SURVEYING AND GEOMATICS II

Course Code: CE401

Module I: Triangulation and Trilateration- Principle of Triangulation& trilateration, Types of Triangulation, Signals, selection of station &base line, base line measurement, choices instruments and accessories, extension of base line, corrections, satellite station, and reduction to centre, inter visibility, **[9hrs]**

Module II: Trigonometric levelling: Curvature & Refraction Correction, axis signal corrections. Method of Single &reciprocal Observations &their relative advantage, **(4 hrs)**

Module III: Theory of errors and adjustment of figures: Types of errors, theory of propagation of errors, law of weights, weighted observation, method to calculate most probable values, least square, normal equation, method to correlate, adjustment of plane and geodetic figures. **[7hrs]**

Module IV : Modern Field Survey Systems: Principle of EDM, types of EDM instruments, Distomat, Total station- parts, accessories, advantages and application, Measurement of distance using EDM, Types of waves, modulation of frequency, resolution of ambiguity, Errors in Total station survey, Introduction to GPS- segment, measurement, errors and biases. **[8hrs]**

Module V: Photogrammetry Surveying: Introduction, basic concepts, perspective geometry of aerial photograph, relief and tilt displacements, terrestrial photogrammetry, flight planning, stereoscopy, ground control extension for photographic mapping- aerial triangulation, No. of Photographs, mosaic. **[6hrs]**

Module VI: Remote Sensing: Introduction and Definition of remote sensing terms, Remote sensing system, electromagnetic radiation and spectrum, atmospheric window, different types of platforms, sensors and their characteristics, orbital parameters of a satellite, multi concept in remote sensing. {Only Introductions of all above} **[6hrs]**

Text Books:

(1) Elements of photogrammetry by P.R. Wolf.
(2) Introduction to remote sensing by J.B. Campbell
(3) Surveying – Vol –II – By B.C. Punmia, A K Jain and A K Jain, Laxmi Publishers
(4) Higher Surveying – Vol –II By B.C. Punmia, A K Jain and A K Jain, Laxmi Publishers

Books for Reference:

(1) Surveying – Vol – I – By S.K.Duggal, Tata McGraw Hill Book Co.
(2) Surveying – Vol – II – By S.K. Duggal, Tata McGraw Hill Book Co.

Course objectives:

1. To get introduced to different geodetic methods of survey such as triangulation, trigonometric levelling
2. To learn about errors in measurements and their adjustments in a traverse
3. To get introduced to modern advanced surveying techniques involved such as remote sensing, Total station, GPS, Photogrammetry etc.

Course outcomes:

1. On the successful completion of this course the students will get a diverse knowledge of surveying practices applied for real life problems.
2. The students will learn to work with various surveying equipment's, like, Theodolite, Total station, etc. in order to apply the theoretical knowledge to carry out practical field work.
3. The knowledge of limits of accuracy will be obtained by making measurements with various surveying equipment employed in practice

Web Materials:

1. http://nptel.iitm.ac.in/courses/Webcourse-contents/IITROORKEE/SURVEYING/home.htm
2. http://nptel.iitm.ac.in
3. http://www.naicc.org

triangulation

Monday, June 28, 2021 6:29 PM

Triangulation

→ It is a system that consists of a number of interconnected triangles in which the length of only one line, called base line and angles of the triangle are measured very precisely.

→ Knowing the length of one side and the three angles, the length of other two sides of each triangle can be computed.

→ The apexs of triangles are known as the triangulation stations and the whole the whole figure is called trianglution system or triangulation system.

→ The objective of Triangulation (Geodetic) is to provide the most accurate system of horizontal control points on which cadastral, topographical, Hydrographical, Engineering and other surveys may be reffered.

CLASSIFICATION OF TRIANGULATION FIGURES

→ the basis of the classification of trianglation figures in the accurecy with which length and azimuth of a line of the triangulation are determined.

① First Order or Primary Triangulation:

→ It is of the highest order of trianglation to furnish the most precise control points to which secondary triangulation may be connected.

→ It covers the vast area (usually whole country)

⇒ Every precaution is taken in making linear and angular measurements

→ Some general specifications –

- Avg. triangle closure : less than 1″
- Max. " " : < 3″
- length of the base line : 5 to 15 km.
- length of the sides of triangle : 30 to 150 km
- Probable error of base : 1 in 1,000,000

(2) Second Order or Secondary Triangulation:-

→ It consists of number of points fixed within the framework of primary triangulation.

→ stations are fixed at close intervals so that the size of the triangles formed are smaller than the primary triangulation.

→ General specifications –

- Avg. triangle closure → 3"
- Max. " " → 8"
- Length of the base line → 1.5 to 5 Km
- " " sides of triangle → 8 to 65 Km
- Probable error of base → 1 in 500,000

(3) Third - Order or Tertiary Triangulation:-

→ It consists of a number of points fixed within the framework of secondary triangulation

→ It forms the immediate control for detailed engineering and other survey.

→ The sizes of the triangles are small and instrument with moderate precision may be used.

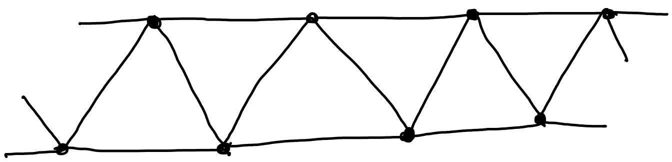
→ Some general specifications -

- Avg. triangle Closure → 6"
- Max. " " → 12"
- Length of the base line → 0.5 to 3 km
- Length of sides of triangle → 1.5 to 10 km
- Probable error of base → 1 in 250,000

TRIANGULATION FIGURES or TRIANGULATION SYSTEMS

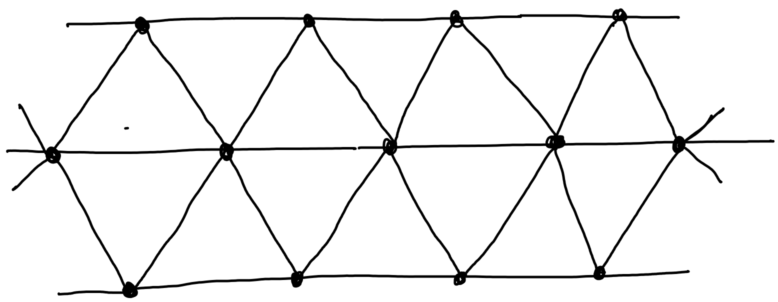
- A triangulation figure is a group or system of triangles such that any figure has one side and only one, common to each of the preceding and following figures.
- The common Figures or Systems are:-

(i) Single Chain of triangles:-



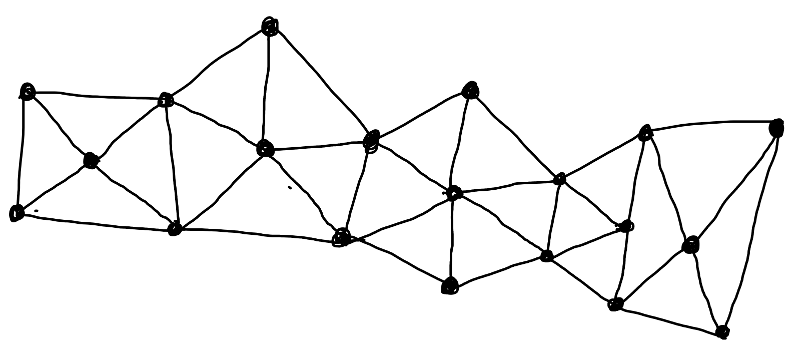
- Used where a narrow strip of terrain is to be covered.
- This type of system is rapid and economical.
- It is not so accurate for primary work since the number of conditions to be fulfilled in the figure adjustment is relatively small.
- Not possible to carry the solution of triangles through the figures by two independent routes.

(ii) Double chain of triangles:-



- This system of figure is similar to single chain of triangle, the only difference is that here two chain of triangles are used.
- It is used to cover greater area.

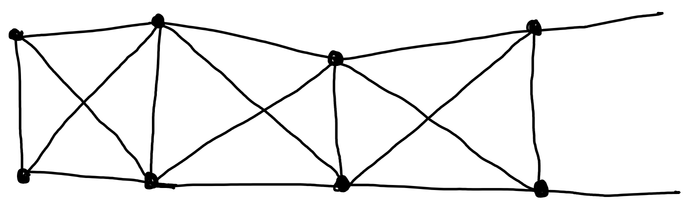
(iii) Centred Figures:-



- Centred figures are used to cover large area.
- It gives satisfactory results in flat country.

- The centred figure may be quadrilaterals, pentagons, or hexagons with central stations.
- The system provides the desired checks on the computations.
- Progress of work is slow due to more setting of the instrument.

(iv) Quadrilaterals :-



- The Quadrilateral with four corner stations & observed diagonal forms the best figure.
- They are best suited for hilly country.
- most accurate system as computed lengths of the sides can be carried through different combinations of sides and angles.

Criteria for selection of the figure :-

(1) fig. should be such that the computation can be done through two independent routes.

(2) The fig. should be such that at least one, and preferably both routes should be well-conditioned.

(3) All the lines in a figure should be of comparable length. Very long line should be avoided.

(4) The fig. should be such that least work may secure max. progress.

(5) Complex fig. should not involve more than about 12 conditions.

Framework for a large country :-

Grid Iron system :-

- Primary triangulation is laid in two series of chains of triangles, which are usually placed roughly north and south, and east & west respectively.

- The enclosed area between the parallel and perpendicular series is filled by secondary and tertiary triangulation figures. This system is known as grid iron system.
- France, Spain, Austria, and India have adopted Grid Iron System of triangulation

Central System:-

- In this system of triangulation the whole area of survey is covered by a network of primary triangulation extending outward in all direction from the initial base line.
- United Kingdom (U.K.) has been adoped central system of triangulation.

Well-Conditioned Triangle:

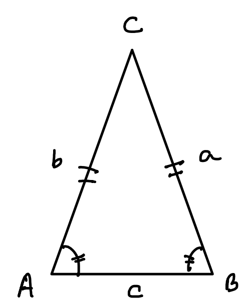
→ there are various types of triangulation figures but the accuracy attained in each figure depend upon—

(i) the magnitude of the angle in each individual triangle.

(ii) the arrangement of triangles.

→ The shape of the triangle should be such that any error in the measurement of angle shall have a minimum effect upon the lengths of the calculated sides. Such triangle is than called well-conditioned triangle.

* In triangulation, one side is known (it is calculated from adjacent triangle) In order that the other two sides calculated is equally accurate, they should be equal in length. This can be attained by making the triangle isosceles.



→ Let AB be the known side and BC and CA be the side of equal length to be computed.

From the fig, $\angle A = \angle B$

Applying sine rule:- $\frac{a}{\sin A} = \frac{c}{\sin C} \Rightarrow \boxed{a = c\,\frac{\sin A}{\sin C}}$

Similarly, $\frac{b}{\sin B} = \frac{c}{\sin C} \Rightarrow \boxed{b = c\,\frac{\sin B}{\sin C}}$

Let, δA and δB be the probable error in the measurement of angle A & angle B respectively.

δa and δb are the probable error in the calculation of side 'a' and 'b' respectively.

$$\therefore \delta_a^2 = \left(\frac{\partial a}{\partial A}\right)^2 \delta_A^2 + \left(\frac{\partial a}{\partial C}\right)^2 (\delta C^2) \qquad \text{Let } \delta A = \delta C = e$$

$$\delta a^2 = \left[\frac{\partial}{\partial A}\left(c\,\frac{\sin A}{\sin C}\right)\right]^2 e^2 + \left[\frac{\partial}{\partial C}\left(c\,\frac{\sin A}{\sin C}\right)\right]^2 e^2$$

$$\delta_a^2 = \left(c\,\frac{\cos A}{\sin C}\right)^2 e^2 + \left(-c\,\frac{\sin A\cos C}{\sin^2 C}\right)^2 e^2$$

$$\delta a^2 = e^2 c^2 \left[\frac{\cos^2 A}{\sin^2 C} + \frac{\sin^2 A\cos^2 C}{\sin^4 C}\right]$$

$$\delta a^2 = e^2 c^2 \left[\frac{\cos^2 A\sin^2 C + \sin^2 A\cos^2 C}{\sin^4 C}\right]$$

$$\delta a = \pm \frac{ce}{\sin^2 C}\sqrt{\cos^2 A\sin^2 C + \sin^2 A\cos^2 C}$$

In order to get δa to be minimum

$\cos^2 A\sin^2 C + \sin^2 A\cos^2 C$ should be minimum

$\cos^2 A\sin^2(180-2A) + \sin^2 A\cos^2(180-2A)$ should be min.

$\Rightarrow \cos^2 A\sin^2 2A + \sin^2 A\cos^2 2A = y$ (let)

In order to get minimum value of y

make $\frac{dy}{dA} = 0$, From which $\boxed{A = 56°15' \text{ (approx)}}$

Hence, the best shape of a triangle is isosceles with base angles equals to <u>56°14'</u>

Note: However, for practical considerations, an equilateral triangle is the most suitable.

→ In general, however, triangles having an angle smaller than 30° and greater than 120° should be avoided.

ROUTINE OF TRIANGULATION SURVEY

- The routine of triangulation survey generally consists of following operations –
  (1) Reconnaissance
  (2) Erection of Signals and towers
  (3) Measurement of Base line
  (4) Measurement of Horizontal angles
  (5) Astronomical observation at laplace stations.
  and (6) Computations.

① RECONNAISSANCE :-

- It is very important part of any kind of survey.
- As economy and accuracy of the whole triangulation system depends upon efficient reconnaissance.
- Reconnaissance includes the following operations –
  (i) Examination of the country to be surveyed
  (ii) selection of suitable site for base lines.
  (iii) selection of suitable points for triangulation stations.
  (iv) Determination of intervisibility and height of stations.
  (v) Collection of miscellaneous information regarding communication of water, food, labour and guide etc
- It is a sort of rapid survey, the following instruments are generally used for the survey:-
  (1) A small theodolite and sextant for measurement of angles.
  (2) Prismatic compass for measurement of bearings.
  (3) Aneroid barometer for ascertaining elevations.
  (4) Steel tape
  (5) Good telescope and powerful field glass
  (6) Heliotropes for testing intervisibility
  (7) Drawing instruments and materials
  (8) Guyed ladders, ropes, creepers etc for climbing trees

Note:- The relative strength and cost of various triangulations or schemes are studied and final scheme is then selected.

Imp. # Selection criteria of a triangulation stations -

→ triangulation stations should be intervisible. For this purpose, they should be placed upon the most elevated ground (such as top of hills etc), so that long sights through undisturbed atmosphere may be secured.

→ They should form well-shaped triangles. As far as possible, the triangles should be isosceles with base angles about 56° or equilateral. In general, however, no angle should be smaller than 30° or greater than 120°

→ The stations should be easily accesible, and should be such that supplies of food and water are easily available, and camping ground or nearest suitable accomodation is available.

→ They should be so selected that the length of sight is neither too small nor too large.

→ Commanding situation so as to serve as the control of the subsidiary triangulation and future extension.

→ Cost or Economy :- In heavily wooden countary, the stations should be so located that the cost of clearing and cutting, and of building tower is minimum.

→ The stations should be situated so that lines of sight do not pass over towns, factories, furnace etc nor graze any obstruction; so that the effect of atmospheric refraction is avoided.

Intervisibility and Height of Stations

- Generally, it is necessary to raise both the instrument as well as the signal to overcome the curvature of the earth and to clear all the intervening obstructions:-
- The height of the instrument as well as the signal depends upon the following factors -

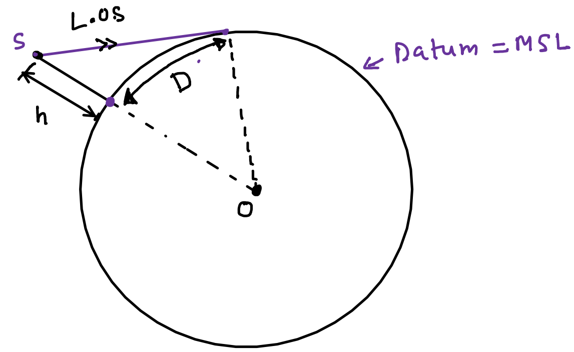
→ (1) Distance between the stations

(2) The relative elevation of stations.

(3) The profile of intervening ground.

→ **The distance between the stations –**

If there is no obstruction due to intervening ground, the distance of visible horizon (D) from a station of known elevation (h) above datum is given by :-



$$\boxed{h = \frac{D^2}{2R}(1-2m)}$$

where,
- h = Height of st^n above datum
- D = Distance of visible Horizon
- R = mean radius of the Earth
- m = mean coefficient of refraction
  - = 0.07 → for sight over land
  - = 0.08 → " " sea

Putting the value of R and 'm' in the above eq^n –

$$\boxed{h = 0.06728\, D^2}$$

where h in meters and D in km.

→ (2) **The relative Elevation between the Stations :-**

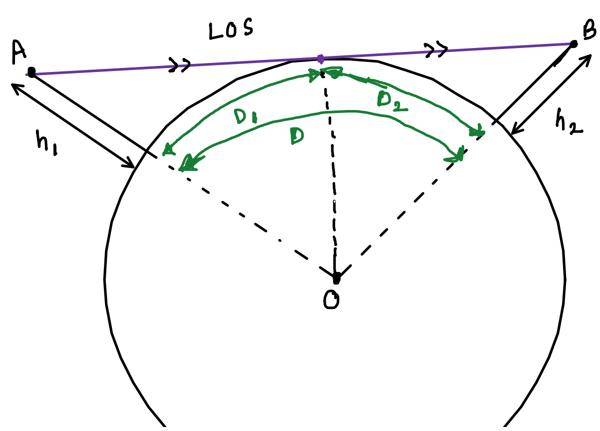
D : the known distance between A & B

h_1 :- known elevation of st^n A above datum.

D_1 – distance from A to point of tangency

D_2 → distance from B to the point of tangency

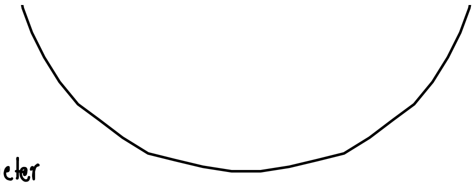
h_2 – required elevation of B above datum.



then,

$h_1 = 0.06728 D_1^2$

$\Rightarrow D_1 = \sqrt{h_1}$



$h_1 = 0.06728 D_1^2$

$\Rightarrow D_1 = \sqrt{\dfrac{h_1}{0.06728}}$

$\Rightarrow \boxed{D_1 = 3.8553\sqrt{h_1}}$, where D_1 in km and h_1 in meter

Knowing D_1 , D_2 is given by $D_2 = D - D_1$

Knowing D_2 , h_2 can be calculated from the relation.

$\boxed{h_2 = 0.06728\, D_2^2}$ → Thus, required elevation h_2 is determined.

If actual ground level at B is known it can be ascertained whether it is necessary to elevate st^n B above the ground or not.

Therefore, height of the tower can be calculated.

Note: At the point of tangency the line of sight (LOS) should be 2 to 3 m above the ground level.

