-::Mine survey 3 fifth semester third year::-

Chapter 1:-

1.0 tacheometry:-

Tacheometry (or Tachemetry or Telemetry) is a branch of angular surveying in which the horizontal and vertical distanceS, of points are obtained by optical means as opposed
to the ordinary slower process of measurements by tape or chain. The method is very rapid and convenient. Although the accuracy of Tacheometry in general compares unfavourably with that of chaining, it is best adapted in obstacles such as sleep and broken ground, deep ravines, stretches of water or swamp and so on, which make chaining difficult or impossible. The accuracy attained is such that under. favourable conditions the error will not exceed 111000 , and if the purpose of the survey does not require greater accuracy, the method is unexcelled.

Instrument used in tacheometry surveying:-

ordinary transit theodolite fitted with a stadia diaphragm is generally used for tacheometric survey. The stadia diaphragm essentially consists of one stadia hair above and the other an equal distance below the horizontal crosshair, the stadia hairs being mounted in the same ring and in the same vertical plane as the horizontal and vertical cross-hairs. Fig. 22.1 shows the different forms of stadia diaphragm commonly used.

Definition of tacheometer:-

The first type is known as stadia theodolite,
while the second type is known as 'tacheometer'.
The 'tacheometer' (as such) has the advantage
over the first and the third type due to the
fact that the additive constant of the instrument
is zero.

The telescope used in stadia surveying
are of three kinds :
(I) the simple external-focusing telescope.
(2) the external-focusing anallactic
telescope (Porro's telescope).
(3) the internal-focusing telescope.
The first type is known as stadia theodolite

1.1 define stadia and its principle:-

THE STADIA METHOD

22.4. PRINCIPLE OF STADIA METHOD

The stadia method is based on the principle that the ratio of the perpendicular to the base is constant in similar isosceles triangles.

In Fig. 22.3 (*a*), let two rays *OA* and *OB* be equally inclined to the central ray *OC*. Let A_2B_2, A_1B_1 and *AB* be the staff intercepts. Evidently,

$$\frac{OC_2}{A_2B_2} = \frac{OC_1}{A_1B_1} = \frac{OC}{AB}$$

$$= \text{constant} \quad k = \frac{1}{2}\cot\frac{\beta}{2}.$$

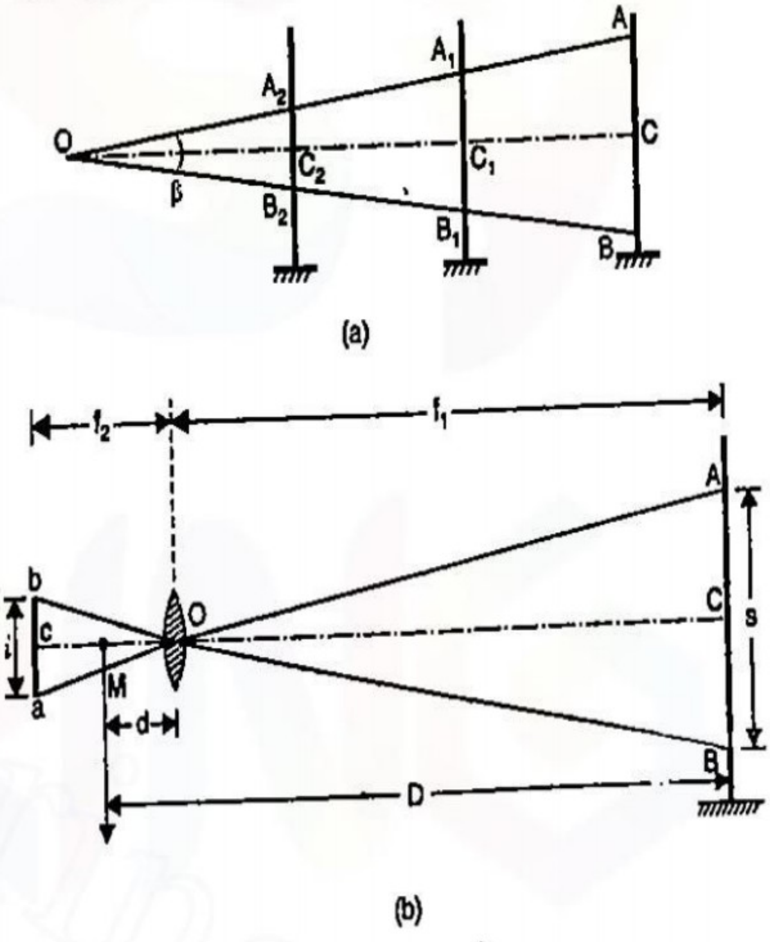


FIG. 22.3. PRINCIPLE OF STADIA METHOD.

This constant *k* entirely depends upon the magnitude of the angle β. If β is made equal to 34′ 22″.64, the constant $k = \frac{1}{2}\cot 17' \, 11''.32 = 100$. In this case, the distance between the staff and the point *O* will be 100 times the staff intercept. In actual practice, observations may be made with either horizontal line of sight or with inclined line of sight. In the latter case, the staff may be kept either vertically or normal to the line of sight. We shall first derive the *distance-elevation formulae* for the horizontal sights.

Horizontal Sight. Consider Fig. 22.3 (*b*) in which *O* is the optical centre of the objective of an *external focusing telesope*.

Let *A*, *C* and *B* = The points cut by the three lines of sight corresponding to the three wires.

b, *c* and *a* = Top, axial and bottom hairs of the diaphragm.

ab = *i* = interval between the stadia hairs (stadia interval)

AB = *s* = staff intercept.

f = focal length of the objective

f_1 = Horizontal distance of the staff from the optical centre of the objective.

f_2 = Horizontal distance of the cross-wires from O.

d = Distance of the vertical axis of the instrument from O.

D = Horizontal distance of the staff from the vertical axis of the instrument.

M = Centre of the instrument, corresponding to the vertical axis.

Since the rays BOb and AOa pass through the optical centre, they are straight so that Δs AOB and aOb are similar. Hence

$$\frac{f_1}{f_2} = \frac{s}{i} \qquad \ldots(i)$$

Again, since f_1 and f_2 are conjugate focal distances, we have from lens formula,

$$\frac{1}{f} = \frac{1}{f_2} + \frac{1}{f_1} \qquad \ldots(ii)$$

Multiplying throughout by ff_1, we get $f_1 = \frac{f_1}{f_2} f + f$.

Substituting the values of $\frac{f_1}{f_2} = \frac{s}{i}$ in the above, we get

$$f_1 = \frac{s}{i} f + f \qquad \ldots(iii)$$

The horizontal distance between the axis and the staff is

$$D = f_1 + d$$

or

$$D = \frac{f}{i} s + (f + d) = k \, . \, s + C \qquad \ldots[22.1\ (a)]$$

Equation 22.1 is known as the *distance equation*. In order to get the horizontal distance, therefore, the staff intercept s is to be found by subtracting the staff readings corresponding to the top and bottom stadia hairs.

The constant $k = f / i$ is known as the *multiplying constant* or *stadia interval factor* and the constant $(f + d) = C$ is known as the *additive constant* of the instrument.

Alternative Method. Equation 22.1 can also be derived alternatively, with reference to Fig. 22.4 in which the rays Bb' and Aa' passing through the exterior principal focus F, become parallel to the optical axis. The rays Aa and Bb pass through O and remain undeviated.

Since the stadia interval ab is fixed in magnitude, the points a' and b' are fixed. Again, since F is also fixed, being the exterior principal focus of the objective, the angle AFB is fixed in magnitude.

From similar triangles AFB and $a'Fb'$ we have

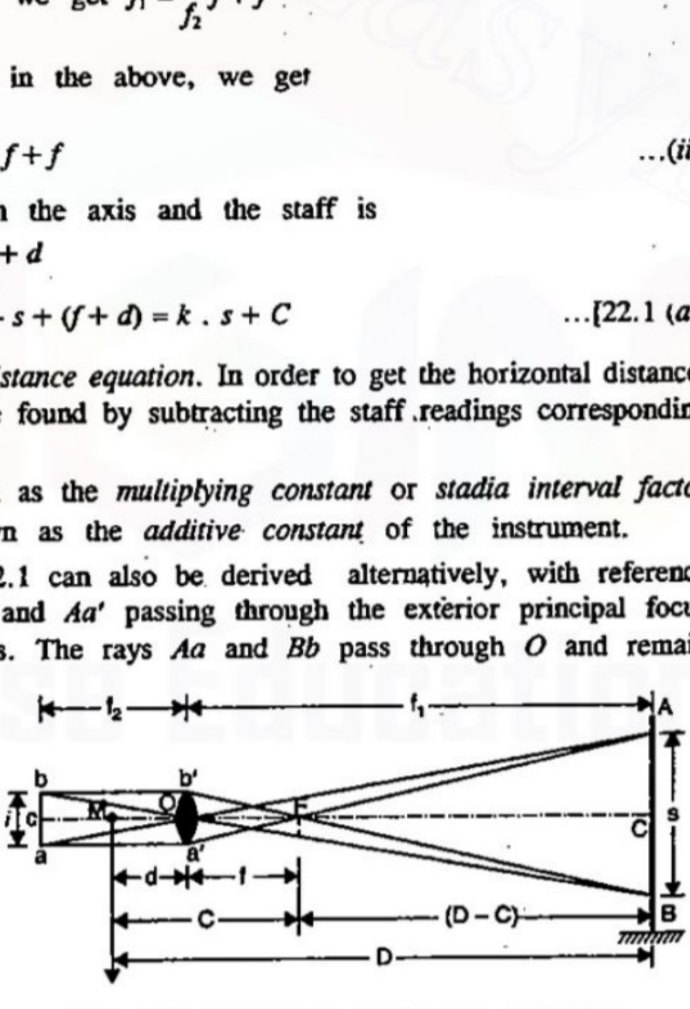


FIG. 22.4. PRINCIPLE OF STADIA METHOD.

$$\frac{FC}{AB} = \frac{OF}{a'b'} = \frac{f}{i} \quad \text{or} \quad FC = \frac{f}{i}\,AB = \frac{f}{i}\,s$$

Distance from the axis to the staff is given by

$$D = FC + (f + d) = \frac{f}{i}\,s + (f + d) = k\,s + C \qquad \text{...(22.1)}$$

Note. *Since point F is the vertex of the measuring triangle, it is also sometimes called the anallactic point.*

Elevation of the Staff Station. Since the line of sight is horizontal, the elevation of the staff station can be found out exactly in the same manner as the levelling. Thus.

Elevation of staff station = Elevation of instrument axis – Central hair reading

Determination of constants k and C

The values of the multiplying constant k and the additive constant C can be computed by the following methods :

1st Method. In this method, the additive constant $C = (f + d)$ is measured from the instrument while the multiplying constant k is computed from field observations :

1. Focus the intrument to a distant object and measure along the telescope the distance between the objective and cross-hairs.

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

Since f_1 is very large in this case, f is approximately equal to f_2, *i.e.*, equal to the distance of the diaphragm from the objective.

2. The distance d between the instrument axis and the objective is variable in the case of external focusing telescope, being greater for short sights and smaller for long sights. It should, therefore be measured for average sight. Thus, the additive constant $(f + d)$ is known.

3. To calculate the multiplying constant k, measure a known distance D_1 and take the intercept s_1 on the staff kept at that point, the line of sight being horizontal. Using equation 22.1, $D_1 = ks_1 + C$ or $k = \frac{D_1 - C}{s_1}$

For average value, staff intercepts, s_2, s_3 etc., can be measured corresponding to distance D_2, D_3 etc., and mean value can be calculated.

Note. *In the case of some external focusing instruments, the eye-piece-diaphragm unit moves during focusing. For such instruments d is constant and does not vary while focusing.*

2nd Method. In this method, both the constants are determined by field observations as under :

1. Measure a line, about 200 m long, on fairly level ground and drive pegs at some interval, say 50 metres.

2. Keep the staff on the pegs and observe the corresponding staff intercepts with horizontal sight.

3. Knowing the values of D and s for different points, a number of simultaneous equations can be formed by substituting the values of D and s in equation 22.1. The

simultaneous solution of successive pairs of equations will give the values of k and C, and the average of these can be found.

For example, if s_1 is the staff intercept corresponding to distance D_1 and s_2 corresponding to D_2 we have

$D_1 = ks_1 + C$ ...(*i*) and $D_2 = ks_2 + C$ ...(*ii*)

Subtracting (*i*) from (*ii*), we get $k = \dfrac{D_2 - D_1}{s_2 - s_1}$ ...(22.2)

Substituting the values of k in (*i*), we get

$$C = D_1 - \frac{D_2 - D_1}{s_2 - s_1} s_1 = \frac{D_1 s_2 - D_1 s_1 - D_2 s_1 + D_1 s_1}{s_2 - s_1}$$

or $$C = \frac{D_1 s_2 - D_2 s_1}{s_2 - s_1} \qquad ...(22.3)$$

Thus, equations 22.2 and 22.3 give the values of k and C.

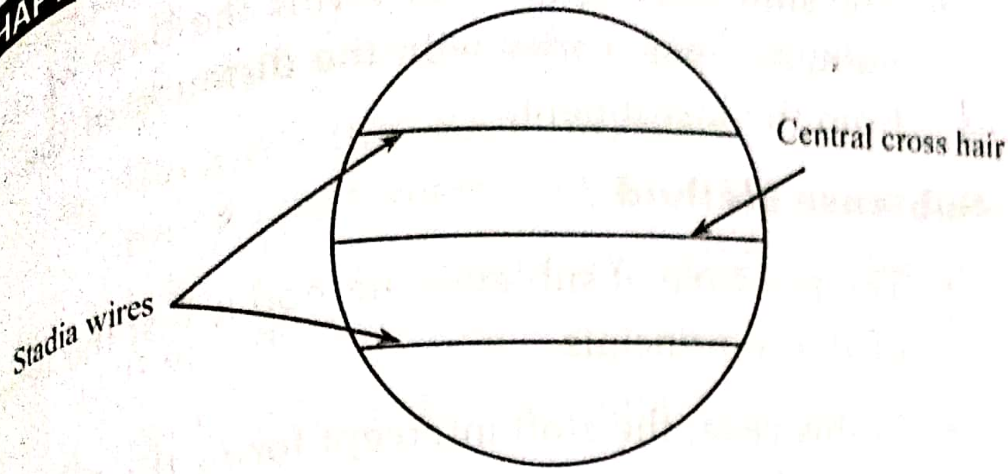
4.0 INTRODUCTION

Tacheometry is a type of angular surveying in which horizontal and vertical distances of points can be determined by instrumental observations only, without the necessity of chaining directly. The method is quick but less accurate. It can be adopted in hilly areas and rough ground where chaining is difficult. It is specially useful in contouring, topographic surveying etc.

