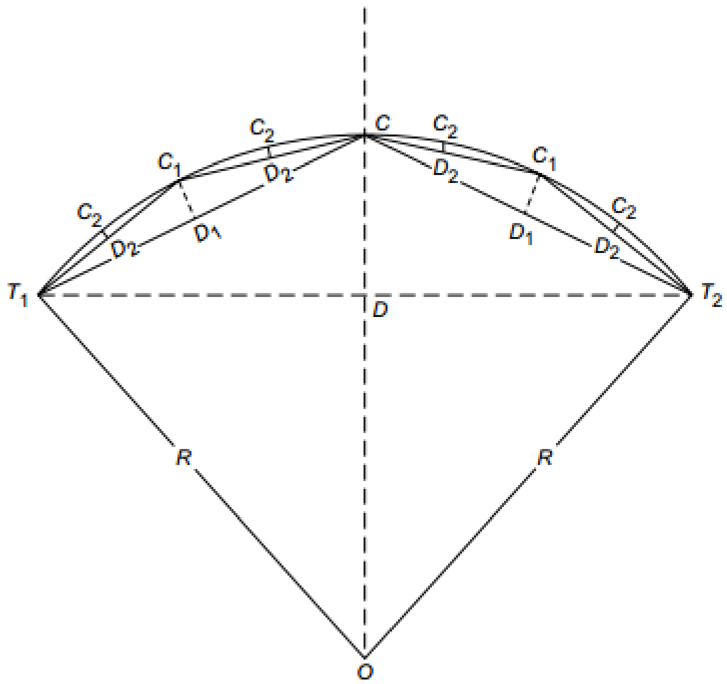
R – radius of the curve L – length of long chord O0 – mid-ordinate Ox – ordinate at distance x from the mid-point of long chord Ordinate at distance x = O_x = E'O – DO

$$= \sqrt{R^2 - x^2} - \sqrt{R^2 - (L/2)^2}$$

The above expression holds good for x-values on either side of D, since CD is symmetric axis.

II. Successive bisection of chords:

In this method, points on a curve are located by bisecting the chords and erecting the perpendiculars at the mid-point.



Perpendicular offset at middle of long chord (D) is

$$CD = R - R\cos\frac{\Delta}{2} = R\left(1-\cos\frac{\Delta}{2}\right)$$

Let D1 be the middle of T1C. Then Perpendicular offset

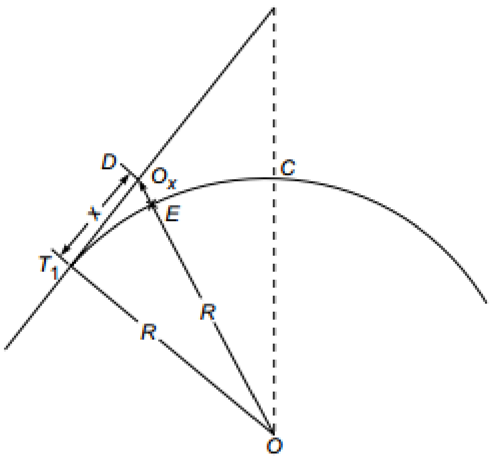
$$C_1D_1 = R\left(1-\cos\frac{\Delta}{4}\right)$$

Similarly, $$C_2D_2 = R\left(1-\cos\frac{\Delta}{8}\right)$$

III. Offsets from tangent produced:

The offsets from tangents may be calculated and set to get the required curve. The offsets can be either radial or perpendicular to tangents.

(i) **Radial offsets**: if the centre of curve O is accessible from the points on tangent, this method of curve setting is possible.



Let D be a point at distance x from T1. Now it is required to find radial ordinate Ox = DE, so that the point C on the curve is located.

From $\Delta\ OT_1D$, we get

$$OD^2 = OT_1^2 + T_1D^2$$

$$(R + O_x)^2 = R^2 + x^2$$

i.e. $$O_x + R = \sqrt{R^2 + x^2}$$

or $$O_x = \sqrt{R^2 + x^2} - R$$

An approximate expression Ox may be obtained as explained below:

$$O_x = \sqrt{R^2 + x^2} - R$$

$$= R\sqrt{1+\left(\frac{x}{R}\right)^2} - R$$

$$\approx R\left(1+\frac{x^2}{2R^2}-\frac{x^2}{8R^4}+\ldots\right) - R$$

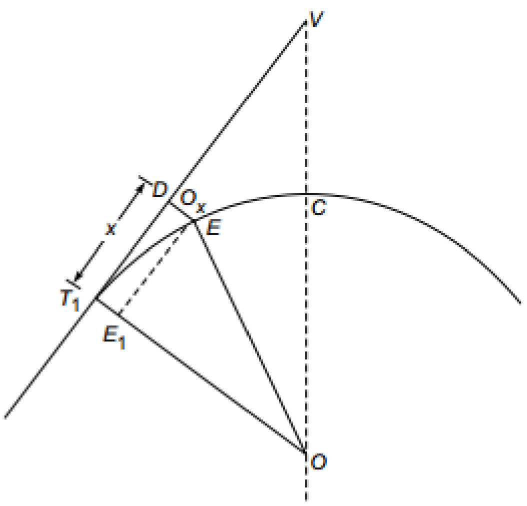
Neglecting small quantities of higher order,

$$O_x = R\left(1+\frac{x^2}{2R^2}\right) - R$$

$$= \frac{x^2}{2R^2} \quad \text{(approx)}$$

(ii) Perpendicular offsets:

If the centre of a circle is not visible, perpendicular offsets from tangent can be set to locate the points on the curve.



The perpendicular offset Ox can be calculated as given below: Drop perpendicular EE1 to OT1. Then,

$$O_x = DE = T_1E_1$$
$$= OT_1 - OE_1$$
$$= R - \sqrt{R^2 - x^2} \quad \text{(Exact)}$$
$$= R - R\left(1 - \frac{x^2}{2R^2} - \frac{x^4}{8R^4}\cdots\right)$$
$$= \frac{x^2}{2R} \quad \text{(approx)}$$

IV. Offsets from the long chord produced:

This method is very much useful for setting long curves. In this method, a point on the curve is fixed by taking offset from the tangent taken at the rear point of a chord. Thus, point A of chord T_1A is fixed by taking offset $O_1 = AA_1$ where T_1A_1 is tangent at T_1. Similarly B is fixed by taking offset $O_2 = BB_1$ where AB_1 is tangent at A.

Let $T_1A = C_1$ be length of first sub-chord
$AB = C_2$ be length of full chord
δ_1 = deflection angle A_1T_1A
δ_2 = deflection angle B_1AB

Then from the property of circular curve

$$T_1OA = 2\delta_1$$

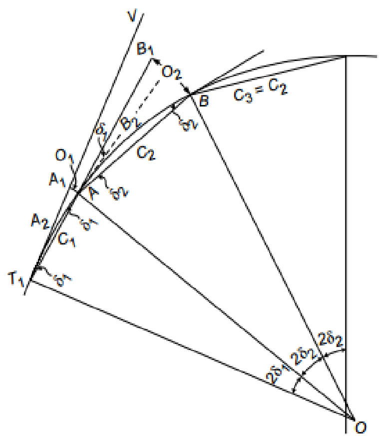
$\therefore$ C_1 = chord $T_1A \approx$ Arc $T_1A = R\,2\,\delta_1$

i.e. $\delta_1 = \dfrac{C_1}{2R}$

Now, offset O_1 = arc AA_1
$= C_1\,\delta_1$

Substituting the value of d1 from equation (i) into equation (ii), we get

$$O_1 = C_1 \times \frac{C_1}{2R} = \frac{C_1^2}{2R}$$



$$O_2 = C_2\,(\delta_1 + \delta_2)$$

$$= C_2\left(\frac{C_1}{2R} + \frac{C_2}{2R}\right)$$

$$= \frac{C_2}{2R}(C_1 + C_2)$$

$$O_3 = \frac{C_3}{2R}\,(C_2 + C_3)$$

$$C_3 = C_2 \qquad \therefore\ O_3 = \frac{C_2^2}{R}$$

Thus, upto last full chord i.e. $n - 1$ the chord,

$$O_{n-1} = \frac{C_2^2}{2R}$$

If last sub-chord has length C_n, then,

$$O_n = \frac{C_n}{2R}(C_{n-1} + C_n)$$

Note that C_{n-1} is full chord.

Angular Methods:

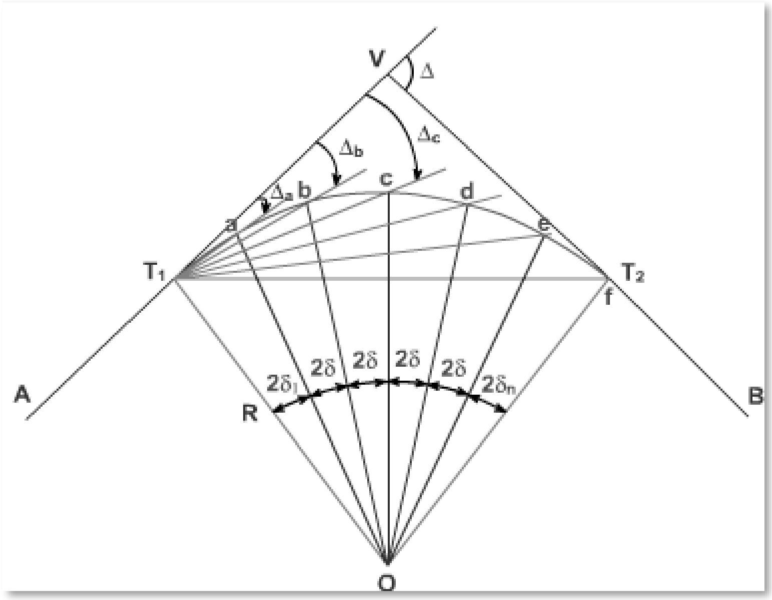
The following are the angular methods which can be used for setting circular curves:

(i) Rankine method of tangential (deflection) angles.
(ii) Two-theodolite method .

In these methods linear as well as angular measurements are used. Hence, the surveyor needs chain/tape and instruments to measure angles. Theodolite is the commonly used instrument.

Rankine's one theodolite method:

In this method, curves are staked out by use of deflection angles turned at the point of curvature from the tangent to points along the curve. The curve is set out by driving pegs at regular interval equal to the length of the normal chord. Usually, the sub-chords are provided at the beginning and end of the curve to adjust the actual length of the curve. The method is based on the assumption that there is no difference between length of the arcs and their corresponding chords of normal length or less. The underlying principle of this method is that the deflection angle to any point on the circular curve is measured by the one-half the angle subtended at the centre of the circle by the arc from the P.C. to that point



Let points a, b, c, d, e are to be identified in the field to layout a curve between T_1 and T_2 to change direction from the straight alignment AV to VB . To decide about the points, chords ab, bc, cd, de are being considered having nominal length of 30m. To adjust the actual length of the curve two sub-chords have been provided one at the beginning, T_1 a and other, eT_2 at the end of the curve. The amount of deflection angles that are to be set from the tangent line at the P.C. are computed before setting out the points. The steps for computations are as follows:

let the tangential angles for points a, b, c,… be d_1, d,…, d, d_n and their deflection angles (from the tangent at P.C.) be D_a, D_b, ….. , D_n.

Now, for the first tangential angle d_1, from the property of a circle

Arc T_1 a = R x $2d_1$ radians

Assuming the length of the arc is same as that of its chord, if C_1 is the length of the first chord i.e., chord T_1 a, then

$$\delta_1 = \frac{C_1}{2R} \text{ radians}$$

$$= \frac{180^\circ C_1}{2\pi R} \text{ degrees}$$

$$= \frac{180 \times 60 C_1}{2\pi R} \text{ minutes}$$

$$= 1718.9 \frac{C_1}{R} \text{ minutes}$$

(Note: the units of measurement of chord and that of the radius of the curve should be same).

Similarly, tangential angles for chords of nominal length, say C,

$$\delta = 1718.9 \frac{C}{R} \text{ minutes}$$

And for last chord of length, say C_n

$$\delta_n = 1718.9 \frac{C_n}{R} \text{ minutes}$$

The deflection angles for the different points a, b, c, etc. can be obtained from the tangential angles. For the first point a, the deflection angle D_a is equal to the tangential angle of the chord to this point i.e., d_1. Thus,

$D_a = d_1$.

The deflection angle to the next point i.e., b is D_b for which the chord length is T_1 b. Thus, the deflection angle

$$\Delta_b = \frac{1}{2} \angle T_1Ob$$

$$= \frac{1}{2}(2\delta_1 + 2\delta)$$

$$= \Delta_a + \delta$$

$$\text{Similarly, } \Delta_c = \frac{1}{2} \angle T_1Oc$$

$$= \frac{1}{2}(2\delta_1 + 2\delta + 2\delta).$$

$$= \Delta_b + \delta$$

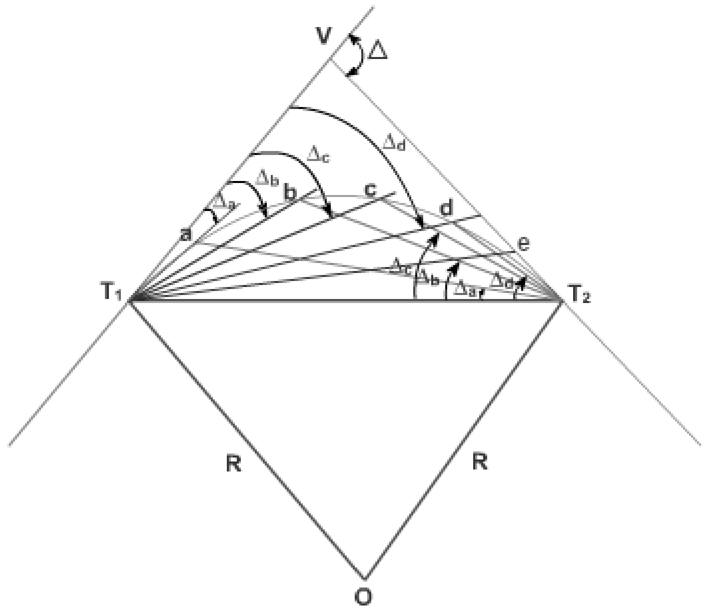
$$\text{Like wise, } \Delta n = \Delta_{n-1} + \delta_n$$

Thus, the deflection angle for any point on the curve is the deflection angle up to previous point plus the tangential angle at the previous point.

Two Theodolite method:

In two theodolite method, curves are staked out by angular measurements only. Accuracy attained in this method is quite high. Thus, the method is used when higher accuracy is required and when the topography is rough or field condition is difficult.

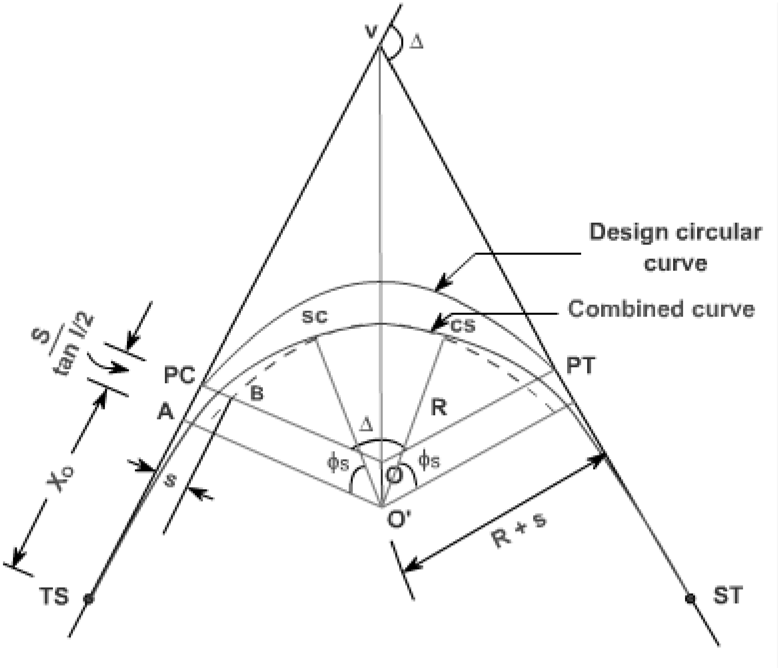
The underlying principle of this method is that the deflection angle between a tangent (at any point on a circle) and a chord is equal to the angle which the chord subtends in the alternate segment.



Two theodolites are used simultaneously placing one at the point of curvature (T_1) and the other at the point of tangent (T_2). Deflection angles for specified chord lengths are computed as defined in the Rankine's method. The deflection angles are set at the theodolites. Ranging from both the theodolites at the defined angles provide the location of the point along curve. Thus, the curve is set out by driving pegs at suitable location identified through the theodolites.

Transition curve:

To minimise discomfort arising out of the sudden change in curvature at the junction of a tangent and a curve, a special type of curve is provided in between for gradual change from the back tangent to the circular curve and again from the circular curve to the forward tangent. The horizontal curve having varying radius is known as transition curve. A transition curve is also provided between two branches of a compound curve or a reverse curve so that the changes in curvature are gradual.



Insertion of a Transition curve:

Transition curves are introduced between the straights TV and T'V by shifting the circular curve slightly inwards. The original circular curve is from the point of curvature (P.C.) to the point of tangency (P.T.), with the centre at o has been shifted as SC to CS, with centre at 0'. The transition curves are at the two ends from TS to SC and CS to ST.

The following notations have been used.

TS = Tangent to transition point

SC = Transition curve to circular curve point

CS = Circular curve to transition curve point

ST = Transition to tangent point

The distance AB through which the main circular curve is shifted inwards to accommodate the transition curve is called shift (s) or throw. The distance between the original centre O and the shifted centre O' is usually small. It is conventional to represent both the points by one point O. which is a simplified diagram of combined curves i.e., circular curve with transition curves at its ends.

Characteristics of a transition curve:

The angle between the initial tangent TV and the common tangent CC_1 at the junction C of the transition curve and the circular curve is called the spiral angle (ϕ_s).

VERTICAL CURVES:

To negotiate a change in gradient smoothly and to provide vision over the crest of a hill far enough ahead for safe driving, a curve in a vertical plane, gets introduced in the adjacent segments of differing grades. Depending on the magnitude and sign of the gradients at the intersection points, vertical curves fundamentally are of two types: summit or convexity upward and sag/valley or convexity downward.

The figure shown below illustrates crest or summit and valley vertical curves. Point A is the beginning of the vertical curve labeled BVC or PVC, V is the P.I. or P.V.I. the intersection of the tangents, and B is the end of the vertical curve labeled EVC or PVT. The two grades in the direction of stationing along tangent AV and VB expressed in percent are G_1 and G_2 respectively. The length of the curve AB is designated L and is measured horizontally. When the tangent rises in the direction of stationing, the grade is positive, and when the tangent slopes downward, the grade is negative.

Design of vertical curves is a function of the difference in grade of the intersecting tangents, stopping or passing sight distance, which in turn are functions of vehicle design speed and height of the driver's eye above the roadway, and drainage. In addition to these factors, design of a sag vertical curve also depends on headlight beam distance, rider comfort, and appearance. Details governing the design of vertical curve are beyond the scope of this course.

Requirements of a vertical curve:

The important requirement of a vertical curve is that they should provide a constant rate of change of grade.

Therefore if y = f (x), be the general equation of a curve, for a vertical curve it is required to have

$$\frac{d^2y}{dx^2} = \text{Constant}$$

This requirement is fulfilled by parabolic curve.

Morever, parabolic curve further fulfills the requirements of a vertical curve in the following ways:

1. It is flatter at the top and hence provides a longer sight distance. Greater the sight distance, lesser is the possibility of any accident.
2. Rate of change of grade is uniform throughout and hence produces best riding qualities.
3. It is simple in computation and setting works.

Thus, a parabolic curve is most commonly used as a vertical curve.

Elevation of points to set out a vertical parabolic curves is computed by using

1. equation of the parabola directly or by using,
2. geometric properties of the parabola (to calculate vertical offsets from the tangent).

Length of a vertical curve:

The length (L) of the vertical curve is measured from the point of commencement of the curve to the end point where it again meets the straightIn other words, it is the distance between the two points of tangency.

Thus the length L of the vertical curve is equal to the algebraic difference of the two gradients divided by the rate of change of grade. Thus,

If G_1 is the % gradient before the intersection point.

G_2 is the % gradient after the intersection point and

r is the rate of change of gradient,

the Length of the vertical curve

$$L = \frac{G_1 - G_2}{r}$$

The length of the curve actually provided is generally taken equal to the nearest full chain of 20 m. One half of the total length is provided on either side of the summit or sag. In the case of highways, the sight distance should also be considered while deciding the length of the curve.

1) Determine the radius of curve if least it is designated as 3° curve on 30m arc.

$$D = \frac{1718.87}{R}$$

$$R = \frac{1718.87}{D}$$

$$R = 572.95 \text{ m}$$

2) A circular curve of radius 250m is to be intersected between two straights meeting at a deflection angle of 70° what is the degree of arc. By arc definition also find the length of curve tangent length, length of long chord apex distance and mid ordinate.

$R = 250m$

$\Delta = 70^\circ = 70^\circ \times \frac{\pi}{180}$

$D = \frac{1718.87}{R}$ for 30m $= 6^\circ 52'$

$D = \frac{1145.91}{R}$ for 20m $= 4^\circ 35'$

length of curve, $l = R\Delta$

$= 250 \times 70^\circ \times \frac{\pi}{180}$

$= 305.43$ m

Tangent length, $= R\tan\frac{\Delta}{2}$

$= 175.05$m.