③. Profile of the Intervening Ground:-

* elevation and positions of the peaks in the intervening ground between the proposed stations should be determined.
* The L.O.S should clear off all the peaks intervening the ground between the proposed stations.
* In order to find out whether the LOS will clear off the peaks or not, Captain G. T. McCaw suggested the formula which is as below:

$$\boxed{h = \frac{1}{2}(h_1 + h_2) + \frac{1}{2}(h_2 - h_1)\frac{x}{S} - (S^2 - x^2)\operatorname{cosec}^2\xi\left(\frac{1-2m}{2R}\right)}$$

where,

h = Height of L.O.S. at the obstruction

h_1 = Height of st^n A above datum

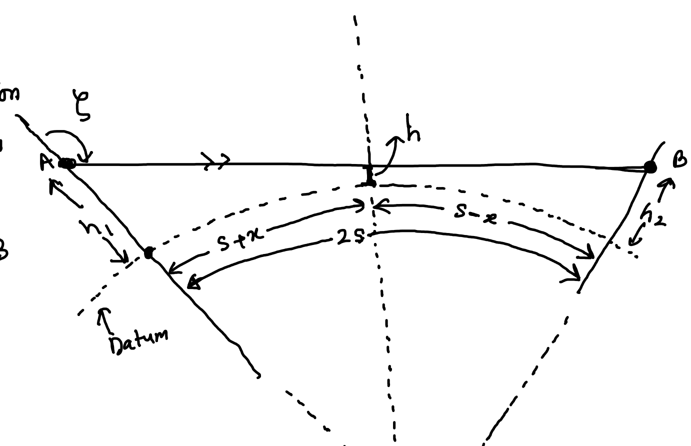
h_2 = " " " B " "

$2S$ = Distance bet^n two stations A & B

$(S+x)$ = Distance of obstruction from A

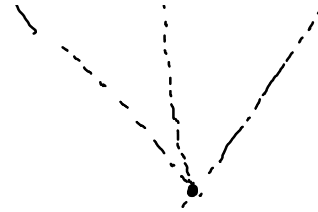
$(S-x)$ = " " " " B

ξ = Zenith angle from A to B



$(S-x)$ = " " " " B

ξ = Zenith angle from A to B



Note: value of $\operatorname{cosec}^2\xi$ may be taken approximately equal to unity.

However, for accurate calculation, $\boxed{\operatorname{cosec}^2\xi = 1 + \frac{(h_2-h_1)^2}{4S^2}}$

and value of $\boxed{\frac{1-2m}{2R} = 0.06728}$

Q.1 Two Triangulation stations A and B are 60 km apart & have elevations 240 m and 280 m respectively. Find the min. height of signal req. at B so that the L.O.S. may not pass near the ground than 2 m. The intervening ground may be assumed to have a uniform elevation of 200 m.

Soln =

AXIS SIGNAL CORRECTION (EYE OBJECT CORRECTION)

- In order to observe the points from the theodolite station, signals of appropriate heights are erected at the points to be observed.
- The signal may or may not be of the same height as that of the instrument.
- If the height of signal is not the same as that of the height of instrument axis above the station, a correction or eye object correction is to be applied.

Let,

h_1 = height of instrument at P, for observation to Q

h_2 = height of instrument at Q for observation to P

S_1 = height of signal at P, instrument & being to Q

S_2 = " " " " Q, " " to P

d = horizontal distance between P & Q

α = observed angle of elevation uncorrected for the axis signal

β = Observed angle of depression uncorrected for the axis signal

α_1 = angle of elevation corrected for axis signal

β_1 = " , depression " " " "

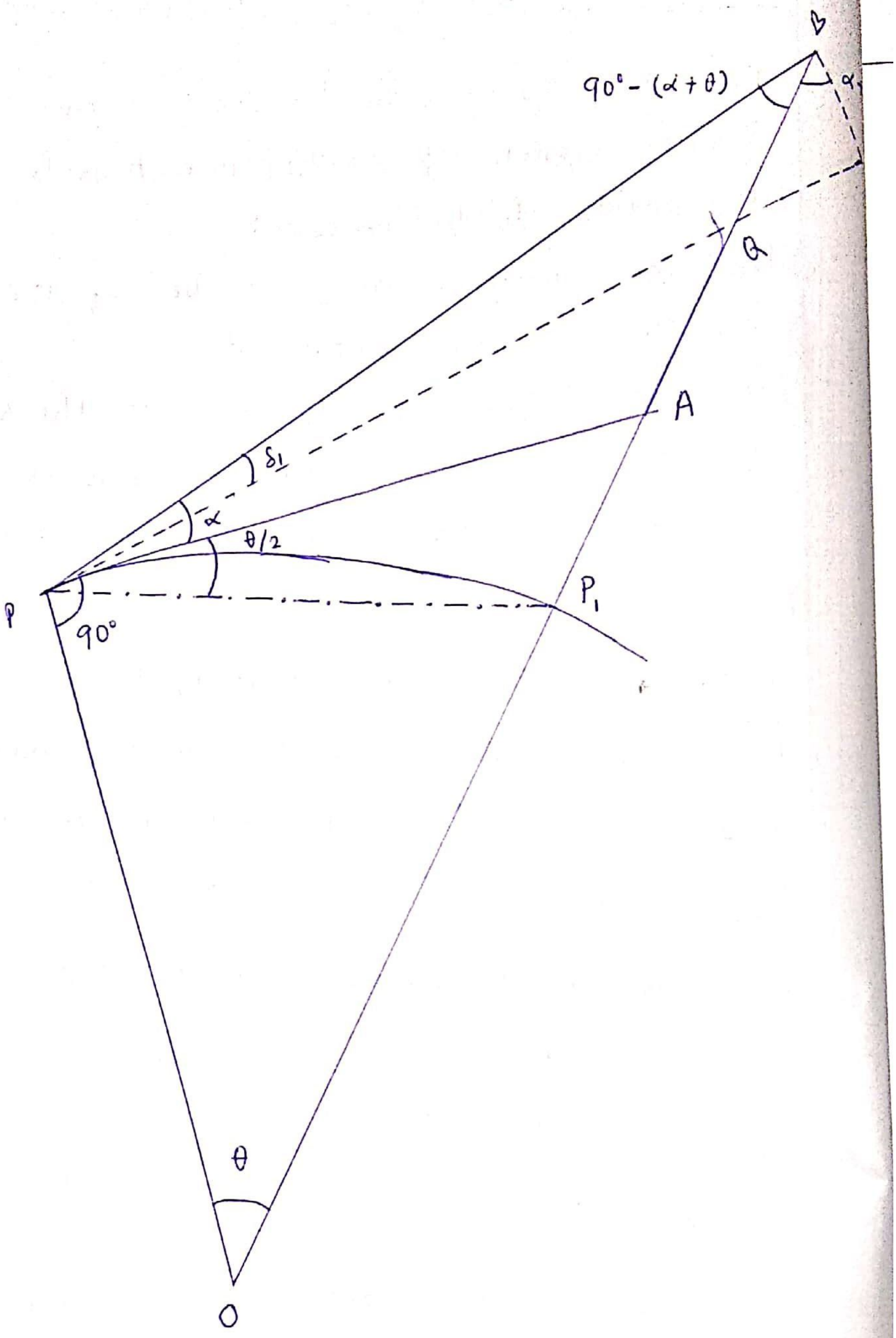
PA = horizontal line at P

Q = point observed.

BQ = difference in the height of signal at Q and the height of instrument at P = $(S_2 - h_1)$

$\therefore \angle BPA = \alpha$ = angle observed from P to Q

$\angle BPQ = \delta_1$ = axis signal correction (angular) at P.



AXIS SIGNAL CORRECTION

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At B, draw BC $\perp$ to BP to meet PQ produced at C.

In, triangle ΔPBO

$\angle BPO = \angle BPA + \angle APO = \alpha + 90^\circ = 90^\circ + \alpha$

$\angle POB = \theta$

$\therefore \angle PBO = 180^\circ - [(90^\circ + \alpha) + \theta] = 90^\circ - (\alpha + \theta)$

$\therefore \angle QBC = 90^\circ - [90^\circ - (\alpha+\theta)] = \alpha + \theta$

The angle δ_1 is usually very small and hence $\angle BCQ$ can be approximately taken equal to 90°.

$$\therefore \boxed{BC = BQ\cos(\alpha+\theta) = (S_2 - h_1)\cos(\alpha+\theta)} \quad \cdots (1)$$

Now, In ΔPP_1B

$\angle BPP_1 = \alpha + \theta/2$

$\angle PBP_1 = 90^\circ - (\alpha + \theta)$

$\angle PP_1B = 180^\circ - [(\alpha + \theta/2) + 90^\circ - (\alpha + \theta)]$

$= 90^\circ + \frac{\theta}{2}$

Now, $\dfrac{PB}{\sin PP_1B} = \dfrac{PP_1}{\sin PBP_1}$

$\Rightarrow PB = PP_1 \times \dfrac{\sin PP_1B}{\sin PBP_1} = \dfrac{d \sin[90^\circ + \theta/2)}{\sin[90^\circ - (\alpha+\theta)]}$

$$\Rightarrow \boxed{PB = \frac{d\cos\theta/2}{\cos(\alpha+\theta)}} \quad \cdots (11)$$

From, ΔPBC

~~PB =~~ PP_1 $\qquad \tan\delta_1 = \dfrac{BC}{PB}$

$\Rightarrow BC = PB\tan\delta_1$

$$(S_2 - h_1)\cos(\alpha+\theta) = \frac{d\cos\frac{\theta}{2}}{\cos(\alpha+\theta)} \times \tan\delta_1$$

$$\therefore \tan\delta_1 = \frac{(S_2 - h_1)\cos(\alpha+\theta)}{\frac{d\cos\theta/2}{\cos(\alpha+\theta)}}$$

$$\Rightarrow \boxed{\tan\delta_1 = \frac{(S_2 - h_1)\cos^2(\alpha+\theta)}{d\cos\theta/2}} \quad \text{...... (exact Eq}^n\text{)}$$

Usually θ is small in comparision to α, therefore may be ignored.

$$\therefore \boxed{\tan\delta_1 = \frac{(S_2 - h_1)\cos^2\alpha}{d}}$$

And, the correction is negative in this case. (Substractive)

Similarly, if observations are taken from Q towards P, ~~it can~~ and if δ_2 is the axis signal correction, then,

$$\boxed{\tan\delta_2 = \frac{(S_1 - h_2)\cos^2\beta}{d}} \quad \text{--- (additive)}$$

Note:- The correction for axis signal is negative for angles of elevation and positive for angle of depression.

If however, the vertical angle α (or β) is very small, we can take, with ~~suf~~ sufficient accuracy,

$$\tan\delta_1 = \delta_1 = \frac{S_2 - h_1}{d} \text{ rad}$$

$$\Rightarrow \delta_1 = \frac{S_2 - h_1}{d\sin 1''} \text{ seconds}$$

and, similarly $\boxed{\delta_2 = \frac{S_1 - h_2}{d\sin 1''}}$ seconds

Alternatively, the above eqn can be derived by considering $PB = PQ = PP_1 = d$ and taking BQ as the arc with radius equal to d, then

$$\delta_1 = \frac{BQ}{d} \text{ radians}$$

$$= \frac{S_2 - h_1}{d} \text{ radians}$$

$$\boxed{\delta_1 = \frac{S_2 - h_1}{d \sin 1''} \text{ seconds}}$$

Hence, corrected angle, after applying axis signal corrections.

$\alpha_1 = \alpha - \delta_1$ (elevation)

$\beta_1 = \beta + \delta_2$ (depression)

DETERMINATION OF DIFFERENCE IN ELEVATION

Difference in elevation between two points P & Q can be found out by two methods:-

(a) single obervation method

(b) Reciprocal obervation method.

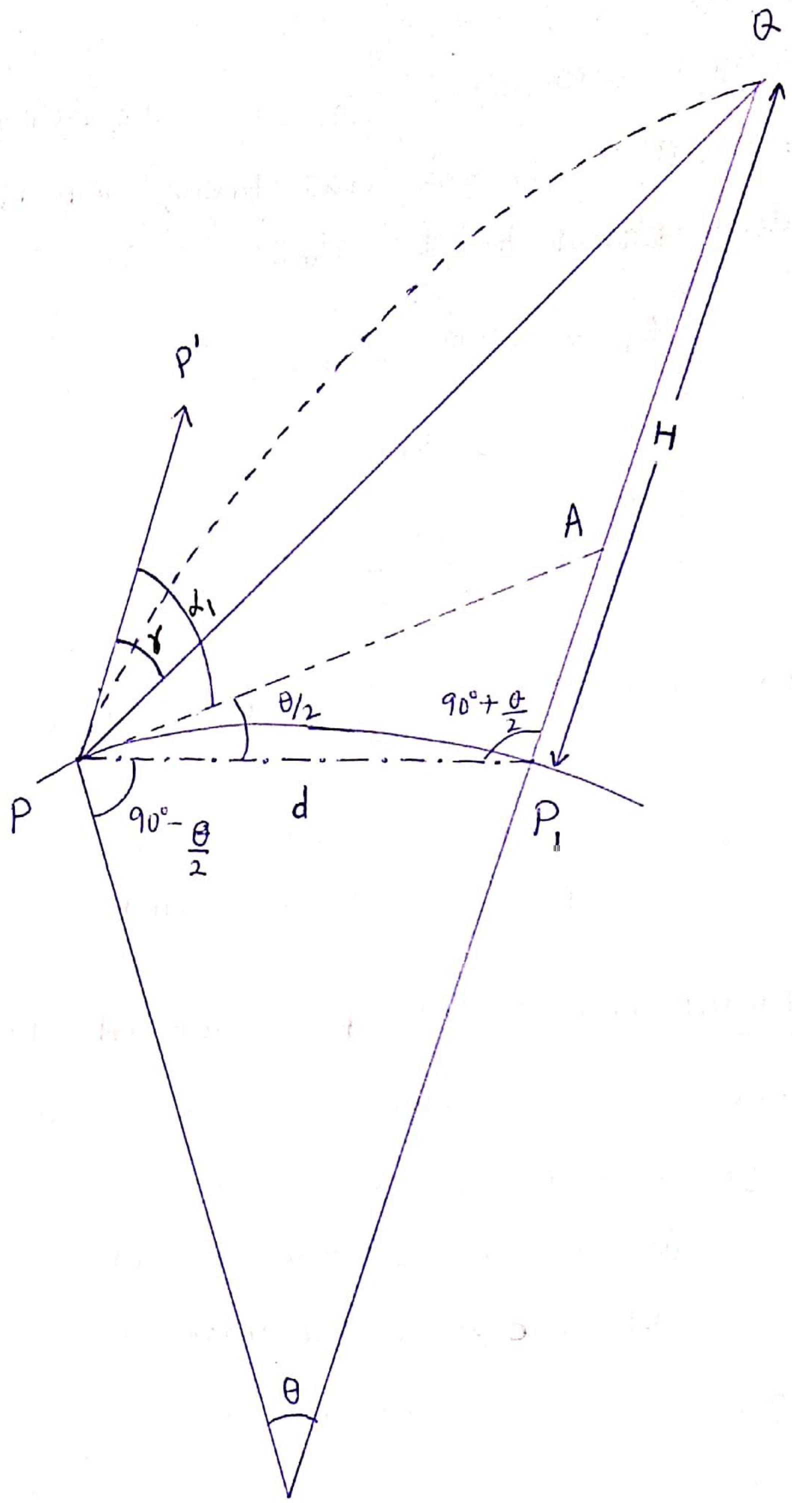
(a) Difference in Elevation by single observation:-

In this case, the observation are made from only one station (say P). And the following correction will have to be applied:-

(i) correction for curvature

(ii) correction for refraction and

(iii) correction for axis & signal.



Difference in elevation By single observation

Angle of elevation.

Sign of these correction will depend upon the sign of the angle observed.

(i) When the observed angle is the angle of elevation
(ii) When the observed angle is the angle of depression.

(1) **For angle of Elevation:-**

α = observed angle of elevation to Q

α_1 = observed angle corrected for axis signal

$= (\alpha - \delta_1) = \left(\alpha - \frac{S_2 - h_1}{d \sin 1''}\right)$ second

or $= \alpha - \tan^{-1}\left\{\frac{(S_2 - h_1)\cos^2\alpha}{d}\right\}$

d = horizontal distance = arc $PP_1 \simeq$ chord $PP_1 \approx PA$

$\angle P'PQ = r = m\theta$

$QP = H$ = difference in elevation between P & Q

In ΔPQP_1

$\angle QPP_1 = \angle P'PA - \angle P'PQ + \angle APP_1$

$= \alpha_1 - m\theta + \frac{\theta}{2}$

$\because \angle PP_1Q = 90° + \frac{\theta}{2}$

and $\angle PQP_1 = 180° - (\alpha_1 - m\theta + \theta/2) - (90° + \frac{\theta}{2})$

$= 90° - (\alpha_1 - m\theta + \theta)$

$$\frac{QP_1}{\sin QPP_1} = \frac{PP_1}{\sin PQP_1}$$

$$\Rightarrow QP_1 = H = PP_1 \times \frac{\sin QPP_1}{\sin PQP_1}$$

$$H = d \times \frac{\sin(\alpha_1 - m\theta + \theta/2)}{\sin[90^\circ - (\alpha_1 - m\theta + \theta)]}$$

$$\boxed{H = \frac{d \sin(\alpha_1 - m\theta + \frac{\theta}{2})}{\cos(\alpha_1 - m\theta + \theta)}} \quad \ldots (exact)$$

$$= \frac{d \sin\left(\alpha_1 - \frac{md}{R\sin 1''} + \frac{d}{2R\sin 1''}\right)}{\cos\left(\alpha_1 - \frac{md}{R\sin 1''} + \frac{d}{R\sin 1''}\right)}$$

$$= \frac{d \sin\left\{\alpha_1 + (1-2m)\frac{d}{2R\sin 1''}\right\}}{\cos\left\{\alpha_1 + (1-m)\frac{d}{R\sin 1''}\right\}}$$

Approximate Equation :-

If θ is very small, we can consider the angle $\angle PP_1Q$ to be equal to 90°, then

$$QP_1 = H = PP_1 \tan QPP_1$$

$$= d \tan\left(\alpha_1 - m\theta + \frac{\theta}{2}\right)$$

$$= d \tan\left\{\alpha_1 + (1-2m)\frac{d}{2R\sin 1''}\right\}$$

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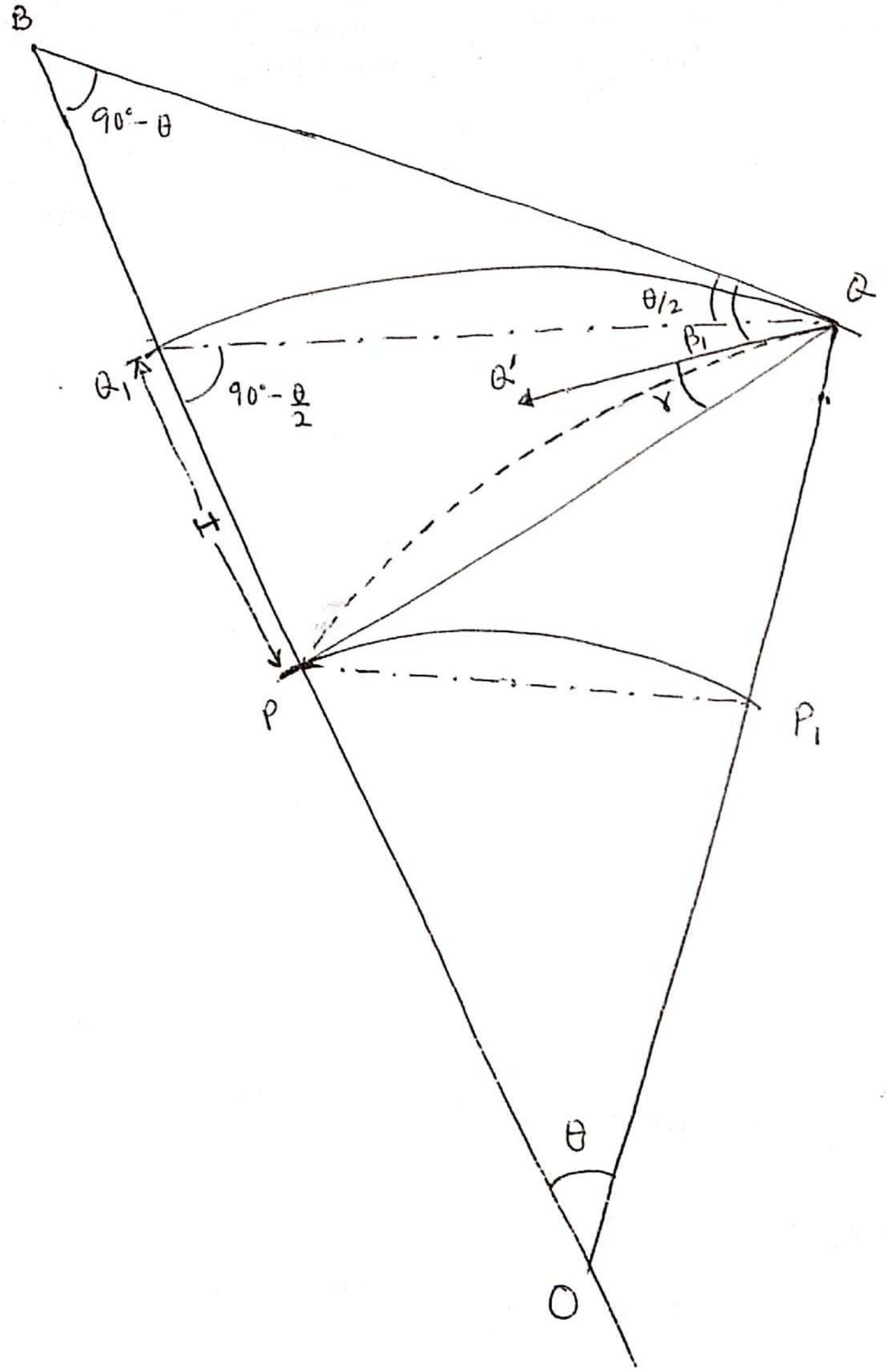

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(ii) For Depression Angle.