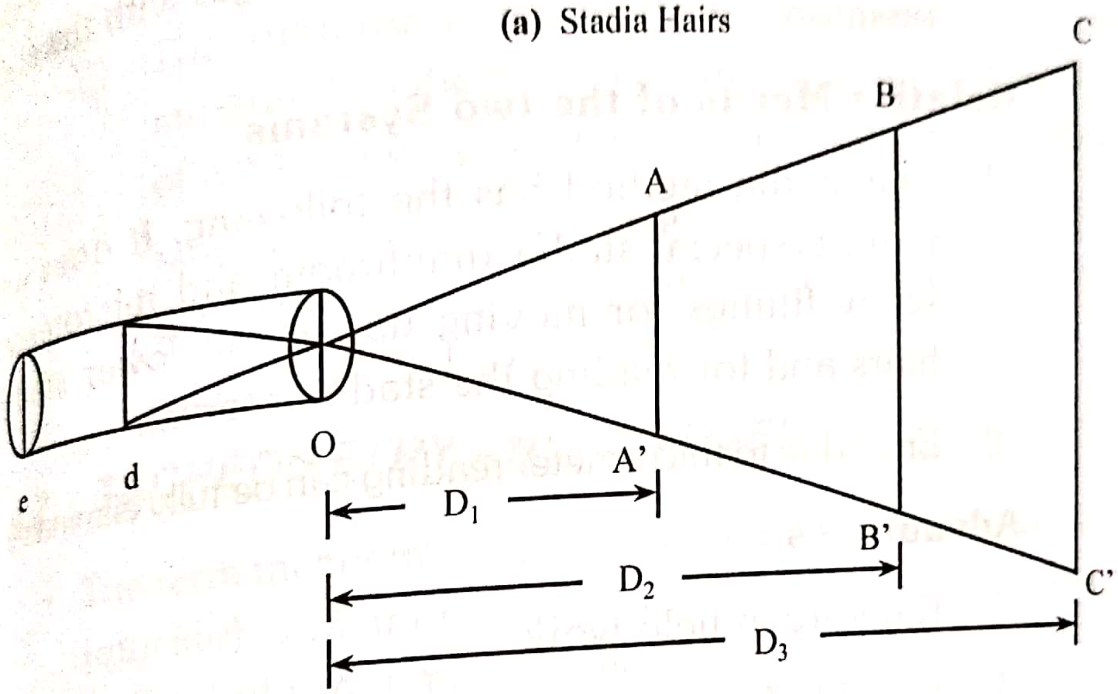
4.1 PRINCIPLES OF TACHEOMETRIC SURVEYING

4.1.1 *Basic Principle of Stadia Tacheometry*

Tacheometry is based on the principle known as stadia surveying. The method is illustrated in Fig. 4.1. The term 'stadia' comes from the stadia diaphragm (of a theodolite) which has three horizontal cross hairs as shown in Fig. 4.1 (a). The cross hairs may be arranged in several forms. Most levels and theodolites have a stadia diaphragm. The readings on a staff are taken against all the three cross hairs in tacheometry. While the reading against the middle hair is used for finding differences in elevation, the readings against the top and bottom hairs are used to find horizontal distances. One method of tacheometry (the tangential method) does not use these hairs at all and reading from the middle hair is used to calculate the distance.



(a) Stadia Hairs



(b)

FIG 4.1 : Basic Principle of Stadia Tacheometry

Stadia Method :

The stadia method is based on the principle that the ratio of the perpendicular to the base is constant in similar isosceles.

- In the stadia principle, whatever may be the distance between the staff and the tacheometer, the tacheometric angle is always a constant.

- The staff intercept, which forms the base of stadia measurement, varies with the distance of the staff from the instrument.

Subtense Method :

- The principle of subtense method is just the reverse of stadia principle.
- In this case, the staff intercept forms the fixed base while the tacheometric angle changes with the staff position.

Relative Merits of the two Systems

1. The stadia method has the following. It does not require special stadia diaphragm and micrometer screw fittings for moving upper and lower stadia hairs and for reading the stadia interval.
2. Error due to micrometer reading can be fully eliminated.

Advantages :

1. Rapidity in field work.
2. Suitable for short sight.
3. An ordinary transit theodolite fitted with a stadia telescope can be used.
4. It does not require special stadia diaphragm and micrometer screw fittings for moving upper and lower stadia hairs and for reading the stadia interval.
5. Error due to micrometer reading can be fully eliminated.

This Subtense Method has the following Advantages :

1. It gives more accurate result through the process is slow.

2. This method can be advantageously used in case of rough countries and for long sights.
3. Because the staff intercept between the two prominent targets is of fixed length, it is easier to take the reading accurately on the subtance diaphragm.
4. Both vertical and horizontal base measurement can be taken.
5. The subtense angle made by the horizontal base measured on the theodolite, the necessary refinement of reading being obtained by the method of repition.
6. Moreover, when the base is horizontal, refraction discrepancies are cancelled and the accuracy correspondingly increased.

4.2 TACHEOMETRY AND ITS USES

- The term tacheometer is derived from the Greek tacheos (quickly) and metron (measure) and so indicates a method of rapid measurement.
- Tacheometry is a branch of angular surveying in which the horizontal and vertical distances of points are obtained by optical means as opposed to the ordinary slower process of measurements by tape or chain.
- The method is very rapid and convenient.
- Although the accuracy of tachemetry in general compares unfavorably with that of chaining it is best adopted in obstacles such as
  - steep and broken ground,
  - stretches of water or swamp and so on,
  - which make chaining difficult or impossible.

Uses of Tacheomoetry :

The tachemoetry can be put to a great variety of uses the principal being the following

1. It is extensively used in hydrographic surveys, location surveys for roads, railways, reservoirs, etc.
2. Contouring, involving the location or setting out and surveying of level contour lines.
3. Rapid sectioning of steep ground, involving elevations of points and there location along a line.
4. Surveying the coal heaps to estimate its cubical contents.
5. Surveying rough and difficult country where ordinary leveling is tedious and chaining is inaccurate, difficult and slow.

Merits of Tacheometric Survey

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, tacheometric 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

Demerits :

1. In terms of precision tacheometry is not very suitable as an accuracy of 1 in 600 can be achieved.
2. With the use of EDM instrument conventional tacheometry is time taking.

4.3 THE VARIOUS SYSTEMS OF TACHEOMETRIC SURVEY

1. The stadia method
   a) Fixed hair method
   b) Movable hair method or sub tense method.
2. The tangential Method
3. Measurements by means of special instruments.

4.4 DETERMINATION OF CONSTANTS

- The value of the two constants $\frac{f}{i}$ (multiplying constants) and f+D (additive constant) for a given instrument can be determined by the following method :
- On a fairly level ground the stations B and C are marked properly.
- The distance AB and AC are measured accurately with a steel tape from the instrument station A. let the two distance measured are D_1 and D_2.

The instrument is not up at A and with the line of collimation horizontal the staff intercepts S_1 and S_2 on the staff held truly vertical at the respective stations B and C are obtained.

Two simultaneous equation are obtained by substituting these values ($D_1.S_1$) and ($D_2.S_2$) in the equation :

$$D = \frac{f}{i} S + (f + d)$$

$$D_1 = \frac{f}{i} S_1 + (f + d) \qquad \text{...... (1)}$$

$$D_2 = \frac{f}{i} S_2 + (f+d) \quad \ldots\ldots (2)$$

By subtracting equation (1) and (2)

$$D_2 - D_1 = \frac{f}{i} (S_2 - S_1)$$

$$\text{or, } \frac{f}{i} = \frac{D_2 - D_1}{S_2 - S_1}$$

Again substituting this value of $\frac{f}{i}$ in one of the equations (1) or (2).

$$(f+d) = \frac{D_1S_2 - D_2S_1}{S_2 - S_1}$$

$\therefore$ Multiplying constant, $\frac{f}{i} = \frac{D_2 - D_1}{S_2 - S_1}$

And Additive constant, $(f+d) = \frac{D_1S_2 - D_2S_1}{S_2 - S_1}$

4.5 THE STADIA METHOD OF TACHEOMETRIC SURVEY

Principle :

- The principle of tacheometric is the geometrical theorem that n similar triangles homologous sides are proportional,
- The common vertex of the triangles, in this case, is not the center of the instrument, but a point in front of the telescope, objective, at a distance equal to f, the focal length of the objective.

Principle of Stadia Method :

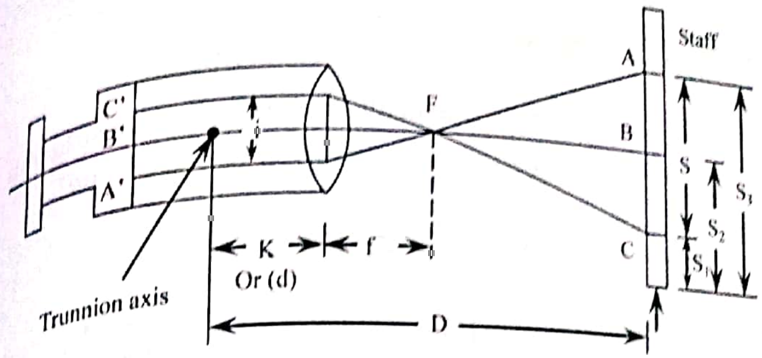


FIG 4.2 :

Where the line of sight is horizontal and the staff is held vertically

Let f = Focal length of the object glass.

i = Distance between the upper and lower stadia hairs.

$S = S_2 - S_1$ = Staff intercept.

D = Horizontal distance from the instrument station to the staff station

K = Distance of trunion axis from the object glass.

S_2 = Axial hair reading.

From similar triangles FAC and FA^1C^1,

$$\frac{FB}{FB^1} = \frac{AC}{A^1C^1}$$

$$\text{or, } \frac{D-K-f}{f} = \frac{S}{i}$$

$\therefore D = \frac{f}{i} s + (f + k)$ or,

$\therefore D = \frac{f}{i} s + (f + d)$

- Evidently, (f+k) is practically a constant for any given instrument (varied only by focusing the telescope).
- the other function $(\frac{f}{i} s)$ is a variable.

$$\frac{f}{i} = 100.$$

- But, it is customary to stadia hairs so that the constant $\frac{f}{i}$ is known as multiplying constant or stadia interval factor
- And the constant (f+k) is known as additive constant, the value of which for external focusing telescope varies from 30 cm to 60 cm
- And for internal focusing type from 10 cm to 20 cm which being small can be ignored.
- However to make the additive constant equal to zero another convex lens called anallatic lens is fitted in the telescope between the objective and eyepiece at fixed distance from the objective glass.

$$\text{Horizontal distance} = \frac{f}{i} S + (f + k)$$

$$= 100S + \text{Additive constant.}$$

The elevation (R.L.) of the staff station

= elevation of the instrumental axis - Axial hair reading.

= R.L. of the instrument station + Height of instrument - S_2.

Fixed hair Method :

- In this method, the observation is made with the help of a stadia diaphragm having stadia hairs at fixed distance apart.
- When th sight is taken to a distant staff, three different readings will be obtained.
- The centre or collimation web will give the true reading for level.
- The differnce of the readings on the shaft corresponding to the top and bottom stadia hairs known as staff intercept, will be directly proportional to the distance of the shaft from the instrument station (apart from the correction required in certain cases).
- It should be noted that the subtense angle remains constant.

4.6 DERIVATION OF FORMULA FOR HORIZONTAL DISTANCE AND ELEVATION

a) With Horizontal sights In a tacheometer, with horizontal line of sight and with staff vertical and perpendicular to it, the horizontal distance where d = horizontal distance from optical centre to the vertical axis of the instrument.

$$D = \frac{F}{i} S + (f + d)$$

With Inclined Sights

- In case the ground is rough and horizontal sights are not possible,
- The staff may be held either vertically or normal to the line of sights.
- Inclined observations require two calculations to reduce them to there horizontal equivalents, since, in the first place.
- The staff is held vertically and is not normal to the line of the sight and, in the second place, the inclined distance must it self be converted to the horizontal equivalent.
- The former method is generally preferred as keeping the staff vertical is easier.

The Tangential Method

The height and horizontal distance of a point relative to the instrument may be found by observing shaft and measuring the vertical angle as shown in the figure :

- This method involves the reading of vertical angles to two fixed targets upon a graduated staff.
- A stadia diaphragm carrying only one horizontal web (central hair) will be required.
- The telescope is set level at T an and shaft read at B. the telescope is then tilted to read a definite division on the shaft and the angle (α) noted.
- Let this intercept be S_1 then the horizontal distance $D = S \cot \alpha$.
- The elevation of C is deduced from the reading B as in ordinary leveling.

- When the ground does not permit a horizontal reading of the staff, two vertical angles are read.