Length of long chord $= 2R\sin\frac{\Delta}{2}$

$= 2 \times 250 \sin\left(\frac{70^\circ}{2}\right)$

$= 286.78$ m

Apex distance $= R\left(\sec\left(\frac{\Delta}{2}\right) - 1\right)$

$= 250\left(\sec\left(\frac{70^\circ}{2}\right) - 1\right)$

$= 55.19$ m

mid ordinate $= R\left(1 - \cos\left(\frac{\Delta}{2}\right)\right)$

$= 250\left(1 - \cos(35^\circ)\right)$

$= 45.21$m

2) The chainage of the intersection of the two straights having the deflection angle of 50° is 1680.5 m. The radius of curve is 450m. Calculate tangent distance length of curve degree of curve, length of longchord, chainage of point of curvature and point of tangency and apex distance.

$R = 450m$

$\Delta = 50°$

chainage = 16805m.

Tangent length = $R \tan(\frac{\Delta}{2})$

= 209.83m

Length of curve = $R\Delta$ = $450 \times (50° \times \frac{\pi}{180})$

= 392.69 m

~~Length~~ Degree of curve = $\frac{1718.87}{R}$

for 30m = 3°49'

for 20m = $\frac{1145.91}{R}$ = 2°32'

Length long chord = $2R\sin(\frac{\Delta}{2})$

= $2 \times 450 \times \sin(\frac{50°}{2})$

= 380.35 m

Chainage of point of curvature

= 1680.5 − 209.83 m

= 1470.67. m.

Point of tangency = chainage of T_2.

$= 1470.67 + 392.7$

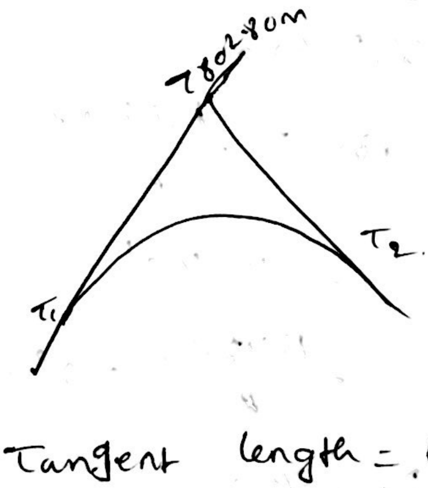
$= 1863.37$ m.

3) Two straights T_1B and T_2B intersect at the chainage of 390+14 and the angle of deflection is 115° for a right hand circular curve of radius 380m. Compute the chainage of tangent point T_1 and T_2 if 20m chainage was used.

$R = 380$m $\Delta = 115°$

Chainage $= 390 \times 20 + 14 \times 0.2$

$= 7802.80$m



length of curve

$= R\Delta$

$= 380 \times 115° \times \frac{\pi}{180}$

$= 762.70$m

Tangent length $= R \tan\frac{\Delta}{2}$

$= 596.48$ m

chainage of $T_1 = 7802.80 - 596.48$

$= 7206.32$ m $= 360 + 31.6$

chainage of $T_2 = 7206.32 + 762.70$

$= 7969.02$ m. $= 398 + 45.1$

4) A circular curve of radius ~~300m~~ 800m has a deflection angle of 40° between tangents calculate the radial and perpendicular offsets of 20m interval for 200m.

Perpendicular Offsets :

$$O_x = \frac{x^2}{2R} \Rightarrow R - \sqrt{R^2 - x^2}$$

Radial offsets $O_x = \frac{x^2}{2R} \Rightarrow R - \sqrt{R^2 + x^2}$

$R = 800m$, $\Delta = 40°$.

$x = 200m$.

perpendicular

$$O_x = \frac{20^2}{2 \times 800} = 0.25$$

$$O_x = R - \sqrt{R^2 - x^2} = 0.25$$

Radial = 0.249 m.

offsets distance (m)	Radial offset ⊥r	Radial perpendicular offset	approximate method
20	−0.25	+0.249	0.25
40	−1.00	+0.99	1.00
60	−2.25	2.26	2.25
80	−4.01	3.99	~~4.00~~ 4.00
100	−6.27	6.22	6.25
120	−9.05	8.94	9
140	−12.34	12.15	12.25
160	−16.16	15.84	16
180	−20.51	20.0	20.25
200	−25.40	24.62	25.0

A curve of radius 300m has a deflection angle of 32°. calculate the radial and ⊥r offsets from the tangent to locate the points on the curve and calculate the offsets. The no. of offsets must be such that the offset length is < 20 m and interval of offsets is 20m.

07/03/17

Angular methods:-

Angles are measured by using Compass. and distances are measured by using tape.

methods:-

(1) Rankines deflection angle method.

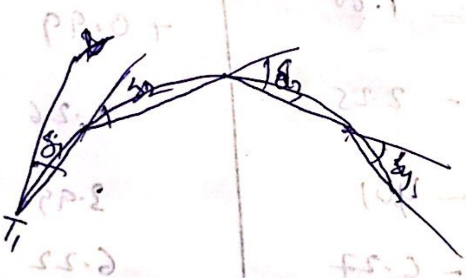
(2) Two theodolite method.

(3) Tacheometric method.

(4) .

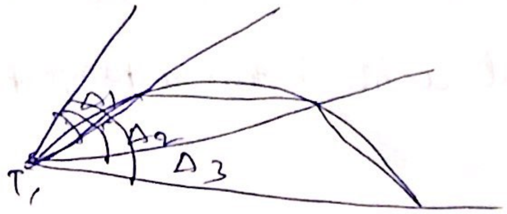
(1) Rankines deflection method:-

Tangential angles.



Let $\delta_1, \delta_2, \delta_3$ etc be the tangential angles means angle subtended by the chords GA, AB, BC and so on with the respective tangents

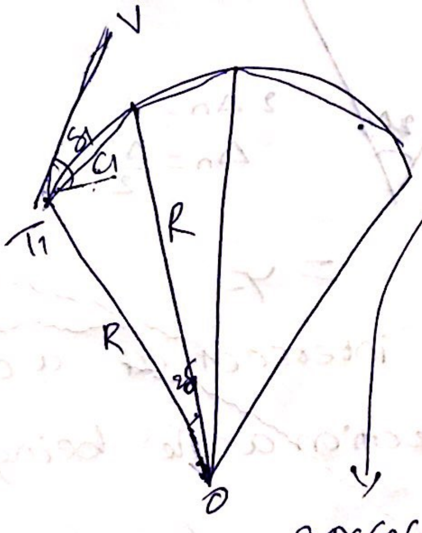
Deflection angles:-



Angle between rear tangent to the chord produced from point of curvature is known as deflection angle.

~~LOF A_1.~~
~~Means it is the angle~~

Let $\Delta_1, \Delta_2, \Delta_3$ etc be the deflection angles made by the back tangent T_1V with the chords T_1A, T_1B, T_1C - - -



$$\delta_1 = \frac{90C_1}{\pi R}$$

$$C_1 = R \times 2\delta_1$$

$$C_1 = R \times 2\delta_1 \times \frac{\pi}{180}$$

$$2\delta_1 = C_1 \times \frac{180}{\pi R}$$

$$\delta_1 = \frac{90 \times 60 C_1}{\pi R} = \frac{1718.87 C_1}{R}$$

$$\delta_2 = \frac{1718.87 C_2}{R}, \quad \delta_3 = \frac{1718.87 C_3}{R}$$

Here $\Delta_1 = \delta_1$

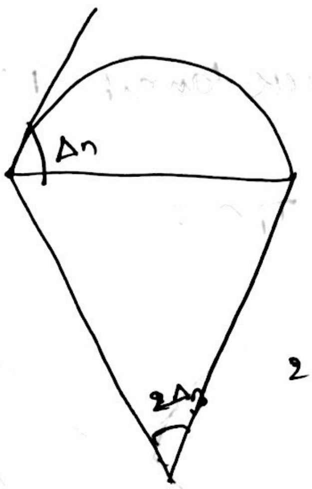
$\Delta_2 = \angle VT_1A + \angle AT_1B$

$\Delta_2 = \Delta_1$

According to theory of circle the angle subtended by the chord in the opposite segment is equal to the tangential angle between tangent of a successive chord.

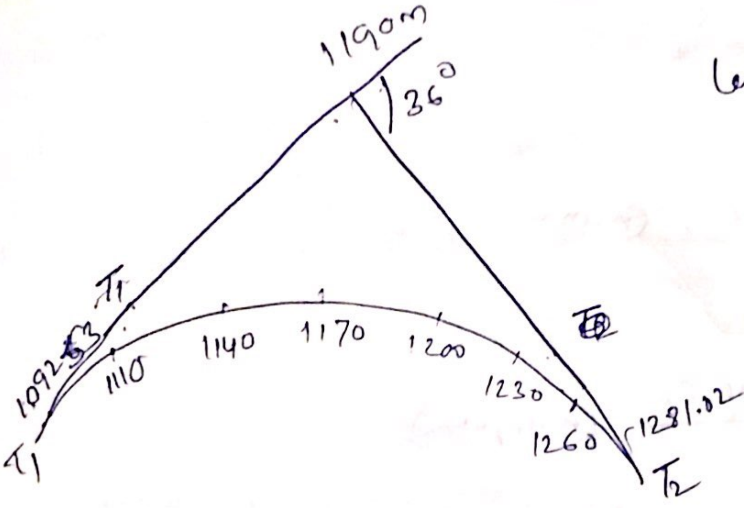
$$\Delta_2 = \angle VT_1A + \angle AT_1B$$
$$= \Delta_1 + \angle UAB$$
$$= \Delta_1 + \delta_2$$

$$\Delta_3 = \delta_1 + \delta_2 + \delta_3$$
$$= \Delta_1 + \delta_2 + \delta_3$$
$$= \Delta_2 + \delta_3.$$



$$2\Delta n = A$$
$$\Delta n = \frac{\Delta}{2}$$

1) Two tangents intersect at a chainage of 1190 m the deflection angle being 36°. Calculate all the data neccessaly. for settingout a curve with a radius of 300 m by deflection angle method. Peg interval is 30m.



Length of tangent

$= R \tan\frac{\Delta}{2}$

$= 300 \tan 18°$

$= 97.47m$

Chainage of T_1

= chainage of V − length of tangent

$= 1190 - 97.47$

$= 1092.53$ m.

Length of curve $= R\Delta$

$= R \times D \times \frac{\pi}{180}$

$= 306.60 \times 36 \times \frac{\pi}{180}$

$= 188.4$ m

Chainage of T_2 = chainage of T_1 + length of curve

$= 1281.02$

$C_1 = 17.47$m

$C_2 = C_3 = C_4 = C_5 = C_6 = 30$m

$C_7 = 21.05$m

$\delta_1 = \frac{1718.87\, C_1}{R} = \frac{1718.87 \times 17.47}{300}$

$= 100°05'43''$

~~$\delta_2 = \delta_3 = \delta_4 = \delta_5 = \delta_6 =$~~

$\delta_1 = \frac{1718.87 C_1}{20 R}$ (min)

$= \frac{28.64 C_1}{R}$ (in degree)

$= 1°40'$

$\frac{28.64 C_2}{R} = \delta_2 = \delta_3 = \delta_4 = \delta_5 = \delta_6 = 2°51'$

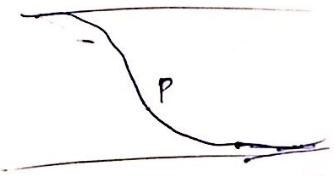
$\delta_7 = \frac{28.64 \cdot C_3}{R} = 2°0'$

Chord	Length	tangential angle	deflection angle
T_1A	17.47	1°40'	1°40'
AB	30	2°51'	4°31'
BC	30	2°51'	7°22'
CD	30	2°51'	10°13'
DE	30	2°51'	13°4'
EF	30	2°51'	15°55'
FG	21.05	2°0'	17°55'

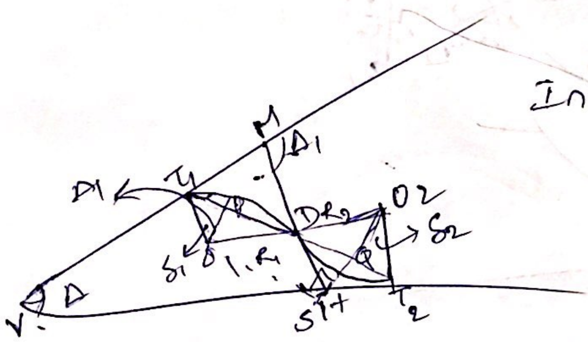
2) Two tangents intersect at a chainage of 106+055 links in terms of chainage the deflection angle being 72°. Calculate all the necessary data for setting out a curve with the radius of 200 m by deflection angle method. peg interval is ~~20m~~ 20m

14/03/17

Reverse curves



Reverse curve is used when two straights are parallel to each other and θ



$\Delta + \Delta_2 = \Delta_1$

$\Delta = \Delta_1 - \Delta_2$

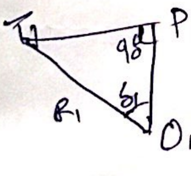
In Δle VT_1T_2

$\Delta + \delta_2 = \delta_1$

$\Delta = \delta_1 - \delta_2$

$\Delta_1 - \Delta_2 = \delta_1 - \delta_2$

Extend the the from O_1 which is parall to PQ and draw perpendicular O_2S which meets O_1S and O_2S at 'S'.



$O_1P = R_1 \cos\delta_1$

$O_2Q = R_2 \cos\delta_2$

~~O_1P~~ $O_2S = O_1P + O_2Q$

$O_2S = R_1\cos\delta_1 + R_2\cos\delta_2$

$\Delta_1 - \delta_1 = \Delta_2 - \delta_2$

$$\cos(\Delta_2 - \delta_2) = \frac{O_2 S}{R_1 + R_2}$$

$$O_2 S = (R_1 + R_2)\cos(\Delta_2 - \delta_2)$$

$$R_1 \cos\delta_1 + R_2 \cos\delta_2 = (R_1 + R_2)\cos(\Delta_2 - \delta_2)$$

Equation of element curve.

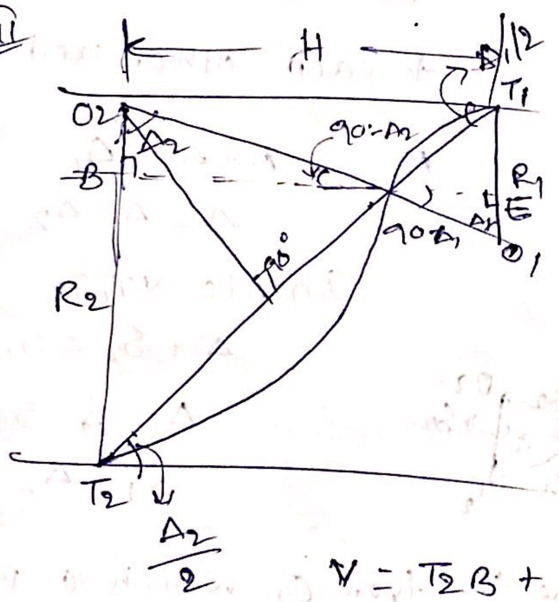
$$\cos(\Delta_1 - \delta_1) = \frac{R_1 \cos\delta_1 + R_2 \cos\delta_2}{R_1 + R_2}.$$

case-I

Reverse curve between two parallel straight

$R_1 = R_2$

case-II

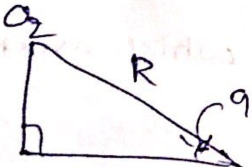


$$V = T_2B + T_1E$$

$$T_2B = O_2T_2 - O_2B.$$

$$= R_2 - R_2\cos\Delta_2$$

$$= R_2(1 - \cos\Delta_2).$$



$$\sin\left(90 - \frac{\Delta}{2}\right) = \frac{O_2B}{R_2}$$

$$\therefore O_2B = R_2\cos\Delta_2.$$

$$ET_1 = O_1T_1 - O_1E$$

$$= R_1 - R_1\cos\Delta_1$$

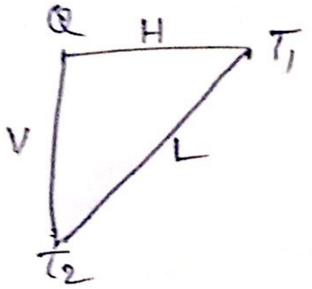
$$= R_1(1 - \cos\Delta_1)$$

$V = (R_1 + R_2)(1 - \cos A)$

$V = 2(R_1 + R_2)\sin^2 \frac{\Delta_1}{2}$

~~V=2~~ Let H be the maximum horizontal distance between the tangent points parallel to straights.

Let L be the distance between T_1 and T_2.



$L = 2R_1 \sin\frac{\Delta_1}{2} + 2R_2 \sin\frac{\Delta_2}{2}$

$= 2(R_1 + R_2)\sin\frac{\Delta_1}{2}.$

$\tan\frac{\Delta_1}{2} = \frac{V}{H}$

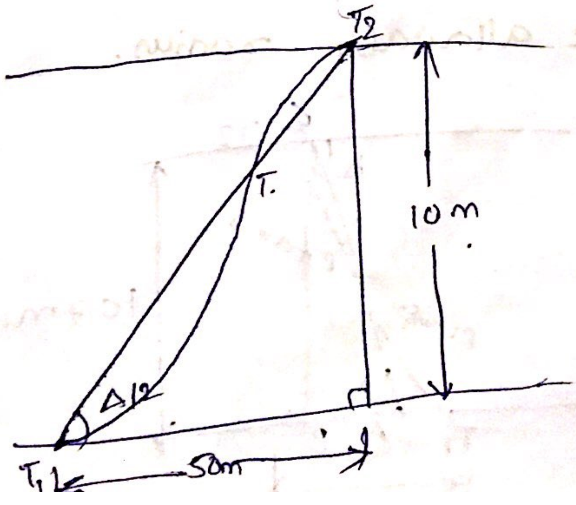
$H = V\cot\frac{\Delta_1}{2}$

1) Two parallel Railway lines are to be connected. if ~~the lines~~ by a reverse curve. If the lines are 10cm apart the max. distance b/w the tangent points, measure parallel to the ~~starting~~ straight is 50m. Find

(a) The radius 'R' if $R_1 = R_2 = R$

(b) The radius R_2 if $R_1 = 50m$

Also calculate the length of the both curves.



$\tan\frac{\Delta}{2} = \frac{10}{50}$, $\Delta = 22°37'$

$T_1T = 2R_1 \sin\frac{\Delta}{2}$

$T_2T = 2R_2 \sin\frac{\Delta}{2}$

$L = 2R_2 (\sin\Delta/2)$

$V = 2(R_1+R_2)\sin^2\frac{\Delta}{2}$

$10 = 2(R+R)\sin^2(\frac{22°37'}{2})$

$R \Rightarrow \frac{10}{4\sin^2(\frac{22°37'}{2})}$

~~R = 16.90 m 63.16 m~~

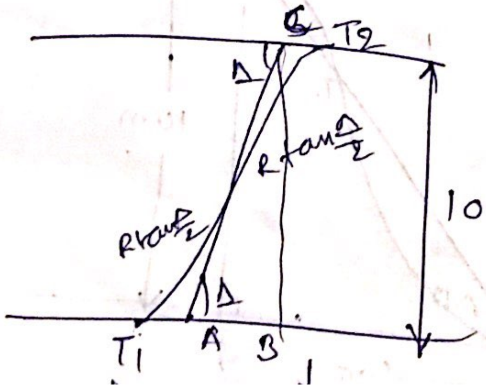
$R_1 = 65.01$ m

$R_2 = 80$ m

$L_1 = \frac{\pi R \Delta}{180}$ $L_1 = -$

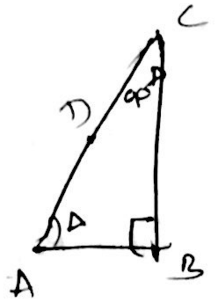
16/03/17

1) Two parallel roads distance 10.7 m Centre to Centre apart are to be Connected by a reverse curve of same radius such that max distance b/w tangent points is 41.5 m. what is the allowable radius.



$41.5 = T_1A + AB + BT_2$

$\Rightarrow 41.5 = R\tan\frac{A}{2} + AB + R\tan\frac{A}{2}$



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

~~$AB = AC\cos A$~~

$AB = 2R\tan\frac{A}{2}\cos A$

$\Rightarrow 41.5 = R\tan\frac{A}{2} + 2R\tan\frac{A}{2}\cos A + R\tan\frac{A}{2}$

$\Rightarrow 2R\tan\frac{A}{2}(1+\cos A) = 41.5$

$\Rightarrow 2R\tan\frac{A}{2}\cdot\cos^2\frac{A}{2} = 41.5m$

$2R\,2\cdot\sin\frac{A}{2}\cdot\cos\frac{A}{2} = 41.5m$

$2R\sin A = 41.5$

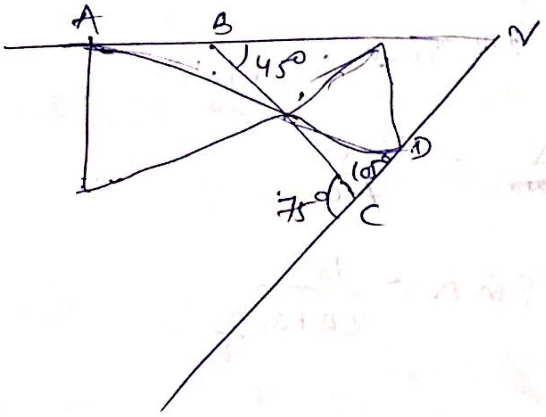
~~$\tan A$~~ I $\sin A = \frac{BC}{AC}$

$\sin A = \frac{BC}{2R\tan\frac{A}{2}}$

$2R\tan\frac{A}{2}\cdot\sin A = BC$

~~There are~~

2) There are two straights AB and CD which intersect at B. The angle VBC is 45° as ~~BCV~~ BCV is 105°. A reverse curve is proposed to connect the two straights such that the two reverse curves meet on line BC. The length of line BC is 803 m. Radius of curve for straight AB is 815 m. chainage of B is 2349.7m. Compute the radius of curve for straight CD, both the length of the ~~B~~. curves and chainage of point D.