Let β = observed angle of depression to P.

β_1 = observed angle corrected for axis signal $= \beta + \delta_2$

$$= \beta + \frac{S_1 - h_2}{d \sin 1''} = \beta + \tan^{-1}\left\{\frac{(S_3 - h_2)\cos^2\beta}{d}\right\}$$

d = horizontal distance = arc QQ_1 = chord QQ_1 = QB

$\angle Q'QP = \gamma = m\theta$

$Q_1P = H$ = difference in elevation between P & Q

In ΔQPQ_1, $\angle PQQ_1 = \beta_1 + \gamma - \frac{\theta}{2}$

$$= \beta_1 + m\theta - \frac{\theta}{2}$$

$\angle PBQ = 90° - \theta$

$\angle QQ_1P = (90° - \theta) + \frac{\theta}{2} = 90° - \frac{\theta}{2}$

and $\angle Q_1PQ = 180° - (90° - \theta/2) - (\beta_1 + m\theta - \frac{\theta}{2})$

$$= 90° - (\beta_1 + m\theta - \theta)$$

Now, $$\frac{PQ_1}{\sin PQQ_1} = \frac{QQ_1}{\sin Q_1PQ}$$

$$H = PQ_1 = QQ_1 \cdot \frac{\sin PQQ_1}{\sin Q_1PQ}$$

$$= \frac{d \sin(\beta_1 + m\theta - \theta/2)}{\sin[90° - (\beta + m\theta - \theta]}$$

$$= \frac{d \sin(\beta_1 + m\theta - \frac{\theta}{2})}{\cos(\beta_1 + m\theta - \theta)} \quad \text{---(exact.)}$$

$$= \frac{d \sin\left[\beta_1 - (1-2m)\frac{d}{2R\sin 1''}\right\}}{\cos\left(\beta_1 - (1-m)\frac{d}{R\sin 1''}\right\}}$$

Approximate Expression

If, θ is very small, we can assume $\angle PQ_1Q \simeq 90°$

$$\therefore Q_1P = H = QQ_1 \tan PQQ_1$$

$$= d \tan\left(\beta_1 + m\theta - \frac{\theta}{2}\right)$$

$$= d \tan\left\{\beta - (1-2m)\frac{d}{2R\sin 1''}\right\}$$

* Application of correction in linear measure.

The difference in elevation between P & Q can also be obtained by applying the three corrections i.e. curvature, refraction and axis signal) in linear measure.

Curvature correction $= \dfrac{d^2}{2R}$

Refraction correction $= rd = m\theta d = m\dfrac{d}{R}d = \dfrac{md^2}{R}$

Combined correction for refraction & curvature

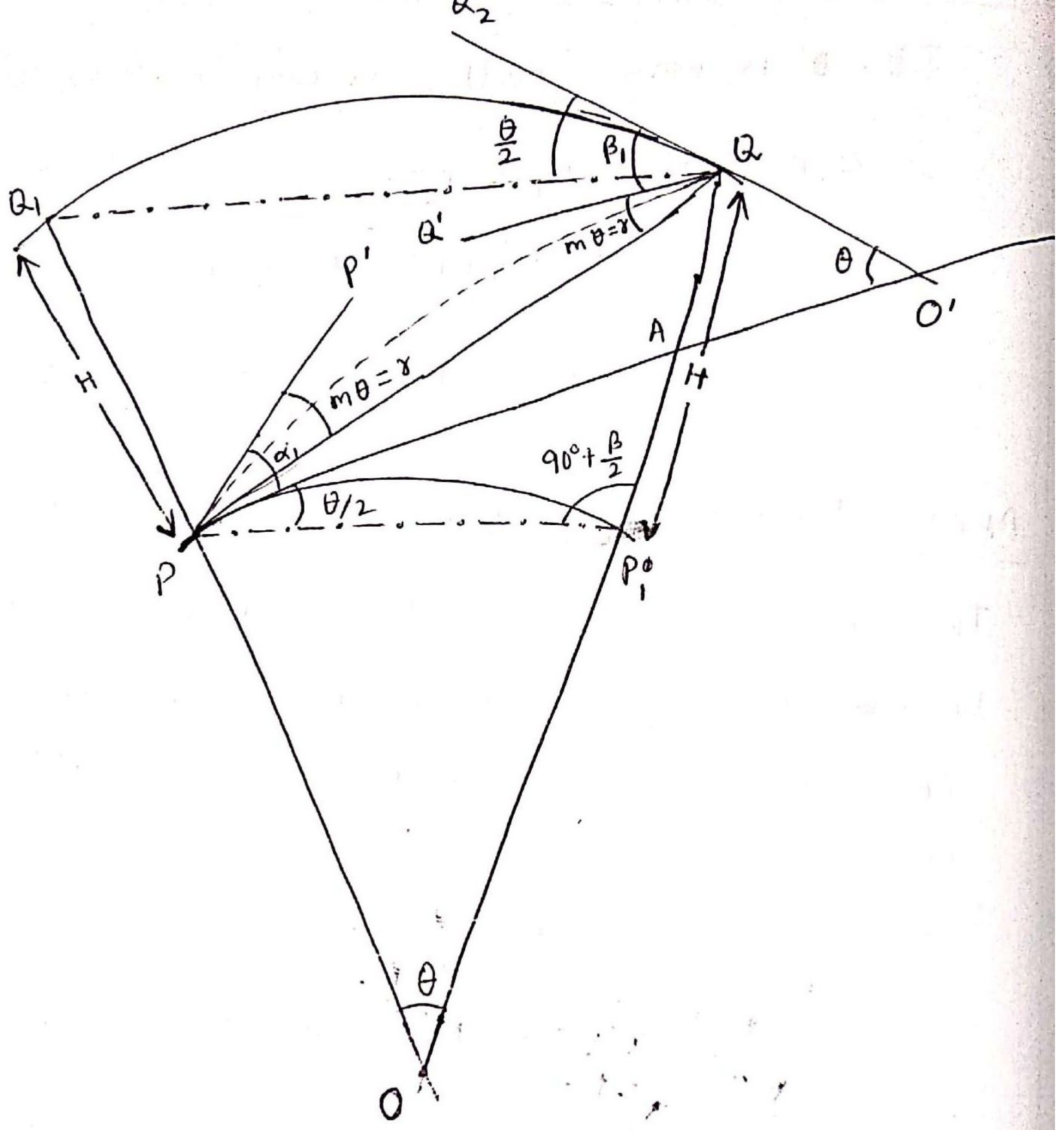
$$= \frac{d^2}{2R} - \frac{md^2}{R} = (1-2m)\frac{d^2}{2R}$$

So, if α is the observed angle, uncorrected for curvature, refraction and axis-signal,

$H = d\tan\alpha$ − (Ht. of signal − Ht. of instrument) + Curvature corr^n − refraction corr^n

$$= d\tan\alpha - (S_2 - h_1) + \frac{d^2}{2R} - \frac{md^2}{R}$$

$$= d\tan\alpha - (S_2 - h_1) + (1-2m)\frac{d^2}{2R}$$



Reciprocal Observations

Similarly, for angle of depression β, we have,

$H = d\tan\beta + (\text{Ht. of signal} - \text{Ht. of instrument}) - \text{curvature} + \text{refraction}$

$= d\tan\beta + (S_1 - h_2) - \frac{d^2}{2R} + \frac{md^2}{R}$

$= d\tan\beta + (S_1 - h_2) - (1-2m)\frac{d^2}{2R}$

(b) Difference in elevation by reciprocal observations-

- Reciprocal observations are generally made to eliminate the effect of refraction.
- In this method, observations are made simultaneously from both the stations (i.e. P & Q), So that refraction effect is the same.
- However, if it is not possible to take the observations simultaneously, observations at one station may be taken on first day and at the second on next day, during the time during which refraction is almost const. (i.e bet^n 10 a.m. to 4.p.m)
- This method is more accurate than the single observation method specially when the exact value of m is not known.

let,

$\angle P'PO' = \alpha_1$ = observed angle of elevation at P corrected for axis signal $= \alpha - \frac{S_2 - h_1}{d\sin 1''}$

$\angle P'PQ = \gamma = m\theta$ = refraction error at P

$\angle O'PP_1 = \frac{\theta}{2}$ = curvature effect.

$QP_1 = H$ = difference in elevation between P & Q

$\angle Q_2QO' = \beta_1$ = observed angle of depression at Q corrected for axis signal $= \beta + \frac{S_1 - h_2}{d\sin 1''}$

$\angle Q'QP = \gamma = m\theta$ = refraction error at Q

$\angle Q_1QQ_2 = \frac{\theta}{2}$ = curvature effect.

Arc PP_1 = chord PP_1 = arc QQ_1 = Chord $QQ_1 = d$ = horizontal distance.

$\angle QPP_1$ = angle of elevation corrected for axis signal, curvature and refraction,

$$= \alpha_1 + \frac{\theta}{2} - m\theta$$

Similarly,

$\angle PQQ_1$ = angle of depression corrected for axis signal, curvature and refraction.

$$= \beta_1 - \frac{\theta}{2} + m\theta$$

$$\therefore \alpha_1 + \frac{\theta}{2} - m\theta = \beta_1 - \frac{\theta}{2} + m\theta$$

$$= \frac{1}{2}\left\{\left(\alpha_1 + \frac{\theta}{2} - m\theta\right) + \left(\beta - \frac{\theta}{2} + m\theta\right)\right\}$$

$$= \frac{\alpha_1 + \beta_1}{2}$$

Thus, each corrected angle $= \frac{\alpha_1 + \beta_1}{2}$

Module- III

Theory of Error & its Adjustments

15.1 Introduction

- Measurement of lengths and angles done in various survey operations in field are accompanied with errors.
- It is almost impossible to have true measured value. Errors occur due to many reasons some of them are as follows:
  (a) Errors due to imperfect instruments
  (b) Errors due to environmental conditions or carelessness
  (c) Errors due to human limitations
- Due the measurement operations, as far as possible, errors should be minimized.
- Errors which still occur must be adjusted or eliminated so as to counteract their effects.
- In triangulation, all the observed angles of the triangulation stations are required to be adjusted before using them in the computation of sides.
- The measured angles are so adjusted so as to satisfy the required geometrical conditions.

15.2 Types of Errors

(a) Gross errors or mistakes
(b) Systematic or cumulative errors
(c) Accidental or random errors

15.2.1 Gross Errors or Mistakes

- This mistake occurs on the part of survey personnel due to lack of experience or carelessness. **For example:** If a surveyor reads the tape reading as 29.5 m instead of 30 m, then it is a mistake or the gross error.
- Mistakes, if not detected, can lead to erroneous results thereby making the whole survey as faulty. Adequate check measurements are thus made to detect this type of error.

15.2.2 Systematic or Cumulative Errors

- These errors are called as systematic because they always follow a definite pattern or a mathematical/ physical law. These errors are of same magnitude and sign.
  For example: Measuring a length with a steel tape and error involved due to temperature. This is a systematic error because it follows the physical law of expansion of solids on increasing the temperature.
- This type of error makes the result either too large or too small.

15.2.3 Accidental or Random Errors

- This type of error occurs due to human limitation in reading an observation.

For example: While measuring an angle from a protector (say 30.6°), then it is quite possible that the observer may read 30.5° or 30.7° due to inability of human eye to judge the exact division.

- A good thing about accidental errors is that when a large number of observations are made, then they use to cancel out because there is equal probability of the error to be positive or negative. Thus this type of error is also called as **compensating error.**
- But compensating effect of accidental errors is not full proof and there always remains some accidental errors. This error cannot be eliminated altogether from the observations whatever precautions are taken but magnitude of this error is generally very small.
- Smaller the random error, more precise is the measurement. Thus random/accidental errors limit the level of precision while taking an observation.
- Accidental errors occur purely as a matter of chance and thus theory of probability is used to account for these types of errors.

NOTE: The theory of errors deals with accidental/random errors only with the presumption that all the systematic and gross errors have been eliminated from the measured values.

15.3 Important Definitions

15.3.1 Observation

- It is the numerical value of an observed quantity in the field.
- When the quantity is directly measured then it is called as **direct observation** and when the quantity is found indirectly (from the direct observations of other quantities), then it is called as **indirect observation.**

15.3.2 Precision

- Degree of perfection used in measurement is called precision.
- Precision is adopted by using high quality instrument, skilled surveyor and using correct manner of taking measurement.

15.3.3 Accuracy

- Degree of perfection obtained in measurement is called accuracy.
- If any quantity is more nearer to the true value of quantity. It is called more accurate.

15.3.4 Observed Value

- The observed value of a quantity is the value obtained from the observation after applying the corrections of systematic errors and gross errors.
- **Independent quantity:** When the value of observed quantity is independent of the values of other quantities then the observed quantity is called as **independent quantity.**
- **Dependent quantity:** When the value of observed quantity depends on other quantities then the observed quantity is called as **dependent quantity.**

15.3.5 True Value

- It is the value of the quantity which is free from all errors.
- Now because it is impossible to eliminate all the errors from the observed quantity, true value cannot be found.
- It is a purely hypothetical concept.

15.3.6 Most Probable Value

- It is the value of the quantity which has more chances of being true than any other value.
- Most probable value is thus very close to (but NOT equal to) the true value of an observed quantity.

15.3.7 Principle of Least Square

- Most probable value of a quantity is that value for which sum of square of error is least.
- If for a single quantity multiple measurement are taken as x_1, x_2, x_3 ....., x_n with weight w_1, w_2, w_3, ... w_n respectively, then most probable value (MPV) is given as:

$$\text{MPV} = \frac{w_1x_1 + w_2x_2 + w_3x_3 + \ldots\ldots + w_nx_n}{w_1 + w_2 + w_3 + \ldots.w_n}$$

or

$$\text{MPV} = \frac{\sum_{i=1}^{n} w_i x_i}{\sum_{i=1}^{n} w_i}$$

- If all the observations have been measured with equal weight, the arithmetic mean value is the most probable value which is given as below:

$$\text{MPV} = \frac{x_1 + x_2 + \ldots. + x_n}{n}$$

or

$$\text{MPV} = \frac{\sum_{i=1}^{n} x_i}{n}$$

15.3.8 Residual Error

It is the difference between observed value and the most probable value of a quantity i.e.

Residual error = Observed value – Most probable value

15.3.9 Residual Error

It is the difference between observed value and the most probable value of a quantity i.e.

Residual error = Observed value – Most probable value

15.3.10 Observation Equation

The relationship between the observed quantities is called as observation equation.

For example:

$$A + B = 90°$$

It is an observation equation for the observed angles A and B.

15.3.11 Condition Equation

It is the equation which expresses the relation between several dependent quantities.

For example:

$$A + B + C = 180°$$

It is a condition equation for the dependent quantities.

Example - 15.1 Theory of least squares can be represented as

(a) $\Sigma e^2 = 0$ (b) $\Sigma We\delta e = 0$

(c) $\Sigma e^2\,\delta e$ = minimum (d) $\Sigma 2\,We\,\delta e$ = minimum

Where W = weight of an observation

e = residual error

Solution: (b)

According to the theory of least square, the most probable value of quantity is the one for which the sum of squares of the residual errors is minimum.

Let $x_1, x_2, x_3 \ldots x_n$ are different measurement with corresponding weights, $w_1, w_2, w_3 \ldots w_n$.

Assuming x is most probable value of quantity.

Errors	Square errors	Total error
$(x - x_1) = e_1$	e_1^2	$W_1e_1^2$
$(x - x_2) = e_2$	e_2^2	$W_2e_3^2$
$(x - x_3) = e_3$	e_3^2	$W_3e_3^2$
—	—	—
$(x - x_n) = e$	e_n^2	$W_ne_n^2$

Sum of squares of error,

$$y = W_1e_1^2 + W_2e_2^2 + W_3e_3^2 + \ldots W_ne_n^2$$

$$y = \Sigma We^2$$

According to principle of least square

$$\frac{dy}{dx} = \Sigma 2We\,\delta e = 0$$

or $\Sigma\, We\delta e = 0$

Hence option (b) is correct.

Example - 15.2 The residual error is the difference between

(a) true value and observed value of a quantity

(b) most probable value and observed value of a quantity

(c) most probable value and true value of a quantity

(d) none of the above

Solution: (b)

True error: It is the difference between true value and measured value.

Mean error: It is the average error of a quantity during different-different observations.

Conditional error: This type of error always occurs in same direction.

Residual error: It is the difference between the most probable value of a quantity and its observed value.

Hence option (b) is correct.