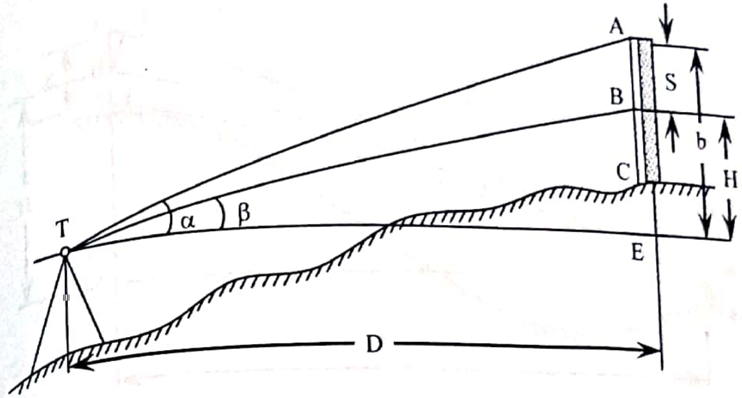


FIG 4.3 : Tangential Method with Inclined Sights

- The horizontal distance D is required.
- The vertical angle α and β are measured, the reading B being the height of the instrument and AB the staff intercept (S),

Now $S = b - a = AB$

$$b = D \tan \alpha \text{ and } a = D \tan\beta,$$

There fore $(b-a) = S = D(\tan \alpha - \tan\beta)$

and $$D = \frac{S}{\tan\alpha - \tan\beta}$$

When ∞ is an angle of elevation and β an angle of.

depression : $$D = \frac{S}{\tan\alpha - \tan\beta}$$

and $a = D\tan\beta = \dfrac{S\tan\beta}{\tan\alpha - \tan\beta}$

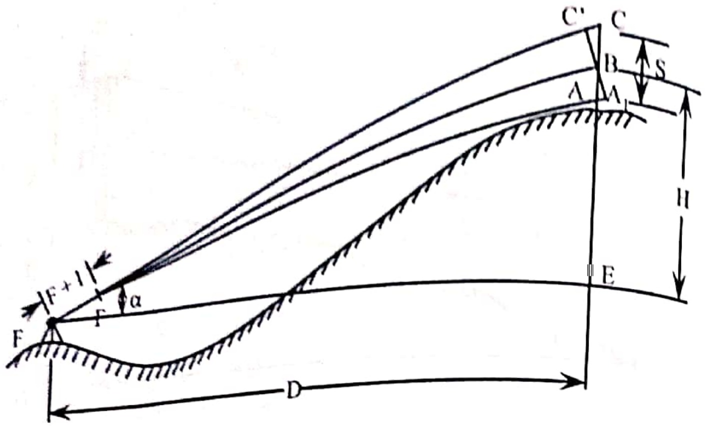


FIG 4.4 :

Staff held vertical

- In the following calculation it is assumed that the multiplying factor is 100 and the additive constant (f+d) is C.
- In figure, for an inclined sight to a vertical staff, reading AC must be first reduced to the equivalent reading A_1C_1 normal to the line of sight, i.e. at right to FB,
- Now the angle CBC_1 is equal to the vertical angle ∞, and the triangle CBC_1 may be considered right-angled at C_1 with negligible error.

  Therefore,
- $A_1C_1 = AC\cos\alpha = S\cos\alpha$

- The distance FB = $100S\cos\alpha$ and TF = (f+d)=C
- Slope distance = TB = $100S\cos\alpha + C$
- Horizontal distance = D = TB $\cos\alpha$ = $(100S\cos\alpha + C)\cos\alpha$

$$= \frac{f}{i}\cos\alpha.\sin\alpha + (\text{ft}.\sin\alpha$$

$$= 100\,S\cos^2\alpha + C\cos\alpha$$

Again, vertical height EB, from the axis of the instrument to the point cut by the middle stadia hair on the staff

$H = TB\sin\alpha = (100S\cos\alpha + C)\sin\alpha$

$= 100S\cos\alpha\sin\alpha + C\sin\alpha$

It is also possible to deduce H from D from the relaton

$H = D\tan\alpha$

If no additive constant is involved.

Slope distance = $100S\cos\alpha$

Horizontal distance = $100S\,COS^2\alpha$

- The height H is not the difference of the level between the instrument station and the staff station, this may be found as follows :
- When the angle of elevation is positive, the difference in level is given by
- h = H+ height of instrument axis-central stadia reading.
- But when the line of sight is depressed below the horizontal, the procedure (for calculating the difference in level) is exactly the same as before, except that the height H is prefixed with the negative

sign because it represents as a depth below the horizontal line of sight.

- General for inclined sights, the staff is held vertically as this can be done accurately by plumb line or spirit level.

4.7 SOLVED PROBLEM

PROBLEM-1

(a) Find out the constants of a tacheometer from the following data:

(b) Also find the distance when the reading of the stadia hairs were 1.20m and 3.70m.

The line of sight is horizontal in all cases

Horizontal Distance	Stadia Readings	
	Lower	Upper
200m	1.50m	3.46m
400m	0.40m	4.33m

Solution :

(a) The horizontal distances

When the line of sight is horizontal.

In the first case, we have S = 3.446 – 1.50 = 1.96m

and H = 200 $H = \frac{f}{i}S + (f = d)$

in the second case, we have

S = 4.33–0.40 = 3.93m and H = 400m

$\therefore 200 = \frac{f}{i} \times 1.96 + (f + d) \Rightarrow (i)$

$\therefore 400 = \frac{f}{i} \times 3.93 + (f + d) \Rightarrow (ii)$

Substracting the first from the second, we get

$400 - 200 = \frac{f}{i}(3.93 - 1.96)$

or $200 = \frac{f}{i} \times 1.97$

$\therefore \frac{f}{i} = \frac{200}{1.97} = 101.52$

and $(f+d) = \frac{400}{101.52 \times 3.93} = 1.00m (\because \text{from} \rightarrow ii)$

b) The distance,

$H = \frac{f}{i}S + (f + d)$

= 101.52 x (3.70–1.20)+1.00

= 101.52 x 2.50 + 1.00

= 254.80m

PROBLEM - 2

To determine the multiplying constants of a Tacheometer the following observations were taken on the staff held vertical at a distance measured from the instrument:

Observation	H.Dist.	V.Dist	Staff Intercept
1	50m	+3°48'	0.50m
2	100m	+1°06'	1.00m
3	200m	+0°36'	1.50m

1.2 EXPLAIN DIAPHRAGM, RETICULES, TACHEOMETRY INSTRUMENT CONSTANT:-

DIAPHRAGM:-

Diaphragm. Diaphragm is provided in front of the eye piece. It contains cross hairs made of dark metal which are arranged in perfect perpendicular positions. These cross hairs are used by the eye piece to bisect the objective through objective lens.

RETICULES:-

A reticle, or reticule (from Latin reticulum, meaning 'net'), also known as a graticule (from Latin craticula, meaning 'gridiron'), is a pattern of fine lines or markings built into the eyepiece of a sighting device, such as a telescopic sight in a telescope, a microscope, or the screen of an oscilloscope, to provide measurement references during visual examination. Today, engraved lines or embedded fibers may be replaced by a computer-generated image superimposed on a screen or eyepiece. Both terms may be used to describe any set of lines used for optical measurement, but in modern use reticle is most commonly used for gunsights and such, while graticule is more widely used for the oscilloscope display, microscope slides, and similar roles.

Tacheometer:-

A tacheometer which is essentially nothing more than a theodolite fitted with stasia our hairs is generally used for metric surveying. The stadia diaphragm consist of one stadia hair above And The other at equal distance below the horizontal cross hair. the stadia of hairs are kept in the same vertical plane the horizontal and vertical cross hair.

Instrument constant:-

known as stadia interval factor, also instrument constant. It is denoted by K and thus. d = K.s --------------------- Equation (23.1) The horizontal distance (D) between the center of the instrument and the. station point (Q) at which the staff is held is d + f + c.

i.e.

13.10. MOVABLE HAIR METHOD

In this method the staff intercept is kept constant whereas the distance between stadia hairs is variable. Instruments used in this method are a theodolite with a special type of diaphragm and a staff provided with two targets at a known distance.

1. Diaphragm of the Theodolite [Fig. 13.19]

In this type of diaphragm, the central or axial wire is fixed in the plane of the telescope. The stadia hairs are moved in vertical plane by means of two finely threaded micrometer screws. The distance through which either wire is moved from the fixed central wire, is measured by the number of turns made by the micrometer screw. The full turns are read on the graduated scale seen in the field of view and the fractional part of a turn is read on the graduated drum of the micrometer screw placed one above and one below the eye piece. The total distance through which stadia wires move, is equal to the sum of the micrometer readings.

It may be noted that graduations on the micrometer drums are in opposite directions.

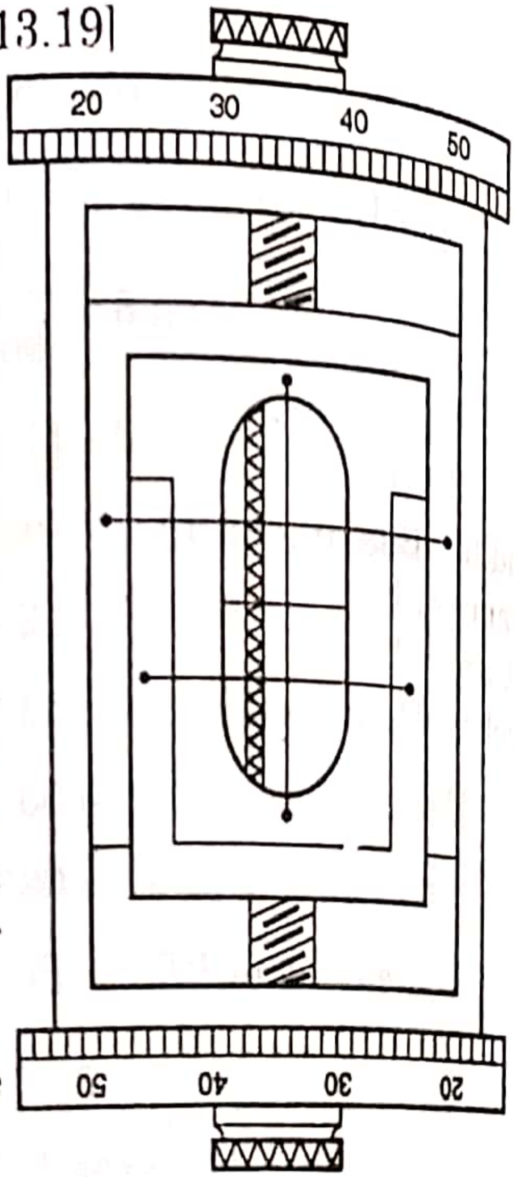


Fig. 13.19. A special type diaphragm of a moving hair theodolite.

2. The staff targets. If the distance between the instrument station and staff position is within 200m, an ordinary levelling staff may be used and a full metre reading used for the purpose of observing a constant intercept. For distances exceeding 200 m, it becomes difficult to read graduations. In such cases two vanes or targets fixed at a known distance apart on a staff, are observed. A third target is fixed at the mid-point of the two targets.

13.11. METHOD OF OBSERVATIONS

While making observations with a theodolite fitted with special type of diaphragm, the central target is first bisected with the axial wire. Micrometers are then turned simultaneously to move the stadia wires in vertical plane. The readings are then noted.

1. Tacheometric formulae for subtense theodolite. A theodolite fitted with a diaphragm in which stadia wires are movable, is known as a *subtense theodolite*. The tacheometric horizontal formula, $D = \frac{f}{i}s + (f + d)$ is equally applicable to the movable hair method. In this case all terms on right hand side are constant except i, the stadia distance. Hence, the multiplying constant is (sf) and the additive constant is $(f + d)$. If m is the total number of the revolutions of the micrometer of pitch p, for a staff intercept then $i = mp$.

Substituting the value of i in tacheometric equation, we get

$$D = \frac{fs}{mp} + (f + d)$$

or

$$D = \frac{A}{m} S + B \quad ...(13.25)$$

However, if e is the index error eqn. (13.25) reduces to

$$D = \frac{A}{m - e} s + B. \quad ...(13.25a)$$

2. Determination of tacheometric constants. The value of additive constant $B = (f + d)$ may be easily obtained by measuring distances along the telescope of the theodolite. Values of both the constants A and B may be calculated by making field observations as detailed below :

Procedure. The following steps are followed:

1. Measure two distances D_1 and D_2 on a fairly level ground, from the instrument station.
2. Hold the staff carrying two targets S metres apart at the end of distance D_1.
3. Bisect the central target and rotate both the micrometers simultaneously to bisect upper and lower targets. Let the total distance moved be m_1.
4. Now shift the staff to the end of distance D_2.
5. Bisect the central target and rotate both the micrometers simultaneously to bisect upper and lower targets. Let the total distance moved be m_2.

$m = 16.7$ turns. Ans.

or

13.12. THE TANGENTIAL METHOD OF TACHEOMETRY

In tangential tacheometry, horizontal and vertical distances from the instrument to the staff position, are computed from the observed vertical angles to two targets fixed at a known distance S on the staff.

Depending upon the vertical angles, three cases may arise :

1. Both vertical angles may be elevation angles.
2. Both vertical angles may be depression angles.
3. One of the angles may be an elevation angle and the other may be a depression angle.

Case I. Distance and Elevation Formulae

Let A and B represent two targets fixed S metres apart on a staff held vertical at D. (Fig. 13.20).