Tangent length AB = $R \tan \frac{\Delta}{2}$

$= 337.5m$

Given BC = 803m, AB = BT = 337.5m

BC = BT + TC = 803

TC = 803 - 337.5 = 254.5m

$TC = R_2 \tan \frac{\Delta_1}{2}$

$4~~635~~-5 \cdot 465.5 = R_2 \tan\left(\frac{87.5^\circ}{2}\right)$

$R_2 = 606.54\ m$

$L_1 = R\Delta \times \frac{\pi}{180}$ $\quad L_1 = \frac{\pi R \Delta}{180} = 640\ m$

$= 606.54 \times \cdot \quad L_2 = 793.95\ m.$

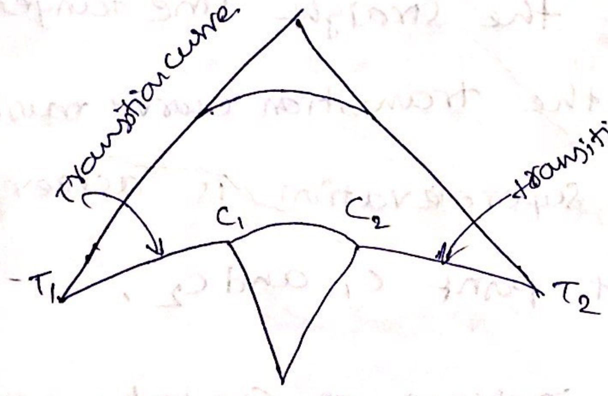
Chainage of A = chainage of B − tangent length

= 2349.7 − 337.5

= 2012.2 m.

Chainage of D = chainage of B & A

Transition curves :-



Curve of varying radius

curvature $= \frac{1}{R}$

Radius of the transition curve at the point of tangents is infinite.

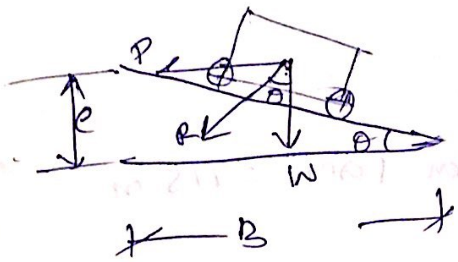
when a vehicle travelling on a straight road. enters into a horizontal curve instantaneously it will cause discomfort to the driver. to avoid this it is required to provide a transition curve (Transition curve is a curve of varying radius)

Foremen

Superelevation

It is also called as cant (or) banking

It is the rising of outer edge of road w.r.t inner edge so as to avoid skidding of the vehicle due to centrifugal force while traversing in a circular path.



$$\tan\theta = \frac{e}{B} = \frac{P}{W}$$

$$P = \frac{mv^2}{R} = \frac{Wv^2}{gR}$$

R = Radius

$$\frac{e}{B} = \frac{P}{W} \Rightarrow \frac{Wv^2}{gRW}$$

$$\frac{e}{B} = \frac{P}{W} = \frac{v^2}{gR}$$

$\frac{P}{W}$ = Ratio of centrifugal force to the weight of the vehicle.

For roadways $\Rightarrow \frac{P}{W} = \frac{1}{4}$

For Railways $\Rightarrow \frac{P}{W} = \frac{1}{8}$

UNIT-IV

AERIAL PHOTOGRAPHY

Introduction:

Aerial survey is another type of survey where in photographs are taken from air that depicts a part of earth's surface. Other terms are used synonymously are **aerial photogrammetry.**

in other words, 'photogrammetry' can be defined as the process of developing a map by combining different photographs of earth's surface.

Terrestrial photograph and Terrestrial Photogrammetry:

- It is also known as **ground photograph.**
- Here the instrument being used is photo theodolite.
- Photo theodolite is nothing but a conventional camera fitted with the camera axis horizontal and a theodolite.
- It is very similar to plane table surveying and various ground features are shown in photographs. this features are located by intersection of line of sight from two or more stations.
- Similar to plane tabling, the plotting work is done in the field only.

Aerial Photograph and Aerial photogrammetry:

- Here also the same camera is used but the camera axis is vertical here.
- The camera is mounted on an aircraft. Aerial photography covers a alarge area as compared to terrestrial photography.
- Now a days, it has almost replaced the terrestrial photogrammetry due to the fact that here the pace of work and accuracy is more than the terrestrial photogrammetry.
- In aerial photogrammetry, the camera axis is kept parallel to the direction of gravity, camera being mounted on an aircraft and vertical photographs of the ground are taken. The air craft flies along the parallel predetermined flight paths.

Aerial Photograph:

- Aerial photograph is the photograph of an area taken from the air with a camera mounted on aircraft.
- This image of the ground that is being photographed gets formed on the focal plane of the camera's objective lens at which a sensitive film is placed.
- In a vertical photograph it is required to keep the camera axis vertical. But it is very difficult to maintain the optical axis of the camera truly vertical. This gives rise to tilted photographs.

Tilted Photograph:

In a tilted photograph, the camera axis unintentionally inclined to the vertical by an angle not exceeding 3^o.

Oblique photograph:

In an oblique photograph, the camera axis is incline intentionally to the vertical and the resulting photograph is called as oblique photograph.

A limiting case of photograph is the **high- oblique photograph** which contains the horizon, while in a **low oblique photograph**, the photograph does not contains the horizon.

Difference between a Map and an Aerial Photograph:

S.No	Map	Aerial Photograph
1	It is an orthogonal projection	It is a perspective projection
2	Selected details are shown	A vast number of details are available
3	More clarity due to use of legends and other symbolic representations	Less clarity due to no symbolic representations
4	It has a constant scale	Here the scale differs due variations of elevations

Terminologies in aerial surveying:

Altitude:height of the air craft above the ground

Flying height: Height of the air craft above a chosen datum.

Exposure Station: position of the air craft at the time of exposure of the film.it is essentially the position of the optical center of the camera lens when the film is exposed.

Air Base: distance between two consecutive exposure stations.

Tilt and tip: tilt is the inclination of the optical axis of the camera about the line of flight. Tip is the inclination of the camera axis about a line perpendicular to the line of flight.

Picture Plane: plane that contains the image at the time of camera exposure.

Ground Plane: horizontal surface from which heights can be measured and which can be used as a datum surface.

Perspective center: optical center of the camera through which all rays of light pass.

Principal Ground Point: when the optical axis is extended downwards, the point of intersection with the surface is known as the principal ground point.

Isocentre: point on the photograph at which the bisector of the angle of tilt meets the photographic plane.

Plumb points: the points at which the vertical line through the optical centre meets the photographicplane and the ground surface. The plumb point on the photograph is known as naidar point.

Homologus points: points on the ground and their representations in the photograph in perspective projection.

Crab: crab of a photograph is the angle between the flight line of the air craft and the edges of the photograph in the direction of flight.

Drift: it is the sideways shift of the photograph since flight line does not remain straight on the predetermined flight due to various substances like wind etc.

Stereoscopic Vision:

An aerial photograph is two dimensional view of an object as it lies on a plane. However, if photographs are available in stereo pairs, it is possible to get a three dimensional view of the object. Stereoscopic vision essentially lends height or depth to the object in photograph as it would have been seen by human eye.

Stereoscopic or Binocular Vision:

The human brain receives two images of the same object through the two eyes as seen from slightly different angles and fuses them into a three dimensional view. The two images received by the retina are fused into a single image giving depth to vision. When the distance between the eye and the object is large, the parallax angle becomes smaller and at 600m the relative depth is no longer perceived by the eye.

Stereoscopic Pairs:

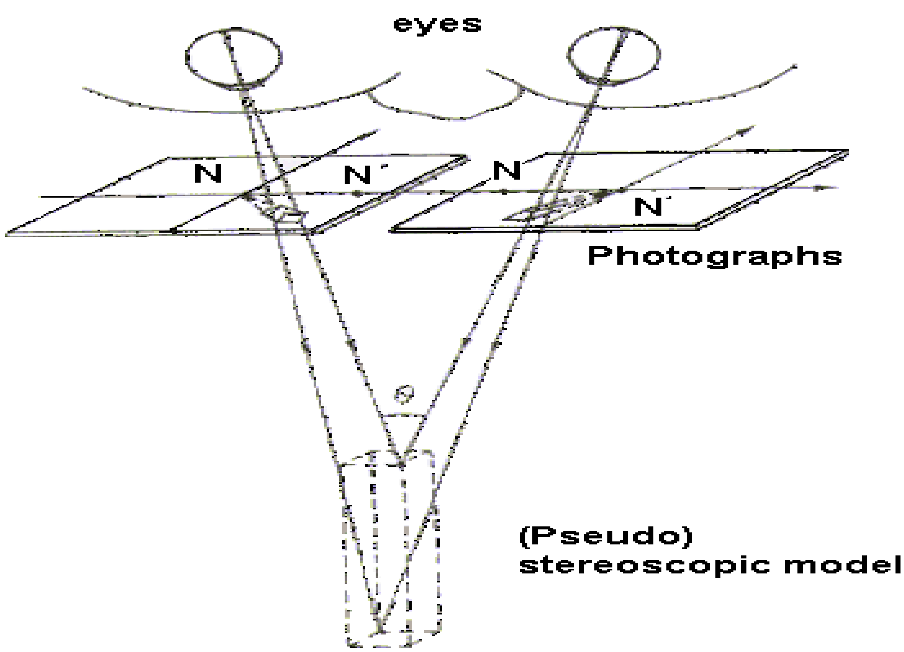
To enable stereoscopic vision, it is essential to have photographs in pairs covering common areas. In aerial photography, photographs are taken from two camera positions with sufficient overlap in the photographs. Only the areas seen in both the photographs are amenable to stereoscopic vision. The common part of the photograph gives us two views of the same object from slightly different angles, as seen by the human eye. When the photographs are suitably placed and the left eye views one and the right eye other, the common area comes in relief or in three dimensions due to stereoscopic fusion. Stereoscopic vision enables one to view the depth or height of points on the photograph.

Stereoscopes:

There are many types of stereoscopes-mirror stereo scopes, lens stereoscopes, scanning mirror and zooming stereoscopes. Lens and mirror stereoscopes are handy and commonly used.

Mirror stereoscope:

The schematic diagram of the mirror stereoscope is shown below. The mirror stereoscope consists of two viewing eyepieces. A stereoscopic pair of photographs is placed at a distance from the stereoscope. The photographs are adjusted so that one photograph is seen through one eyepiece. As the viewer looks through the stereoscope, he/she sees the image of the same object on the two photographs and this gives a stereoscopic view by fusion. The terrain is seen in relief due to this.



Lens stereoscope:

A lens stereoscope has two eyepieces through which the observer sees the photographs, providing the experience of stereoscopic or spatial view. The lenses help to magnify the image as seen by each eye. The distance between the eyepieces is adjustable and can be set by the observer as per requirement. This distance is approximately equal to the distance between human eyes. The lenses tend to magnify the object and its height. Lens stereoscopes are more compact than mirror stereoscopes.

Mosaics:

On way to use the photographs taken from an aerial platform is to arrange them as stereo pairs. This give a better idea of the ground relief, there by enabling to study and intercept the photographs. Another method of using them is to get a photographic view of the area by cutting and positioning them to form a total image of the area. The photograph that results after the tilt and ground relief corrections have been made is known as a controlled mosaic. If corrections are not made before hand, then the built up image is called an uncontrolled mosaic.

A mosaic is built by first obtaining the contact prints in the serial order of taking them and removing the overlapping portions. Generally the mosaic contains the center portion of the photograph which has generally an average scale. The first photograph is suitably cut with a fine cutter to give a slanted edge. The next photograph is cut similarly so that when pasted to the first it forms a complete image of the area. A number of photographs are used in building up a mosaic in this way to give a complete photographic image of the area surveyed.

Photo Interpretation:

Photo interpretation is the key to effective use of photographs. It refers to accurate identification of the features seen in photographs. Objects seen in photographs are often not easy to recognize, and it takes some amount of skill on the part o the interpreter to correctly identify the objects and judge their significance. It is more difficult to identify objects in vertical photographs than in tilted photographs owing to the familiarity of view in oblique photographs. Colour photographs are easier to interpret than black and white photographs due to depth available in photographs when seen through a stereoscope. Considerable amount of practice and experience is required to correctly interpret photographs.

Interpretation of aerial photographs is required extensively in developmental project design and execution. It has been successfully applied in a variety of fields. The success of project planning depends on the effective and efficient interpretation of photographs by engineers and others. A good deal of patience and ingenuity is required to interpret photographs.

REMOTE SENSING

Remote Sensing:

It is science of acquiring information about the earth's surface without actually being in contact with target.

This is done by sensing and recording reflected or emitted energy and processing, analysing.

Remote sensing provides flexibility to observe large area at finer spacial and temporal frequencies.

History: The development of remote sensing over time can be broadly divided into following 3 phases.

1. The early age (1839-1907)

2. The middle age (1908-1945)

3. The modern age (1946 onwards)

Early age (1839-1907):

- In 1840 the director of Paris observatory advocated the use of photography for topographic surveying and that time balloon photography flourished.
- In 1858 gasper Felix photographed the house of French village from a balloon at a height of 80m.
- After 2 years in 1860, Nadar took aerial photos of the enemy troop moments for the French army during the Franco-Prussian war-I.
- Later cameras moved from balloons to kites and other platforms.
- In 1903 Julius Neubronne patented a breast mounted camera for pigeons, which are capable to expose automatically at 30-second intervals. But pigeons were not well accepted remote sensing platforms.
- In 1906 Albert maul used a rocket, powered by compressed air to lift a camera and took an aerial photograph from height of 2,600ft.

The middle age (1908-1945):

- First time aeroplane was used as a platform to obtain aerial photography was in 1908 first aerial motion picture was recorded in Italy by Wilbur wright.
- The camera strobe was first developed by Dr. Edgerton to take pictures at night during world war-II(1940)
- World war-II brought more sophisticated techniques in aerial photo interpretation as well which was widely used for military intelligence purposes. And it gave real boots to photo interpretation; some notable successes from the war are identification of radar, water depth detectors, and vegetation indicators.

The modern age (1946 onwards):

- A commission on the utilization of aerial photographs was set up by International Geographical Union (IGU) in 1949.
- The members of the commission emphasized the need of knowledge of those parts of world which were not earlier photographed and also attention was given to cover more area by aerial photographs and techniques essential for interpretation.
- The techniques of photo interpretation became much more an applied technique. A number of instruments was developed and introduced for interpretation during this period. It opened a new horizon for accurate and fast analysis and also for monitoring the changes.
- Hence a considerable advanced interpretation was made in many disciplines such as Geography, Geology, Geophysics, Agriculture and Archaeology. This phase is very significant in the history of Remote Sensing as artificial satellites were launched in the space for acquiring information of earth surface.
- Though two American satellites, i.e. Explorer I and II were launched in 1958 and 1959 respectively under Explorer and Discover Programme, they were not important from Remote Sensing point of view.
- On 1st April, 1960, one satellite of eight members of TIROS (Television and Infrared Observation Satellites) family was launched as a research and development project. ***As TIROS's name suggested, the satellite carried two types of sensing devices – firstly, television, camera etc. which took picture***

of the visible spectrum; and secondly, infrared detectors which measured the non-visible part of spectrum and provided information of local and regional temperature of earth's surface.

- The supply of remotely sensed data of earth surface was greatly increased with the launching of ERTS-I (Earth Resources Technology Satellite) on 23rd July, 1972. It was placed in a sunsynchronous polar orbit about 600 miles above the earth surface. It makes 14 revolutions in a day around the earth and its sensors were covering a series 160 kms. wide strip.
- Then it was followed by ERTS-2 in 1975. With the launch of this satellite, the name of these satellites has been changed from ERTS-1, 2 to LANDSAT-1, 2 respectively. Four other satellites in these series were launched one after another in this phase, with improved cameras and sensors. Beside this, many other satellites were launched in the space by European and Asian Countries during this period.
- In this period, ***Remote Sensing technique has been improved in two ways. Firstly, there have been developments of sensors which can use infrared and microwave spectrum other than visible spectrum to get information about earth's surface***.
- ***Secondly, there have been very important advances with respect to the platforms in which sensors are mounted***. Besides, satellites have been launched for specific purposes and with specific capability. The ground resolution is continuously increasing till today. Hence, interpretation and mapping is becoming very easy, accurate and purposive.
- The European Radar satellite (ERS-I) launched in 1991 opened the avenue for systematic global observation in the microwave region.
- The French Satellite 'SPOT' is producing the imagery to provide the three dimensional view under stereoscope.
- The satellite – IKONOS, launched on 24th September, 1999 has 1 m. resolution in panchromatic and 4 m. resolution in multi-spectral cameras.
- USA, France and India have planned and launched a series of satellites, with improved capability, so that the users are assured continuity of data.

Passive/ Active Remote Sensing:

Depending on the source of electromagnetic energy, remote sensing can be classified as passive or active remote sensing.

Passive remote sensing:

- Source of energy is that naturally available such as the Sun.
- Most of the remote sensing systems work in passive mode using solar energy as the source of EMR.
- Solar energy reflected by the targets at specific wavelength bands are recorded using sensors onboard air-borne or space borne platforms.
- In order to ensure ample signal strength received at the sensor, wavelength / energy bands capable of traversing through the atmosphere, without significant loss through atmospheric interactions, are generally used in remote sensing
- Any object which is at a temperature above 0^0 K (Kelvin) emits some radiation.
- Passive sensors can also be used to measure the Earth's radiance but they are not very popular as the energy content is very low.

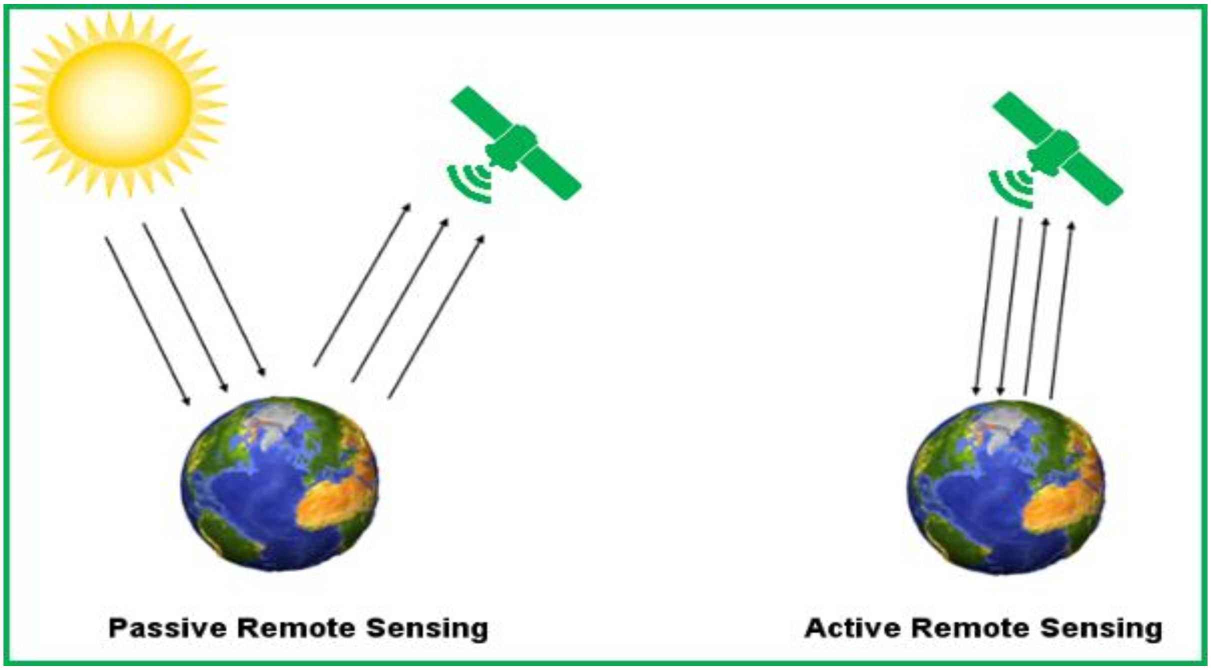
  Example: passive remote sensing is similar to taking a picture with an ordinary camera

Active remote sensing:

- Energy is generated and sent from the remote sensing platform towards the targets.
- The energy reflected back from the targets are recorded using sensors onboard the remote sensing platform.

  Most of the microwave remote sensing is done through active remote sensing.

Example: Active remote sensing is analogous to taking a picture with camera having built-in flash



Remote sensing process:

1. Radiation by energy source.
2. Interaction of energy with atmosphere.
3. Interaction of EMR with the object /target.
4. Interaction of energy with atmosphere again.
5. Recording of energy by the sensor.
6. Transmission, reception and processing.
7. Interpretation and analysis.
8. Application.

1) Radiation by energy source:

- ❖ In remote sensing technique, electromagnetic radiations emitted / reflected by the targets are recorded at remotely located sensors and these signals are analysed to interpret the target characteristics.
- ❖ Characteristics of the signals recorded at the sensor depend on the characteristics of the source of radiation / energy, characteristics of the target and the atmospheric interactions.