15.4 Indices of Precision for Observation of Equal Weight

15.4.1 Standard Deviation

- It is a numerical value that indicates the amount of precision about a central value.

$$\text{Standard deviation, } \sigma = \sqrt{\frac{\Sigma V^2}{n-1}} \quad \text{...(15.1)}$$

where, n = number of observation made

V = Residual variation = Measured value – Most probable value

- The standard deviation establishes the limits of the error bound within which 68.3% of the values of the set should lie.

15.4.2 Variance

- The square of the standard deviation is known as the variance (V).

$$V = \sigma^2 = \frac{\Sigma V^2}{n-1} \quad \text{...(15.2)}$$

- It is used as a measure of dispersion or spread of the observations around a mean value.

15.4.3 Standard Error of the Mean

- The standard deviation of the mean is called as the standard error of mean (σ_m).

Thus,

$$\sigma_m = \pm\sqrt{\frac{\Sigma v^2}{n(n-1)}} = \pm\frac{\sigma}{\sqrt{n}} \quad \text{...(15.3)}$$

- It indicates the limits of error bound within which the true value of the mean lies.

15.4.4 Standard Error of Single Observation

- The standard error of single observation is given by:

$$\sigma_1 = \pm\sqrt{\frac{\Sigma v^2}{(n-1)}} \quad \text{...(15.4)}$$

- The standard error of single observation is the same as the standard deviation (σ). These two terms are often used synonymously.

15.4.5 Most Probable Error

It the error for which there is equal chances that the true error will be less than the probable error and equal chances that the true error will be more than the probable error i.e. each is having the probability of 50%.

$$\text{Most probable error} = \pm 0.6745\sqrt{\frac{\Sigma v^2}{n-1}} = \pm 0.6745\sigma \quad \text{...(15.5)}$$

15.4.6 Most Probable Error of Mean

It is equal to 0.6745 times the standard error of mean i.e.,

$$\text{Probable error mean} = \pm 0.6745\sqrt{\frac{\Sigma v^2}{n(n-1)}} \quad \text{...(15.6)}$$

15.4.7 Maximum Error

The maximum error of a quantity is almost impossible to determine absolutely. Thus, often 99.9% error is taken as the maximum error in surveying. This maximum error corresponds to $\pm 3.29\sigma$.

15.4.8 Different Percentage Error

Sometimes, the following percentages of errors are also used:

(a) 90% error (E_{90}) = $\pm 1.645\sigma$ (b) 95% error (E_{95}) = $\pm 1.96\sigma$

(c) 95.5% error ($E_{95.5}$) = $\pm 2.0\sigma$ (d) 99.7% error ($E_{99.7}$) = $\pm 3.0\sigma$

Example - 15.3 The relationship between the probable error of single observation (E_s) and the probable error of the mean (E_m) is :

(a) $E_m = \dfrac{E_s}{n}$ (b) $E_m = \dfrac{E_s}{\sqrt{n}}$

(c) $E_m = \dfrac{E_s}{n^{2/3}}$ (d) $E_m = \dfrac{E_s}{2n^{1/2}}$

where, n = number of obsrvations made

Solution: (b)

The relationship between the probable error of single observation (E_s) and the probable error of the mean (E_m) is equals to

$$E_m = \frac{E_s}{\sqrt{n}} = 0.6745\sqrt{\frac{\Sigma v^2}{n(n-1)}}$$

where, n = difference between any single measurement and mean of the series

n = no. of observations

15.5 Weight Concept

15.5.1 Definition of Weight

- Weight of a quantity indicates the precision of the quantity within a set of observations or in other words it represents the trustworthiness of the quantity being measured.
- Greater the weight of an observation, greater is the precision with which the quantity is measured.
- Weights are expressed in terms of natural numbers with higher number representing higher weight thereby higher precision.

15.5.2 Allocation of Weights

(a) Weights are assigned as inverse proportion to **variance** or **square of standard deviations.**

For example: Let variance of set A observation = 80

Variance of set B observation = 120

Thus, $$\frac{\text{Weight of set } A}{\text{Weight of set } B} = \frac{1/80}{1/120} = 1.5$$

(b) Weights to the quantities measured in similar conditions are assigned in direct proportion to the number of times (say n) a quantity is measured.

For example: Let a quantity A is measured five times, then the weight of quantity A is 5.

(c) Many a times, weights are assigned based on personal perception based on field or other environmental conditions. Lower weights are generally allocated to quantities measured in difficult conditions and higher weights are assigned for quantities measured in relatively easy conditions.

(d). Weights are often assigned as in inverse proportion to the lengths of lines being measured.

15.5.3 Laws of Weight

(a) Weight of Arithmetic mean of number of observations of unit weight is equal to the number of observations.

For example : If an angle A is measured three times and the values are obtained as below:

1. 40°10′ Weight = 1
2. 40°15′ Weight = 1
3. 40°40′ Weight = 1

$$\text{then, arithmetic mean} = \frac{40°10' + 40°15' + 40°40'}{3} = 40°21.66'$$

The arithmetic mean will have weight = 3

(b) The weight of the weighted arithmetic mean is equal to the sum of the individual weights.

For example : If an angle A has the following values:

1. 40°10′ Weight = 1
2. 40°15′ Weight = 2
3. 40°40′ Weight = 3

$$\text{Weighted arithmetic mean} = 40° + \frac{1\times 10' + 2\times 15' + 3\times 40'}{6} = 40°26.66'$$

- The weighted arithmetic mean 40°26.66′ has weight = (1 + 2 + 3) = 6

(c) The weight of algebraic sum of two or more quantities is equal to the sum of reciprocals of their individual weights.

- If measurement x_1 is taken with weight w_1 and measurement x_2 is taken with weight w_2 then for addition/substraction.

	Results (s)	Weight of result
Addition	$(x_1 + x_2)$	$\frac{1}{\frac{1}{w_1} + \frac{1}{w_2}}$
Substraction	$(x_1 - x_2)$ or $(x_2 - x_1)$	$\frac{1}{\frac{1}{w_1} + \frac{1}{w_2}}$

For example : If the value of the angle A is 70° of a weight = 3 and that of the angle B is 40° of a weight = 2, then weight of (A + B) = $\dfrac{1}{\left(\frac{1}{3} + \frac{1}{2}\right)} = \dfrac{6}{5}$.

Similarly, weight of (A – B) = $\dfrac{1}{\left(\frac{1}{3} + \frac{1}{2}\right)} = \dfrac{6}{5}$.

(d) If a quantity of given weight is multiplied by a factor, the weight of the result is obtained by dividing its given weight by the square of that factor.

If measurement x_1 taken with weight w_1 is multiplied by a constant k then

	Result	Weight of Result
Multiplication	k_1x_1	$\frac{W_1}{k^2}$

For example : If the angle A has a value of 60° having weight = 3, then

$$\text{Weight of } 2A = \frac{3}{(2)^2} = \frac{3}{4}$$

(e) If a quantity of a given weight is divided by a factor, the weight of the result is obtained by multiplying its given weight by the square of that factor.

If measurement x_1 taken with weight w_1 is divide by a constant k then

	Result	Weight of Result
Division	$\frac{x_1}{k}$	k^2W_1

For example : If the angle A has a value of 60°, weight then weight of $\frac{A}{2} = 3 \times (2)^2 = 12$

NOTE

- If a quantity of given weight is multiplied by its own weight, weight of resulting quantity is obtained as reciprocal of its own weight.
- If a quantity of x_1 is measured with weight = w_1.

	Result	Weight of Result
Multiplication	$W_1 \cdot x_1$	$\frac{W_1}{W_1^2} = \frac{1}{W_1}$

(f) The weight of an equation remains unchanged when all the signs of the terms of equation are changed.

For example: If weight of equation $x + y = 79$ is 3

then the weight of equation $-x - y = -79$ is 3 only.

(g) The weight of an equation remains unchanged when it is added or subtracted from a constant.

For example: If weight of equation $x + y = 55$ is 5

then the weight of equation $10 + x + y = 65$ is 5 only.

Similarly, weight of equation $60 - x - y = 5$ is also 5.

Example - 15.4 If the weight of an angle A = 40°24′24″ is 2 then the weight of the angle $\frac{A}{3}$ = 13°28′08″ will be

(a) 4 (b) $\pm\sqrt{3}$

(c) 9 (d) 18

Solution: (d)

If a quantity of a given weight is divided by a factor, the weight of the result is obtained by multiplying its given weight by the square of that factor.

$$\therefore \quad \text{Weight of angle } \left(\frac{A}{3}\right) = (3)^2 \times 2 = 18$$

Example-15.5 If the weight of an angle A is 3 and weight of angle B is 4, what will be the weight of (3A – B + 90°)?

(a) 1/7 (b) 1

(c) 4/13 (d) 91

Solution: ***(c)***

Given, $A = 3$ (weight); $B = 4$ (weight)

$$\text{Weight of } 3A = \frac{3}{3^2} = \frac{1}{3}$$

$$\therefore \quad \text{Weight of } 3A - B = \frac{1}{\left(3+\frac{1}{4}\right)} = \frac{4}{13}$$

$$\therefore \quad \text{Weight of } \quad 3A - B + 90 = \frac{4}{13}$$

Hence option (c) is correct.

15.6 Indices of Precision for Observations of Different Weights

15.6.1 Standard Deviation of Weighted Observations

The standard deviation of weighted observations is given by:

$$\sigma_w = \pm\sqrt{\frac{\Sigma w v^2}{n-1}} \qquad ...(15.7)$$

Where, n = Number of observations made

ν = residual / variation

15.6.2 Standard Error of Mean of Weighted Observations

The standard deviation of the mean is called as the **standard error of mean $(\sigma_m)_w$**.

Thus,
$$(\sigma_m)_w = \pm\sqrt{\frac{\Sigma w v^2}{(n-1)\Sigma w}} = \pm\frac{\sigma_w}{\sqrt{\Sigma w}} \qquad ...(15.8)$$

It indicates the limits of error bound within which the true value of the mean lies.

15.6.3 Standard Error of Single Observation of Weight w_i

The standard error of single observation is given by:

$$(\sigma_1)_w = \pm\sqrt{\frac{\Sigma w v^2}{w_i(n-1)}} = \pm\frac{\sigma_w}{\sqrt{w_i}} \qquad ...(15.9)$$

15.6.4 Most Probable Error of Single Observation of Weight w_i

If the error for which there is equal chances that the true error will be less than the probable error and equal chances that the true error will be more than the probable error i.e. each is having the probability of 50%.

$$\text{Most probable error} = \pm 0.6745\sqrt{\frac{\Sigma w v^2}{w_i(n-1)}} = \pm 0.6745(\sigma_1)_w \qquad \text{...(15.10)}$$

15.6.5 Most Probable Error of Mean

It is given by,

$$\text{Most Probable error of mean} = \pm 0.6745\sqrt{\frac{\Sigma w v^2}{(n-1)\Sigma w}} \qquad \text{...(15.11)}$$

15.7 Law of Propagation of Error

Let us consider a derived quantity A which is dependent quantity.

If A is function of x, y, z, then standard error in A due to standard errors e_x, e_y, e_z in x, y, z is obtained from the following relation:

$$e_A^2 = \left(\frac{\partial f}{\partial x} e_x\right)^2 + \left(\frac{\partial f}{\partial y} e_y\right)^2 + \left(\frac{\partial f}{\partial z} e_z\right)^2 \qquad \text{...(15.12)}$$

Above equation (15.12) is the general expression for the standard error,

Case 1 : If $A = x + y + z$

e_x, e_y, e_z be the standard errors in x, y, z then

$$e_A = \pm\sqrt{e_x^2 + e_y^2 + e_z^2}$$

Case 2 : If $A = xyz$

$$e_A = \left[(yze_x)^2 + (xze_y)^2 + (xye_z)^2\right]^{1/2}$$

Case 3 : If $A = kx^n$

$$e_A = \pm knx^{n-1}e_x$$

Case 4 : If $A = x \pm k$

$$e_A = \pm e_x$$

Example - 15.6 The probable values of two angles are 40°20′30″± 2″ and 84°44′ 20″± 3″. The probable error of the sum of these two angles will be

(a) ±5″ (b) ±1″

(c) $\pm\sqrt{5}''$ (d) $\left(\pm\sqrt{(2)^2 + (3)^2}\right)''$

Solution: (d)

Given : LA = 40°20′30″ ± 2″; LB = 84°44′20″ ± 3″

$\Rightarrow$ $$e_A = 2, \quad e_B = 3''$$

$$e_{A+B} = \pm\sqrt{e_A^2 + e_B^2} = \left(\pm\sqrt{(2)^2 + (3)^2}\right)''$$

Example - 15.7 The sides of a rectangle are (120 ± 0.05 m) and (180 ± 0.06 m). The probable error in the area will be

(a) ±16.8 sq.m
(b) ±12.35 sq.m
(c) ±16.2 sq.m
(d) ±11.53 sq.m

[UPPSC 2008]

Solution: (d)

$$A = xy$$
$$e_x = 0.05 \text{ m}$$
$$e_y = 0.06 \text{ m}$$

Now,
$$e_A = \pm\left[(120)(0.06)^2 + (180)(0.05)^2\right]$$
$$= \pm\left[\frac{(120)^2 \times 36}{10000} + \frac{(180)^2 \times 25}{10000}\right]^{1/2}$$
$$= \pm[144 \times 0.36 + 324 \times 0.25]^{1/2}$$
$$= \pm 11.53 \text{ m}^2$$

Example - 15.8 The two sides of a rectangle are 50 ± 0.02 m and 60 ± 0.03 m. The probable error of the area of the rectangle is

(a) ±0.05
(b) $\pm\sqrt{(0.02 \times 50)^2 + (60 \times 0.03)^2}$
(c) $\pm\sqrt{(0.02)^2 + (0.03)^2}$
(d) $\pm\sqrt{(0.02 \times 60)^2 + (0.03 \times 50)^2}$

Solution: (d)

Let $L = 60 \pm 0.03$ m $\Rightarrow e_L = 0.03$; $B = 50 \pm 0.02$ m $\Rightarrow e_L = 0.02$

$$\text{Area} = \text{L.B}$$

Now, probable error in area of rectangle is

$$e_A = \pm\left[(L \cdot e_B)^2 + (B e_L)^2\right]^{1/2}$$
$$= \pm[(60 \times 0.02)^2 + (50 \times 0.03)^2]^{1/2}$$

15.8 Theory of Least Square

- According to the theory of least squares, if the measurements are of equal weight, the most probable value is that value which makes the sum of the squares of the residual (V) to a minimum value.

  i.e. $\Sigma V^2 = \text{Minimum}$

- If the measurements are of unequal weights, the most probable value is that value which makes the sum of the products of the weight (w) and the squares of the residuals to a minimum value. Thus,

  $$\Sigma wV^2 = \text{Minimum}$$

- The least square adjustments can be done by either of the following two methods:
  1. Normal equations method.
  2. Method of correlates or condition equations method.

15.8.1 Normal Equation Method

- Normal equation method also known as observation equation.
- For obtaining the most probable value of observations, normal equation formed for each of the observed quantity. These normal equations are solved simultaneously in order to arrive at the most probable value of observations.

Formation of Normal Equation

Rule 1: For observation of equal weight : To form normal equation for each of the unknown quantity, multiply each observation equation by the algebric coefficient of that unknown quantity in that equation and add the result.

Rule 2: For observation of unequal weight : To form the normal equation for each of the unknown quantity, multiply each observation equation with the product of algebric coefficient of that unknown quantity in that equation and weight of that observation and add the result.

Example - 15.9 Find the most probable value of the angle A from the following observations equation

$A = 40°20'15''$, Weight = 1
$2A = 80°40'50''$, Weight = 1
$4A = 161°21'20''$, Weight = 1

Solution:

Normal equation for A

$$A = 40°20'15'', \quad \text{Weight} = 1 \qquad \text{...(i)}$$
$$2 \times 2A = 80°40'50'', \quad \text{Weight} = 1 \qquad \text{...(ii)}$$
$$4 \times 4A = 161°21'20'', \quad \text{Weight} = 1 \qquad \text{...(iii)}$$

Adding (i), (ii) and (iii), we get

$$21A = 847°07'15''$$

$$\therefore \quad A = \frac{847°07'15''}{21} = 40°20'20.7''$$

Example - 15.10 Find the most probable value of the angle from the following observations equations:

$A = 40°20'15''$, Weight = 3
$2A = 80°40'30''$, Weight = 2
$4A = 161°21'40''$, Weight = 1

Solution:

Normal equation for A

$$3 \times A = 121°00'45'' \qquad \text{...(i)}$$
$$2 \times 2 \times 2A = 322°43'20'' \qquad \text{...(ii)}$$
$$1 \times 4 \times 4A = 645°26'40'' \qquad \text{...(iii)}$$

Adding (i), (ii) and (iii), we get

$$27A = 1089°10'45''$$

$$A = \frac{1089°10'45''}{27} = 40°20'23.89''$$

Example-15.7 The sides of a rectangle are (120 ± 0.05 m) and (180 ± 0.06 m). The

$A = 25° 30'$

$2A = 51° 10'$

The normal equation in A will be

(a) $3A = 76° 40'$ (b) $5A = 127° 50'$
(c) Both (a) and (b) (d) None of the above

[UPPSC 2007]

Solution: (a)

$$A = 25° 30'$$
$$2A = 51° 10'$$

The normal equation in A,

$$A + 2A = 25° 30' + 51° 10'$$
$$3A = 76° 40'$$

Hence option (a) is correct.

15.8.2 The Method of Correlates

- This method is also known as the **method of condition equations** or **method of Lagrange multiplier.**
- When there are a large number of condition equations, then this method is more suitable than the method of normal equations.
- After forming all the condition equations, additional equation from the theory of least squares is also applied.
- Then condition equation is multiplied by an unknown multiplier called as the **correlate** or the **Lagrange multiplier (λ).**
- The resultant condition equations are then combined with the condition of least squares, which on differentiation is expressed as a linear function of correlates. These equations are then solved to find the values of the correlates.

Student's Assignment

Q.1 Error due to carelessness of an observer is called

(a) Method of correlates

(c) Systematic error (d)

(d) Method of least squares

(a) MPV and true value
(b) MPV and observed value
(c) Observed value and true value

(a) $\frac{3}{2^2}$ (b) 3×2^2

(c) $\overline{2}$ (d) $\frac{3^2}{2^2}$

Q.3 Which of the following is not a method of solving

Module IV [8hrs]

Modern Field Survey Systems: Principle of EDM, types of EDM instruments, Distomat, Total station- parts, accessories, advantages and application, Measurement of distance using EDM, Types of waves, modulation of frequency, resolution of ambiguity, Errors in Total station survey, Introduction to GPS- segment, measurement, errors and biases.