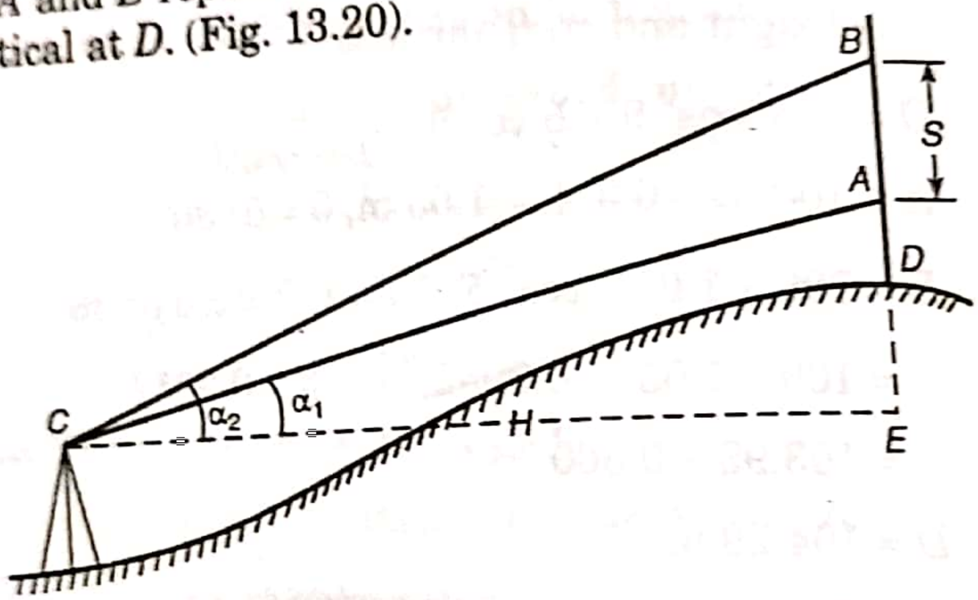


Fig. 13.20. Both vertical angles are elevations.

Let O represent the trunnion axis of the theodolite

Let α_1 and α_2 be the angles of elevation to the targets A and B respectively.

Horizontal distance formula :

From ΔACE, $CE = AE \cot \alpha_1$ ...(13.30)

From ΔBCE, $CE = BE \cot \alpha_2$ ...(13.31)

Comparing Eqs. (13.30) and (13.31), we get

$$AE \cot \alpha_1 = BE \cot \alpha_2$$

$$AE \cot \alpha_1 = (AE + AB) \cot \alpha_2$$

$$AE \cot \alpha_1 = EA \cot \alpha_2 + S \cot \alpha_2 \quad \text{where } AB = S.$$

or $EA (\cot \alpha_1 - \cot \alpha_2) = S \cot \alpha_2$

$$EA = \frac{S \cot \alpha_2}{\cot \alpha_1 - \cot \alpha_2}$$

$$EA = \frac{S \tan \alpha_1}{\tan \alpha_2 - \tan \alpha_1} \quad ...(13.32)$$

$$H = AE \cot \alpha_1$$

∴

$$H = \frac{S}{\tan \alpha_2 - \tan \alpha_1} \quad ...(13.33)$$

∴

$$H = S \cos \alpha_1 \cos \alpha_2 \operatorname{cosec} (\alpha_2 - \alpha_1) \quad ...(13.34)$$

or

Eq. (13.34) is a useful form of the Eqn. (13.33) for logarithmetical calculations.

Elevation formula :

R.L. of D = R.L. of trunning axis + $EA - AD$

$$= \text{R.L. of trunning axis} + \frac{S \tan \alpha_1}{\tan \alpha_2 - \tan \alpha_1}$$

$$- \text{height of lower target above } D \quad ...(13.35)$$

Case 2. Distance and Elevation Formulae (Fig. 13.21)

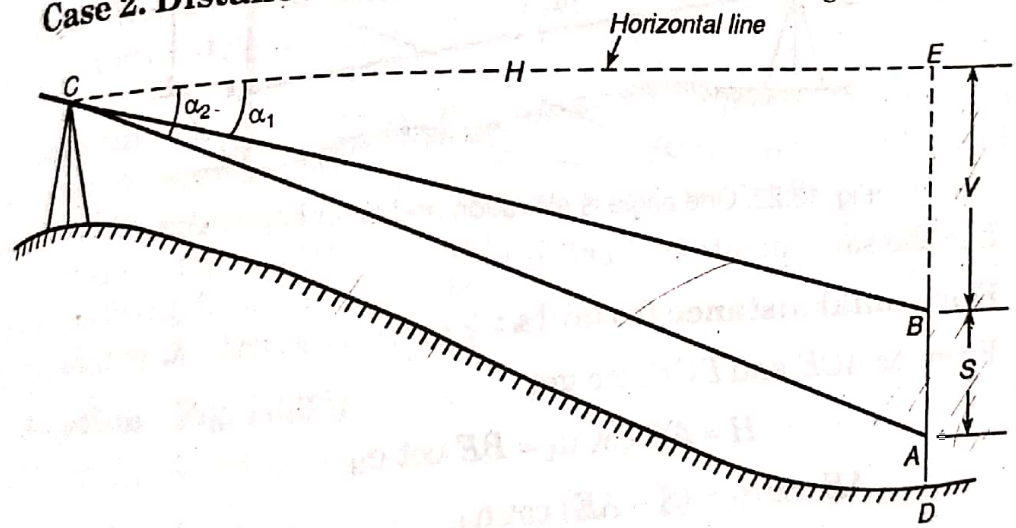


Fig. 13.21. Both vertical angles are depressions.

Use of the same notations as in case 1.

Horizontal distance formula :

From Δs ACE and BCE, we get

$$H = AE \cot \alpha_2 = BE \cot \alpha_1$$

$$(AB + BE) \cot \alpha_2 = BE \cot \alpha_1$$

$$AB \cot \alpha_2 + BE \cot \alpha_2 = BE \cot \alpha_1$$

$$AB \cot \alpha_2 = BE (\cot \alpha_1 - \cot \alpha_2$$

$$BE = \frac{S \cot \alpha_2}{\cot \alpha_1 - \cot \alpha_2} = \frac{S \tan \alpha_2}{\tan \alpha_2 - \tan \alpha_1}$$

$$H = BE \cot \alpha_1$$

But

$$H = \frac{S}{\tan \alpha_2 - \tan \alpha_1} \quad ...(13.36)$$

∴

$$= S \cos \alpha_1 \cos \alpha_2 \operatorname{cosec} (\alpha_2 - \alpha_1) \quad ...(13.37)$$

Elevation formula :

R.L. of D = R.L. of trunnion axis --EB--BD

$$= \text{R.L. trunning axis} - \frac{S \tan \alpha_2}{\tan \alpha_2 - \tan \alpha_1}$$

–height of the upper target above D. ...(13.38)

Case 3. Distance and Elevation Formulae (Fig. 13.22)

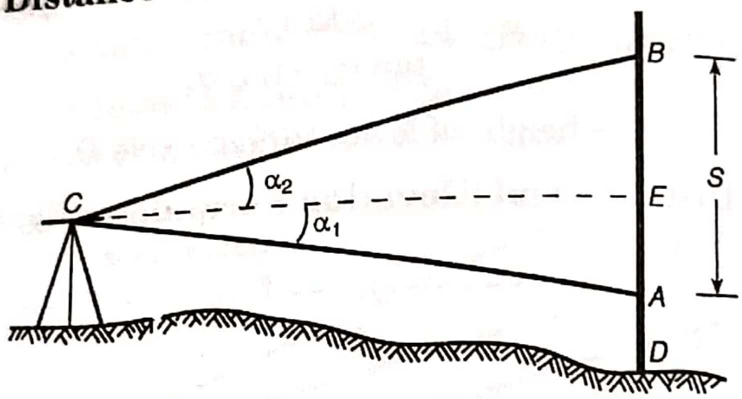


Fig. 13.22. One angle is elevation and other depression.

Use the same notations in case 1.

Horizontal distance formula :

From Δs ACE and BCE, we get

$$H = AE \cot \alpha_1 = BE \cot \alpha_2$$

or $$AE \cot \alpha_1 = (S - AE) \cot \alpha_2$$

or $$AE \cot \alpha_1 = S \cot \alpha_2 - AE \cot \alpha_2$$

or $$AE (\cot \alpha_1 + \cot \alpha_2) = S \cot \alpha_2$$

or $$AE = \frac{S \cot \alpha_2}{\cot \alpha_1 + \cot \alpha_2}$$

$$= \frac{S \tan \alpha_1}{\tan \alpha_1 + \tan \alpha_2}$$

$\tan \alpha_1 + \tan \alpha_2$

– height of *lower* target ...(13.41)

13.13. DISADVANTAGES OF THE TANGENTIAL METHOD

The tangential method of tacheometry has the following disadvantages :

1. It lacks speed.
2. It involves more computations for reducing distances and elevations.
3. Two vertical angles are observed for computing a distance.
4. During the interval of observing vertical angles, the instrument might get disturbed unnoticed.

Due to above disadvantages, tangential method is considered inferior to the stadia method and is generally not adopted.

Note. The most common method of tacheometry is a fixed hair stadia method, using a staff held vertically.

TACHEOMETRIC SURVEYING

Tacheometry or tachemetry or telemetry is a branch of angular surveying in which the horizontal and Vertical distances of points are obtained by optical means as opposed to the ordinary slower process of measurements by tape or chain.

- **The method is very rapid and convenient.**
- **It is best adapted in obstacles such as steep and broken ground, deep revines, stretches of water or swamp and so on, which make chaining difficult or impossible,**
- **The primary object of tacheometry is the preparation of contoured maps or plans requiring both the horizontal as well as Vertical control. Also, on surveys of higher accuracy, it provides a check on distances measured with the tape.**

Tacheometry (from Greek, quick measure), is a system of rapid surveying, by which the positions, both horizontal and vertical, of points on the earth surface relatively to one another are determined without using a chain or tape or a separate leveling instrument.

Uses of Tacheometry

The tacheometric methods of surveying are used with advantage over the direct methods of measurement of horizontal distances and differences in elevations. Some of the uses are:

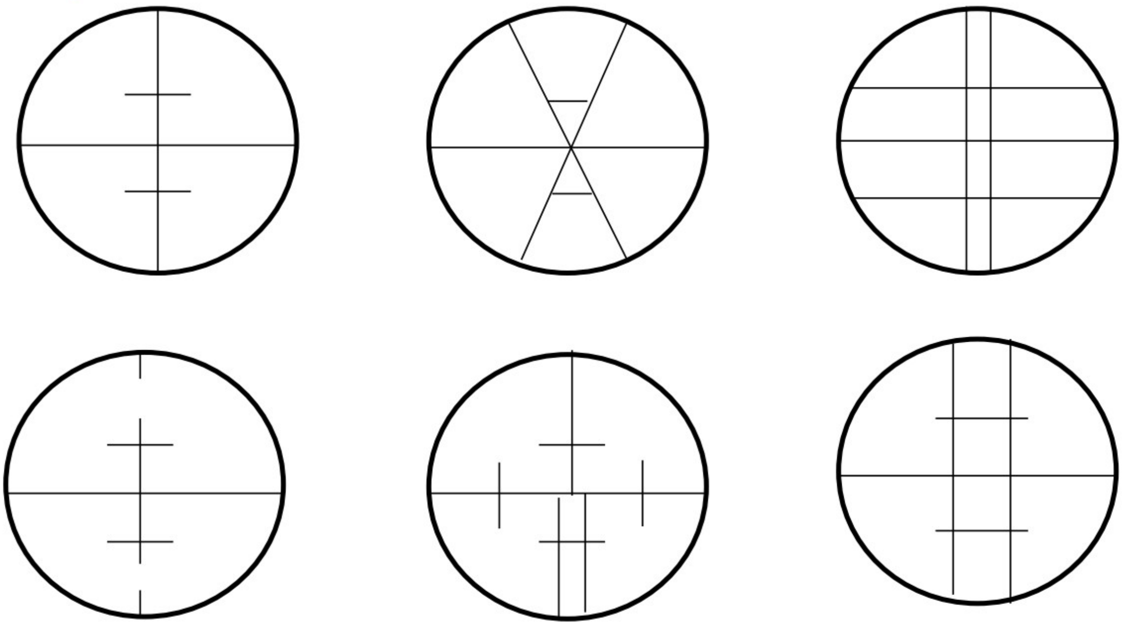
- ✓ Preparation of topographic maps which require both elevations and horizontal distances.
- ✓ Survey work in difficult terrain where direct methods are inconvenient
- ✓ Detail filling
- ✓ Reconnaissance surveys for highways, railways, etc.
- ✓ Checking of already measured distances
- ✓ Hydrographic surveys and
- ✓ Establishing secondary control.

INSTRUMENTS

-An ordinary transit theodolite fitted with a stadia diaphragm is generally used for tacheometric survey.

- The stadia diaphragm essentially consists of one stadia hair above and the other an equal distance below the horizontal cross-hair, the stadia hairs being mounted in the ring and on the same vertical plane as the horizontal and vertical cross-hairs.

Stadia is a tacheometric form of distance measurement that relies on fixed angle intercept.



Different forms of stadia diaphragm commonly used

The telescope used in stadia surveying are of three kinds:

(1) The simple external-focusing telescope

(2) the external-focusing anallactic telescope (Possor`s telescope)

(3) the internal-focusing telescope.

A tacheometer must essentially incorporate the following features:

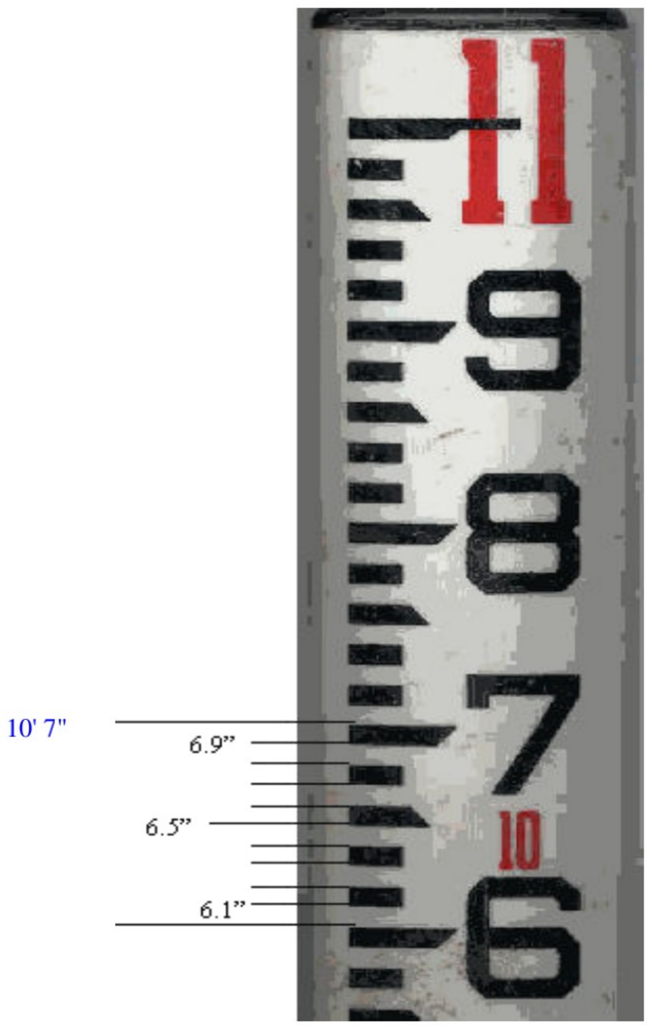
(i) The multiplying constant should have a nominal value of 100 and the error contained in this value should not exceed 1 in 1000.