Source of energy:

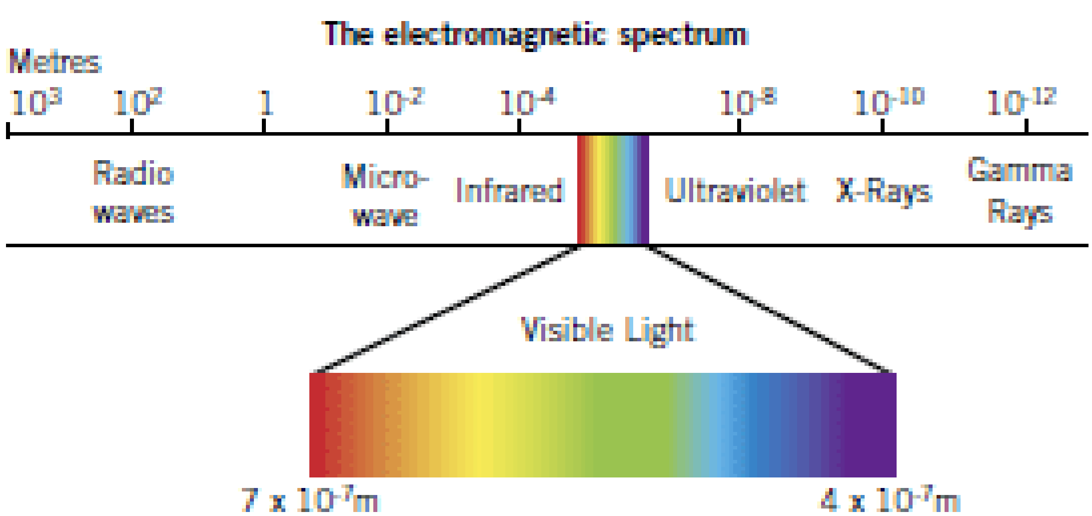
Sun is natural source of energy. Artificial sources also used in remote sensing. Whether the energy is radiated from an external source or emitted from object itself it is in the form of EMR.

Electromagnetic Energy:

"Electromagnetic (EM) energy includes all energy moving in a harmonic sinusoidal wave pattern with a velocity equal to that of light. Harmonic pattern means waves occurring at frequent intervals of time.
Electromagnetic energy has both electric and magnetic components which oscillate perpendicular to each other and also perpendicular to the direction of energy propagation"
Concept of EMR can be described by using 2 different models
Wave model and ***Particle model.***

Electromagnetic spectrum:

- ✓ Distribution of radiant energy can be plotted as a function of wavelength (or frequency) and is known as the electromagnetic radiation (EMR) spectrum.
- ✓ EMR spectrum is divided into regions or intervals of different wavelengths and such regions are denoted by different names.
- ✓ The EM spectrum ranges from gamma rays with very short wavelengths to radio waves with very long wavelengths.



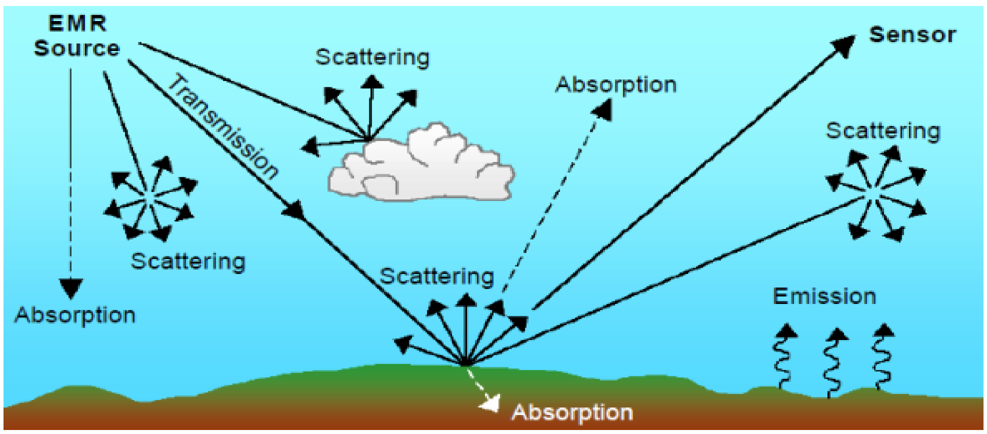
- ✓ The visible region (human eye is sensitive to this region) occupies a very small region in the range between 0.4 and 0.7 μm. The longest visible wavelength is red and the shortest wavelength is violet. However blue, green, red are primary colours or wavelengths of the visible spectrum.
- ✓ Remote sensing is generally performed within the range of ultraviolet to microwave region.
- ✓ Different bands of electromagnetic spectrums are used for different types of remote sensing.
- ✓ Gamma rays are not available for remote sensing. Incoming radiation is absorbed by the atmosphere.
- ✓ X-ray are also not available for remote sensing since it is absorbed by atmosphere.
- ✓ Ultraviolet (UV) rays 0.03 - 0.4 Wavelengths less than 0.3 are absorbed by the ozone layer in the upper atmosphere. Wavelengths between 0.3- 0.4 μm are transmitted and termed as "Photographic UV band".
- ✓ Visible 0.4 - 0.7 detectable with film and photo detectors. Hence this is used for aerial remote sensing
- ✓ Infrared (IR) 0.7 – 100 atmospheric windows exist which allows maximum transmission. Portion between 0.7 and 0.9 μm is called photographic IR band, since it is detectable with film.
- ✓ Microwave can penetrate rain, fog and clouds. Both active and passive remote sensing is possible. Radar uses wavelength in this range.
- ✓ Radio have the longest wavelength. Used for remote sensing by some radars.

2) <u>Interaction of energy with atmosphere:</u>

- ❖ EMR is generated first it is propagated through the vacuum and through the earths atmosphere.
- ❖ In vacuum EMR travels with speed of light with any change in its property.
- ❖ But when it enters into earth's atmosphere it may affect not only in speed of radiation but also its wavelength, its intensity, and spectral distribution.
- ❖ Because atmosphere consists of presence of different types gases in addition to gases, the atmosphere also contains water vapour, methane, dust particles, pollen from vegetation, smoke particles etc.

Size of these particles in the atmosphere varies from approximately 0.01µm to 100µm.

❖ The gases and the particles present in the atmosphere cause scattering and absorption of the electromagnetic radiation passing through it. These Scattering and absorption are the main processes that alter the properties of the electromagnetic radiation in the atmosphere.
❖ EMR also diverted its original path due to refraction.



Scattering:

✓ Scattering is unpredictable diffusion of radiation by particles in the atmosphere.
✓ It occurs when particles or large gas molecules present in the atmosphere interacts with EMR and causes to be redirected from its original path.
✓ Amount of scattering depends on several factors like wavelength of the radiation, diameter of particles or gaseous particles, and the distance the distance travelled through atmosphere.

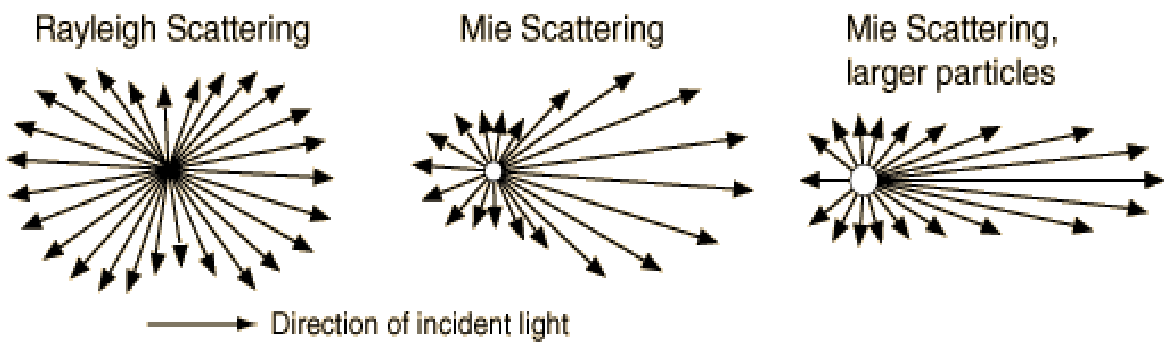
There are three different types of scattering:

□ Selective

□ Non-selective scattering

In **selective** scattering again there are 3 different types

□ Rayleigh scattering □ Mie scattering □ Raman scattering

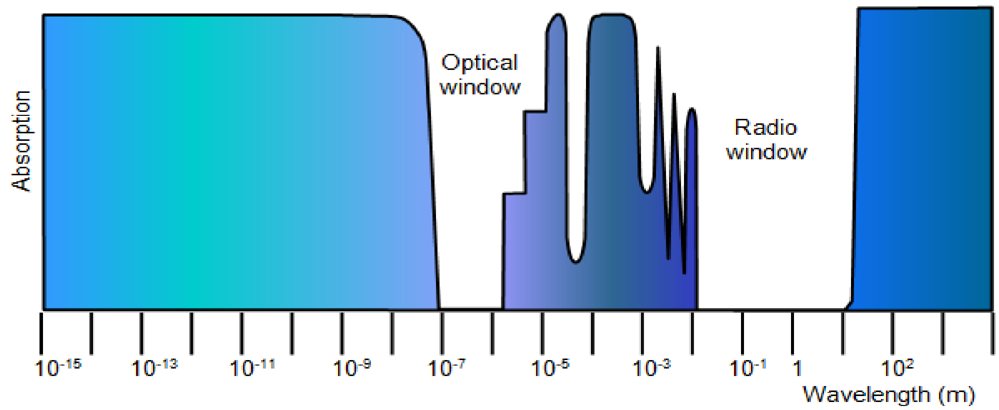


- **<u>Rayleigh scattering</u>**
  - This occurs when the particles causing the scattering are much smaller in diameter (less than one tenth) than the wavelengths of radiation interacting with them.
  - Smaller particles present in the atmosphere scatter the shorter wavelengths more compared to the longer wavelengths.
  - Rayleigh scattering is also known as selective scattering or molecular scattering.
  - Within the visible range, smaller wavelength blue light is scattered more compared to the green or red. The blue light is scattered around 4 times and UV light is scattered about 16 times as much as red light.
- **<u>Mie scattering</u>**
  - When the wavelengths of the energy is almost equal to the diameter of the atmospheric particles.
  - Mie scattering is usually caused by the aerosol particles such as dust, smoke and pollen. Actual size of particle may varies from 0.1 to 10 times of wavelength of incident energy.
  - This scattering happens lower 4.5km of the atmosphere.
- **<u>Raman scattering</u>**
  - This also caused by atmospheric particles, which are larger, smaller, or equal to the that of the wavelength the radiation.
  -

- **Non-selective scattering:**
  - This takes place in the lowest portions of the atmosphere where air particles greater than 10 times the wavelength of the incident EMR.
  - Particles such as pollen, cloud droplets, ice crystals and raindrops can cause non-selective scattering of the visible light.
  - For visible light (of wavelength 0.4-0.7μm), non-selective scattering is generally caused by water droplets which is having diameter commonly in the range of 5 to 100 μm. This scattering is non-selective with respect to wavelength since all visible and IR wavelengths get scattered equally.

Absorption:

- Radiant energy is absorbed and converted into other forms of energy.
- The absorbing medium will not only absorb a portion of the total energy, but will also reflect, refract or scatter the energy.
- The most efficient absorbers of solar radiation are water vapour, carbon dioxide, and ozone.
- Even though all the wavelengths from the Sun reach the top of the atmosphere, due to the atmospheric absorption, only limited wavelengths can pass through the atmosphere. The ranges of wavelength that are partially or wholly transmitted through the atmosphere are known as "***atmospheric windows***."
- Remote sensing data acquisition is limited through these atmospheric windows.
- It can be observed that electromagnetic radiation at different wavelengths is completely absorbed, partially absorbed or totally transmitted through the atmosphere.
- In the visible part of the spectrum, little absorption occurs.



- ❖ Infrared (IR) radiation is mainly absorbed due to the ***rotational and vibrational transitions of the molecules***. The main atmospheric constituents responsible for infrared absorption are water vapour (H_2O) and carbon dioxide (CO_2) molecules. Most of the radiation in the far infrared region is also absorbed by the atmosphere.
- ❖ However, absorption is almost nil in the microwave region.

Refraction:

- ✓ When EMR passed through different substances of different densities, like air and water, refraction takes place.
- ✓ Refraction is nothing but bending of light when it passes from one medium to another medium of different densities.
- ✓ Errors in location due to refraction can occur in images formed from energy detected at high altitude.
- ✓ However these errors are predictable by snell's law and can be removed.
  $n_1 \sin a1 = n_2 \sin a2$

Reflection:

- ❖ Whereby radiation "*bounces off* "an object like cloud, water body.
- ❖ Reflection is different from scattering. Where angle of incident and reflection all lie in same plane. And angle of incident and reflection are approximately same.
- ❖ This results in blurred image and appearance of cloud on the imagery are main problems of atmospheric reflection.

- When electromagnetic energy is incident on the surface, it may get reflected or scattered depending upon the roughness of the surface relative to the wavelength of the incident energy.
- If the roughness of the surface is less than the wavelength of the radiation or the ratio of roughness to wavelength is less than 1, the radiation is reflected. When the ratio is more than 1 or if the roughness is more than the wavelength, the radiation is scattered.
- Variations in the spectral reflectance within the visible spectrum give the colour effect to the features.
- For example, blue colour is the result of more reflection of blue light. An object appears as "green" when it reflects highly in the green portion of the visible spectrum. Leaves appear green since its chlorophyll pigment absorbs radiation in the red and blue wavelengths but reflects green wavelengths.

3) <u>Interaction of EMR with the object /target:</u>

- ✓ Radiation that is not absorbed or scattered in the atmosphere can reach and interact with the earth's surface.
- ✓ There are 3 types of interaction can take place when energy strikes, or incident upon the earth's surface. This incident electromagnetic energy may interact with the earth surface features in three possible ways: Absorption, Transmission and Reflection.
- ✓ Reflection occurs when radiation is redirected after hitting the target. According to the law of reflection, the angle of incidence is equal to the angle of reflection.
- ✓ Absorption occurs when radiation is absorbed by the target. The portion of the EM energy which is absorbed by the Earth's surface is available for emission and as thermal radiation at longer wavelengths.
- ✓ Transmission occurs when radiation is allowed to pass through the target. Depending upon the characteristics of the medium, during the transmission velocity and wavelength of the radiation changes, whereas the frequency remains same. The transmitted energy may further get scattered and / or absorbed in the medium.
- ✓ These three processes are not mutually exclusive. Energy incident on a surface may be partially reflected, absorbed or transmitted.

Which process takes place on a surface depends on the following factors:

- Wavelength of the radiation
- Angle at which the radiation intersects the surface
- Composition and physical properties of the surface

- ✓ The relationship between reflection, absorption and transmission can be expressed through the principle of conservation of energy. Let EI denotes the incident energy, ER denotes the reflected energy, EA denotes the absorbed energy and ET denotes the transmitted energy. Then the principle of conservation of energy(one form of energy neither be created nor be destroyed but one form of energy can be converted into another form) (as a function of wavelength λ) can be expressed as

$$\mathbf{E_I(\lambda) = E_R(\lambda) + E_A(\lambda) + E_T(\lambda)} \qquad (1)$$

Since most remote sensing systems use reflected energy, the energy balance relationship can be better expressed in the form

$$\mathbf{E_R(\lambda) = E_I(\lambda) - E_A(\lambda) - E_T(\lambda)} \qquad (2)$$

The reflected energy is equal to the total energy incident on any given feature reduced by the energy absorbed or transmitted by that feature.

Reflection:

Types of reflections

Diffuse and Specular Reflection

Energy reflection from a surface depends on the wavelength of the radiation, angle of incidence and the composition and physical properties of the surface.

Roughness of the target surface controls how the energy is reflected by the surface. Based on the roughness of the surface, reflection occurs in mainly two ways.

i) Specular reflection:

It occurs when the surface is smooth and flat. A mirror-like or smooth reflection is obtained where complete or nearly complete incident energy is reflected in one direction. The angle of reflection is equal to the angle of incidence. Reflection from the surface is the maximum along the angle of reflection, whereas in any other direction it is negligible.

ii) <u>Diffuse (Lambertian) reflection:</u>

It occurs when the surface is rough. The energy is reflected uniformly in all directions. Since all the wavelengths are reflected uniformly in all directions. Hence, in remote sensing diffuse reflectance properties of terrain features are measured. Since the reflection is uniform in all direction, sensors located at any direction record the same reflectance and hence it is easy to differentiate the features.

i. Diffuse reflectors are considered ideal for remote sensing. The reflection from an ideal diffuse surface will be the same irrespective of the location of the sensor. On the other hand, in case of an ideal specular reflector, maximum brightness will be obtained only at one location and for the other locations dark tones will be obtained from the same target. This variation in the spectral signature for the same feature affects the interpretation of the remote sensing data.

ii. Most natural surfaces observed using remote sensing are approximately Diffuse at visible and IR wavelengths. However, water provides specular reflection. Water generally gives a dark tone in the image. However due to the specular reflection, it gives a pale tone when the sensor is located in the direction of the reflected energy.

- ✓ The basic property by which an object can be identified is called ***signature.***
- ✓ 3types of signatures are there spatial, spectral, and temporal.
- ✓ Temporal signature is change in reflectance with time.
- ✓ Spatial signature are arrangements of terrain features like shape, size, texture.
- ✓ Spectral signature is change in reflectance with change in wavelength. For any given material, the amount of radiation that reflects, absorbs, or transmits is varies with wavelength. This important property of

matter makes it possible to identify different substances or classes and separate them by their ***spectral signatures***.

- ✓ A graph of the spectral reflectance of an object as a function of wavelength is termed as spectral reflectance curve.

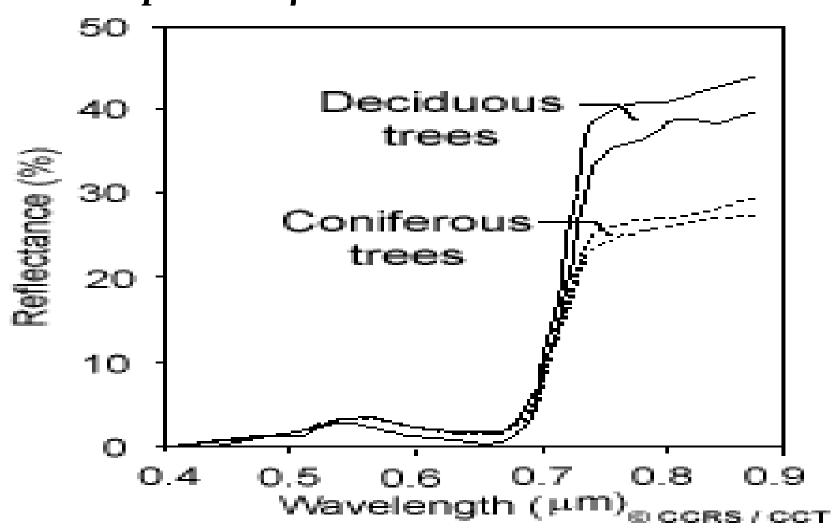
Spectral Reflectance Curves

- ❖ The *reflectance characteristics of earth surface features are expressed as the ratio of energy reflected by the surface to the energy incident on the surface. This is measured as a function of wavelength and is called* ***spectral reflectance*** *(R_λ). It is also known as albedo of the surface.*
- ❖ Spectral reflectance vary within a given material class.
- ❖ Spectral reflectance or albedo can be mathematically defined as

R_λ = Energy of wavelength reflected from the object*100/

Energy of wavelength incident on the object

- ✓ Albedo is low at lower incidence angle and increases for higher incidence angles.
- ✓ The energy that is reflected by features on the earth's surface over a variety of different wavelengths will give their spectral responses. "***The graphical representation of the spectral response of an object over different wavelengths of the electromagnetic spectrum is termed as spectral reflectance curve***"

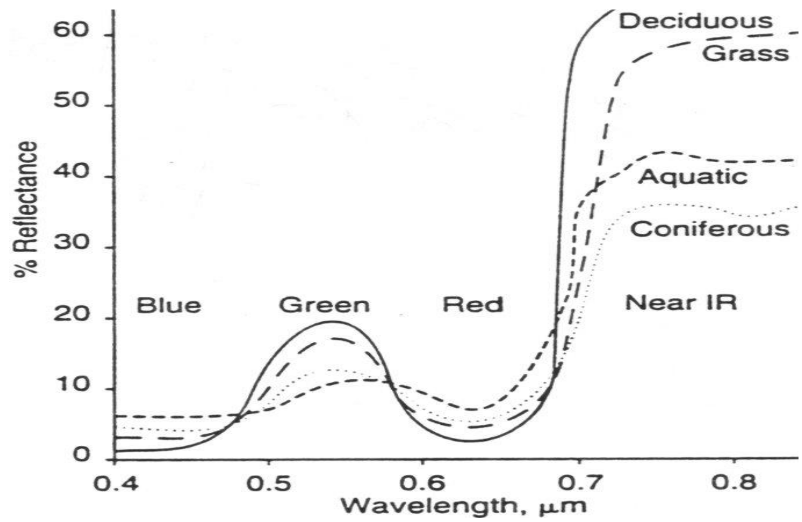


- ✓ These curves give an insight into the spectral characteristics of different objects, hence used in the selection of a particular wavelength band for remote sensing data acquisition.
- ✓ Spectral reflectance's varies within a given material i.e., spectral reflectance of one deciduous tree will not be identical with another. **These curves help in the selection of proper sensor system in order to differentiate deciduous and coniferous trees.**
- ✓ Spectral reflectance curves for deciduous and coniferous trees spectral reflectance curves for each tree type are ***overlapping*** in most of the ***visible portion***.
- ✓ A choice of visible spectrum is not a feasible option for differentiation since both the deciduous and coniferous trees will essentially be seen in shades of green.
- ✓ A comparison of photographs taken in visible band and NIR band. In visible band, the tone is same for both trees. However, on infrared photographs, deciduous trees show a much lighter tone due to its higher infrared reflectance than conifers.
- ✓ In remote sensing, the spectral reflectance characteristics of the surface features have been used to identify the surface features and to study their characteristics. This requires basic understanding of the general reflectance characteristics of different feature.