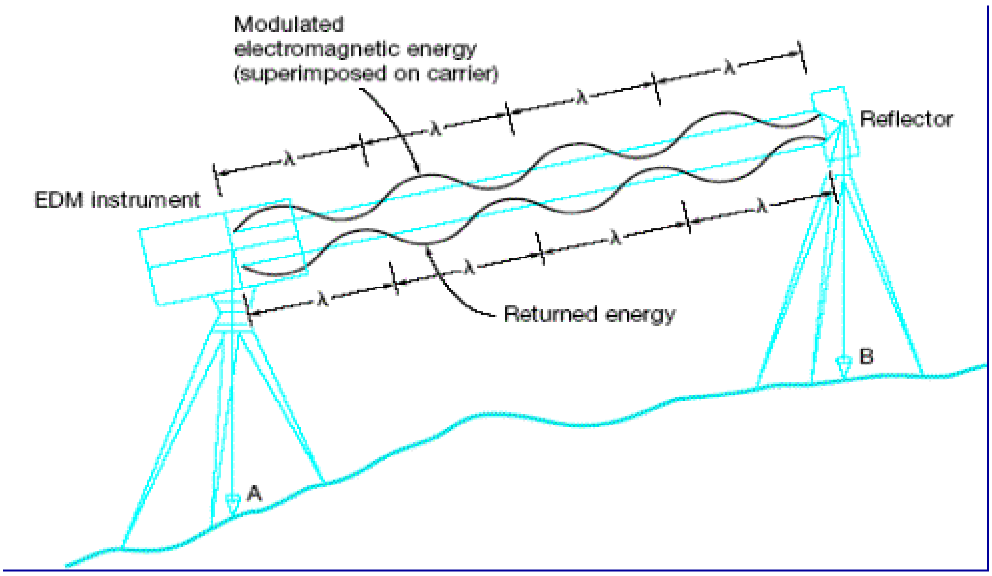
Electronic Distance Measuring (EDM):

- EDMIs were first introduced in 1950's by Geodimeter Inc. Early instruments were large, heavy, complicated and expensive. Improvements in electronics have given lighter, simpler, and less expensive instruments. EDM can be manufactured for use with theodolites (both digital and optical) or as an independent unit. These can be mounted on standard units or theodolites or can also be tribrach mounted.
- The electronic methods depend on the value of velocity of Electromagnetic radiation (EMR), which itself is dependent upon measurement of distance and time. Hence, there is no inherent improvement in absolute accuracy by these methods. The advantage is mainly functional - precise linear measurement can now be used for longer base lines, field operations can be simplified and trilateration can replace or augment triangulation.

Principle of EDM:

- The general principle involves sending a modulated Electro-magnetic (EM) beam from one transmitter at the master station to a reflector at the remote station and receiving it back at the master station. The instrument measures slope distance between transmitter and receiver by modulating the continuous carrier wave at different frequencies, and then measuring the phase difference at the master station between the outgoing and the incoming signals. This establishes the following relationship for a double distance (2D):

$$\boxed{2D = m\lambda + \frac{\phi}{2\pi}\lambda + k}$$



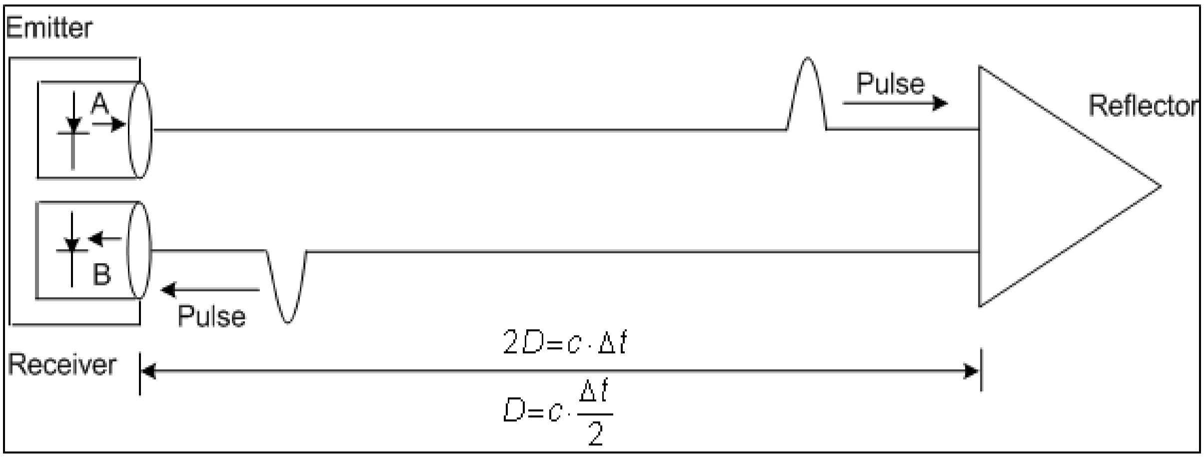
Where,

m is unknown integer number of complete wavelengths contained within double distance
Φ is the measured phase difference
λ is modulation wavelength, and
k is constant

There are basically two methods of measurement:

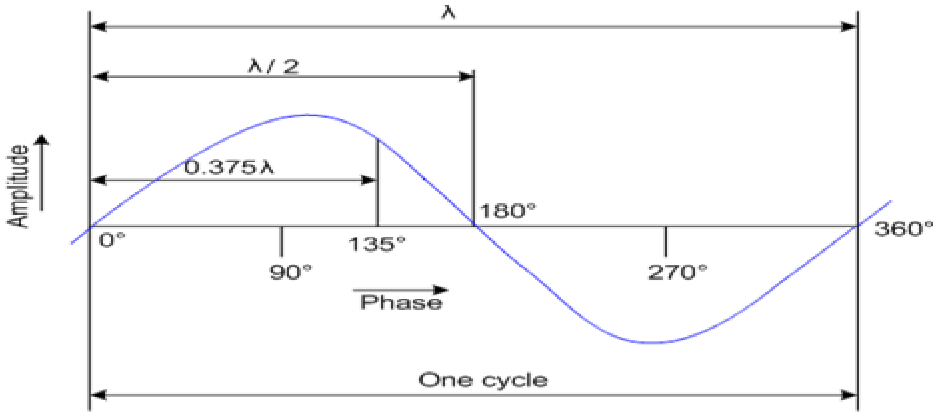
Pulse techniques:

All such measurements incorporate a very precise measurement of time usually expressed in units of nanoseconds (1x10-9 s), which a EM wave takes to travel from one station to another. In this method, a short, intensive pulse radiation is transmitted to a reflector target, which is immediately transmitted back to the receiver. As shown in Figure given below, the distance (D) is computed as the velocity of light (V) multiplied by half the time (Δt/2) the pulse took to travel back to the receiver (D = V x Δt/2).



Phase difference techniques

The relationship between wavelength and associated phase difference, which shows that for a given complete cycle of EM wave, the phase difference can be expressed both in terms of angular (degrees) and linear (fraction of wavelengths) units. In phase difference method used by majority of EDMI, the instrument measures the amount δλ by which the reflected signal is out of phase with the emitted signal.



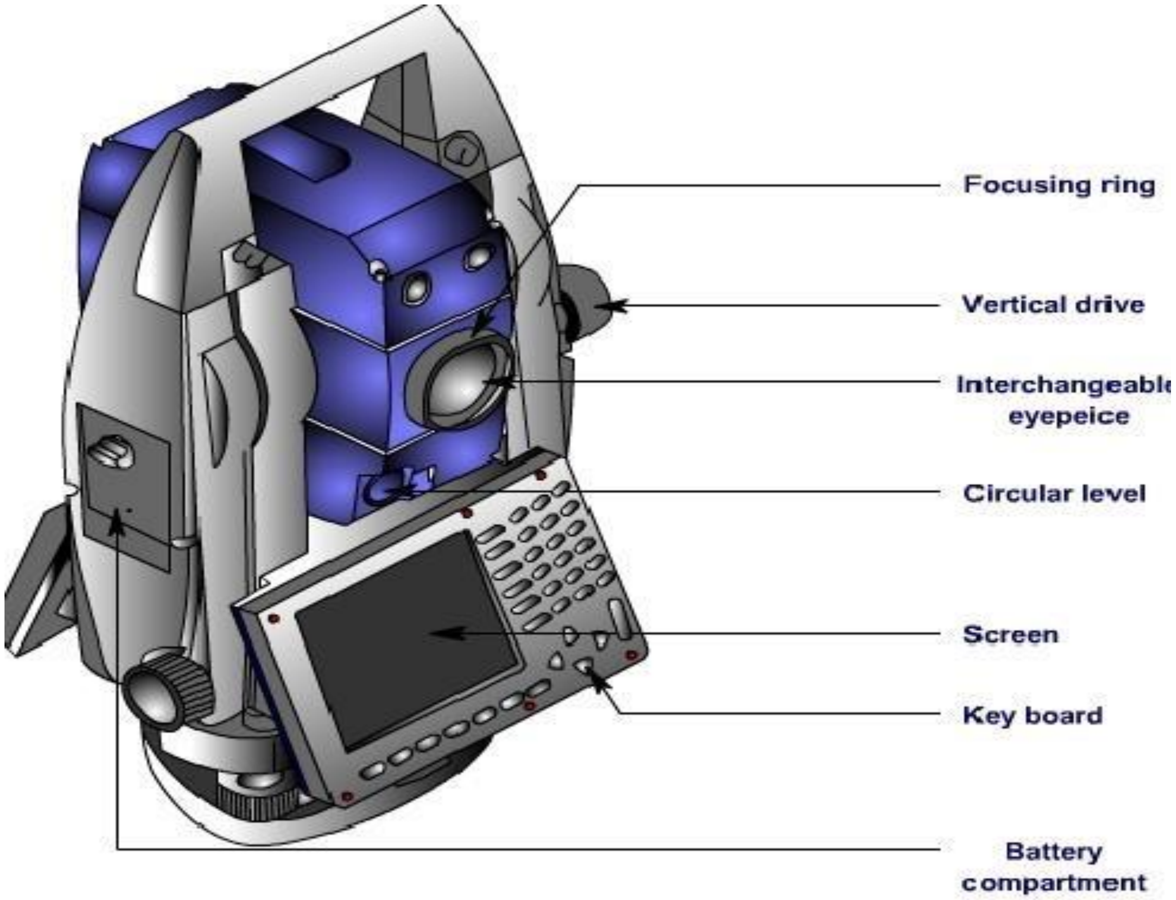
Classification on the basis of range

EDMs are also available as:

- **High range** radio wave equipment for ranges up to 100 km
- **Medium range** microwave equipment with frequency modulation for ranges up to 25 km
- **Short range** electro-optical equipment using amplitude modulated infra-red or visible light for ranges up to 5 km

Total Station:

This is an electronic instrument. In this instrument, all the parameters required to be observed during surveying can be obtained. The value of observation gets displayed in a viewing panel. The precision of this type of instrument varies in the order of 0.1" to 10". Total station surveying - defined as the use of electronic survey equipment used to perform horizontal and vertical measurements in reference to a grid system. It is also a form of an electronic theodolite combined with an electronic distance measuring device (EDM).



These instruments can record horizontal and vertical angles together with slope distance and can be considered as combined EDM plus electronic theodolite. The microprocessor in TS can perform various mathematical operations such as averaging, multiple angle and distance measurements, horizontal and vertical distances, X, Y, Z coordinates, distance between observed points and corrections for atmospheric and instrumental corrections.

Due to the versatility and the lower cost of electronic components, future field instruments will be more like total stations that measure angle and distance simultaneously having:

- all capabilities of theodolites
- electronic recording of horizontal and vertical angles
- Storage capabilities of all relevant measurements (spatial and non-spatial attribute data) for manipulation with computer
- Nowadays surveying systems are available which can be use in an integrated manner with Global Positioning System (GPS). Hence, future theodolites/total stations may have integrated GPS receivers as part of the measurement unit.

Advantages of Total Station:

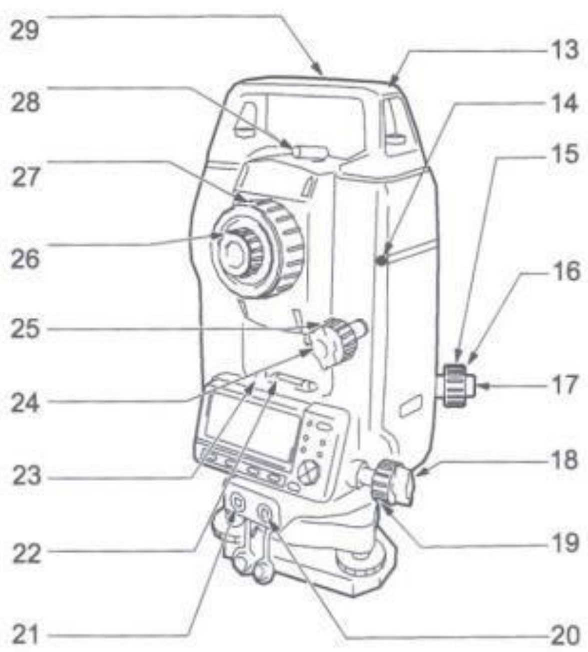
- ➢ Relatively quick collection of information
- ➢ Multiple surveys can be performed at one set-up location.
- ➢ Easy to perform distance and horizontal measurements with simultaneous calculation of project coordinates (Northings, Eastings, and Elevations).

➢ Layout of construction site quickly and efficiently.
➢ Digital design data from CAD programs can be uploaded to data collector.
➢ Daily survey information can also be quickly downloaded into CAD which eliminates data manipulation time required using conventional survey techniques.

Disadvantages of Total Station:

➢ Vertical elevation accuracy not as accurate as using conventional survey level and rod technique.
➢ Horizontal coordinates are calculated on a rectangular grid system. However, the real world should be based on a spheroid and rectangular coordinates must be transformed to geographic coordinates if projects are large scale. Examples: highways, large buildings, etc.
➢ As with any computer-based application "Garbage in equals Garbage out". However, in the case of inaccurate construction surveys "Garbage in equals lawsuits and contractors claims for extras."

<u>Parts of Total Station:</u>



13 Tubular compass slot
14 Beam detector for wireless keyboard (Not included on SET610/610S)
15 Optical plummet focussing ring
16 Optical plummet reticle cover
17 Optical plummet eyepiece
18 Horizontal clamp
19 Horizontal fine motion screw
20 Data input/output connector (Beside the operation panel on SET610/610S)
21 External power source connector (Not included on SET610/610S)
22 Plate level
23 Plate level adjusting screw
24 Vertical clamp
25 Vertical fine motion screw
26 Telescope eyepiece
27 Telescope focussing ring
28 Peep sight
29 Instrument center mark

Field techniques with TS:

Various field operations in TS are in the form of wide variety of programs integrated with microprocessor and implemented with the help of data collector. All these programs need that the instrument station and at least one reference station be identified so that all subsequent stations can be identified in terms of (X, Y, Z). Typical programs include the following functions:

- Point location
- Slope reduction
- Missing line measurement (MLM)
- Resection
- Azimuth calculation
- Remote distance and elevation measurement
- Offset measurements
- Layout or setting out operation
- Area computation
- Tracking

FUNCTIONS PERFORMED BY TOTAL STATIONS

Total Stations, with their microprocessors, can perform a variety of functions and computations, depending on how they are programmed. The capabilities vary with different instruments, but some standard computations include:

- Averaging multiple angle and distance measurements.
- Correcting electronically measured distances from prism constant, atmospheric pressure, and temperature.
- Making curvature and refraction corrections to elevations determine by trigonometric levelling.
- Reducing slope distances to their horizontal and vertical components.
- Calculating point elevations from the vertical distance components (supplemented with keyboard input of instrument and reflector heights).
- Computing coordinates of survey points from horizontal angle and horizontal distance.
    - Averages multiple angle measurements.
    - Averages multiple distance measurements.
    - Computes horizontal and vertical distances.
    - Corrections for temp, pressure and humidity.
    - Computes inverses, polars, resections.
    - Computes X, Y and Z coordinates.

Applications of Total Station

There are many other facilities available, the total station can be used for the following purposes.

- Detail survey i.e., data collection. Control Survey (Traverse).
- Height measurement (Remove elevation measurement- REM). Fixing of missing pillars (or) Setting out (or) Stake out.
- Resection.
- Area calculations, etc.
- Remote distance measurement (RDM) or Missing line measurement (MLM).

Global Positioning System:

History:

The GPS project was launched in the United States in 1973 to overcome the limitations of previous navigation systems,[11] integrating ideas from several predecessors, including a

Introduction:

- Official name of GPS is Navigational Satellite Timing And Ranging Global Positioning System (NAVSTAR GPS)
- Global Positioning Systems (GPS) is a form of Global Navigation Satellite System (GNSS)
- GPS is funded and controlled by the U. S. Department of Defense (DOD). While there are many thousands of civil users of GPS world-wide, the system was designed for and is operated by the U. S. military.
- The GPS receivers convert the satellite's signals into position, velocity, and time estimates for navigation, positioning, or geodesy.
- Four GPS satellite signals are used to compute positions in three dimensions and the time offset in the receiver clock.
- GPS units are becoming smaller and less expensive, there are an expanding number of applications for GPS. In transportation applications, GPS assists pilots and drivers in pinpointing their locations and avoiding collisions.
- GPS can provide accurate positioning 24 hours a day, anywhere in the world. Uncorrected positions determined from GPS satellite signals produce accuracies in the range of 50 to 100 meters. When using a technique called differential correction, users can get positions accurate to within 5 meters or less.
- Billions and billions of dollars have been invested in creating this technology for military uses. However, over the past several years, GPS has proven to be a useful tool in non-military mapping applications as well.
- The Term GPS stands for Global Positioning System. The GPS is used to locate a location with the help of Latitude and Departure. With the help of GPS it's possible to locate a point very precisely. GPS consist of two main ends, the one is the Locating Sattelites and the other is the Receiver. Most of the people now a days are familier with GPS due to the huge use of Smart Phones.

Advantages

- It helps to survey with many times greater Precision.
- It helps to complete a Survey with lesser time and thus helps to cut down the Completion Period.
- It Reduces the Difficulty of taking manual measurements to great extent.
- With GPS there is a very less chances of error. And this error may come only due to the Instrument malfunction.

Disadvantages

- The main Disadvantage is that, it requires high initial investments.
- To conduct such High End Survey works and to operate such Electronic Equipments much skilled persons are required.

Application of GPS:

Some of these applications are:

- Establishment of high precision zero order Geodetic National Survey Control Network of GPS stations.
- Strengthening, densification and readjustment of existing Primary Control Networks using GPS stations.
- Connecting remote islands to mainland Geodetic Control Networks. Determination of a precise geoid using GPS data.
- Earth rotation and Polar Motion Studies from GPS data. Estimating gravity anomalies using GPS.
- Marine Geodesy: positioning of oceanic stations, buoys etc.
- Earthquake monitoring: Crustal movements of the order of few cm/year can be monitored using GPS method, thus making GPS most suitable for monitoring continental drifts, seism tectonic movement, etc.
- Vertical Control Network : High accuracy of few mm in heights achievable with GPS at much less cost and time compared to levelling to make GPS method most suitable for establishing lower accuracy vertical control networks.
- Geophysical positioning, mineral exploration and mining. Survey control for topographical and cadastral surveys.
- Ground control for photogrammetric control surveys and mapping. Offshore positioning: Shipping, offshore platforms, fishing boats etc.
- Instantaneous time transfer over trans-continental distances with accuracies of few nano seconds.
- Space craft tracking: Vector separation between GPS satellites and any other satellites can be monitored by GPS, e.g., pinpointing the location of LANDSAT etc.
- General aircraft navigation, approach to runways, navigation/positioning in remote areas like deserts, dense jungles, shaded areas of microwave, precise sea navigation, approach to harbours etc. It is expected that in 1990s most civilian aircrafts, ships, boats will be fitted with GPS equipment’s and even hikers, boat and car owners, truck drivers will be using it extensively.,
- Military ; Improved weapon delivery accuracies i.e. for missiles etc., for ranging in artillery, navigation for Army, Navy, Airforce - thus affecting ultimate saving of upto 1billion dollars annually on navigation in U.S.A.
- Scientific applications, like studies related to the ionosphere and troposphere, glaciology, etc.