(ii) The axial horizontal line should be exactly midway between the other two lines.

(iii) The telescope should be truly anallactic.

(iv) The telescope should be powerful having a magnification of 20 to 30 diameters.

- **The aperture of the objective should be 35 to 45 mm in diameter to have a sufficiently bright image.**
- **For small distances (say upto 100 meters), ordinary levelling staff may be used. For greater distances a stadia rod may be used.**
- **A stadia rod is usually of one piece, having 3 – 5 meters length.**
- **A stadia rod graduated in 5 mm (i.e. 0.005 m) for smaller distances and while for longer distances, the rod may be graduated in 1 cm (i.e. 0.01 m).**



FOOT
GRADUATION READ
TO 0.01 FT
A

METRIC
GRADUATION READ
TO 1 CM
B

Different systems of Tacheometric Measurement:

The various systems of tacheometric survey may be classified as follows:

- **The stadia System**
  - (a) **Fixed Hair method of Stadia method**
  - (b) **Movable hair method, or Subtense method**
- **The tangential system**
- **Measurements by means of special instruments**

The principle common to all the systems is to calculate the horizontal distance between two points A and B and their distances in elevation, by observing

(i) The angle at the instrument at A subtended by a known short distance along a staff kept at B, and

(ii) the vertical angle to B from A.

(a) Fixed hair method

- **In this method, *the angle at the instrument at A subtended by a known short distance along a staff kept at B* is made with the help of a stadia diaphragm having stadia wires at fixed or constant distance apart.**
- **The readings are on the staff corresponding to all the three wires taken.**
- **The staff intercept, i.e., the difference of the readings corresponding to top and bottom stadia wires will therefore depend on the distance of the staff from the instrument.**
- **When the staff intercept is more than the length of the staff, only half intercept is read.**
- **For inclined sight, readings may be taken by keeping the staff either vertical or normal to the line of sight.**
- **This is the most common method is tacheometry and the same 'stadia method' generally bears reference to this method.**

Subtense Method

- This method is similar to the fixed hair method except that the stadia interval is variable.

- Suitable arrangement is made to vary the distance between the stadia hair as to set them against the two targets on the staff kept at the point under observation.

- Thus, in this case, the staff intercept, i.e., the distance between the two targets is kept fixed while the stadia interval, i.e., the distance between the stadia hair is variable.

- As in the case of fixed hair method, inclined sights may also be taken.

Tangential Method

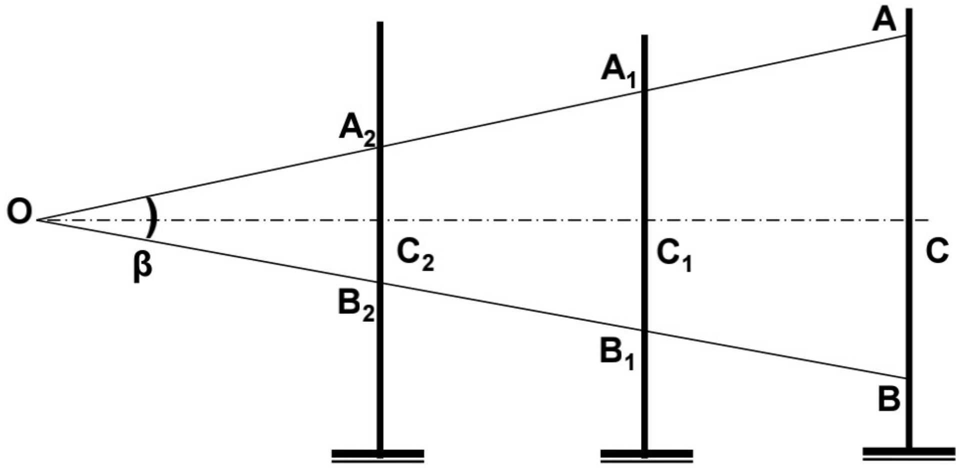
- In this method, the stadia hairs are not used, the readings being taken against the horizontal cross-hair.

- To measure the staff intercept, two pointings of the instruments are, therefore, necessary.

- This necessitates measurement of vertical angles twice for one single observation.

PRINCIPLE OF STADIA METHOD

The stadia method is based on the principle that the ratio of the perpendicular to the base is constant in similar isosceles triangles.



In figure, let two rays OA and OB be equally inclined to central ray OC. Let A_2B_2, A_1B_1 and AB be the staff intercepts. Evidently,

$$\frac{OC_2}{A_2B_2} = \frac{OC_1}{A_1B_1} = \frac{OC}{AB}$$

$$= \text{constant } k = \tfrac{1}{2} \cot \frac{\beta}{2}$$

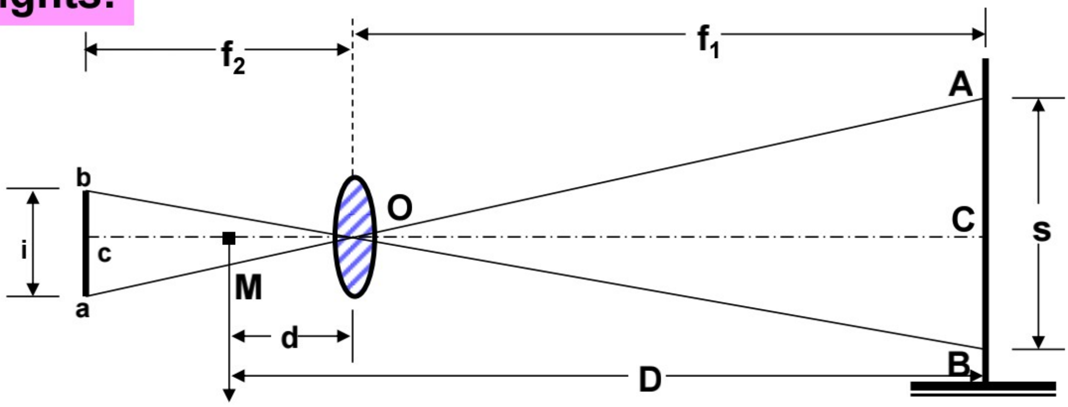
This constant k entirely depends upon the magnitude of the angle β.

✓ In actual practice, observations may be made with either horizontal line of sight or with inclined line of sight.

✓ In the later case the staff may be kept either vertically or normal to the line of sight.

✓ First the *distance-elevation* formulae for the horizontal sights should be derived.

Horizontal Sights:



Consider the figure, in which *O* is the optical centre of the objective of an *external focusing telescope*.

Let A, C, and B = the points cut by the three lines of sight corresponding to three wires.

b, c, and a = top, axial and bottom hairs of the diaphragm.
ab = i = interval b/w the stadia hairs (stadia interval)
AB = s = staff intercept;
f = focal length of the objective

f_1 = horizontal distance of the staff from the optical centre of the objective
f_2 = horizontal distance of the cross-wires from O.
d = distance of the vertical axis of the instrument from O.
D = horizontal distance of the staff from the vertical axis of the instruments.
M = centre of the instrument, corresponding to the vertical axis.

Since the rays *BOb* and *AOa* pass through the optical centre, they are straight so that *AOB* and *aOb* are similar. Hence,

$$\frac{f_1}{f_2} = \frac{s}{i}$$

Again, since f_1 and f_2 are conjugate focal distances, we have from lens formula,

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

Multiplying throughout by ff_1, we get $f_1 = \frac{f_1}{f_2} f + f$

Substituting the values of $\frac{f_1}{f_2} = \frac{s}{i}$ in the above, we get

$$f_1 = \frac{s}{i} f + f$$

Horizontal distance between the axis and the staff is $D = f_1 + d$

$$D = \frac{f}{i} s + (f + d) = k \,.\, s + C$$

Above equation is known as the *distance equation*. In order to get the horizontal distance, therefore, the staff intercept s is to be found by subtracting the staff readings corresponding to the top and bottom stadia hairs.

The constant k = f/i is known as the *multiplying constant* or *stadia interval factor* and the constant (f + d) = C is known as the *additive constant* of the instrument.

Determination of constant k and C

The values of the multiplying constant *k* and the additive constant C can be computed by the following methods:

1st method:

In this method, the additive constant C = (f + d) is measured from the instrument while the multiplying constant k is computed from field observations:

1. Focus the instrument to a distant object and measure along the telescope the distance between the objective and cross-hairs,

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

2. The distance d between the instrument axis and the objective is variable in the case of external focusing telescope, being greater for short sights and smaller for long sights. It should, therefore be measured for average sight. Thus, the additive constant (f + d) is known.

3. To calculate the multiplying constant k, measure a known distance D_1 and take the intercept s_1 on the staff kept at that point, the line of sight being horizontal. Using the equation,

$$D_1 = ks_1 + C \qquad \text{or} \qquad k = \frac{D_1 - C}{s}$$

For average value, staff intercepts, s_2, s_3 etc., can be measured corresponding to distance D_2, D_3 etc., and mean value can be calculated.

Note: ***In case of some external focusing instruments, the eye-piece-diaphragm unit moves during focusing. For such instruments d is constant and does not vary while focusing.***

2nd method:

In this method, both the constants are determined by field observations as under:

1. Measure a line, about 200m long, on fairly level ground and drive pegs at some interval, say 50 meters.
2. Keep the staff on the pegs and observe the corresponding staff intercepts with horizontal sight.
3. Knowing the values of D and s for different points, a number of simultaneous equations can be formed by substituting the values of D and s in equation D = k.s + C. The simultaneous solution of successive pairs will give the values of k and C, and the average of these can be found.

For example, if s_1 is the staff intercept corresponding to distance D_1 and s_2 corresponding to D_2 we have,

$D_1 = k.s_1 + C$ . . . . . (i) and $D_2 = k.\ s_2 + C$ . . . . . (ii)

Subtracting (i) from (ii), we get

$$k = \frac{D_2 - D_1}{s_2 - s_1} \qquad \text{. . . . . (1)}$$

Substituting the values of k in (i), we get

$$C = D_1 - \frac{D_2 - D_1}{s_2 - s_1}\ s_1$$

$$= \frac{D_1 s_2 - D_2 s_1}{s_2 - s_1} \qquad \text{. . . . . (2)}$$

Thus equation (1) and (2) give the values of k and C.

Distance and Elevation formulae for Staff Vertical : Inclined Sight

Let **P** = Instrument station; **Q** = Staff station

M = position of instruments axis; **O** = Optical centre of the objective

A, C, B = Points corresponding to the readings of the three hairs

s = AB = Staff intercept; **i** = Stadia interval

ϴ = Inclination of the line of sight from the horizontal

L = Length MC measured along the line of sight

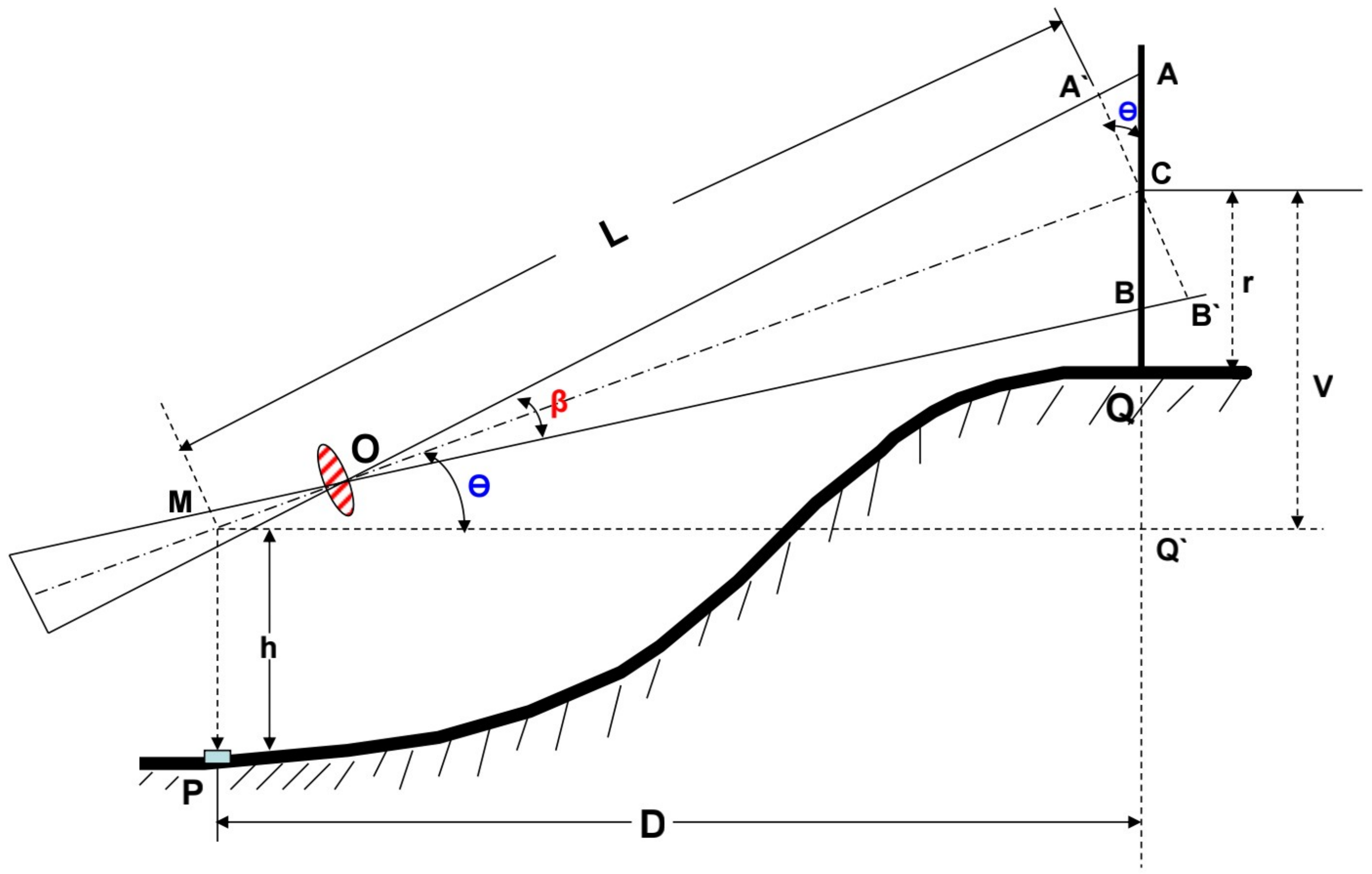
D = **MQ'** = Horizontal distance between the instrument and the staff

V = Vertical intercept at Q, between the line of sight and the horizontal line

h = height of the instrument; **r** = central hair reading

β = angle between the two extreme rays corresponding to stadia hairs.