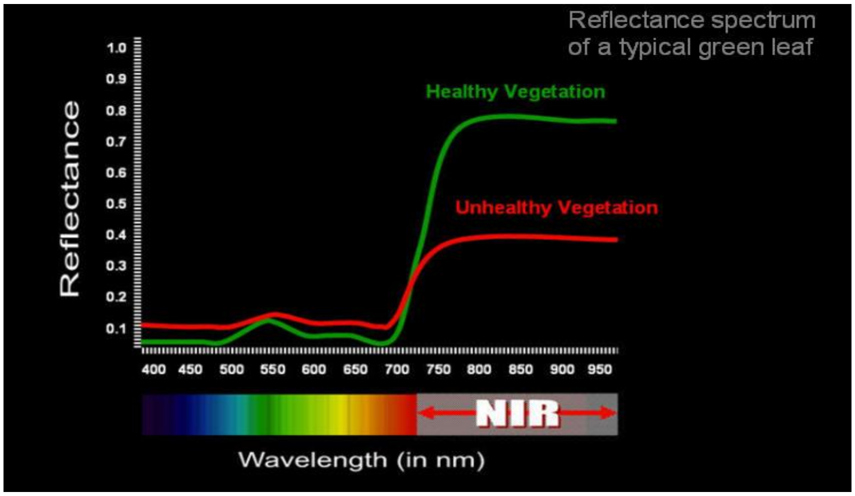
Spectral Reflectance Curve for Vegetation

- ❖ Spectral reflectance curve for healthy green vegetation exhibits the "peak-and-valley". The peaks indicate strong reflection and the valleys indicate predominant absorption of the energy in the corresponding wavelength bands.
- ❖ In general, ***healthy vegetation's are very good absorbers of electromagnetic energy in the visible region.*** The absorption greatly reduces and reflection increases in the red/infrared boundary near 0.7 μm.
- ❖ ***Spectral response of vegetation depends on the structure of the plant leaves.***
- ❖ The valleys in the visible portion of the spectrum are due to the pigments in plant leaves. The palisade cells containing sacs of green pigment

(chlorophyll) strongly absorb energy in the wavelength bands centered at 0.45 and 0.67 μm within visible region.



- On the other hand, reflection peaks for the green colour in the visible region, which makes our eyes perceive healthy vegetation as green in colour. However, only 10-15% of the incident energy is reflected in the green band.
- ***In the reflected infrared portion (or near infrared, NIR) of the spectrum, at 0.7 μm, the reflectance of healthy vegetation increases dramatically.***
- In the range from 0.7 to 1.3 μm, a plant leaf reflects about 50 percent of the energy incident upon it.
- Healthy vegetation therefore shows brighter response in the NIR region compared to the green region.
- If a plant is subjected to some form of stress that interrupts its normal growth and productivity, it may decrease or cease chlorophyll production.



- ***The result is less absorption in the blue and red bands in the palisade. Hence, red and blue bands also get reflected along with the green band, giving yellow or brown colour to the stressed vegetation.***
- Also in stressed vegetation, the NIR bands are no longer reflected by the mesophyll cells, instead they are absorbed by the stressed or dead cells causing dark tones.
- Similar to the reflection and absorption, transmittance of the electromagnetic radiation by the vegetation also varies with wavelength. "Transmittance of electromagnetic radiation is less in the visible region and it increases in the infrared region".

Spectral Reflectance of Soil

- ✓ Some of the factors effecting soil reflectance are moisture content, soil texture (proportion of sand, silt, and clay), surface roughness, presence of iron oxide and organic matter content. These factors are complex, variable, and interrelated.
- ✓ For example, the presence of moisture in soil decreases its reflectance.
- ✓ Soil moisture content is strongly related to the soil texture. For example, coarse, sandy soils are usually well drained, resulting in low moisture content and relatively high reflectance. On the other hand, poorly drained fine textured soils generally have lower reflectance. In the absence of water, however, the soil itself exhibits the reverse tendency i.e., coarse textured soils appear darker than fine textured soils.

- ✓ Two other factors that reduce soil reflectance are surface roughness and the content of organic matter. Presence of iron oxide in a soil also significantly decreases reflectance, at least in the visible region of wavelengths.

Spectral Reflectance for Water

- ❖ Water provides a semi-transparent medium for the electromagnetic radiation. Thus the electromagnetic radiations get reflected, transmitted or absorbed in water.
- ❖ The spectral responses vary with the wavelength of the radiation and the physical and chemical characteristics of the water.
- ❖ *Spectral reflectance of water varies with its physical condition*: In the solid phase (ice or snow) water give good reflection at all visible wavelengths. On the other hand, ***reflection in the visible region is poor in case of water in liquid stage.*** This difference in reflectance is due to the difference in the atomic bond in the liquid and solid states.
- ❖ Water in the liquid form shows high reflectance in the visible region between 0.4µm and 0.6µm. Wavelengths beyond 0.7µm are completely absorbed. Thus clear water appears in darker tone in the NIR image.
- ❖ Locating and delineating water bodies with remote sensing data is done more easily in reflected infrared wavelengths because of this absorption property.
- ❖ The reflectance from a water body can stem from an interaction with the water's surface (specular reflection), with material suspended in the water, or with the bottom surface of the water body.
- ❖ Even in deep water, where bottom effects are negligible, the reflectance properties of a water body are not only a function of the water, but also of the material in the water Clear water absorbs relatively less energy having wavelengths shorter than 0.6 µm.
- ❖ However, as the turbidity of water changes (because of the presence of organic or inorganic materials), transmittance and therefore reflectance change dramatically.
- ❖ For example, water bodies containing large quantities of suspended sediments normally have much higher visible reflectance than clear water.
- ❖ Likewise, the reflectance of water changes with the chlorophyll concentration involved. Increase in chlorophyll concentration tends to

decrease reflectance in blue wavelengths and increase reflectance in green wavelengths.

- ❖ These changes have been used in remote sensing to monitor the presence and to estimate the concentration of algae. Reflectance data have also been used to determine the presence vegetation in lowland areas, and to detect a number of pollutants, such as oil and certain industrial wastes.
- ❖ Many important characteristics of water such as dissolved oxygen concentration, pH, and salt concentration cannot be observed directly through changes in water reflectance.
- ❖ Variation in the spectral reflectance in the visible region can be used to differentiate shallow and deep waters, clear and turbid waters, as well as rough and smooth water bodies.

4) <u>Interaction of energy with atmosphere again:</u>

The radiant flux reflected or emitted from the earth's surface once again enter the atmosphere, where it interacts with different gases, water vapours. Thus atmospheric scattering, absorption, reflection and refraction influences the radiant flux once again before recorded the sensor.

5) <u>Recording of energy by the sensor:</u>

- ❖ Radiant energy recorded by the camera or detector is a true function of the amount of radiance leaving the terrain at a specific solid angle.
- ❖ Other radiant energy may enter the field of view from various other paths like atmospheric interaction, solar irradiance, sky irradiance, scattering etc., and also introduce confuse noise into the remote sensing process.
- ❖ The light from a target outside the field of view of the sensor may be scattered into the field of view of the sensor. This effect is known as ***adjacent effect***.
- ❖ Near to the boundary between two regions of different brightness, the adjacency effect results in an increase in the apparent brightness of the darker region while the apparent brightness of the brightness region is reduced.
- ❖ Only small amount of total radiance at the sensor is actually reflected by the terrain in the direction of the sensor system.

- Amount of radiance recorded by the sensor (L_s) doesn't equal to the radiance returned from the interest (L_t). Because some additional radiance from different path which may fall within field of view of the sensor system. This is called path radiance (L_p).

$$L_s=L_t+L_p$$

- This path radiance generally introduces unwanted radiometric noise in the remotely sensed data and complicates the image interpretation process. However these noises can be reduced while doing digital image processing.

6) **<u>Transmission, reception and processing:</u>**

- ✓ Remotely sensed data can be collected using onboard aircraft sensors/camera and/or onboard satellite remote sensors.
- ✓ Data obtained during airborne remote sensing missions can be retrieved once the aircraft lands. It can be processed and delivered to the end user.
- ✓ Data collected from satellite need to be electronically transmitted to the earth. There are 2 main options for transmitting data acquired by satellites to the surface.
  - A) Data can be directly transmitted to the earth if a ground receiving station (GRS) is in the line of sight of the satellite.
  - B) If case A is not possible then data transmitted to another satellite which is same geosynchronous orbit until they reach the vicinity of appropriate ground receiving station (GRS).
- ✓ Data received at the GRS in a raw digital format.
- ✓ If required be processed to correct systematic, geometric, and atmospheric distortion to the imagery and be translated into a standardized image format.

7) **<u>Interpretation and analysis:</u>**

Data alone cannot be used for decision making. It must be interpreted or analysed before one can extract information. Analysis of remotely sensed data is performed using a variety of image interpretation and processing techniques are categorised as ***visual image interpretation*** and ***digital image processing.***

<u>Visual image interpretation:</u>

Fundamental image interpretation are used in this is image analysis, including size, shape, shadow, colour, parallax, pattern, texture, site.

<u>Digital image processing:</u>

Information derived from remote sensor data are usually interpreted as enhancing image, image map, orthophoto map, thematic map, filtering etc.,

8) **<u>Application:</u>**

- ✓ Remote sensing may be used for numerous application including guidance system, medical image analysis, analysis of earth's resources etc.
- ✓ Earth resource information is like information concerning terrestrial vegetation, soil, minerals, water, and urban infrastructure as well as certain atmospheric characteristics.
- ✓ Examples remote sensing uses in civil engineering
  - **Water resources mapping:** Identification and mapping of the surface water boundaries has been one of the simplest and direct applications of remote sensing in water resources studies
  - **Estimation of watershed physiographic parameters:** Various watershed physiographic parameters that can be obtained from remotely sensed data include watershed area, size and shape, topography, drainage pattern and landforms.
  - **Estimation of hydrological and meteorological variables:** Remote sensing applications in estimating precipitation, evapotranspiration and soil moisture.
  - **Water conservation:** Rainwater harvesting, wherein water from the rainfall is stored for future usage, is an effective water conservation measure particularly in the arid and semi-arid regions.
  - **Urban and regional planning:** Our urban areas are expanding at a rapid rate mainly due to the population growth and the large

scale migration from the rural areas. This urban area expansion creates additional pressure on the land, water and infrastructural resources.

- **Identification of geothermal energy sources:** Geo-thermal energy is produced from underground reservoirs of steam or hot water. Being the most reliable, and sustainable source of energy, several studies have been ongoing to develop technologies to tap these geo-thermal energy resources for human use.
- **Assessment of snow cover and water equivalent:** Periodic snow cover depth and extent are some of the essential information's required for snow-melt runoff forecasting. Field-based surveys for periodic monitoring of Snow covered areas (SCA) are not easy due to the difficulties in the physical access to the snow covered areas. Satellite remote sensing techniques, being operational from space-borne platforms, help to overcome the accessibility issues.
- **Groundwater studies:** Remote sensing application in the groundwater studies are generally classified into three broad areas:

  • Estimation of the geomorphologic parameters essential for the groundwater modelling

  • Estimation of the groundwater potential

  • Estimation of the groundwater storage
- **Earthquake and Tsunami studies:** Remote sensing techniques have been successfully employed for assessing the damage caused during natural calamities like earthquake and tsunami. Very high resolution remote sensing data can be used to identify the structural damage and the extent of affected areas.

✓ Along with those remote sensing applications in rainfall-runoff modelling, remote sensing applications in irrigation management, remote sensing applications in flood mapping, remote sensing applications in drought assessment, remote sensing applications in environmental monitoring are few more applications.

Advantages and Disadvantages of Remote Sensing

Advantages of remote sensing are:

a) Provides data of large areas

b) Provides data of very remote and inaccessible regions

c) Able to obtain imagery of any area over a continuous period of time, natural changes in the landscape can be analyzed

d) Relatively inexpensive when compared to employing a team of surveyors

e) Easy and rapid collection of data

f) Rapid production of maps for interpretation

Disadvantages of remote sensing are:

a) The interpretation of imagery requires a certain skill level

b) Needs cross verification with ground (field) survey data

c) Data from multiple sources may create confusion

d) Objects can be misclassified or confused

e) Distortions may occur in an image due to the relative motion of sensor and source

Ideal Remote Sensing System:

i. **A Uniform Energy Source** which provides energy over all wavelengths, at a constant, known, high level of output

ii. **A Non-interfering Atmosphere** which will not modify either the energy transmitted from the source or emitted (or reflected) from the object in any manner.

iii. **A Series of Unique Energy/Matter Interactions at the Earth's Surface** which generate reflected and/or emitted signals that are selective with respect to wavelength and also unique to each object or earth surface feature type.

iv. **A Super Sensor** which is highly sensitive to all wavelengths. A super sensor would be simple, reliable, accurate, economical, and requires no power or space. This sensor yields data on the absolute brightness (or radiance) from a scene as a function of wavelength.

v. **A Real-Time Data Handling System** which generates the instance radiance versus wavelength response and processes into an interpretable format in real time. The data derived is unique to a particular terrain and hence provide insight into its physicalchemical-biological state.

vi. **The Multiple Data Users** The success of any remote sensing mission lies on the user who ultimately transforms the data into information. This is possible only if the user understands the problem thoroughly and has a wide knowledge in the data generation. The user should know how to interpret the data generated and should know how best to use them.

Unit - 4

22/03/17

AERIAL SURVEYING

Aerial survey is another type of Survey where in photographs are taken from air that Contains a part of the earth Surface. other term that are used are synonymously are Aerial photography and Aerial photogrametry.

The term aerial surveying incorporates with in two terms

(1) photogramatry means the process of taking photographs.

(2) The process of photointerpretation.

In otherwords photogrametry can be defined as the process of developing a Map. By combining different photographs of the earth Surface.

Types of photography :-

(1) Terrestrial photographs and terrestrial photo gramatry

(2) Aerial photograhs and aerial photo-grametry

(1) Terrestrial photographs (or) Terrestrial photogrammetry:-

(1) This is also known as Ground photograph.

(2) Here the instrument being used is photo theodolite.

(3) Photo theodolite is nothing but a conversional camera fitted on a tripod with the camera axis horizontal.

(4) It is very similar to planetable surveying and various ground features are shown in photographs.

(5) The features are located by intersection of line of sight from two or more station.

(2) Aerial photograph and Aerial photogrammetry.

(1) Here also the same camera is use for the camera axis is vertical.

(2) The camera is mounted on a aircraft

(3) Aerial photography covers a large area as compared to terrestrial photography.

In aerial photogrammetry, the camera axis is kept parallel to the direction of gravity, camera being mounted on air craft and vertical photographs of the ground are taken.

But it is very difficult to maintain the optical axis of camera to be vertical. This gives rise to tilted photographs.

Tilted photograph :-

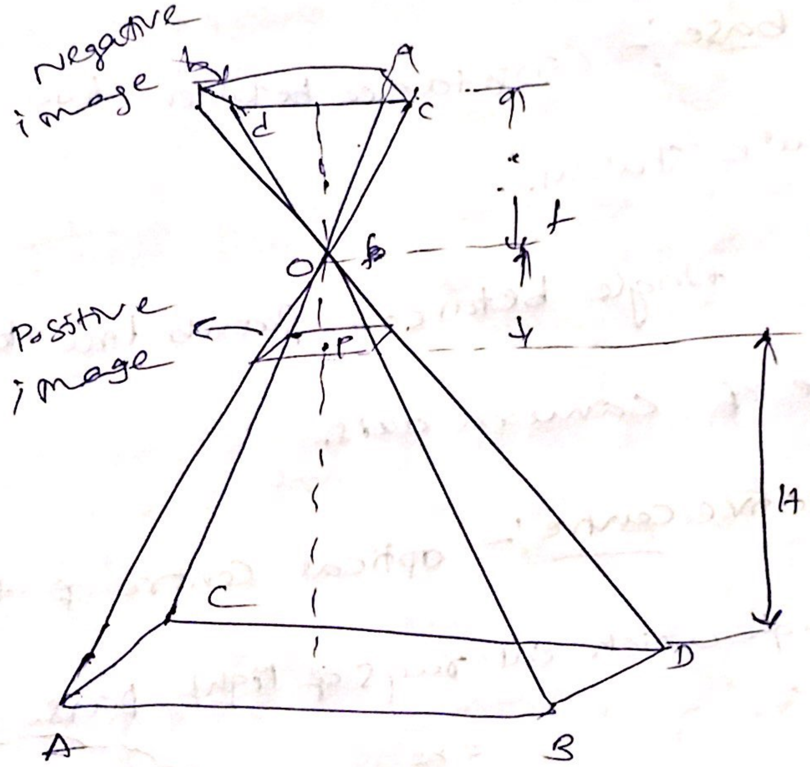
In a tilted photograph the camera axis is ~~or it~~ un intensionally inclined to the vertical axis by an angle not less than exceeding 3°.

oblique photograph:-

In an oblique photograph the camera is inclined intensionally to the vertical and resulting photograph is called 'oblique photograph.

Every two Consecutive photography taken with adequate overlaps form a pair which is known as Sterio ~~to~~ pair, For the ~~topograi~~ photographic map of ~~fixd~~ whole area A no. of Sterio pairs are required.

Terminology in Aerial photograph



Altitude :- Height of camera axis (or) air craft above the ground.

Flying height :- Height of aircraft chosen from datum.

Scale of photograph:-

It is defined as photo distance / by ground distance.

Exposure station:-

Position of the aircraft at the type time of exposure of the film. It is essentially the position of the optical centre of the camera lines when the film is exposed.

Air base:- Distance between two consecutive exposure station.

Tilt:- Angle between plumb line to optical centre of camera axis.

Perspective centre:- optical centre of the camera through which all rays of light pass.

=x=

23/03/17

1) Given scale of a map is 1 in 2000 and the dimensions of a rectangular building measured in map is 2 m × 4 m. calculate the area of the building on the ground.

$$2m = \frac{x}{2000} \times 100$$

$$\frac{2 \times 2000}{100} = x$$

Scale :- 1 : 2000

$$= \frac{\text{map distance}}{\text{Ground distance}}$$

$$\frac{1}{2000} = \frac{4}{\text{Ground}}$$

$\Rightarrow$ Ground distance $\Rightarrow 4 \times 2000$

$\Rightarrow 8000\,m$

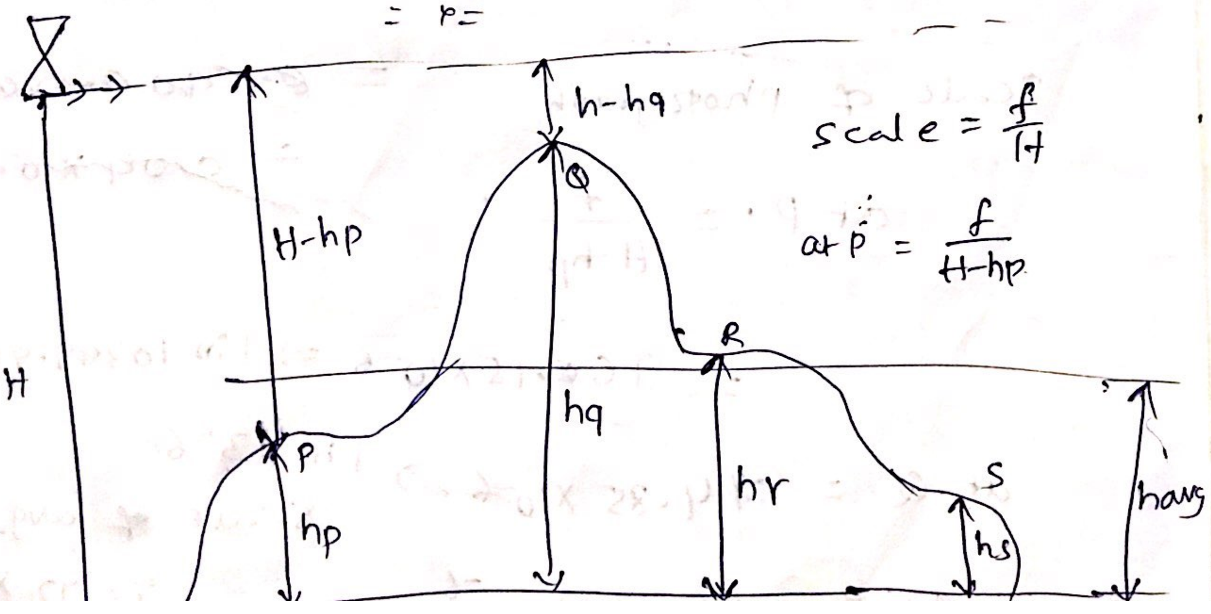
$$\frac{1}{2000} = \frac{2}{\text{Ground}}$$

$\Rightarrow$ Ground distance $= 2 \times 2000$

$= 4000\,m$

Area $= 8000 \times 4000 = 32000000\ m^2$

$A = 32\ km^2$.



$$\text{scale} = \frac{f}{H}$$

$$\text{at } P = \frac{f}{H-hp}$$

1) There are three points P, Q and R which are 1750 m, 1380 m and 1150 m above datum. the flying height of camera is 3050 m above datum. The focal length of camera is 125 mm. Determine different scales of photography. Scale of photograph at P, Q & R.

H = 3050 m.

hp = 1750 m

hQ = 1380 m

hR = 1150 m.

f = 125 mm.

Scale of photograph = $\frac{f}{H}$

$= \frac{125 \times 10^{-3}}{3050}$

$= 0.00004$

$= 0.04 \times 10^{-3}$

Scale of photograph

at P = $\frac{f}{H - hp}$

$= 96.15 \times 10^{-6}$ ⇒ 1 in 10399.98

at Q = 74.85×10^{-6} ⇒ 1 in 13360.

at R = 65.78×10^{-6}

↓

1 in 15200

Scale of avg.