Module V: (6 hours)

Photogrammetry Surveying: Introduction, basic concepts, perspective geometry of aerial photograph, relief and tilt displacements, terrestrial photogrammetry, flight planning, stereoscopy, ground control extension for photographic mapping- aerial triangulation, No. of Photographs, mosaic

The photogrammetry has been derived from three Greek words:

- Photos: means light
- Gramma: means something drawn or written
- Metron: means to measure
- Photo = "Picture“, Grammetry = "Measurement“,
- therefore **Photogrammetry = “Photo-Measurement”**
- Objects are measured **WITHOUT TOUCHING**.
- It is a **REMOTESENSING** technique.
- It is a close range method of measuring objects.
- It is a 3-dimensional coordinate measuring technique that uses **PHOTORAPHS** as the fundamental medium for measurement.

Photogrammetric Surveying:

- It is the branch of surveying in which maps are prepared from photographs taken from ground or air stations. Photographs are also being used for interpretation of geology, classification of soils, crops, etc.
- The art, science, and technology of obtaining reliable information about physical objects and the environment through process of recording, measuring, and interpreting photographic images and patterns of recorded radiant electromagnetic energy and phenomenon.
- Originally photogrammetry was considered as the science of analysing only photographs.

Advantages and Disadvantages:

Some advantages of photogrammetry over conventional surveying and mapping methods are:

- It provides a permanent photographic record of conditions that existed at the time the aerial photographs were taken. Since this record has metric characteristics, it is not only a pictorial record but also an accurate measurable record.
- If information has to be re-surveyed or re-evaluated, it is not necessary to perform expensive field work. The same photographs can be measured again and new information can be compiled in a very timely fashion. Missing information, such as inadequate offsets for cross sections, can be remedied easily.

- It can provide a large mapped area so alternate line studies can be made with the same data source can be performed more efficiently and economically then other conventional methods.
- It provides a broad view of the project area, identifying both topographic and cultural features.
- It can be used in locations that are difficult, unsafe, or impossible to access. Photogrammetry is an ideal surveying method for toxic areas where field work may compromise the safety of the surveying crew.
- An extremely important advantage of photogrammetry is that road surveys can be done without closing lanes, disturbing traffic or endangering the field crew. Once a road is photographed, measurement of road features, including elevation data, is done in the office, not in the field.
- Intervisibility between points and unnecessary surveys to extend control to a remote area of a project are not required. The coordinates of every point in the mapping are be determined with no extra effort or cost.
- Aerial photographs can be used to convey or describe information to the public, State and Federal agencies, and other divisions within the Department of Transportation.

Some disadvantages are:

- Weather conditions (winds, clouds, haze etc.) affect the aerial photography process and the quality of the images.
- Seasonal conditions affect the aerial photographs, i.e., snow cover will obliterate the targets and give a false ground impression. Therefore, there is only a short time normally November through March,that is ideal for general purpose aerial photography. A cleared construction site or a highway that is not obstructed by trees, is less subjected to this restriction. These types of projects can be flown and photographed during most of the year.
- Hidden grounds caused by man-made objects, such as an overpass and a roof, cannot be mapped with photogrammetry. Hidden ground problems can be caused by tree canopy, dense vegetation, or by rugged terrain with sharp slopes. The information hidden from the camera must be mapped with other surveying methods.
- The accuracy of the mapping contours and cross sections depends on flight height and the accuracy of the field survey.

History of Photogrammetry:

- 1851: French officer Aime Laussedat develops the first photogrammetrical devices and methods. He is seen as the initiator of photogrammetry.
- 1858: The German architect A. Meydenbauer develops photogrammetrical techniques for the documentation of buildings and installs the first photogrammetric institute in 1885 (Royal Prussian Photogrammetric Institute).
- 1885: The ancient ruins of Persepolis were the first archaeological object recorded photogrammetrically.
- 1889: The first German manual of photogrammetry was published by C. Koppe.
- 1911: The Austrian Th. Scheimpflug finds a way to create rectified photographs. He is

considered as the initiator of aerial photogrammetry, since he was the first succeeding to apply the photogrammetrical principles to aerial photographs
- 1913: The first congress of the ISP (International Society for Photogrammetry) was held in Vienna.
- 1980: Due to improvements in computer hardware and software, digital photogrammetry is gaining more and more importance.
- 1996: 83 years after its first conference, the ISPRS comes back to Vienna, the town, where it was founded.

Classification of Photogrammetry:

Photogrammetry is divided into different categories according to the types of photographs or sensing system used or the manner of their use as given below:

1. **On the basis of orientation of camera axis:**

- Terrestrial or ground photogrammetry : When the photographs are obtained from the ground station with camera axis horizontal or nearly horizontal
- Aerial photogrammetry: If the photographs are obtained from an airborne vehicle. The photographs are called vertical if the camera axis is truly vertical or if the tilt of the camera axis is less than 3°. If tilt is more than (often given intentionally), the photographs are called oblique photographs.

2. **On the basis of sensor system used:**

Following names are popularly used to indicate type of sensor system used:

- Radargrammetry: Radar sensor
- X-ray photogrammetry: X-ray sensor
- Hologrammetry: Holographs
- Cine photogrammetry: motion pictures
- Infrared or colour photogrammetry: infrared or colour photographs

3. **On the basis of principle of recreating geometry:**

- When single photographs are used with the stereoscopic effect, if any, it is called Monoscopic Photogrammetry.
- If two overlapping photographs are used to generate three dimensional view to create relief model, it is called Stereo Photogrammetry. It is the most popular and widely used form of photogrammetry.

4. **On the basis of procedure involved for reducing the data from photographs:**

Three types of photogrammetry are possible under this classification:

- Instrumental or Analogue photogrammetry: It involves photogrammetric instruments to carry out tasks.

- Semi-analytical or analytical: Analytical photogrammetry solves problems by establishing mathematical relationship between coordinates on photographic image and real world objects. Semi-analytical approach is hybrid approach using instrumental as well analytical principles.
- Digital Photogrammetry or softcopy photogrammetry: It uses digital image processing principle and analytical photogrammetry tools to carry out photogrammetric operation on digital imagery.

5. **On the basis of platforms on which the sensor is mounted:**

- If the sensing system is space borne, it is called **Space Photogrammetry, Satellite Photogrammetry or Extra-terrestrial Photogrammetry**. Out of various types of the photogrammetry, the most commonly used forms are **Stereo Photogrammetry** utilizing a pair of vertical aerial photographs (stereo pair) or terrestrial photogrammetry using a terrestrial stereo pair.

Application of Photographic Survey:

Photogrammetry has been used in several areas. The following description give an overview of various applications areas of photogrammetry

1. **Geology:** Structural geology, investigation of water resources, analysis of thermal patterns on earth's surface, geomorphological studies including investigations of shore features.

- Stratigraphic studies
- General geologic applications
- Study of luminescence phenomenon
- Recording and analysis of catastrophic events
- Earthquakes, floods, and eruption.

2. **Forestry:** Timber inventories, cover maps, acreage studies

3. **Agriculture:** Soil type, soil conservation, crop planting, crop disease, crop-acreage.
4. **Design and construction:** Data needed for site and route studies specifically for alternate schemes for photogrammetry. Used in design and construction of dams, bridges, transmission lines.
5. **Planning of cities and highways:** New highway locations, detailed design of construction contracts, planning of civic improvements.
6. **Cadastre:** Cadastral problems such as determination of land lines for assessment of taxes. Large scale cadastral maps are prepared for reapportionment of land.

7. **Environmental Studies:**
8. **Land-use studies.**
9. **Urban area mapping.**
10. **Exploration:** To identify and zero down to areas for various exploratory jobs such as oil or mineral exploration.
11. **Military intelligence**: Reconnaissance for deployment of forces, planning manoeuvres, assessing effects of operation, initiating problems related to topography, terrain conditions or works.
12. **Medicine and surgery**: Stereoscopic measurements on human body, X-ray photogrammetry in location of foreign material in body and location and examinations of fractures and grooves, biostereometrics
13. **Mountains and hilly areas can be surveyed easily.**
14. **Miscellaneous**

Classification of Photographs:

The following paragraphs give details of classification of photographs used in different applications

1. **On the basis of the alignment of optical axis**

- **Vertical:** If optical axis of the camera is held in a vertical or nearly vertical position.
- **Tilted:** An unintentional and unavoidable inclination of the optical axis from vertical produces a tilted photograph.
- **Oblique:** Photograph taken with the optical axis intentionally inclined to the vertical. Following are different types of oblique photographs:
- **High oblique:** Oblique which contains the apparent horizon of the earth.
- **Low oblique:** Apparent horizon does not appear.
- **Trimetrogon:** Combination of a vertical and two oblique photographs in which the central photo is vertical and side ones are oblique. Mainly used for reconnaissance.
- **Convergent:** A pair of low obliques taken in sequence along a flight line in such a manner that both the photographs cover essentially the same area with their axes tilted at a fixed inclination from the vertical in opposite directions in the direction of flight line so that the forward exposure of the first station forms a stereo-pair with the backward exposure of the next station.

Comparison of photographs

Type of photo	**Vertical**	**Low oblique**	**High oblique**
Characteristics	Tilt < 3^o	Horizon does not appear	Horizon appears
Coverage	Least	Less	Greatest
Area	Rectangular	Trapezoidal	Trapezoidal
Scale	Uniform if flat	Decreases from foreground to background	Decreases from foreground to background
Difference with map	Least	Less	Greatest

Advantage	Easiest to map	-	Economical and illustrative

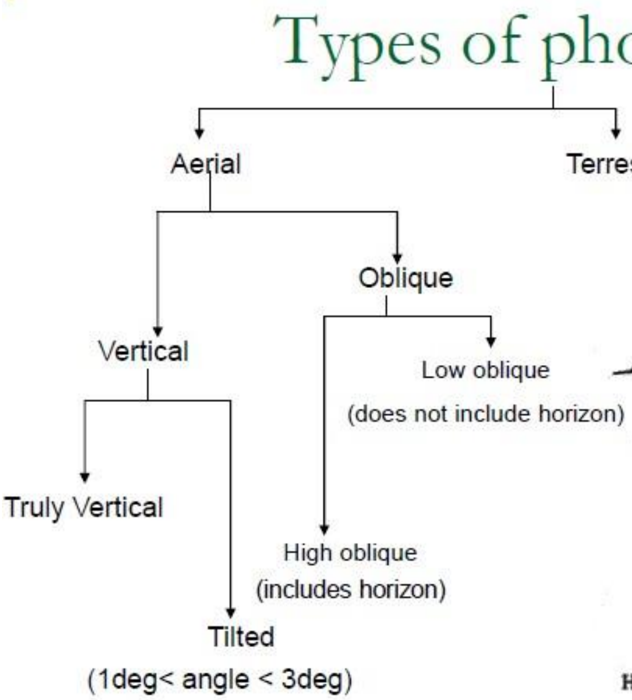
On the basis of the scale

- **Small scale** - 1: 30000 to 1: 250000, used for rigorous mapping of undeveloped terrain and reconnaissance of vast areas.
- **Medium scale** - 1: 5000 to 1: 30000, used for reconnaissance, preliminary survey and intelligence purpose.
- **Large scale** - 1: 1000 to 1: 5000, used for engineering survey, exploring mines.

On the basis of angle of coverage

- The angle of coverage is defined as the angle, the diagonal of the negative format subtends at the real node of the lens of the apex angle of the cone of rays passing through the front nodal point of the lens.

Name	Coverage angle
Standard or normal angle	60°
Wide angle	90°
Super wide or ultra wide angle	
Narrow angle	< 60°



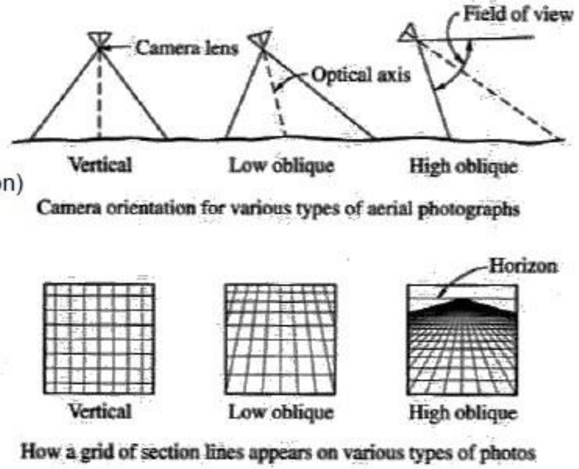


FIGURE 1-6
Camera orientation for various types of aerial photographs.

Introductory definitions of Aerial Photogrammetry:

i. **Vertical photograph**: A photograph taken with the optical axis coinciding with direction of gravity.
ii. **Tilted or near vertical :** Photograph taken with optical axis unintentionally tilted from vertical by a small amount (usually < 3°)
iii. **Focal length (f):** Distance from front nodal point to the plane of the photograph (from near nodal point to image plane).
iv. **Exposure station (point L) :** Position of frontal nodal point at the instant of exposure (L)

v. **Flying height (H):** Elevation of exposure station above sea level or above selected datum.
vi. **Principal point:** The point where the perpendicular dropped from the front nodal point meets/strikes the plane of photograph.
vii. **Principal Line**: The trace (intersection) of the principal plane upon the photograph; also, the line on the photograph which passes through the principal point and the nadir point (and the "isocenter").
viii. **Tilt**: The angle formed between the optical axis of the camera and the plumb line.
ix. **Isocentre:** The point where the bisector of angle of tilt meets the plane of photograph.
x. **Ground Nadir:** The point on the ground that is vertically beneath (directly below) the perspective center of the camera lens.

xi. **Nadir Point or Photographic Nadir:** The point on the photograph which corresponds to the ground nadir. The point at which a vertical line (plumb line) from the perspective center to the ground nadir intersects the photograph.
xii. **Photograph Perpendicular:** The perpendicular from the interior perspective center (real nodal point) to the plane of the photograph.
xiii. **Photograph Center:** The point on the photograph that is located at the intersection of the fiducial axes. (The photograph center is sometimes called the "center of collimation.") In a perfectly adjusted camera, the photograph center and the principal point are identical (i.e., unless camera calibration indicates otherwise, the principal point is generally assumed to coincide with the photography center).
xiv. **Scale:** The ratio of a distance on a photograph or map to its corresponding distance on the ground. Although photographic scale varies from point to point (due to relief and/or tilt), it is usually taken as f/H' . . . where f = focal length and H' = height of camera above mean ground elevation. Scale may be expressed as a ratio (1:24,000), a fraction (1/24,000), or an equivalence (1 in. = 2,000 ft.).

xv. **Relief Displacement:** If a ground object is below (above) the elevation of the ground nadir, its image will be displaced radially inward (outward) with respect to the nadir point. Relief displacements may be measured accurately from the photography center if two conditions are met: (1) the photography is truly vertical (i.e., the nadir and principal points coincide), and (2) the camera is in perfect adjustment (i.e., the principal point and photograph center coincide).

xvi. **Overlap**: The amount by which one photograph covers the same area as covered by another (customarily expressed as a percentage). The overlap between aerial photographs in the same flight line is called "end lap," and the overlap between photographs in adjacent, parallel flight lines is called "side lap."

xvii. **Parallax Difference:** The difference in the absolute stereoscopic parallaxes of two points imaged on a pair of photographs. Customarily used to determine the elevation difference between the two objects.

xviii. **Azimuth:** The horizontal angle measured clockwise about the ground nadir from a reference plane (usually the ground-survey north meridian) to the principal plane. (The azimuth of a photograph is the ground-survey direction of tilt, while swing is the direction of tilt with respect to the photograph axes).

Scale of a Vertical Photograph / Scale of Photograph:

CASE-I: Due to perspective geometry of photographs, the scale of photograph varies as a function of focal length, flying height, and the reduced level of terrain over a certain reference datum. In the figure given below, for a vertical photograph,

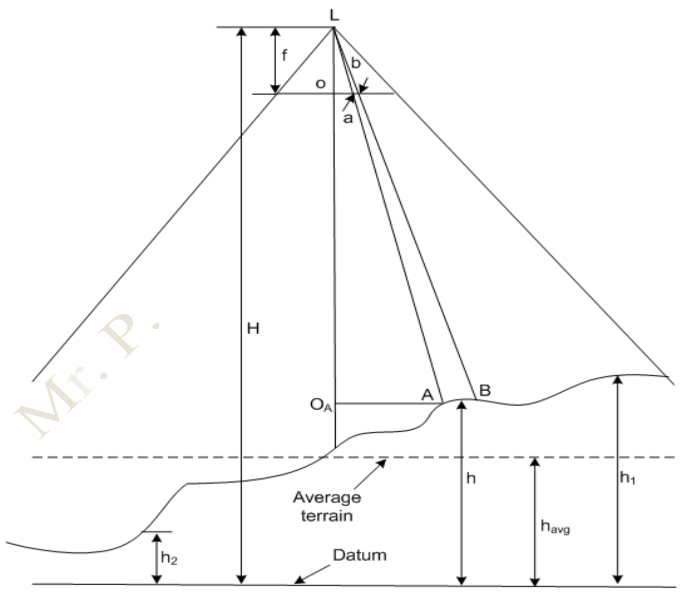
L = Exposure station

f = Focal length

H = Flying height above datum

h = the height of ground point A above datum.

Point A is imaged as a in the photograph. From the construction and using similar triangles Loa and LOAA, we can write the following relations:



Determination of Scale of photograph

Scale of photograph can be determined by various methods such as

- By using known full length and altimeter reading, the datum scale can be found.