- Draw a line A’CB’ normal to the line of sight OC.
- Angle AA`C = $90^0$ + β/2, being the exterior angle of the ΔCOA`.
- Similarly, from ΔCOB`, angle OB`C = angle BB`C = 90^0 – β/2.



Since β/2 is very small (its value being equal to 17' 11" for k = 100), angle AA'C and angle BB'C may be approximately taken equal to 90^0.

$$\angle AA'C = \angle BB'C = 90^0$$

From Δ ACA', A'C = AC cos Θ or A'B' = AB cos Θ = s cos Θ ....(a)

Since the line A'B' is perpendicular to the line of sight OC, equation D = k s + C is directly applicable. Hence, we have

$$MC = L = k \cdot A'B' + C = k\, s \cos\Theta + C \qquad \text{.......(b)}$$

The horizontal distance

$$D = L \cos\Theta = (k\, s \cos\Theta + C) \cos\Theta$$

$$D = k\, s \cos^2\Theta + C \cos\Theta \qquad \text{......(1)}$$

Similarly, $V = L \sin\Theta = (k\, s \cos\Theta + C) \sin\Theta = k\, s \cos\Theta \cdot \sin\Theta + C \sin\Theta$

$$V = k\, s \frac{\sin 2\Theta}{2} + C \sin\Theta \qquad \text{......(2)}$$

Thus equations (1) and (2) are the distance and elevation formulae for inclined line of sight.

(a) Elevation of the staff station for angle of elevation

If the line of sight has an angle of elevation ϴ, as shown in the figure, we have

Elevation of staff station = Elevation of instrument station + h + V – r.

(b) Elevation of the staff station for the angle of depression:

Elevation of Q = Elevation of P + h – V - r

Distance and Elevation formulae for Staff Normal : Inclined Sight

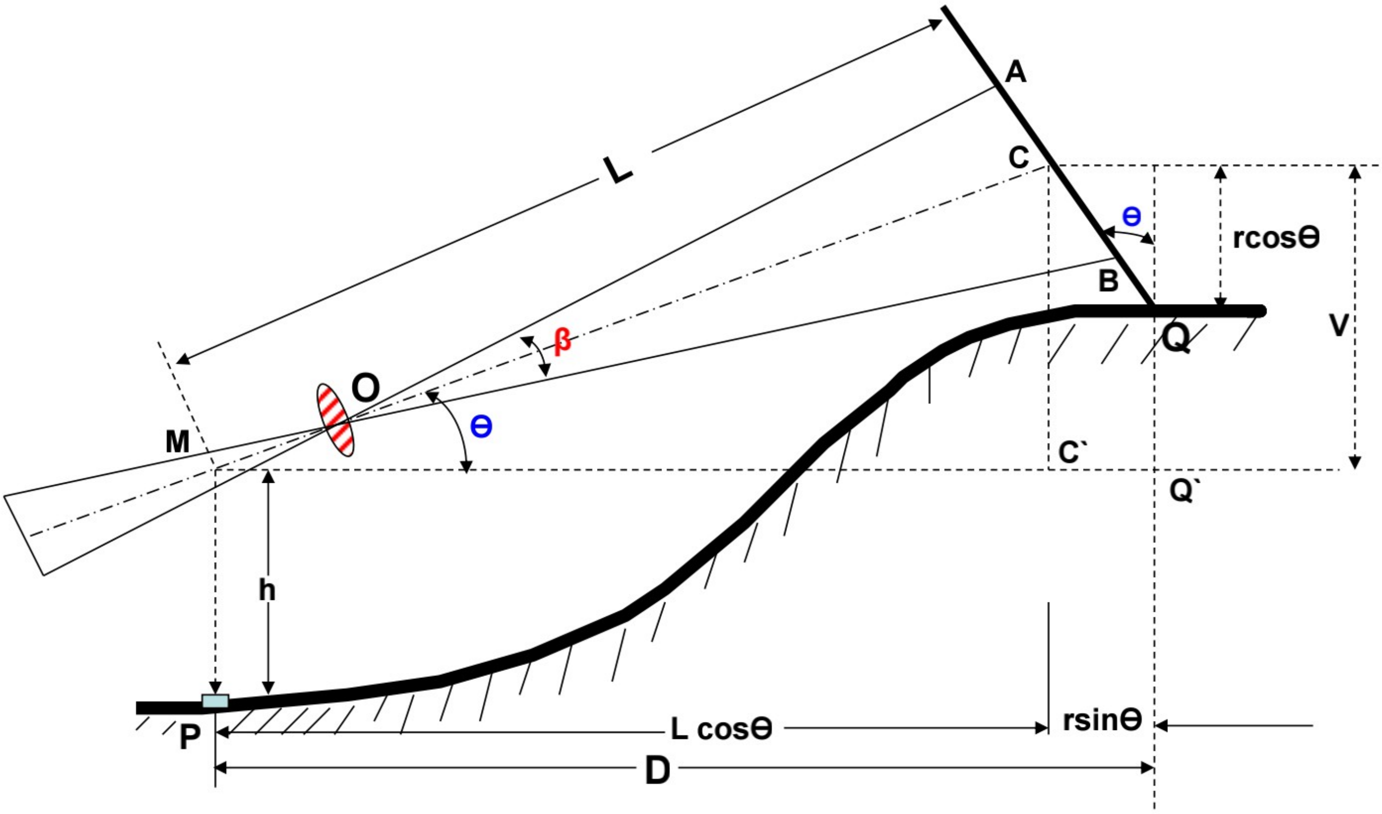


Figure shows the case when the staff is held normal to the line of sight.

Case (a): **Line of Sight at an angle of elevation Θ**

Let *AB* = s = staff intercept;

CQ = r = axial hair reading

With the same notations as in the last case, we have

$$MC = L = K\,s + C$$

The horizontal distance between P and Q is given by

$$D = MC' + C'Q' = L\cos\Theta + r\sin\Theta$$

$$= (k\,s + C)\cos\Theta + r\sin\Theta \qquad \ldots\ldots (3)$$

Similarly, $$V = L\sin\Theta = (k\,s + C)\sin\Theta \qquad \ldots\ldots (4)$$

Case (a): **Line of Sight at an angle of depression Θ**

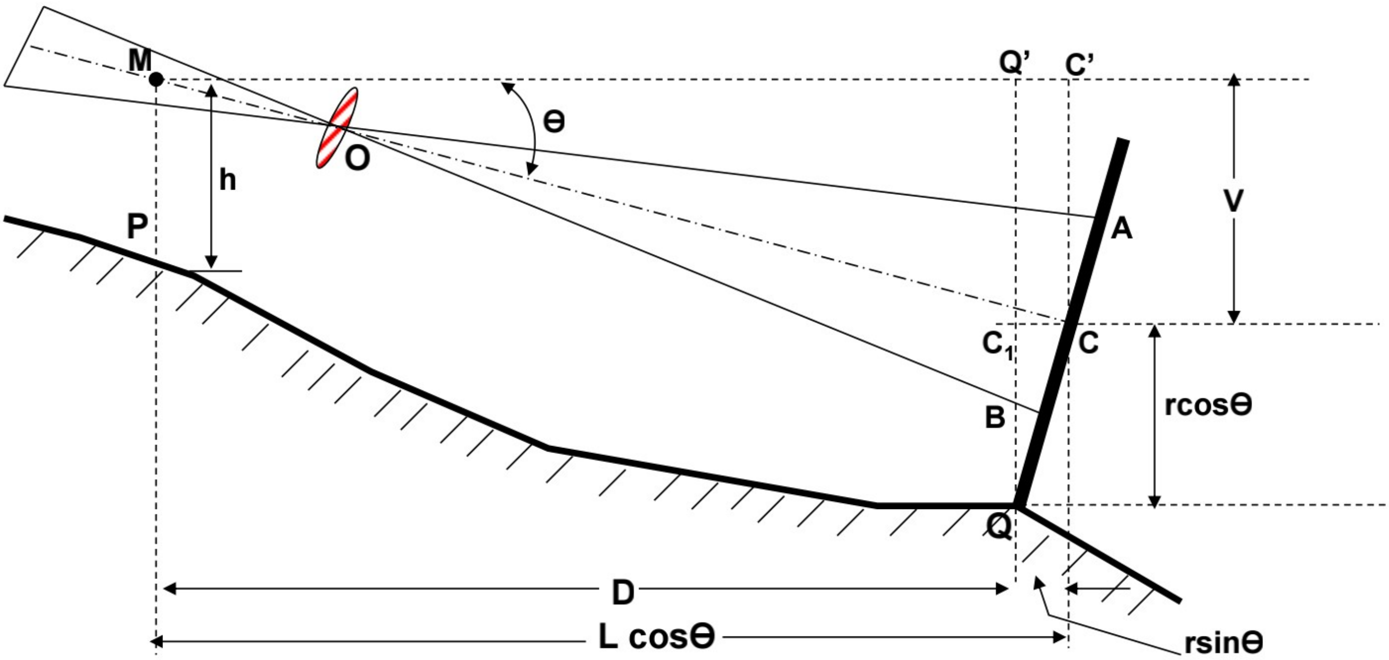


Figure shows the line of sight depressed downwards,

$$MC = L = k\,s + C$$

$$D = MQ' = MC' - Q'C'$$

$$= L\cos\Theta - r\sin\Theta$$

$$D = (k\,s + C)\cos\Theta - r\sin\Theta \quad \text{.....(5)}$$

$$V = L\sin\Theta = (k\,s + C)\sin\Theta \quad \text{.....(6)}$$

Elevation of Q = Elevation of P + h – V – r cosΘ

24.1. INTRODUCTION

Remote sensing is a terminology which refers to any method adopted for gathering information about an object without actually coming in contact with it. In a broader sense, the term 'remote sensing' is used more commonly to denote identification of earth features by detecting their characteristics with the help of electromagnetic radiations either reflected or emitted by the earth surface features. The advent of satellites for weather forecasting, for communications, for studying the earth and for studying the space, is one of the most exciting developments of the modern times with an extensive application of remote sensing for resource management. The United Nations has defined the remote sensing on December 3, 1986 as under:

Remote sensing means seeing the earth's surface by making use of the properties of electromagnetic waves emitted, reflected or diffracted by the sensed objects for the purpose of improving the natural resource management, land use and protection of the environment.

The remote sensing techniques by aeroplanes and satellites in combination with the ground surveys, has revolutionised topographical surveys. The technique of remote sensing has made available to man visible to nacked eye macroscopic, affording a comprehensive mental synoptic visualized view for time, in several bands to electromagnetic spectrum.

Space instruments and remote sensing tools are used to look at the earth with new eyes. Both the types of tools have helped the man to an extended vision of the earth's surface. Remote sensing in simple language means the sensation received from a distance, without any direct contact. It is a technology for sampling the electromagnetic radiations to acquire and interpret geospatial data to extract and develop information about features, objects and classes on the surface of the earth, and oceans and also in atmosphere. Detection and measurement of electromagnetic energy emanating from distant objects made of various materials to identify and categorize these objects by either class or type, is the prime job of the remote sensing.

24.2. FUNDAMENTAL PRINCIPLE OF REMOTE SENSING

The fundamental principle of remote sensing methods, is to measure the varying energy levels of a single entity, the *photon*, a quantum of electromagnetic energy proportional to the frequency of its radiation. The photon is the fundamental unit in electromagnetic (abbreviated as EM) force field.

The phenomenon of interference and polarization require *EM* radiation to behave like a wave while for some interaction such as in the photo electric effect, the radiation behaves like particles. In other words it may be said that *EM* radiation has duel nature-wave and particle. The particulate nature of the *EM* radiation is generally explained in terms of the Quantum Theory. According to this theory, the *EM* radiation propagates in space as discrete packets or quanta of energy propagating with the same speed (e_v) and direction defined by the wave theory. The energy of the photons is related by their frequencies *i.e.*,.

$$e_b = h\upsilon$$

where h is the Plank's constant (6.63×10^{-34} Ws^2).