= 78.92×10^{-6}

↓

1 in 12670

In a map points are located at a scale of 1 in 15500, the length of highway on the map is 150 mm. If ~~photo~~ photo distance of the highway is 215 mm. Then what is the scale of the photograph.

~~Photo~~

$$\text{scale} = \frac{\text{Photo distance}}{\text{Graund distance}}$$

length of highway on the map = 150 mm.

$$\text{scale of map} = \frac{\text{map distance}}{\text{ground distance}}$$

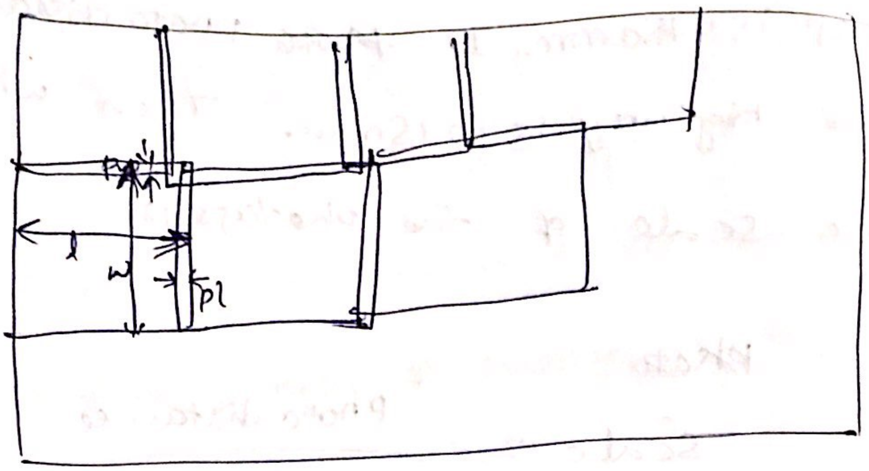
$$\frac{1}{15500} = \frac{150 \times 10^{-3}}{\text{Graund}}$$

⇒ Graund length = 2325 m

$$\text{Scale of photograph} = \frac{215 \times 10^{-3}}{2325}$$

⇒ 1 in 10814.

NO. OF PHOTOGRAPHS REQUIRED



Let us assume 'A' be the total area of the ground to be surveyed and 'a' be the ~~length~~ area of one photograph taken. 'L' be the length of photograph and 'w' be the width of one photograph. 'A'' be the area of ~~ground~~ one photograph on the ground.

'P_L' be the percentage of longitudinal overlap. P_w be the percentage of side overlap.

$$l' = l - P_l \cdot l$$

$$w' = w - P_w \cdot w$$

$$area = l' w'$$

$$= (l - P_l l)(w - P_w w)$$

$a' =$ area of ground

$S =$ scale of photograph

$$S = \frac{\text{Photo distance} - l'}{\text{Ground distance} - L}$$

$$L = \frac{l'}{S} = \frac{l - Pl \cdot l}{S}$$

$$= \frac{l(1-Pl)}{S}$$

$$W = \frac{w'}{S} = \frac{w - Pw \cdot w}{S}$$

$$= \frac{w(1-Pw)}{S}$$

$$a' = L \cdot W$$

$$= \frac{l(1-Pl)}{S} \cdot \frac{w(1-Pw)}{S}$$

$$a' = lw(1-Pl)(1-Pw)\frac{1}{S^2}$$

No. of photographs required

$$= \frac{A}{a'}$$

1) Find the no. of photography required to cover an area of 750 sq. km. scale of photograph is 1 in 15600. The size of the photograph is 6 inches X 4 inches, the longitudinal and side overlaps are 55% and 25% respectively.

$$A = 750 \times 10^3 \text{ sq. m.}$$

Size of photograph = 6 inch x 4 inch

0.1016 m.

= 0.154 m x 0.1016 m.

Scale of photograph, $S = 1$ in 15600

$P_l = 55\%$. $P_w = 25\%$.

$l = 0.15 m$, $w = 0.1 m$

$P_l = 0.55$ $P_w = 0.25$

Area of one photograph

$= 0.154 \times 0.1016 (1-0.55)(1-0.25) \times (15600)^2$

$a' = 1.285 \times 10^6 m^2$

$= 1.285 km^2$

No. of photographs required

$= \frac{750}{1.285}$

$= 584$

$= 15$

1) A rectangular plot was measured by 20m chain. was 450m x 250 m.
It was found that the used for measuring the sides of plot was 15cm too long. what is the true area of plot.

True length of chain = 20m + 15cm

= 20m + 0.15 m

= 20.15 m.

measured area of plot = 450 x 250 m

~~In chang~~ ⇒ $\frac{450}{20.15}$

Total increase = $\frac{450}{20} \times 0.15$

= 3.375 m

True length = 3.375 + 450 = ~~450~~

= 453.375 m

width increased = $\frac{250}{20} \times 0.15$ = 1.875

True width = 250 + 1.875

= 251.875 m

True area = 453.375 (251.875)

= 114193.82 m²

4) Two points A and B have elevations of 750m and 325 m respectively above datum. These points are photograph with a camera of focal length 22.7 cm at a flying altitude of 2850 m above datum. what is the length of ground AB

Point.	Photographic coordinates	
a	+4.65	+3.95
b	-3.45	+7.78

Elevation of A = 750m

Elevation of B = 325 m.

focal length = 22.7 cm.

Scale of photograph at A,

$$= \frac{0.227}{2850-750}$$

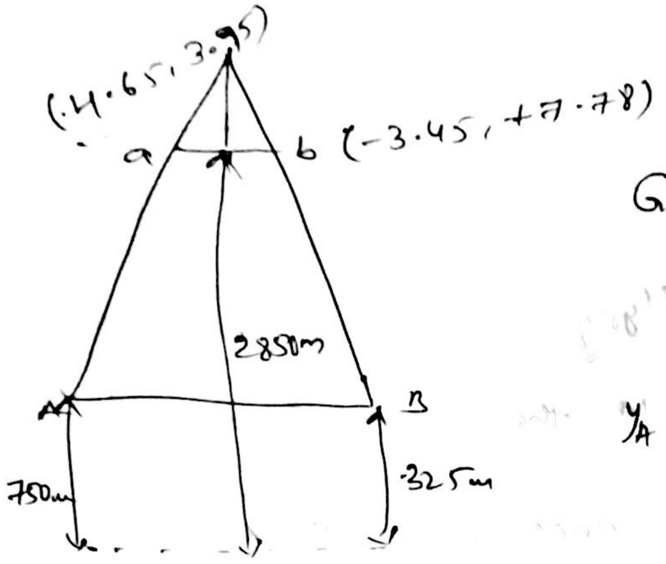
$$= \frac{1}{9251.10}$$

$$\text{scale} = \frac{\text{photo coordinates}}{\text{ground coordinates}}$$

$$\frac{1}{9251.10} = \frac{0.0465}{x_A}$$

$$\Rightarrow x_A = 430.176 \text{ m}$$

Scanned by CamScanner



Grand coordinate.

$x_A = 430.176 m$

$y_A \Rightarrow \frac{1}{9251.0} = \frac{0.0391}{y_A}$

$\Rightarrow y_A = 365.41 m$

$\frac{1}{11123.24}$

$x_B = -383.7 m$

$y_B = 865 m$

5) A scale of an aerial photograph 30cm × 30cm is 1 km = 10 cm, find no. of photography required to cover any area of 25 Km². If longitudinal overlap is 60% side overlap is 25%.

Scanned by CamScanner

Unit - V

TOTAL STATION

The main instrument for surveyors on site today is the total station.Total station is an electronic device which can determine the coordinate of a target point in a digital form. It is the combination of EDM and microprocessor.It transmits beam of infrared light towards the target and receive the reflected beam from the prism and calculate the distance, bearing and 3D coordinates of a target. A microprocessor in the instrument takes care of recording readings and the necessary computation.

Types of Total Stations:

1. Manual Total Station
2. Semi Automatic Total Station
3. Automatic Total Station

Manual Total Station: It was necessary to read the horizontal and vertical angles were shown digitally. Slope distance were measured.

semi automatic Total Station: The user had to manually read the horizontal angles, but vertical angles were measured electronically.

Automatic Total station: This type is the most common total station used now a days. They sense both the horizontal and vertical angles electronically and measure the slope distance. Compute the horizontal and vertical components of those distances and determine the coordinates of observed points.

Basic components of Total Station:

Handle: The part of the Total Station which is used to carry the instrument and to fix the total station on instrument. The handle can be removed from the instrument. To remove it, loosen the handle locking screw.

Tribach Clamp: When the instrument is shipped, the tribach clamp is held firmly in place with a locking screw to prevent the instrument from shifting on the tribachs. Before using the instrument first time, loosen this screw with a screw driver. And before transporting it, tighten the locking screw to fasten the tribach clamp in place so that it will not shift on the tribaches.

Base Plate: The plate which give support to the foot screws to with stand on tripod. Leveling Screws: The foot screws which are used for level the total station is called leveling screws.

Objective lens: The lens which are used to focus the instrument are called objective lens.

Telescope eye piece: The part of the instrument which is used for focusing the object.

Sighting collimator: Use sighting collimator to aim the telescope in the direction of the measurement point. Turning the instrument until the triangle in the sighting collimator is aligned with the target.

Trigger key: Press the trigger key when the instrument is in the OBS mode or when [MEAS]/[STOP] is indicated on the display unit. You can start/stop measurement in the screen displaying [AUTO], press trigger key to perform automatic operation from distance measurement to record.

Laser point function: A target can be sighted with a red beam laser in dark locations without use of the telescope.

PRISM REFLECTOR:

- it is a combination of ranging rod, staff and optical cuboidal mirror.
- Adjustable height from 1.5m to 3.75m with 5cms interval graduations.
- More number of prisms will give more accuracy.

Setting up total station: Mount the instrument onto the tripod and secure firmly. Level and center the instrument precisely to ensure the best performance. Use the tripod with a 5/8” tripod screw. Operation Reference: Leveling and Centering the Instrument

1. Setting up the tripod:

First extend the extension legs to suitable length and tighten the screws, firmly plant the tripod in the ground over the point of beginning.

2. Attaching the instrument to the tripod:

Secure the instrument carefully on the tripod and slide the instrument by loosening the tripod mounting screw. If the optical plumb site is positioned over the center of the point tighten the mounting screw.

3. Roughly leveling the instrument by using the circular vial:

Turn the leveling screw A and B to move the bubble in the circular vial, in which case the bubble is located on a line perpendicular to a line running through the centers of the two leveling screw being adjusted. Turn the leveling screw C to move the bubble to the center of the circular vial. Recheck the position of the instrument over the point and adjust if needed.

4. Leveling by using the plate vial:

Rotate the instrument horizontally by loosening the Horizontal Clamp Screw and place the plate vial parallel with the line connecting leveling screws A and B, then bring the bubble to the center of the plate vial by turning the leveling screws A and B. Rotate the instrument 90° (100g) around its vertical axis and turn the remaining leveling screw or leveling C to center the bubble once more. Repeat the procedures for each 90 ° (100g) rotation of the instrument and check whether the bubble is correctly centered in all directions.

5. Centering by using the optical plummet (or laser plummet):

Adjust the eyepiece of the optical plummet telescope to your eyesight. Slide the instrument by loosening the tripod screw; place the point on the center mark of the optical plummet. Sliding the instrument carefully as to not rotate the axis will allow you to get the least dislocation of the bubble.(Place star-key after power on, then press F4(LASER)key, press F1(ON)key to turn on the laser plummet. Slide the instrument by loosening the tripod screw; Place laser facular on the occupied pointing, Sliding the instrument carefully as to not rotate the axis will allow you to get the least dislocation of the bubble. The last, press ESC key, and laser plummet turn off automatically.)

6. Complete leveling the instrument:

Level the instrument precisely as in Step 4. Rotate the instrument and check to see that the bubble is in the center of the plate level regardless of the telescope direction then tighten the tripod screw firmly.

Functions of Total station;

- It simultaneously measures angles and distances and record.
- Correcting the measured distances with
  1. prism constant
  2. Atmospheric pressure
  3. Temparature

4. Curvature of earth
5. Refraction correction

- Computing the point elevation
- Computing the coordinates of every point
- Remote elevation measurement
- Remote distance measurement
- Area calculations
- Data transferring facility from instrument to S/W and S/W to instrument
- Format of conversion of units

Operations:

- **Establishing the site datum:**
  1. Selecting the site datum
- **Setting up the Total Station:**
  1. Placing and leveling tripod on datum
  2. Placing and leveling the total station on tripod
  3. Linking the data connector to the instrument.
- **data collector options and setting**
  1. Main menu
  2. Basic setting
- **Creating and operating job files:**
  1. Creating a new job file
  2. Opening an existing file
- **Shooting points:**
  1. Identifying the important points to shoot.
  2. Shooting points
  3. Shooting additional points
  4. Noting the special feature
- **Post processing**
  1. Data downloading, conversion
- **Plotting, map generation**

Precautions:

- Use the both handles to hold the total station handle.
- Set up the tripod as stable as possible.
- Do not move or carry a tripod with the total station fixed on it, except for centering.
- Never point the instrument at the sun.
- Never store the instrument in extreme temperatures to avoid sudden changes of temperature.
- When not using the instrument, place it in the case to avoid shock, dust and humidity.

- If there is great difference in temperature between the work site and the instrument storage location leave the instrument in the case until it adjusts to the temperature of the suurounding environment.
- Please remove the battery for separate storage if the instrument is to be in storage for an extended time, the battery should be charged once in a month during storage
- Clean exposed optical parts with degreased cotton or lens tissue only.
- Clean the instrument's surface with a woolen cloth when finished with use. Dry it immediately if it gets wet.
- Check the battery, functions, and indications of the instrument as well as its initial setting and correction parameters before operating.
- Unless you are a maintenance specialist do not attempt to disassemble the instrument for any reason. Unauthorized disassembly of the instrument can result in a void warranty.

Unit-VI

Global Positioning System

Geodesy:

- Geodesy is a science based on earth and mathematics used to make global positioning possible and measuring, understanding, monitoring the geometric shape, size, orientation and its gravity field by representing in a three dimensional space.
- The term geodesy is divided from the Greek word "geodesic" means "dividing the earth"
- The sub disciplines of geodesy are:
    - i. Geometrical geodesy
    - ii. Physical geodesy
    - iii. Mathematical geodesy
    - iv. Dynamical geodesy
    - v. Satellite geodesy
    - vi. Marine geodesy
    - vii. Geophysical geodesy etc,

Geoid:

- It is a model having same gravitational potential of the earth's gravitational field.
- It acts as close mathematical and physical representation including geometric shape, size of the earth.

Introduction to GPS:

- GPS is a global navigation satellite system (GNSS). It is the commonly used acronym of NAVSTAR (Navigation System with Time And Ranging) GPS (Global Positioning System) operated by US DOD (Department of Defence).
- It helps the user to know his position anywhere on the earth by giving solution to the problem-"Where on earth am I?".
- 4 GPS coded satellite signals make possible the computation of position in 3- dimensional form.
- A new beginning in new project of GPS has been proposed by US Department of Defense in the starting day of 1970's. This new concept found success in fulfilling all requirements related to position determination accurately at any time in any weather conditions for US government.

GPS surveys provides following advantages:-

- 3- Dimensional with no need of site Inter visibility.
- All weather and day or night operation.
- Data processing with high speed having common reference system.
- high quality control with achieving high precision.
- Less labor but skilled persons are needed.

After Post Processing the data, following values would be possible to visualize:

- plane coordinates with lattitude, longitude, geodetic height
- Cartesian coordinates X,Y,Z.
- Point to point varying vertical angle

GLONASS:

- Global Navigation Satellite System by Russian Aerospace Defence Forces.
- Space based satellite navigation system.
- It is provide an alternative to NAVSTAR GPS of U.S.
- The present GPS receivers are compatible to both NAVSTAR and GLONASS, thus providing more flexibility of positioning and better accuracy.
- Soviet union started the development oh GLONASS in 1976. GLONASS is the most expensive program of the Russain Federal Space Agency, consuming a third of its budget in 2010.

GALILEO:EUROPEAN NAVIGATION STAELLITE SYSTEM**.**

- Developed by collaboration of European Union and European Space Agency.
- The headquarters of Galileo project is in Prague, Czech Republic
- This system is not fully operational yet**.**

BEIDOU: CHINESE NAVIGATION SATELITE SYSTEM

QUASI ZENITH- QZSS (JAPAN NAVIGATION SYSTEM)

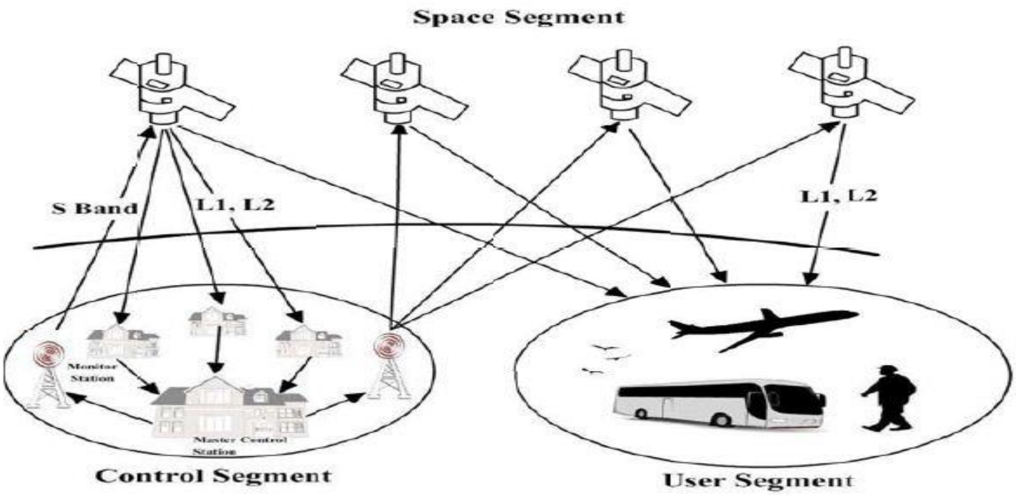
IRNSS: INDIAN REGIONAL NAVIGATION SATELLITE SYSTEM

- GPS with aided augmented navigation system is initiated India with the collaboration of ISRO and AAI which is termed as Geo augmented system (GAGAN)

GPS SEGMENTS:

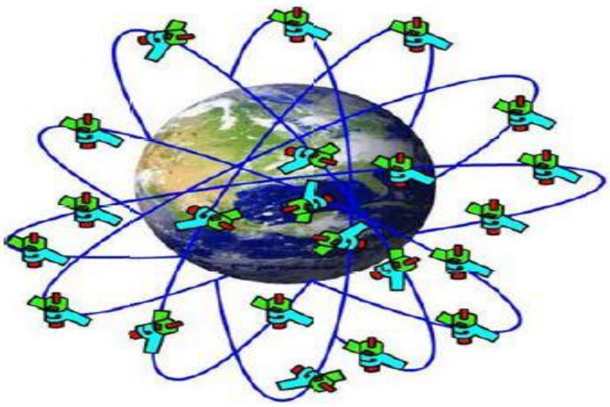
The GPS configuration comprised of 3 segments.

- Space segment
- Control segment
- User segment



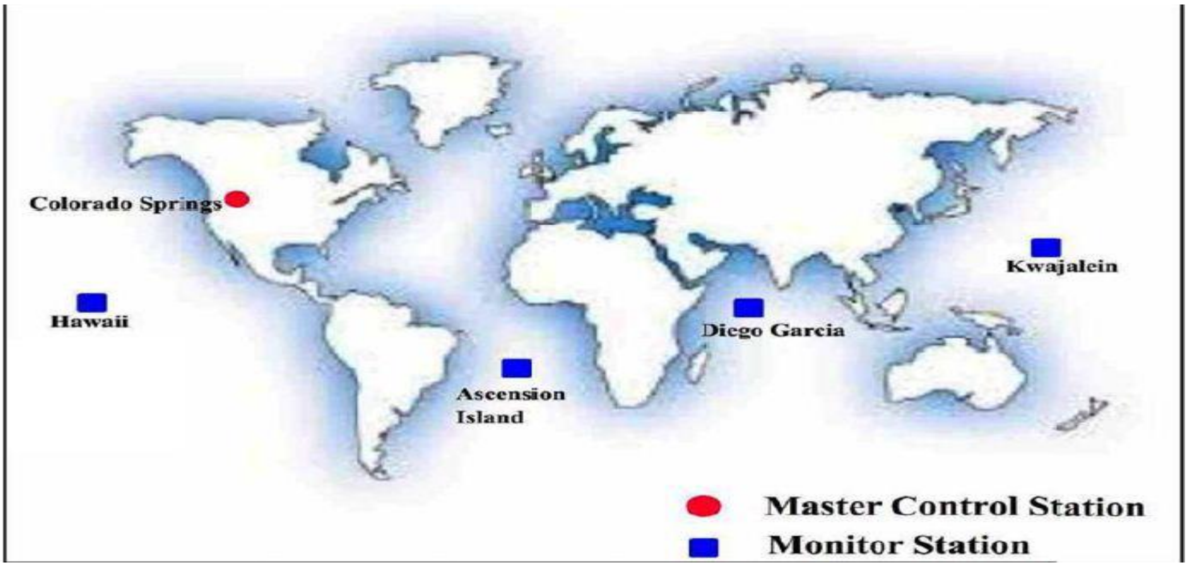
Space Segment:

- US govt first launched satellite in 1978.
- Now GPS satellites constellation to 24(21+3 spare) satellites at an altitude of 20200 above the surface of earth.
- These are working under NiCa batteries for secondary power supply.
- Each satellite takes 12 hours for complete rotation in an orbit.
- The satellites are arranged in 6 orbits 4 in each orbit.