- Any scale can be determined if h_{avg} known. h_{avg} can be obtained from a topographic map.
- By comparing length of the line on the photo with the corresponding ground length. To arrive at fairly representative scale for entire photo, get several lines in different area and the average of various scales can be adopted.
- Use the formula

$$\frac{\text{Photo Scale}}{\text{Map Scale}} = \frac{\text{Photo Distance}}{\text{Map Distance}}$$

$$\text{Scale} = \frac{ao}{AO_A} = \frac{f}{H - h_A}$$

$$\text{Datum Scale} = S_d = \frac{f}{H}$$

$$\text{Average Scale} = S_{avg} = \frac{f}{H - h_{avg}}$$

CASE-II:

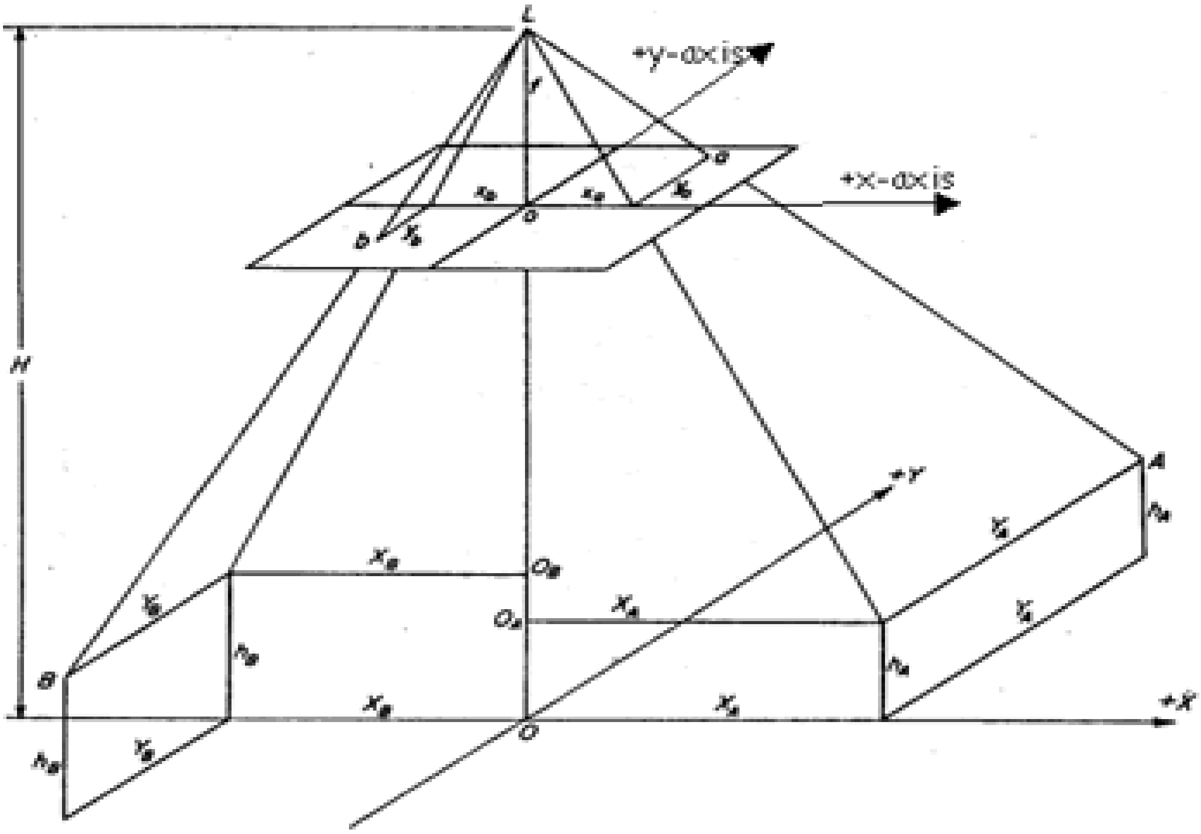
In the figure given below, X and Y are ground co-ordinates with respect to a set of axes whose directions are parallel with the photographic axes and whose origin is directly below the exposure station, x and y indicate x and y photo coordinates with respect to the photo coordinate system with origin at o axes as shown. Using similar triangles, we can write the following relations:

$$\frac{Lo}{LO_A} = \frac{x_a}{X_A} = \frac{y_a}{Y_A} = \frac{f}{H - h_A}$$

$$\frac{Lo}{LO_B} = \frac{x_b}{X_B} = \frac{y_b}{Y_A} = \frac{f}{H - h_B}$$

$$X = \frac{H - h}{f} . x$$

$$Y = \frac{H - h}{f} . y$$



In this method, if the ground coordinates of two points, A and B are given (X_A, Y_A) and (X_B, Y_B), then distance (D) is given by:

$$D^2 = (\text{length of line})^2 = (X_A - X_B)^2 + (Y_B - Y_A)^2$$

$$D^2 = \left[\frac{H - h_B}{f} \cdot x_b - \frac{H - h_A}{f} \cdot x_a\right]^2 + \left[\frac{H - h_B}{f} \cdot y_b - \frac{H - h_A}{f} \cdot y_a\right]^2$$

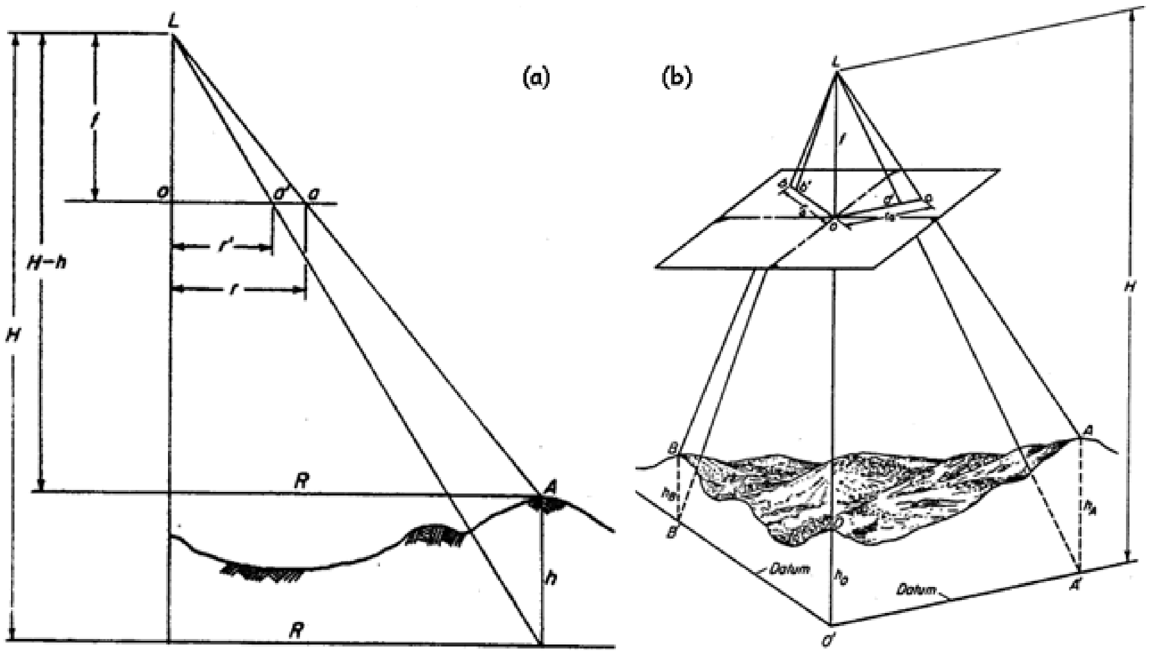
$$aH^2 + bH + c = 0$$

$$H = \frac{-b + \sqrt{b^2 - 4ac}}{2a}$$

Relief displacement on Vertical photographs:

Relief displacement is the radial distance between where an object appears in an image to where it actually should be according to a **Planimetric** coordinate system. The images of ground positions are shifted or displaced due to terrain relief, in the central projection of an aerial photograph. If a photograph is truly vertical, the displacement of images is in a direction radial from the photograph centre. This displacement is called the radial displacement due to relief. Radial displacement due to relief is also responsible for scale differences within any one photograph, and for this reason a photograph is not an accurate map. Relief displacement is caused by differences in relative elevation of objects photographed. All objects that extend above or below a datum plane have their photographic images displaced to a greater or lesser extent. This displacement occurs always along the line which connects the photo point and the nadir and is, therefore termed “radial line displacement”. Or this displacement is always radial with respect to principal point. It increases with increasing height of the feature and the distance from nadir.

In figure, **L** is the perspective center of the camera system. **A** is the point on ground at an elevation of **h** with respect to the datum. **a** is the image of ground point on photograph. **a'** is the location of projected point **A'** on the datum. These figures indicate that although point **A** is vertically above point **B**, their images are not coinciding and are displaced on photographic plane due to relief.



- The displacement of the point a on the photograph from its true position, due to height, is called the height or relief displacement or relief distortion (RD). This distortion is due to the perspective geometry.
- It can also be noticed form these figures that the relief displacement is radial from nadir point. In case of vertical photographs, the nadir point and the principal point coincide. Hence, in this case relief displacement can be considered to be radial from the principal point also. The following derivation using figure 4(a) provides the magnitude of relief distortion

$$\frac{f}{H-h}=\frac{r}{R}$$

$$\frac{f}{H}=\frac{r'}{R}$$

$$r=\frac{Rf}{Hh}\ and\ r'=\frac{Rf}{H}$$

$$R=\frac{r(H-h)}{f}\quad and\quad R=\frac{r'H}{f}$$

$$\text{Relif Distortion }=d=r-r'=\frac{Rf}{H-h}-\frac{Rf}{H}=\frac{Rfh}{H(H-h)}$$

$$d=r-r'=\frac{rh}{H}=\frac{r'h}{H-h}$$

Differentiating d with respect to H gives the following equations:

$$\frac{\partial d}{\partial H}=-\frac{rh}{H^2}$$

From these equations, the following observations can be made:

i. For a given elevation, RD of a point increases as the distance from principal point increases.
ii. Other things being equal, an increase in H decreases RD of a point. (This point is important for mosaicing or combining photographs along common features). For the same reason, for satellite imagery, RD is very small since H is large.
iii. If ground point is above datum then RD will be outward or positive; if point below datum then h has negative sign and RD will be inward or negative.
iv. RD is radial from nadir point regardless of unintentional or accidental tilt of the camera. This is a fundamental concept of photography. It has important implication for photo rectification (this concept will not be discussed in this course).
v. Large relief displacement is objectionable in pure plannimetric mapping by

graphical methods but advantageous in contouring with stereoplotting instruments. Most effective way to control RD is to select proper flying height.

Number of Photographs:

CASE-I: The number of photographs required is calculated by dividing the total area to be photographed by net area covered by a single photograph.

So, $$\boxed{\text{Number of Photographs (N)} = \frac{A}{a}}$$

Let,

A = Total area to be photographed

l = Length of the photograph in the direction of flight

w = Width of the photograph normal to the direction of flight L = Actual ground length covered by each photograph

W = Actual ground width covered by each photograph a = Net ground area covered by each photograph

P_l = % of overlap between successive photographs in the direction of flight (expressed as ratio)

P_w= % of side lap (expressed as ratio)

$$S = \text{Scale of the photograph} = \frac{H\ (cm)}{f\ (cm)} = \frac{\text{Height above the ground}}{\text{Focal Length}}$$

$$L = (1 - P_l) \times S \times l$$

$$W = (1 - P_w) \times S \times w$$

$$a = L \times W$$

$$\text{So, } N = \frac{A}{a}$$

$$\text{Number of Photographs (N)} = \frac{A}{a}$$

CASE-II:

If the rectangular dimensions (length and width) of ground are given, the number of photographs required are computed by calculating the number of strips and the number of photographs required in each strip and multiplying two.

Let,

L_1 = dimension of the area parallel to the direction of flight

L_2 = dimension of the area normal to the direction of flight

N_1 = Number of photographs in each strip

N_2 = Number of strips required

N = Total number of photographs to covered the whole area Now, net length covered by each photograph = L= (1- P_l) ×S×l

Similarly, net width covered by each photograph = W= (1- P_w) ×S×w

So, N_1 = Number of photographs in each strip is given by = $\frac{L1}{L} + 1$

And, N_2 = Number of strips required = $\frac{L2}{W} + 1$

So, Total number of Photographs = N = $N_1 \times N_2$

Module VI [6hrs]
Remote Sensing: Introduction and Definition of remote sensing terms, Remote sensing system, electromagnetic radiation and spectrum, atmospheric window, different types of platforms, sensors and their characteristics, orbital parameters of a satellite, multi concept in remote sensing.

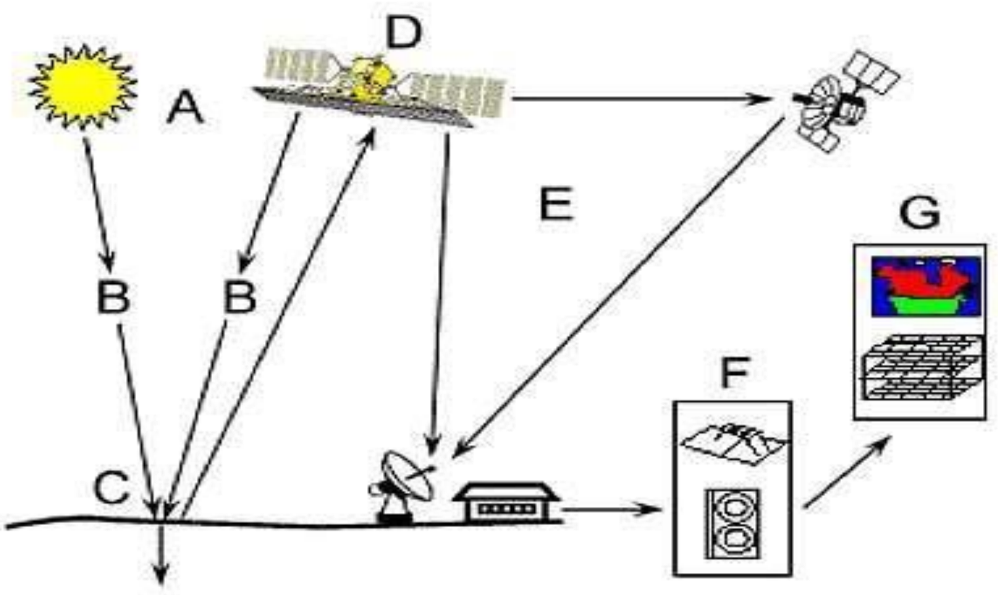
Remote sensing:

History:

- Indian remote sensing program was initiated in 1970, following the successful demonstration flights of Bhaskara-1 and Bhaskara-2 satellites launched in 1979 and 1981, India began to develop the indigenous Indian Remote Sensing (IRS) satellite program to support the national economy in the areas of agriculture, water resources, forestry and ecology, geology, water sheds, marine fisheries and coastal management and launched first IRS sat in 1989.
- India established the National Natural Resources Management System (NNRMS) for which the Department of Space (DOS) is the nodal agency, providing operational remote sensing data services.
- With the advent of high-resolution satellites new applications in the areas of urban sprawl, infrastructure planning and other large scale applications for mapping have been initiated.
- The IRS system is the largest constellation of remote sensing satellites for civilian use in operation today in the world, with 10 operational satellites. All these are placed in polar sun synchronous orbit and provide data in a variety of spatial, spectral and temporal resolutions.

Remote sensing is science of

- acquiring,
- processing, and
- interpreting



Images and related data that are obtained from ground-based, air-or space-borne instruments that record the interaction between matter (target) and electromagnetic radiation**. Remote Sensing:** using electromagnetic spectrum to image the land, ocean, and atmosphere.

Advantages

- It is relatively Inexpensive. The cost of software and data (which often represents a one-off cost) is less expensive than sending teams of surveyors out into the field.
- Current (within reason). One particular problem that the developing world faces is that data is old or out of date. Satellite imagery can be acquired for free from the last decade and contemporary data can be acquired fairly inexpensively.
- Provides data about large areas.
- Provides data about inaccessible areas - or even if they’re not inaccessible, then at least you don’t have to go there.
- Rapid production of maps possible.
- Easy to manipulate (relatively!) with computers and derive information for map production.
- Rapid collection of data – much more efficient that ground survey.

Disadvantages

- There will be doubtful and uncertainties of classification related to pixel size. A full field check will be necessary to resolve ground use in these areas.
- Datasets from multiple sources are sometimes difficult to geo reference. Using images and maps that are drawn in different scales and projections can lead to difficulty combining them.
- The sensor performs a sweep and as such can create errors. i.e., only some of the image is directly below the sensor and so pixels toward the edge of the image may be distorted.
- Objects in the image can be confused or mis-classified. For example, shadows may look like metalled roads.
- To get any level of detailed, current data and to buy specialist RS software can be expensive.
- In some active sensing systems (such as lidar) the sensor and source are moving relative to each other distortions can creep to the image. This is a form of Doppler Effect (the visual equivalent of a police siren changing pitch as it moves closer or further away from you).
- The interpretation of imagery requires a certain skill level
- Needs cross verification with ground (field) survey data
- Data from multiple sources may create confusion
- Objects can be misclassified or confused
- Distortions may occur in an image due to the relative motion of sensor and source

Types of remote sensing:

I. Based on Source of Light

- **Passive:** source of energy is either the Sun or Earth/atmosphere
  - Sun
    - wavelengths: 0.4-5 μm
  - Earth or its atmosphere
    - wavelengths: 3 μm - 30 cm

- **Active:** source of energy is part of the remote sensor system
  - Radar
    - wavelengths: mm-m
  - Lidar
    - wavelengths: UV, Visible, and near infrared

i. **Passive remote sensing:**
   - It generally consists of an array of small sensors or detectors, which records the amount of electro-magnetic radiation reflected and/or emitted from the Earth's surface. Thus, passive remote sensing relies on naturally reflected or emitted energy of the imaged surface. Most remote sensing instruments fail into this category, obtaining pictures of visible, near-infrared and thermal infrared energy.
   - It can acquire the data only in presence of solar light.
   - High initial and maintenance cost.

ii. **Active remote sensing:**
   - This type of a system propagates its own electro-magnetic radiation and measures the intensity of the return signal. Thus, active remote sensing means that the sensor provides its own illumination and measures what comes back. Remote sensing technologies that use this type of system include lidar (laser) and radar.
   - It can acquire the data in all-weather condition.
   - High initial and maintenance cost.

II. **Based on Platform:**
   i. Ground-based platforms: ground, vehicles and/or towers => up to 50 m
   ii. Airborne platforms: airplanes, helicopters, high-altitude aircrafts, balloons => up to 50 km
   iii. Spaceborne: rockets, satellites, shuttle => from about 100 km to 36000 km

Ideal Remote Sensing System:

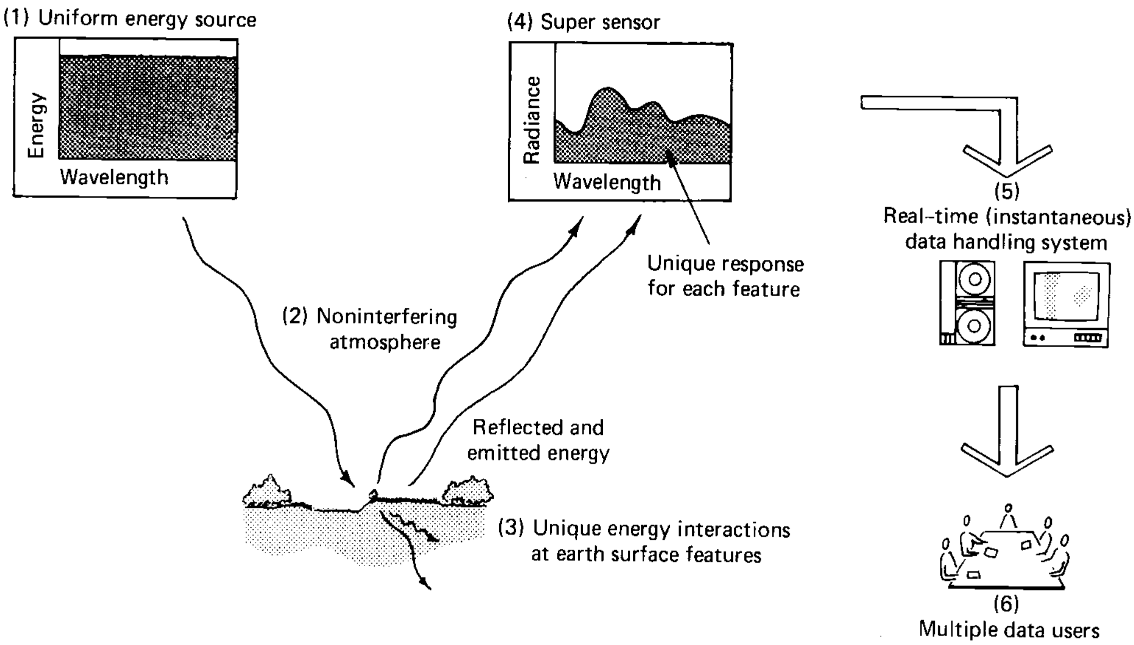
The basic components of an ideal remote sensing system include:

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 physical- chemical-biological state.

vi. Multiple Data Users having knowledge in their respective disciplines and also in remote sensing data acquisition and analysis techniques. The information collected will be available to them faster and at less expense. This information will aid the users in various decision making processes and also further in implementing these decisions.