Hence, the radiometric quantities differ at different wave lengths to enable to diagnose the material. Remote sensing of the earth's surface traditionally uses reflected energy in the visible spectrum (0.4 μ to 0.7 μ) and emitted energy in the thermal infrared energy in infrared and microwave regions together with radiation. Both the reflected energy and emitted energy can be analysed numerically and suitably used to generate images. The gathering to a range of wave lengths is termed as *multispectral remote sensing*. The images obtained from varying intensity signals show variations in grey tones in black and white images. In colour images, they differ in terms of *hue, saturation* and intensity.

24.3. BRIEF HISTORY OF INDIAN REMOTE SENSING (IRS)

India has a glorious tradition in space science since Vedic period. *Brahamanda* Sarah, is a treatise written by Vyasya in space studies. During *Vedic period*, Indians made observations to the sun, the moon, the planets and stars. The Vedic period calender predicted the transit of planets and eclipses accurately. Brahamanda, the famous atronomer of India was born in 476 AD.

Raja Swai Jai Singh (1686-1743) built observatories in five cities *i.e.*, Jaipur, Delhi, Mathura, Ujjain and Varanasi for making astronomical observations. A two-stage sounding rocket was launched in 1963 from a small village Thumba, on the west coast close to the equator in the state of Kerla.

In 1970's, India demonstrated the space applications such as Satellite Instructional Television Experiment (SITE) and Satellite Telecommunication Experiment with the help of the satellites belonging to other

countries. Simultaneously, the satellite Aryabhata Bhaskara, APPLE and Rohini Series were built and also experimental Satellite Launch Vehicles (SLV-3, ASLV) were developed. In 1983, INSAT was successfully developed. The birth of Indian Remote sensing took place in 1988. Polar Satellite Launch Vehicle (PSLV) capable to launch 1250 kg pay load into 820 km polar orbit, was also developed.

Even though, it has been an endevour for man to map the configuration of the earth from tree tops, mountains and even from high rising balloons, the earth was viewed in totality only from satellites. In the last three decades, space borne remote sensing capabilities have grown to such an extent that space-based observations have become the prime source of information on earth's resources and its environment.

Remote sensing enables synoptic observations of large areas of the earth surface on repetitive basis. With a very high speed the satellite provides a global coverage with the same sensor or a set of sensors. In view of several beneficial applications, the Indian space efforts put considerable emphasis on realising an operational remote sensing programme.

In the area of remote sensing, India has the largest number of remote sensing satellites in operation. The most important ones are : IRS-IC and IRS-ID, the best civilian remote sensing satellites. IRS-P4 (OCEANSAT-1) launched in May 1999 is used to monitor ocean resources and for understanding the atmospheric conditions over the oceans. Satellites for cartographic applications are also launched..

Uses of IRS Satellite data. The data obtained from IRS satellite is used for the following purpose:

1. To estimate the acreage and yield of important crops.
2. To survey the dense forest coverage.
3. To forecast the drought conditions.
4. To map the flood area and to demarcate flood-risk zone.
5. To map the areas for land use and land cover for agro-climatic planning.
6. To map the waste land and to classify them.
7. To develop irrigation command area.
8. To survey the snow cover areas and the snow-melt run-off estimation of the Himalayan rivers.

Data from IRS is also usefully employed in other spheres including the sustainable development at micro level.

24.4. IMAGERIES VERSUS AERIAL PHOTOGRAPHS

1. **Aerial photographs.** The photographs taken from a camera station occupied by an aircraft in the air with axis of camera vertically

down, are called *aerial photographs*. Aerial photographs are described in chapter 22, photogrammetic survey in the textbook.

2. **Satellite imageries.** The photographs of the earth taken from space by satellite are called *imageries*. Because of very high flying heights of the satellite imageries are on very small scale. Individual features of the earth are not easily discerned. For reading or viewing the satellite imageries, one has to study various types of tints represented by different features on the earth.

Formation of satellite images. The satellite images are collected by the satellite sensors on board a satellite and the same is relayed to earth as a series of electronic signals which on processing by a computer, produce an image of the earth's surface.

24.5. SIGNATURES

The technique of remote sensing is used to recognize an object or a feature from its surrounding on the surface of the earth. To achieve this, we should be familiar with the characteristics which distinguish them from their surroundings. The characteristic features which help to identify or recognise an object or a feature, is called *signature*. If an object or a feature is identified through the difference in the reflectance/emittance characteristics, with respect to wave length, then it is called *spectral signature*.

Characteristics of ground features. There are many other characteristics which are useful for identification of objects. The important ones are mentioned below:

1. Differences in scattering cross section with respect to polarisation in the microwave region.
2. Measurement of the temperature using thermal *IR* region. The thermal inertia provides signatures to identify certain objects.
3. Temporal variation like the growth profile difference of the plants also acts as signatures to differentiate the crops in agriculture remote sensing.

Parameters of signatures are however not completely deterministic. They are statistical in nature. They have some mean value and some dispersion around.

For defining a sensor system, its time and frequency of observation and also to interpret it, one should understand the physical basis of signatures. We shall only deal with the signatures of the earth surface targets.

24.6. CLASSIFICATION OF THE FEATURES ON THE EARTH SURFACE

The features on the earth surface are broadly classified in the following categories :

1. Vegetation

2. Soil, rock, minerals
3. Water bodies
4. Snow
5. Man-made features.

Keeping in view, the interaction mechanism in the various regions of electromagnetic spectrum, the above five main features of the earth surface are dealt in three broad regions:

(*i*) Reflective optical infrared region (0.4 μm – 3 μm)

(*ii*) Thermal infrared region (8.0 μm – 14 μm)

(*iii*) Microwave region (1 cm – 30 cm)

1. Signatures in the Reflective O/R region. As the source of energy in this region is the sun, we first discuss the physical processes that give rise to signatures for various features on the earth surface.

(*i*) **Vegetation.** Vegetations as agricultural crops, or flora such as forest cover, bushes, shrubs, etc., are of great importance for the existence of human and animal life. Vegetation also plays an important role in regulating the carbondioxide (CO_2) through the process of photosynthesis and also in balancing solar radiation in the atmosphere. Solar radiation adversely affects the weather and overall climate of the region. Keeping in view these important factors, monitoring of vegetation has become most important application of the remote sensing technology.

From the space, through the eye of a remote sensor, vegetation is seen as the integrated effect of leaves, stems, branches, flowers, buds and appendages of plants and trees along with the back ground soil. The scattering and reflection due to vegetative cover largely change the direction and spectral composition of the incident radiation in a complex manner. The leaves of a vegetative canopy contribute to the major effect to the reflected energy as leaves of vegetation, cover the entire body of the tree or plant.

Due to large range of variations in the shape, size and surface including internal characteristics of leaves, there occurs large differences in spectral characteristics of the plants.

Plants absorb very efficiently the required energy throughout the ultravoilet and visible regions of the spectrum for the process of photosynthesis. Plants have very little absorption in the near *IR* region of spectrum. They absorb good amount of energy at wavelengths greater than about 2.5 μ m. It may be noted that solar radiation obtained is not much at spectrum having longer wavelengths. However, radiation obtained from the surroundings gets reflected by plants as they are good radiators and absorbers. Plant cells themselves help by radiation to control temperature.

2. Spectral reflectance mechanism. In spectral reflectance mechanism of a typical leaf of a tree is briefly described below :

(*a*) **Visible spectral region** (0.4 μm – 0.7 μm). **Absorption by leaf pigments dominates the reflectance characteristics in the region** (0.4 μm – 0.7 μm) of the spectrum as explained under :

The blue (–0.45 μm) region and red (–0.67μm) in the visible spectrum absorb the incident radiation corresponding to the absorption bands of chlorophyll. Due to absorption by other pigments (other than chlorophyll) in the reflectance spectra, a green leaf shows a characteristics peak at about 0.55 μm. Leaves with low chlorophyll content have entirely different reflectance characteristics.

(*b*) **Near-infrared region (0.7 μm – 1.3 μ m).** The internal structure of various leaves show marked differences in the reflectance in the (0.7μm - 1.3 μ m) region. In this region about 40 to 50% reflectance takes place with less than 5% of the incident energy absorption. The reflection/transmission in this region mainly takes place in the mesophyll structure of the leaf. The internal structure of leaves of different types of plants and trees differs considerably. Accordingly, their reflectances are also different in the near *IR* region than in visible region.

3. Short wave infrared region (1.3 μm – 2.7 μm). There are three strong water absorption bands at (1.4, 1.9 and 2.7) μm in this region. Water content of the leaf greatly influences the refectance and transmission on characteristics of solar energy. Absorption of solar energy is proportional to the equivalent water thickness which depends on the moisture content of the leaf and its thickness. As the moisture content of a leaf decreases, the reflection activity increases in this region.

Reflectance from the Vegetative Cover. The reflectance characteristics of a leaf or a vegetation canopy as seen by a remote sensor is complex. This complexity is due to the interaction of solar radiation with different parts of the plant, soil back ground and shadow. The vegetation incident radiation duly affected by these variables of the tree canopy when measured by the sensor, is called a *canopy reflectance*. The effect of multiple leaves of a canopy is maximum in the near-*IR* region, the effect is practically negligible in the visible region and marginal in the short wave *IR* region. It may be summarised that reflectance depends primarily on the following factors :

(*i*) Pigment of the leaf
(*ii*) Internal structure of leave cell
(*iii*) Equivalent water content of the leaf.

Effect of the Background on Vegetative Reflectance Spectra. In vegetative cover reflectance sensed by remote sensing sensor, is a mixture of reflectance from the vegetation soil, underneath the plants and their shadow. In low vegetation cover, the background reflectance affects the canopy reflectance. While applying the remote sensing technique to discriminate various type of vegetations, the underlying ground effects need be taken into account especially in agriculture. In crops planted in rows, the reflection of solar radiation is mainly due to the bare soil. As the crop grows with time, it covers the bare soil and the net reflection of the solar radiation is mainly from vegetative cover. Moreover, the relative contribution to the received radiation from plants, soil and plant shadows in the background are dependent on the direction of the sunrays and also due to the view point of the sensor. The most important parameters to be considered for determining the reflectance of a vegetation canopy are as described below :

(*i*) Transmittance of leaves.
(*ii*) Characteristics of components of vegetative canopy.
(*iii*) Number and arrangements of leaves.
(*iv*) Characteristics of the background.
(*v*) Solar zenith angle.
(*vi*) Azimuth angle.
(*vii*) Look angle.

The special reflectance data of vegetation are related to the plant parameters. To correlate with the plant variables, a normalised difference vegetation index is used.

$$NDVI = \frac{IR - RED}{IR + RED}$$

where IR = reflectance in infrared region
RED = reflectance in red region

The value of NDVI may vary from – 1 to +1, depending upon the relative value of RED and *IR* reflectance.

24.7. ELECTROMAGNETIC RADIATION

Electromagnetic waves are produced due to the motion of an electric charge. For understanding the electromagnetic theory, we have to study the relationship between electricity and magentism. It is a well known fact that the light (the rays forming the visible spectrum) which exites the sensation of vision, consists of a transverse wave motion in vacuum. The violet rays of the spectrum possesses the shortest wave length and highest frequency whereas the rays of red colour have have longest wavelength and lowest frequency. Oscillation of the charged particles sets up changing electric fields which induce changing magnetic fields in its surrounding medium. The changing magnetic fields further set up more changing electric fields and thus a chain reaction continues endlessly. The electromagnetic wave is self propagating. The net result is that the wave energy consisting of both the magnetic and electric fields travels, across the space. When the magnetic and electric waves

23.8. TOTAL STATIONS

The era of purely mechanical and optical instruments is over and that has been replaced by an era having digital instruments in all spheres of life including in surveying instruments. Electronic theodolites and total stations are replaced by conventional theodolites. Total stations have dramatically enhanced work efficiency by reducing operation the and eliminating observer fatigue when sighting the survey signals or targets.

Z_1 –8060 **Auto pointing total stations.** While making observations with this total stations, roughly pointing at the prism is made and the measurement key is pressed. Looking through the telescope for accurate sighting if the target is not required. Auto pointing function works with a single APO1 prism from 2 m to 800 m with an accuracy of 2.5 mm upto 100 m. The handling of total stations is so easy that beginner and an experienced surveyor are able to make measurements with the same accuracy and speed. Moreover, in cloudy and hazy climatic atmosphere, observations with a total station are made with the same speed as clear sunny days. The guide line leads the prism along the telescope sighting for setting out. Highly practical and functional softwares are available for enhancing the survey field work. Internal memory of total stations has sufficient storage-roughly 20,000 points of data.