Control Segment:

- The US department of Defense Manages a master control station at falcon airbase in Colorado Springs.
- There are 4 other monitor stations located in Hawaii, Ascension Island, Deigo Garcia and kwajalein.
- The main function of master control station is to upload clock data into satellite vehicles which then send their subsets to GPS receivers via radio signals.
- The control segment is used in tracking stations, uploading gps, satellite position located around the world with calibration.
- It monitors and predicts the orbital path of satellite for the next 24 hours.
- Monitor stations easily observe the satellite signals.



User Segment:

- It comprises anyone who wish to determine his position and/or time.
- The user should be equipped with a GPS receiver to receive the GPS signal.
- Various applications which can be performed in the user segment are surveying and navigation include marine, aerial, machine control, vehicle etc

Global Positioning:

Principles and methods of global position fixing:

- Basic principle is resection.
- The position fixing with the help of GPS can be done using:
    1. Code phase or Pseudo Range measurements
    2. Carrier Phase
- Positioning methods
    1. Point positioning
    2. Relative positioning

Code phase:

a. it is defined as a measure of length of path between satellite and receiver antenna
b. It is done with the help of time of transmission and reception of codes.
c. Each GPS satellite generates a specific PRN code(pseudo random noise) along with its signal.

Carrier phase:

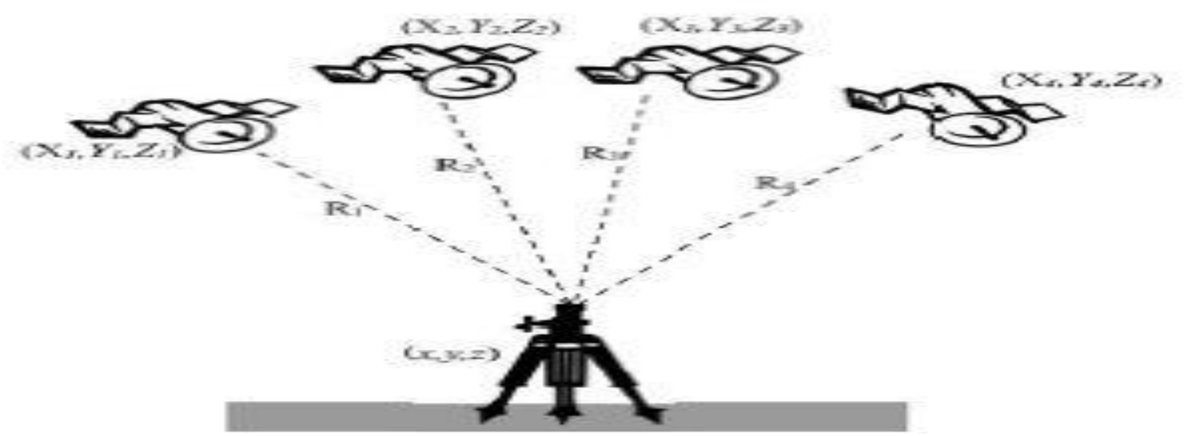
a. It is based on the principle of EDM.

b. In GPS, the measured quantity is the difference between the phase of internal receiver Oscillator and the received satellite carrier phase.

c. Phase measurement has high accuracy of upto 3-10mm.

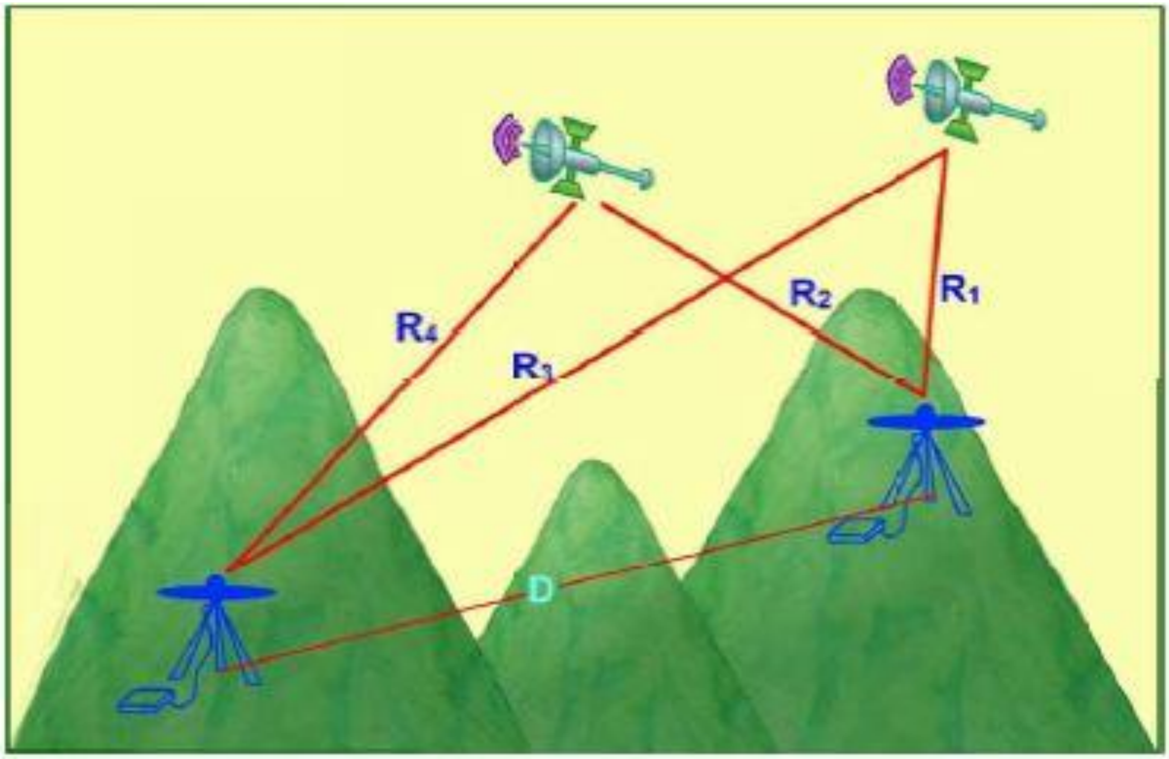
Point Positioning;

- It consists of only one GPS receiver which is able to track four or more satellite to compute its own coordinates on the basis of center of the earth.
- It is also known as stand alone positioning
- A single GPS unit on an unknown point is preferred for the determination of 3D coordinates of unknown point referenced.
- Accuracy of such method depends on the durations of observations.



Relative positioning:

- It consists of two GPS receivers which are able to track four or more satellites to compute their relative coordinates on the basis of centre of earth.
- It is also known as differential positioning.
- Minimum two GPS receivers receive signals from same set of satellites at a same time.
- One GPS unit known as the reference or base unit.
- The observations are processed with respect to the base station to obtain the position of other station known as ROVER STATION.
- the accuracy in this method is much higher than that in point positioning.



Classification of DGPS:

- **Static Positioning:** All receivers remain stationary and collect carrier phase over a period of time.
- **kinematic positioning:** Reference receiver may fixed while rovers vary from point to point.
- **Stop and go GPS surveying:** It is similar to other Kinematic GPS surveying. It is used where large number of unknown points is to be computed with in 10-15km of known point

Geographical Information System

Introduction

- GIS stands for Geographical Information System. The geographical information system (GIS) consists of two distinct disciplines, namely geography and information system.
- Geography is the scientific study of geo-spatial pattern and process. It seeks to identify and account for the location and distribution of human and physical phenomena on the earth's surface.
- Emphasis in geography is placed upon the organization and arrangement of phenomena, and upon the extent to which they vary from place to place and time to time. It is the characteristics of space as a dimension, rather than the properties of phenomena which are located in space, that is of central and overriding concern.
- Geography aims to develop general rather than unique explanations. It proceeds from the assumption that there is basic regularity and uniformity in the location and occurrence of phenomena and that this order can be identified and accounted by geographical analysis. In examining spatial structure, geography focuses upon those distributional characteristics that are common wide range of phenomena.
- Information system most often refers to a system containing electronic records, which involves input of source documents, recording on electronic media, and output of records, along with related documentation and any indexes.
- The information system can be defined as an interactive combination of people, computer hardware and software, communications devices, and procedures designed to provide a continuous flow of information to the people who need information to make decisions or perform analysis.
- The GIS is a computer-based information system used to digitally represent and analyze the geospatial data of geographic data. Geospatial means the distribution of something in a geographic sense; it refers to entities that can be located by geographic coordinate system.

- ‘Every object present on the earth can be georeferenced’, is the fundamental key of associating any database to GIS. The GIS is a particular form of information system applied to geographical data. A system is a group of connected entities and activities which interact for a common purpose.
- Earlier we had paper maps, which were very colorful, but not modifiable. Then, the computer revolution took place, where the maps were digitalized and stored in digital format.

DEFINITION OF GIS

- The GIS is an information system designed to work with data referenced by spatial/geographical coordinates.
- GIS is defined as an information system that is used to input, store, retrieve, manipulate, analyze and output geographically referenced data or geospatial data, in order to support decision making for planning and management of land use, natural resources, environment, transportation, urban facilities, and other administrative records.
- A geographic information system is a facility for preparing, presenting, and interpreting facts that pertain to the surface of the earth.
- A computer based system that provides four sets of capabilities to handle georeferenced data: data input, data management, manipulation and analysis, and data output.

OBJECTIVES OF GIS:

Some of the objectives of GIS are as follows:

- Maximizing the efficiency of planning and decision making.
- Integrating information from multiple sources.
- Facilitating complex querying and analysis.
- Eliminating redundant data and minimizing duplication.

COMPONENTS OF GIS:

- The GIS constitutes of five key components, namely, hardware, software, procedure, data, and users as shown in figure.

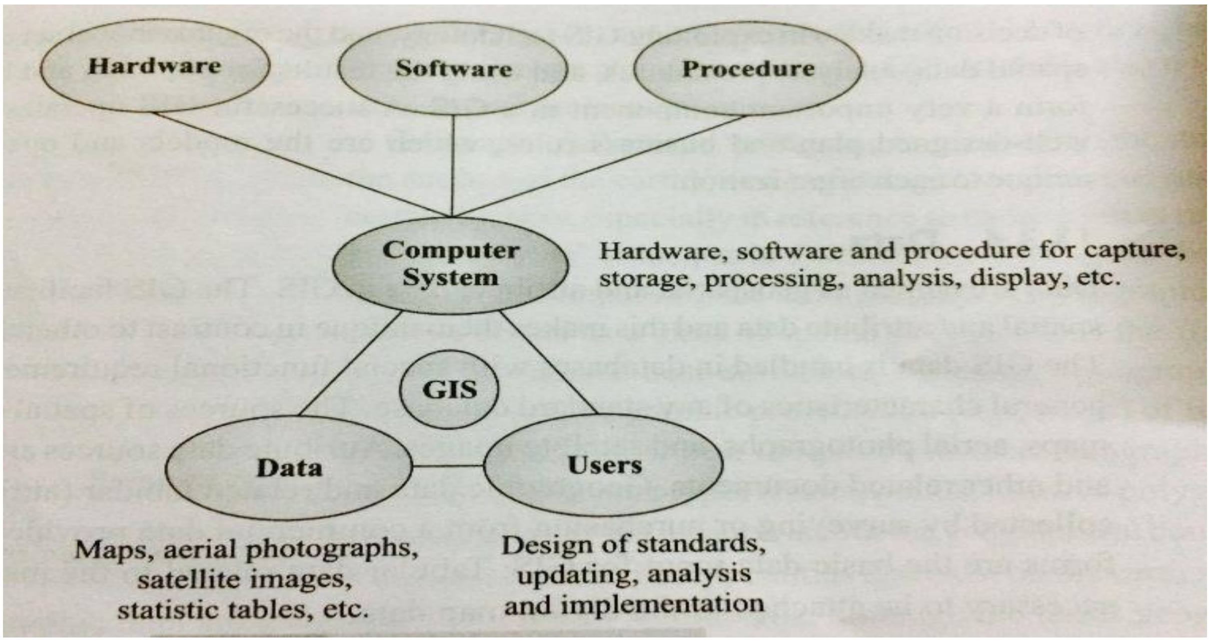


Fig-1. Components of GIS

HARDWARE:

It consists of computer hardware system on which the GIS software runs. The GIS run on the whole spectrum of computer systems ranging from portable personal computers to multi user supercomputers. The hardware of GIS consists of input devices such as digitizers, scanners and GPS receivers, the storage devices such as magnetic tapes and disks, CD ROMs and other optical disks, central processing units, and the output devices such as display devices, printers and plotters.

SOFTWARE:

Software is at the heart of a GIS system. The GIS software must have the basic capabilities of data input, storage, transformation, analysis and providing desired outputs. The interfaces could be different for different software's. The GIS software's

being used today belong to either of the category –proprietary or open source. ArcGIS by ESRI is the widely used proprietary GIS software. Others in the same category are MapInfo, Micro station, Geomedia etc. The development of open source GIS has provided us with freely available desktop GIS such as Quantum, uDIG, GRASS, Map Window GIS etc., GIS software's.

PROCEDURE:

A computer system for GIS consists of hardware, software and procedures designed to support the data capture, storage, processing, analysis, modeling, and display of geospatial data. Besides the technical components like hardware, software and databases, institutional framework and policies are also important for a functional GIS. A successful GIS operates according to a well-designed plan and business rules, which are the models and operating practices unique to each organization.

DATA:

Data are named as geospatial and attribute data in GIS. The GIS facilitates integration of spatial and attribute data and this makes them unique in contrast to other database systems. The GIS data is handled in databases with special functional requirements as well as the general characteristics of any standard database. The sources of spatial data are digitalized maps, aerial photographs and satellite images. Attribute data sources are statistical tables and other related documents. The digital map forms are the basic data input for GIS.

USERS:

The role of the user are to select pertinent information to set necessary standards, to design cost-efficient updating schemes, to analyze GIS outputs for relevant purposes and plan the implementation. Most definition of GIS focuses on the hardware, software, data and analysis components. The GIS projects range from small research applications, where one user is responsible for design and implementation and output,

to international corporate distributes systems, where different type of users interact with the GIS in many different levels and ways.

SPATIAL DATA:

Spatial data also known as geospatial **data** or geographic information it is the **data** or information that identifies the geographic location of features and boundaries on Earth, such as natural or constructed features, oceans, and more. **Spatial data** is usually stored as coordinates and topology, and is **data** that can be mapped.

ATTRIBUTE DATA:

Attribute data is qualitative **data** that can be counted for recording and analysis. **Attribute data** is not acceptable for production part submissions unless variable **data** cannot be obtained.

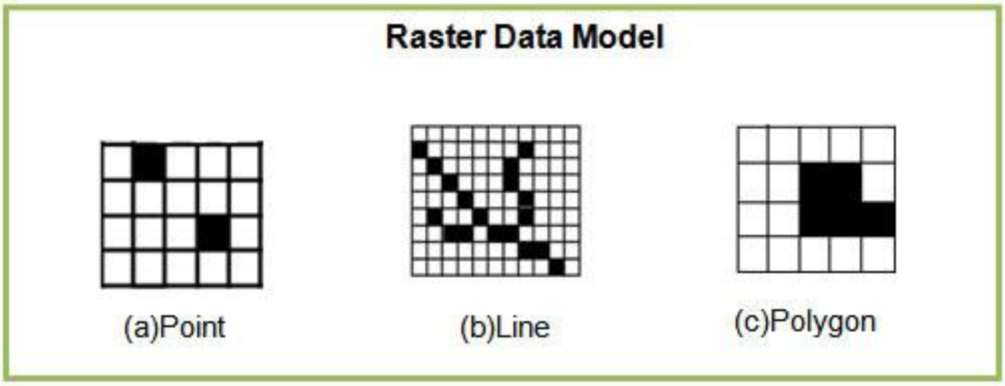
DATA STRUCURES

- Spatial **Data Structures**. Spatial **data** types provide the information that a computer requires to reconstruct the spatial **data** in digital form.
- A data model describes in an abstract way how data is represented in an information system or in a database management system. The manner in which data is generally organized in a database management system is sometimes also called a database model.
- There are two fundamental approaches to the representation of the spatial component of geographic information: vector model and raster model.

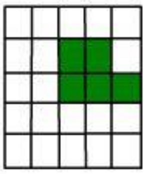
RASTER DATA STRUCTURE:

- The raster data model is commonly associated with the field conceptual model. Here, geographic space is represented by array of cells or pixels which are arranged in rows and columns. Each pixel has a value that represents information. The value can be in the form of integer, floating points or alphanumeric.

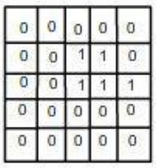
- A point can be represented by a single pixel in raster model. A line is a chain of spatially connected cells with the same value. Similarly, a water body in raster data is represented as a set of contiguous pixels having same value that represents a homogeneous area.



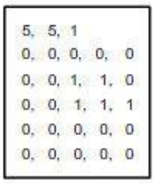
- In a simple raster data structure the geographical entities are stored in a matrix of rectangular cells. A code is given to each cell which informs users which entity is present in which cell. The simplest way of encoding a raster data into computers can be understood as follows:



(a) Entity model: It represents the whole raster data. Let us assume that the raster data belongs to an area where land is surrounded by water. Here a particular entity (land) is shown in green color and the area where land is not present is shown by white.



(b) Pixel values: The pixel value for the full image is shown. Cells having a part of the land are encoded as 1 and others where land is not present are encoded as 0.



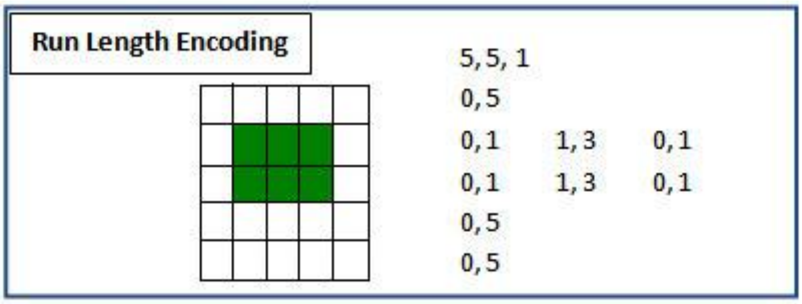
(c) File structure: It demonstrates the method of coding raster data. The first row of the file structure data tells that there are 5 rows and 5 columns in the image, and 1 is the maximum pixel value. The subsequent rows have cells with value as either 0 or 1 (similar to pixel values).

- The huge size of the data is a major problem with raster data. An image consisting of twenty different land-use classes takes the same storage space as a similar raster map showing the location of a single forest. To address this problem many data compaction methods have been developed as discussed below:

Run Length Encoding(RLE):

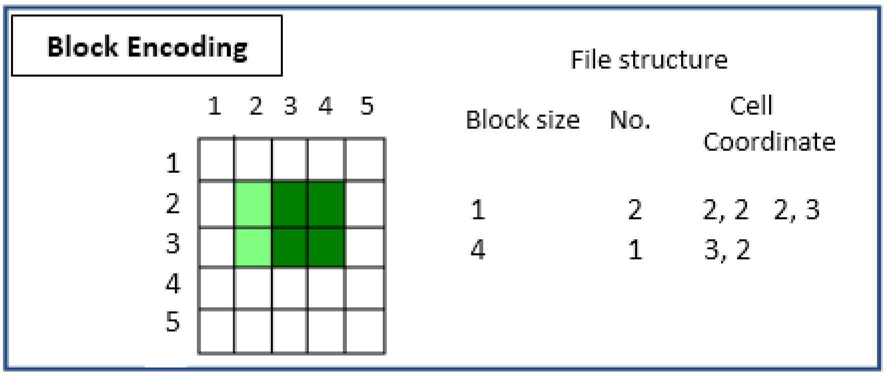
- Reduction of data on a row by row basis
- Stores a single value for a group of cells rather than storing values for individual cells.

- First line represents the dimension of the matrix (5×5) and the number of entities (1) present. In second and subsequent lines, the first number in the pair represents absence (0) or presence (1) of the entity and the second number indicates the number of cells referenced.



Block Encoding:

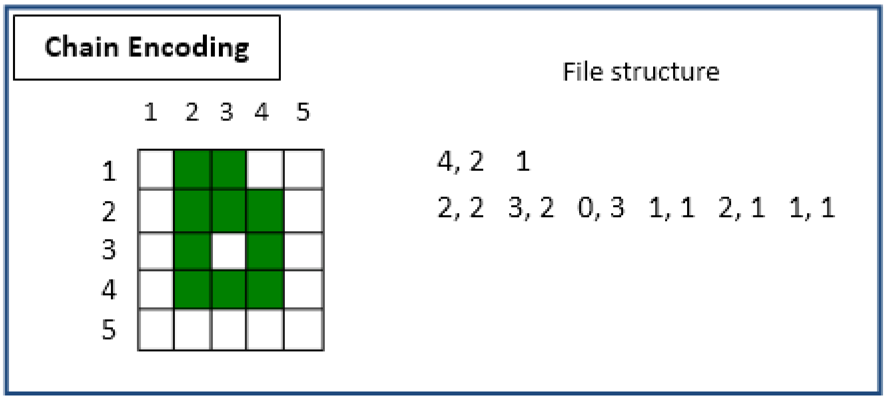
- Data is stored in blocks in the raster matrix.
- The entity is subdivided into hierarchical blocks and the blocks are located using coordinates.
- The first cell at top left hand is used as the origin for locating the blocks.
- Block encoding uses a technique called Medial Axis Transformation (MAT) to create the data structure. In this technique, the larger the square that may be fitted in any given region and the simpler the boundary, the more efficient compaction becomes.
- Both RLE and MAT are most efficient for large simple shapes and less so for small complicated areas.