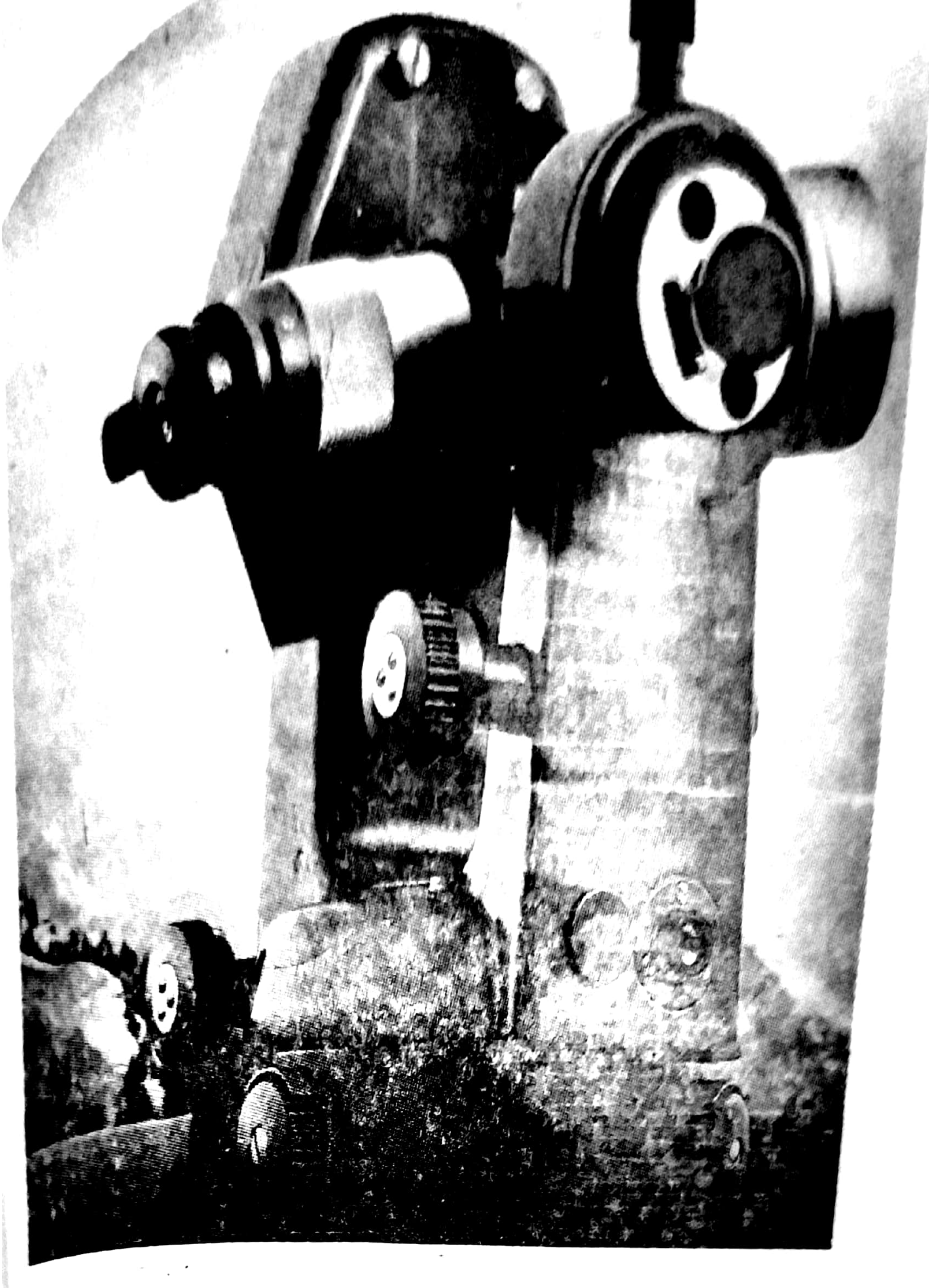


Fig. 23.8. The Kern DKM2A one second theodolite.

By courtesy, Zeal International, 1, Netaji Subhash Marg, Daryaganj, New Delhi-110002 (India)

For quick centering the total station over the ground station, a laser plummet is provided. Focus and laser plummet intensity can be adjusted as pr the requirements. The laser spot falling on the ground surface is clear enough to be seen under the sunlight. Separate provision to turn off the laser power is provided separately from the system power.

Total station observations are made in the same way as by other conventional theodolite. In total stations observations computation of data is done by the instrument itself. The net result is displaced on the key pad.

key p... ...ates of station of observation (Fig. 23.10) ...angle P_1CP_2. Press the

Z_1 –8061 **Non-Prism Total Stations.** In this type of total stations, no prism is provided. This total station measures the distance with or without reflectors. This type of total station is an ideal instrument for making measurements to inaccessible location or in high traffic regions, structural measurements of buildings, surveying management for strip mining, etc. It accurately measures distance to 85 metres without a reflector. Reflection sheet targets extend the measuring distance to about 500 metres (Fig. 13.11).

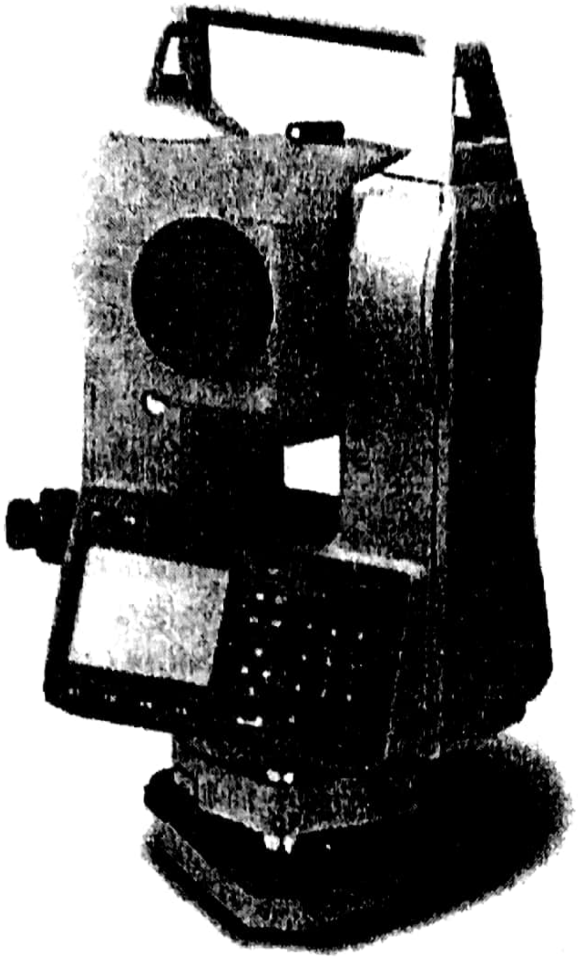


Fig. 23.11. Z_1 8061. Non prism total station.

By Courtsey Zeal International, 1, Netaji Subhash Marg, Daryaganj, New Delhi-110002 (India)

This instrument provides precise measurement even to objects that are at inclination to the line of right. Highly practical and functional softwares are also available to enhance the survey work. Nickel-metal hydride battery having a service of 5.5 hours is provided.

The operation of the total station is similar to that of Z_1 8060 total station.

24.26 GLOBAL POSITIONING SYSTEM (GPS)

The global positioning system (GPS) consists of a network of 24 satellites in roughly 12 hour-orbits, each carrying atomic clocks on board. The orbital radius of satellites is roughly twice the earth diameter. The orbits are nearly circular, with eccentricity of less than 1%. Orbital inclination its the earth's equator is roughly 55 degrees. The satellites have orbital speeds of about 3.9 km/s in a frame centered on the earth. Normally, satellites occupy one of six equally spaced orbital planes. Four satellites occupy each plane spread at roughly 90 degree intervals around the earth in that plane. The precise orbital periods of the satellites are close to 11 hours and 58 minutes so that ground tracks of the satellites repeat day after day.

The satellite atomic clocks are correct to about 1 nano second (ns). As the speed of light is about one foot (0.3048 m) per nano second, the system is capable of desired accuracy in locating any detail object on earth. The satellite clocks are fully synchronized with the ground atomic clocks. Knowing the instant a signal is sent from a satellite and the time delay for that signal in reaching a ground receiver, the accurate distance between the satellite and the ground receiver can be determined.

By using four satellites to triangulate with these determined distances, the position of the unknown location can be determined with good precision. It may be noted that GPS operates by sending atomic clock signals from the orbital altitudes to the ground receiver. The total distance is covered in 0.08 seconds whereas it is very long when it is measured in nano second *i.e.*, 0.08 second is read as 80,000,000 ns by an atomic clock.

Location of points on a plane surface is determined by using the Cartesian system of coordinates. This system of coordinates was first introduced by the great philosopher Desecrates. In this system *OX* and *OY* are two orthogonal fixed straight lines in the plane of the paper. The line *OX* is called the x-axis, the line *OY* is called the *y*-axis whilst two axes together are called the axes of coordinates. The point of intersection of the axes is called, the origin (Fig. 24.25).

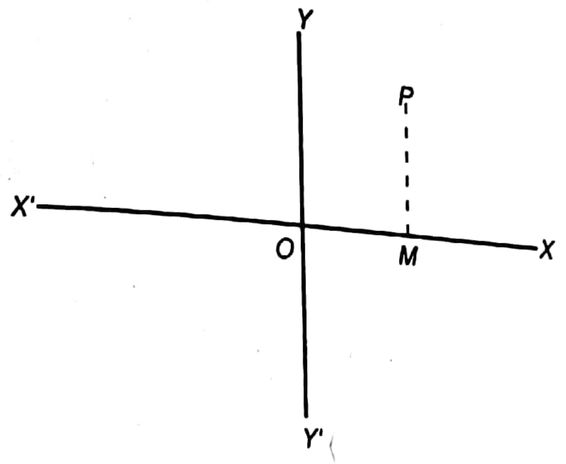


Fig. 24.25. Cartesian coordinate system.

Consider a point *P* on the plane *XY*. The distance *OM* along the *x*-axis is called the abscissa and the distance *MP* measured parallel to *y*-axis is called the ordinate of *P*. Both the abscissa and ordinate of the point *P* are called its coordinates.

Spherical Coordinate System. The location of a point on the spherical surface of the earth is determined by using the spherical coordinates, *i.e.*, latitude and longitude.

(*i*) **Latitude.** The angular distance of the point north or south of the equator measured in degrees along the longitude of the point, is called the **latitude.** The values of latitude vary from 0° to 90° North and South of the equator, Latitude in the northern hemisphere are treated positive.

(*i*) **Longitude.** The angular distance of the point east or west of the Prime Meridian (*i.e., Greenwhich meridian*) measured in degrees, is called the **longitude**. The values of longitude vary from 0° 180° E or W of the Prime meridian.

Spherical coordinates are determined by making geodetic observations to the Celestial bodies and are commonly used for triangulation.

24.27 LOCATION OF A POINT BY GLOBAL POSITIONING SYSTEM

Global Positioning System (GPS) is a satellite navigation system based on the principle of trilateration. The trilateration is a method used to find the location of a point if its distances from at least three other stations of known coordinates, are predetermined.

Location of a point with the help of three stations, in two dimensional space, may be obtained as explained under :

Let *A*, *B* and *C* be any three stations whose coordinates are predetermined. Let the position of the station to be located be marked as *P*.

The distance of stations *A*, *B* and *C* from point *P* be x_1, x_2 and x_3 respectively. Proceed as explained below stepwise :

(*i*) Plot the location of the given points (stations) to a suitable scale.

(*ii*) Taking *A* as the centre and x_1 as radius, draw a circle.

(*iii*) Taking *B* as the centre, and x_2 as radius draw another circle to intersect the first circle at two points say *a* and *b*.

(*iv*) Taking *C* as the centre and x_3 as radius, draw a circle which passes through either *a* or *b*.

The point through which three circles pass, is the required position of the station *P*.

Satellite based navigation method is an extension of this principle of trilateration. (Fig. 24.26)

For locating the position of the observear on the sphere, the following steps are involved :

(*i*) Recognise the locations of three satellites in the space forming a well conditioned spherical triangle.

(*ii*) Name them as S_1, S_2 and S_3.

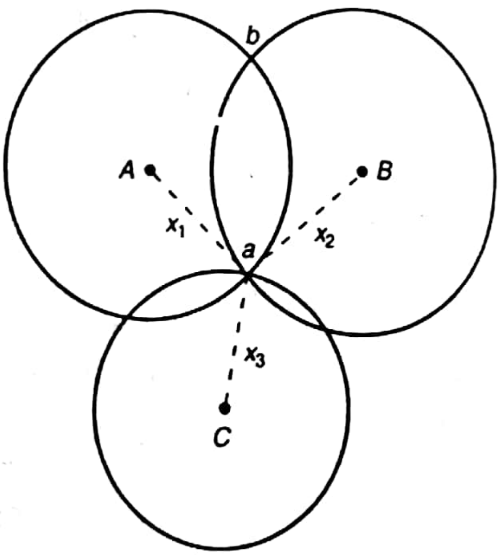


Fig. 24.26. Trilateration method of interpolation.

(*iii*) Draw a sphere with S_1 as centre and its distance from the ground position *P*, as radius. Similarly, draw two spheres with S_2 and S_3 as centres and their respective distances from *P* as radii.

(*iv*) The position on the earth's surface where three spheres intersect is the required position *P*, the observer's location.

Fundamental Components of GPS. The fundamental components of Geographical positioning System (GPS) are described below:

1. Space. This segment of GPS consists of the orbiting satellites making up the constellations composed of 24 satellites and the design of the orbit, and the spacing of the satellites orbital plane.

Every user is able to access at least six or more satellites orbiting in the space.

2. Control. This segment consists of ground station of observation from where user oversees the building, launching, orbital positioning and monitoring of the system.

3. The User. (GPS receiver). The space segment consists of 24 satellites which revolve about the earth at an altitude of about 20,000 km having a period of about 12 hours with a 55° inclination and placed in six differential orbital planes, having four satellites in each plane. Every satellite transmits two *L* band signals (L_1 with 1575.42 MHz and L_2 with 1227.60 MHz). These signals are duly modulated by Pseudo random binary codes (*PN*). GPS receiver reads the code of each satellite even though all the satellites transmit in the same frequency with the help of *PN* code, it is possible to determine the time taken by the signal to reach the receiver. By knowing the accurate time taken by the signal, the distance between the signal and receiver in each case, can be determined accurately.

24.28. ADVANTAGES OF GPS

The basic advantages of GPS are as explained under :

1. **Identification of spherical coordinates.** GPS helps to identify or define geographical coordinates on the satellite image and also to reduce distortions and positional accuracy of the images. By identifying three or four well defined points, the locations of the satellite image on the ground can be obtained by the method of resection. The GPS receivers collect accurate geographical coordinates of these locations. The remaining images are located both on the satellite image and on the ground. The remaining image points are filled in between the locations of the control points by normal method of air surveying to obtain real-world coordinates.

2. **Truthing of satellite images.** In case on a satellite image, there appears a region of unusual or unrecognised reflectivity or back scatter, the coordinates of such region may be reloaded in a GPS receiver.

3. **Cost effective tool.** GPS is a cost effective tool for updating GIS or computer aided design (CAD) systems. The users of GPS equipment