Chain Encoding:

- Chain codes represent the raster boundary of a region by giving a starting point and the cardinal direction (east, north, west and south) to follow as we progress around the boundary.

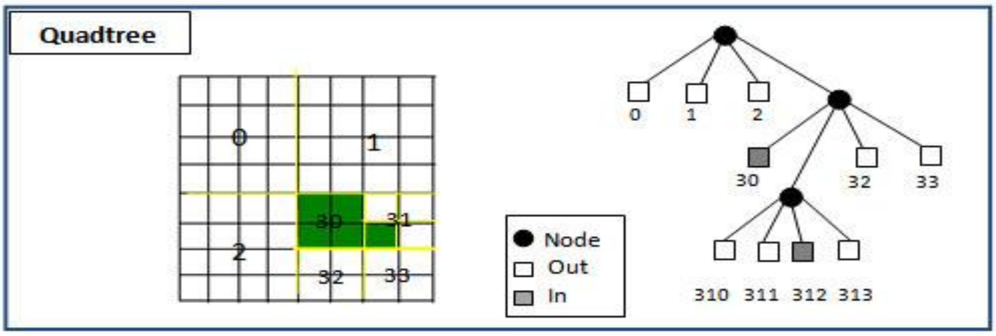
- Works by defining boundary of the entity i.e. sequence of cells starting from and returning to the given origin.
- Direction of travel is specified using numbers. (0 = North, 1 = East, 2 = South, 3 = West).
- The first line tells that the coding started at cell (4, 2) and there is only one chain. In the second line the first number in the pair tells the direction and the second number represents the number of cells lying in this direction.



Quadtree and Binary-tree Encoding:

- One problem with regular raster grids is that the resolution of the data limited by the size of the basic grid cells. The quadtree and binary-tree encoding provide an approach to addressing successively finer levels of details, with in principle, an infinite set of levels.

- The most efficient method of compact representation of space is based on successive, hierarchical division of a 2^n X 2^n array.
- If the division occurs by dividing the area into half each time, the method is known as binary-tree; if the region is tiled by subdividing the area step by step into quadrants, it is known as quadtree. In both the cases, the lowest limit of division is the single cell.
- A quadrant that cannot sub-divided is called a leaf-node.
- It is important to realize that quadtree is more concerned with the overall data model, rather than just saving space.



VECTOR DATA STRUCTURE

- ➢ The vector model is close to the traditional mapping approach where the objects are represented as points, lines, or areas. In a vector model, the positions of points, lines and areas are precisely specified.
- ➢ The position of each object is defined by a coordinate pairs. Vectors are graphical objects that have geometrical primitives such as points, lines, and polygons to represent geographical entities in computer graphics.
- ➢ Vectors have a precise direction, length and shape can be defined by coordinate geometry. A point is described by a single x-y co-ordinate pair and by its name or label. A line is described by a set of co-ordinate pairs and by its name or label.
- ➢ In reality, a line is described by an infinite number of points. In practice, this is not a feasible way of storing a line. Therefore, a line is built up by its starting and ending coordinate pairs.

OBJECT-BASED VECTOR MODEL

- ➢ The vector model is ideal to represent discrete entities. Discrete entities are represented as points, lines, and areas.

POINT:

- A location depicted by a single set of (x, y) coordinates at the scale of abstraction.
- The wells in a village, electricity poles in a town and cities in the world map are the examples of spatial features described by points.

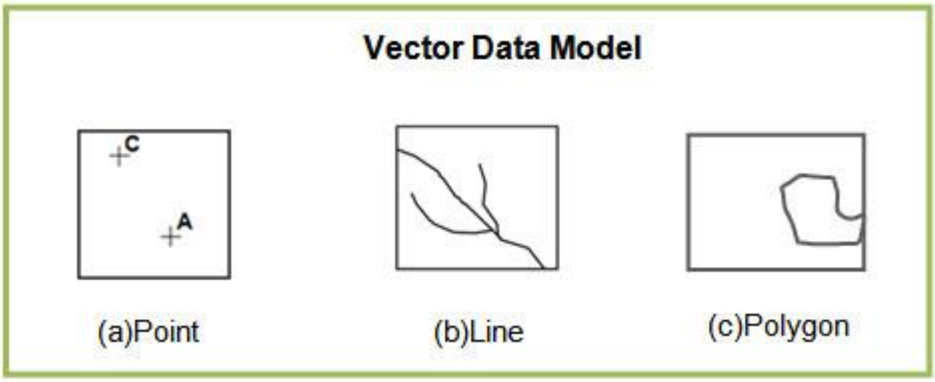
Note: A city can be marked as a single point on a world map but would be marked as a polygon on a state map. The scale plays an important role in deciding the geometry of a geographical feature.

LINE/ARC:

- Ordered sets of (x, y) coordinate pairs arranged to form a linear feature. The curve in a linear feature is generated by increasing the density of points/ vertices.
- The roads, rails and telephone cables are examples of the spatial features described by lines.

POLYGON:

- The set of (x, y) co-ordinate pairs enclosing a homogenous area.
- The land parcels, agricultural farms and water bodies are the spatial features described by polygons.



- In the object-based vector model, points/lines/areas can be represented via different models. Four such models are as follows
    - Spaghetti Model
    - Vertex Dictionary Model.

- Dual Independent Map Encoding (DMIE)
- Topological Model.

Spaghetti Model:

- The spaghetti model uses the simplest type of data structure. All objects are defined as single items and no reference is made to other objects.
- Spaghetti data are collection of points and line segments with no real connection. There are no specific points that designate where the lines cross, nor there any logical relationships between the objects.
- The common boundaries between adjacent polygons are stored twice. This model cannot handle holes within a polygon. The structure is insufficient in data storage and queries, and consistency checks are not possible.

Vertex Dictionary Model:

- Vertex dictionary uses a similar approach as spaghetti but a smarter structure. It uses two files to store the vector data. The first file stores the vertices and the second file stores the description of objects as shown in figure.
- In this data model, if some vertices are shared by two adjacent polygons, these vertices are not required to store twice.
- However, topological relationships are not well defined in this model. The problem of island polygon still exists. Therefore, it is inferior for data analysis and query.

DIME Model:

- The DIME model was developed by the United States bureau of the census. This is a complex model but more intelligent. It uses three files to represent the vector data as shown in figure.
- This model also avoids duplication of data for adjacent polygons and can establish several relationships between objects.
- The DIME was the first attempt to built explicit topological relationships. However, it has several limitations compared to fully topographical model.

Topological Model:

- The mathematical field of topology investigates characteristics of geometry that remain invariant under certain transformations such as stretching or bending.

- The connections and relationships between objects are described independently of their coordinates.
- Topology in GIS is a set of objects and object data that defines the relationship between the objects. Topology refers to the relationships between spatial objects.
- Topology, as it relates to spatial data, consists of three elements such as adjacency, containment and connectivity.
- **Adjacency** and **Containment** describe the geometric relationships which exist between area features. Areas can be described as being adjacent when they share a common boundary.
- The topological model uses arc (chain) and nodes. Arc is the basic logical entity in this data model. Arc is a series of point that starts and end at a node. Because of this reason, topological model is often called Arc-node model.
- The advantage of topological data model are to avoid duplication in storing common boundaries of two polygons, and to solve problems when two versions of the common boundary do not coincide
- The disadvantage are to have to build very correct topological data sets without any single error. Topology can detect lines that do not meet correctly, polygons that are not closed properly, node or line segment.
- In practical applications of GIS, all possible relationships in spatial data should be used logically with more complicated data structures.
- The following topological relationships are commonly used are:
    - Point – point relationship.
    - Point – line relationship.
    - Point – area relationships.
    - Line – line relationships.
    - Line – area relationship.
    - Area – area relationship.

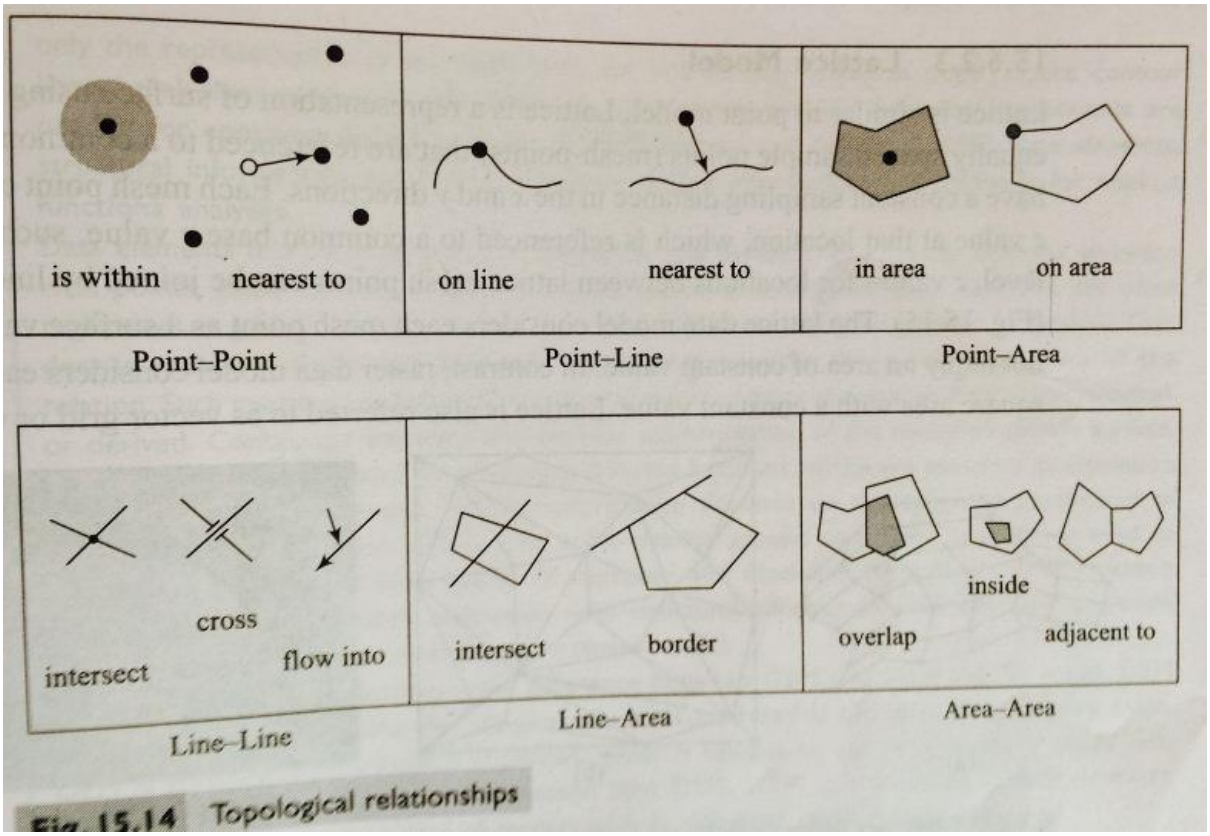


Fig. 15.14 Topological relationships

Field - Based Vector Model

- Although vectors are ideal for representing discrete objects, it can also be used for field-based or continuous data such as elevation, temperature etc.
- Mass points, contour lines/ isolines, lattice, and triangulated irregular network (TIN) are used to represent elevation or other continuously changing values.

Point Model:

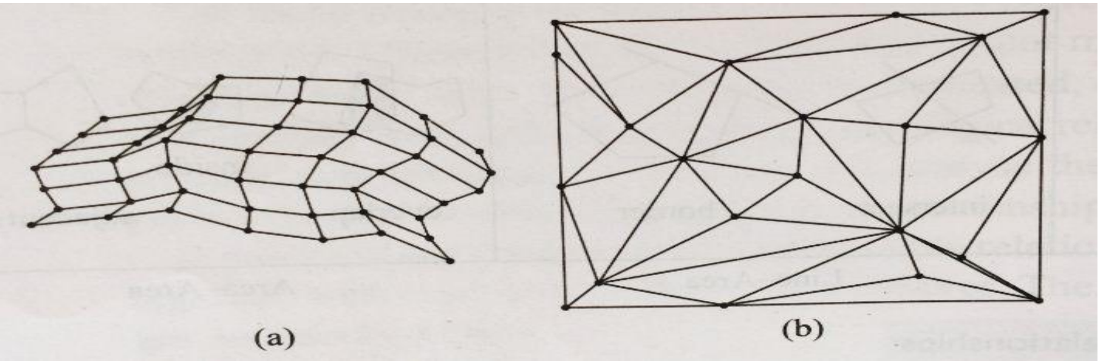
- Multiple points are used to represent the surface. Mass point is a technique to represent surfaces using several points in a very dense manner.
- But point model is not a good approach to represent surfaces, because it requires the viewer to imagine the surface joining the points.

Contour/ Isolines Model:

- Contour is an imaginary line of constant elevation on the ground surface. The corresponding line on a map is called a **contour line.**
- A line on a map that joins places of the same elevation above sea level. Contour interval is the differences in elevation between two contour lines.
- Isolines is a line on a surface, connecting points of equal value such as temperature, rainfall etc.
- Contour/isolines can be used to represent surfaces.

<u>Lattice Model</u>:

- Lattice is similar to point model, it is a representation of surface using an array of equally spaced sample points(mesh-points) that are referenced to a common origin and have a constant sampling distance in the x and y directions
- Each mesh point contains the z value at that location, which is referenced to a common base z value, such as the sea level.
- The lattice model considers each mesh point as a surface value; it does not imply an area of constant value.
- In contrast, raster data model considers each cell as a square area with a constant value. Lattice is also referred to as vector grid or wire mesh.



<u>TIN Model</u>:

- TIN or Triangulated Irregular Network stores GIS data for 3D surface model. In vector GIS, a TIN is used to create a DTM from either regular or irregular height data.
- The TIN method joins the height observations together with straight lines to create a non-overlapping mosaic of irregular triangles.
- A triangle consists of three lines connecting three identified with the coordinates of the three points forming it.
- The surfaces of individual triangle provide area, gradient(slope), and orientation (aspect). Gradient is the steepness of a unit of terrain, usually measured as an angle in degrees or as a percentage.
- Orientation is the direction in which a unit of terrain(triangles) faces, usually expressed in degree from north.

ADVANTAGES:

Raster Model		Vector Model
1.	Simple data structure	It is a smaller file size
2.	Easy and efficient overlaying	Individual identity for discrete objects like line, polygon etc.
3.	Compatible with remote sensing imagery	Efficient for topological relationships.
4.	High spatial variability is efficiently represented.	Efficient projection transformation
5.	Efficient to represent continuous data.	Accurate map output and easy to edit.

Disadvantages:

Raster Model		Vector Model
1.	Larger file size	Complex data structure
2.	All the objects are series of pixels, no identity for discrete objects other than points/pixels.	Difficult overlay operations.
3.	Difficult to build topological relationship.	High spatial variability is inefficiently represented.
4.	Inefficient projection transformation.	Not compatible with remote sensing imagery.
5.	Loss of information when using larger cells	Not appropriate to represent continuous data
6.	Difficult to edit.	

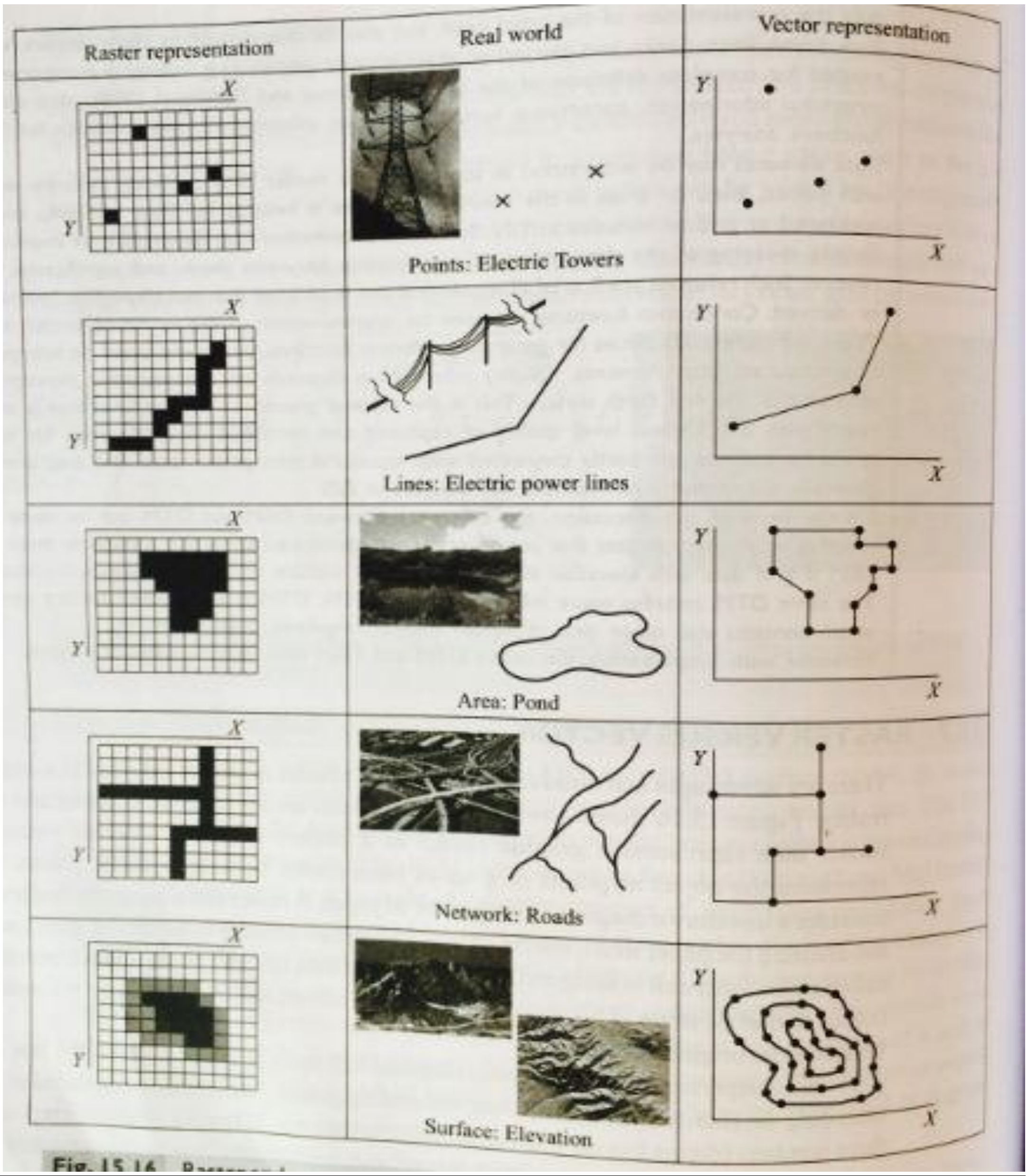


Fig- Rater and Vector Representation

APPLICATIONS OF GIS:

GIS is involved in various areas. These include topographical mapping, socioeconomic and environment modeling, and education. The role of GIS is best illustrated with respect to some of the representative application areas that are mentioned below:

Tax Mapping:

- Raising revenue from property taxes is one of the important functions of the government agencies. The amount of tax payable depends on the value of the land and the property.
- The correct assessment of value of land and property determines the equitable distribution of the community tax.
- A tax assessor has to evaluate new properties and respond to the existing property valuation. To evaluate taxes the assessor uses details on current market rents, sale, maintenance, insurance and other expenses.
- Managing as well as analyzing all this information simultaneously is time consuming and hence comes the need of GIS. Information about property with its geographical location and boundary is managed by GIS.
- Querying the GIS database can locate similar type of properties in an area. The characteristics of these properties can then be compared and valuation can be easily done .

Business:

- Approximately 80 percent of all business data are related to location. Businesses manage a world of information about sales, customers, inventory, demographic profiles etc.
- Demographic analysis is the basis for many other business functions: customer service, site analysis, and marketing. Understanding your customers and their socioeconomic and purchasing behavior is essential for making good business decisions.
- A GIS with relevant data such as number of consumers, brands and sites they go for shopping can give any business unit a fair idea whether their unit if set up is going to work at a particular location the way they want it to run.

Logistics:

- Logistics is a field that takes care of transporting goods from one place to another and finally delivering them to their destinations.

- It is necessary for the shipping companies to know where their warehouses should be located, which routes should the transport follow that ensures minimum time and expenditures to deliver the parcels to their destinations. All such logistics decisions need GIS support.

Environment:

- GIS is being increasingly involved in mapping the habitat loss, urban sprawl, land-use change etc.

- Mapping such phenomena need historical land use data, anthropogenic effects which greatly affect these phenomena are also brought into GIS domain.
- GIS models are then run to make predictions for the future.

Emergency evacuation:

- The occurrence of disasters is unpredictable. We as humans are unable to tell when, where and what magnitude of disaster is going to emerge and therefore solely depend on disaster preparedness as safety measures.
- It is important to know in which area the risk is higher, the number of individuals inhabiting that place, the routes by which the vehicles would move to help in evacuating the individuals.
- Thus preparing an evacuation plan needs GIS implementation.

Remote sensing applications in Water Shed Management:

- Scientific planning and management is essential for the conservation of land and water resources for optimum productivity.
- Watersheds being the natural hydrologic units, such studies are generally carried out at watershed scale and are broadly referred under the term watershed management.
- It involves assessment of current resources status, complex modeling to assess the relationship between various hydrologic components, planning and implementation of land and water conservation measures etc.
- **Water resource mapping, land cover classification, estimation of water yield and soil erosion, estimation of physiographic parameters** for land prioritization and water harvesting are a few areas where remote sensing techniques have been used.
- The remote sensing applications in water resources management under the following five classes:
    - Water resources mapping

- Estimation of watershed physiographic parameters
- Estimation of hydrological and meteorological variables
- Watershed prioritization
- Water conservation