[Components of an ideal remote sensing system]

Real remote sensing systems employed in general operation and utility have many shortcomings when compared with an ideal system explained above.

i. **Energy Source:** The energy sources for real systems are usually non-uniform over various wavelengths and also vary with time and space. This has major effect on the passive remote sensing systems. The spectral distribution of reflected sunlight varies both temporally and spatially. Earth surface materials also emit energy to varying degrees of efficiency. A real remote sensing system needs calibration for source characteristics.

ii. **The Atmosphere:** The atmosphere modifies the spectral distribution and strength of the energy received or emitted (Fig. 8). The effect of atmospheric interaction varies with the wavelength associated, sensor used and the sensing application. Calibration is required to eliminate or compensate these atmospheric effects.

iii. **The Energy/Matter Interactions at the Earth's Surface:** Remote sensing is based on the principle that each and every material reflects or emits energy in a unique, known way. However, spectral signatures may be similar for different material types. This makes differentiation difficult. Also, the knowledge of most of the energy/matter. interactions for earth surface features is either at elementary level or even completely unknown.

iv. **The Sensor**: Real sensors have fixed limits of spectral sensitivity i.e., they are not sensitive to all wavelengths. Also, they have limited spatial resolution (efficiency in recording spatial details). Selection of a sensor requires a trade-off between spatial resolution and spectral sensitivity. For example, while photographic systems have very good spatial resolution and poor spectral sensitivity, non-photographic systems have poor spatial resolution.

v. **The Data Handling System**: Human intervention is necessary for processing sensor data; even though machines are also included in data handling. This makes the idea of real time data handling almost impossible. The amount of data generated by the sensors far exceeds the data handling capacity.

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.

Application remote sensing:

The applications of remote sensing summarized below:

i. **Agricultural:** Agriculture plays an important role in economies of countries. The production of food is important to everyone and producing food in a cost-effective manner is the goal of every farmer and an agricultural agency. The satellites has an ability to image individual fields, regions and counties on a frequent revisit cycle. Customers can receive field-based information including crop identification, crop area determination and crop condition monitoring (health and viability). Satellite data are employed in precision agriculture to manage and monitor farming practices at different levels. The data can be used to farm optimization and spatially-enable management of technical operations. The images can help determine the location and extent of crop stress and then can be used to develop and implement a spot treatment plan that optimizes the use of agricultural chemicals. The major agricultural applications of remote sensing include the following: Vegetation, crop type classification, crop condition assessment (crop monitoring, damage assessment), crop yield estimation, soil, mapping of soil characteristics, mapping of soil type, soil erosion, soil moisture, mapping of soil management practices, compliance monitoring (farming practices)

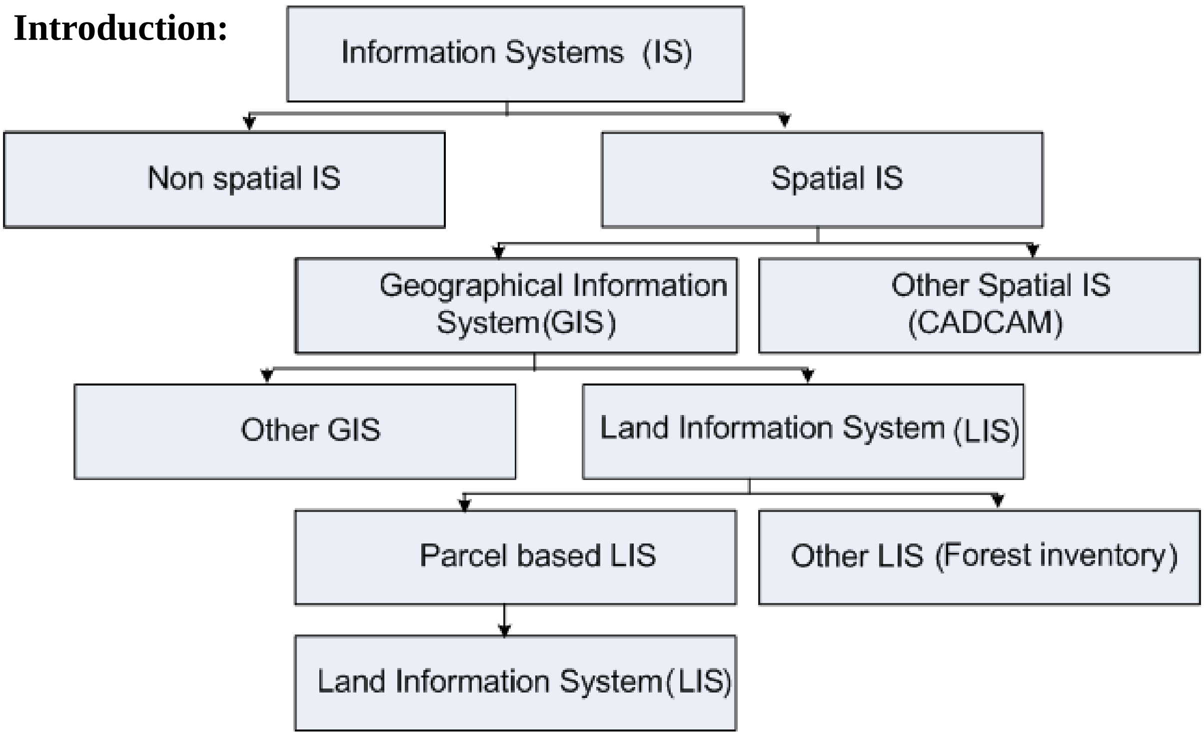
ii. **Forest mapping:** One of the basic applications is forest cover typing and species identification. Forest cover typing can consist of reconnaissance mapping over a large area, while species inventories are highly detailed measurements of stand contents and characteristics (tree type, height, density). Using remote sensing data we can identify and delineate various forest types that would be difficult and time consuming using traditional ground surveys. Data is available at various scales and resolutions to satisfy local or regional demands. Requirements for reconnaissance mapping depend on the scale of study.

iii. **Land cover mapping:** is one of the most important and typical applications of remote sensing data. Land cover corresponds to the physical condition of the ground surface, for example, forest, grassland, concrete pavement etc., while land use reflects human activities such as the use of the land, for example, industrial zones, residential zones, agricultural fields etc Initially the land cover classification system should be established, which is usually defined as levels and classes. The level and class should be designed in consideration of the purpose of use (national, regional or local), the spatial and spectral resolution of the remote sensing data, user's request and so on.

- Assessment and monitoring of vegetation types and their status.
- Monitoring and planning of water resources and groundwater exploration.
- Geographic information
- Urban planning.
- Laser film writing and printing.
- Satellite imagery can provide the visible boundaries of soil types, while remote sensing provide for a shallow penetration of soils. Additional physical data can be obtained from spectral signatures for the soil surfaces.
- Remote sensing allows for classification of soils, which can be interpreted from the remote sensing images and the spectral signatures.

Geographical Information System (GIS)

Introduction:



[Different types of information systems]

A large variety of information systems are available for various applications. Figure given below describes different types of such systems. This module will focus on Geographical Information System (GIS), one of the important spatial information systems with a capability to handle spatial information (information distributed in space).

Definitions

- A powerful set of tools for collecting, storing, retrieving at will, transforming and displaying spatial data from the real world.
- A system for capturing, storing, checking, manipulating, analysing, and displaying data which are spatially referenced to earth.
- An information technology which stores, analyses, and displays both spatial and non-spatial data.
- An automated set of functions that provides professionals with advanced capabilities for the storage, retrieval, manipulation and display of geographically located data.
- An institutional entity, reflecting an organisational structure that integrates technology with a database, expertise, and continuing financial support over time.
  A decision support system involving the integration of spatially referenced data in a problem solving environment
- An information system that is designed to work with data referenced by spatial or geographic co-ordinates. In other words, a GIS is both a database system with specific capabilities for spatially-referenced data, as well as a set of operations for working with the data. In a sense, a GIS may be thought of as a higher-order map.
- A system of hardware and software that links mapped objects with text information that describes them and provides tools for the storage, retrieval and manipulation of both types of data.
- A system of computer hardware, software and procedures designed to support the capture, management, manipulation, analysis, and display of spatially referenced data for solving complex planning and management problems.
- A system that contains spatially referenced data that can be analysed and converted to information for a specific set of purposes, or application. The key feature of a GIS is the analysis of data to produce new information.

Why GIS is required:

Use of GIS is advocated on account of following observations:

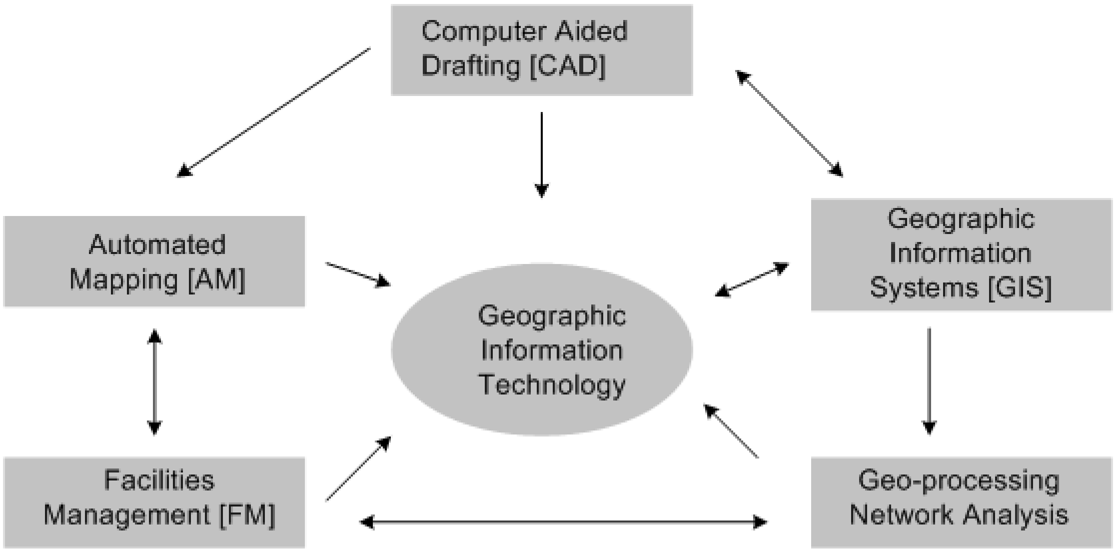
- Poorly maintained geospatial data
- Out of date maps and statistics
- Inaccurate data and information
- Absence of data retrieval service
- Absence of data sharing
- Digital format data is compact and large quantities can be maintained and retrieved at a greater speed and lesser cost
- Planning scenarios, decision models and interactive process are normal functions of GIS

- Ability to perform complex spatial analysis rapidly
- Ability to manipulate different types of data efficiently

Benefits of GIS

- Geospatial data better maintained in a standard format
- Revision and updating easier
- Geospatial data and information easier to search, analyze and represent
- Value added products can be generated
- Geospatial data can be shared and exchanged freely
- Productivity and efficiency of staff is improved
- Saving in time and money
- Better decisions making

GIS Synonyms:



Data Mode of GIS:

There are two fundamental ways of representing topological data which can be summarised as follows:

- Raster Form
- Vector Form

Raster Form	Vector Form
• A representation of the world as a surface divided into a regular grid of cells. Raster models are useful for storing data that varies continuously, as in an aerial photograph, a satellite image, a surface of chemical concentrations, or an elevation surface. • Simple data structure • Divides the entire area into rectangular grid cells. • Overlaid is very simple. • The basic symbol is grid cell. It gives high accuracy.	• A representation of the world using points, lines, and polygons. Vector models are useful for storing data that has discrete boundaries, such as country borders, land parcels, and streets. • More compact data structure • Divides the entire area into set of line segments. • Overlaid is very difficult. • The basic symbols are points, lines & polygons. • It gives less accuracy.

Application of GIS:

1. **GIS in Mapping:** Mapping is a central function of Geographic Information System, which provides a visual interpretation of data. GIS store data in database and then represent it visually in a mapped format. People from different professions use map to communicate. It is not necessary to be a skilled cartographer to create maps. Google map, Bing map, Yahoo map are the best example for web based GIS mapping solution.
2. **Telecom and Network services:** GIS can be a great planning and decision making tool for telecom industries. GDi GISDATA enables wireless telecommunication organizations to incorporate geographic data in to the complex network design, planning, optimization, maintenance and activities. This technology allows telecom to enhance a variety of application like engineering application, customer relationship management and location based services.
3. **Accident Analysis and Hot Spot Analysis:** GIS can be used as a key tool to minimize accident hazard on roads, the existing road network has to be optimized and also the road safety measures have to be improved. This can be achieved by proper traffic management. By identifying the accident locations, remedial measures can be planned by the district administrations to minimize the accidents in different parts of the world. Rerouting design is also very convenient using GIS.
4. **Urban Planning:** GIS technology is used to analyse the urban growth and its direction of expansion, and to find suitable sites for further urban development. In order to identify the sites suitable for the urban growth, certain factors have to consider which is: land should have proper accessibility, land should be more or less flat, land should be vacant or having low usage value presently and it should have good supply of water.
5. **Transportation Planning:** GIS can be used in managing transportation and logistical problems. If transport department is planning for a new railway or a road route then this can be performed by adding environmental and topographical data into the GIS platform. This will easily output the best route for the transportation based on the

criteria like flattest route, least damage to habitats and least disturbance from local people. GIS can also help in monitoring rail systems and road conditions.

6. **Environmental Impact Analysis**: EIA is an important policy initiative to conserve natural resources and environment. Many human activities produce potential adverse environmental effects which include the construction and operation of highways, rail roads, pipelines, airports, radioactive waste disposal and more. Environmental impact statements are usually required to contain specific information on the magnitude and characteristics of environmental impact. The EIA can be carried out efficiently by the help of GIS, by integrating various GIS layers, assessment of natural features can be performed.
7. **Agricultural Applications:** GIS can be used to create more effective and efficient farming techniques. It can also analyse soil data and to determine: what are the best crop to plant? Where they should go? How to maintain nutrition levels to best benefit crop to plant ?It is fully integrated and widely accepted for helping government agencies to manage programs that support farmers and protect the environment. This could increase food production in different parts of the world so the world food crisis could be avoided.
8. **Disaster Management and Mitigation**: Today a well-developed GIS systems are used to protect the environment. It has become an integrated, well developed and successful tool in disaster management and mitigation. GIS can help with risk management and analysis by displaying which areas are likely to be prone to natural or man-made disasters. When such disasters are identified, preventive measures can be developed.
9. **Landslide Hazard Zonation using GIS**: Landslide hazard zonation is the process of ranking different parts of an area according to the degrees of actual or potential hazard from landslides. The evaluation of landslide hazard is a complex task. It has become possible to efficiently collect, manipulate and integrate a variety of spatial data such as geological, structural, surface cover and slope characteristics of an area, which can be used for hazard zonation. The entire above said layer can well integrate using GIS and weighted analysis is also helpful to find Landslide prone area. By the help of GIS we can do risk assessment and can reduce the losses of life and property.
10. **Determine land use/land cover changes:** Land cover means the feature that is covering the barren surface .Land use means the area in the surface utilized for particular use. The role of GIS technology in land use and land cover applications is that we can determine land use/land cover changes in the different areas. Also it can detect and estimate the changes in the land use/ land cover pattern within time. It enables to find out sudden changes in land use and land cover either by natural forces or by other activities like deforestation.
11. **Navigation (routing and scheduling):** Web-based navigation maps encourage safe navigation in waterway. Ferry paths and shipping routes are identified for the better routing. ArcGIS supports safe navigation system and provides accurate topographic and hydrographic data. Recently DNR, s Coastal Resources Division began the task of locating, documenting, and cataloguing these no historic wrecks with GIS. This division is providing public information that make citizens awareness of these vessel locations through web map. The web map will be regularly updated to keep the boating public informed of these coastal hazards to minimize risk of collision and injury.

12. **Flood damage estimation:** GIS helps to document the need for federal disaster relief funds, when appropriate and can be utilized by insurance agencies to assist in assessing monetary value of property loss. A local government need to map flooding risk areas for evaluate the flood potential level in the surrounding area. The damage can be well estimate and can be shown using digital maps.
13. **Natural Resources Management:** By the help of GIS technology the agricultural, water and forest resources can be well maintain and manage. Foresters can easily monitor forest condition. Agricultural land includes managing crop yield, monitoring crop rotation, and more. Water is one of the most essential constituents of the environment. GIS is used to analyse geographic distribution of water resources. They are interrelated, i.e. forest cover reduces the storm water runoff and tree canopy stores approximately 215,000 tons carbon. GIS is also used in afforestation.
14. **GIS Solutions in Banking Sector**: Today rapid development occurs in the banking sector. So it has become more market driven and market responsive. The success of this sector largely depends on the ability of a bank to provide customer and market driven services. GIS plays an important role providing planning, organizing and decision making.
15. **Soil Mapping:** Soil mapping provides resource information about an area. It helps in understanding soil suitability for various land use activities. It is essential for preventing environmental deterioration associated with misuse of land. GIS Helps to identify soil types in an area and to delineate soil boundaries. It is used for the identification and classification of soil. Soil map is widely used by the farmers in developed countries to retain soil nutrients and earn maximum yield.
16. **GIS based Digital Taxation:** In Local Governments, GIS is used to solve taxation problems. It is used to maximize the government income. For example, for engineering, building permits, city development and other municipal needs, GIS is used. Often the data collected and used by one agency or department can be used by another. Example Orhitec ltd can supply you with a system to manage property tax on a geographic basis that can work interactively with the municipal tax collection department. Using GIS we can develop a digital taxation system.
17. **Land Information System:** GIS based land acquisition management system will provide complete information about the land. Land acquisition managements is being used for the past 3 or 4 years only. It would help in assessment, payments for private land with owner details, tracking of land allotments and possessions identification and timely resolution of land acquisition related issues.
18. **Surveying:** Surveying is the measurement of location of objects on the earth’s surfaces. Land survey is measuring the distance and angles between different points on the earth surface. An increasing number of national and governments and regional organizations are using GNSS measurements. GNSS is used for topographic surveys where a centimetre level accuracy is provided. These data can be incorporated in the GIS system. GIS tools can be used to estimate area and also, digital maps can prepared.
19. **Wetland Mapping:** Wetlands contribute to a healthy environment and retain water during dry periods, thus keeping the water table high and relatively stable. During the flooding they act to reduce flood levels and to trap suspended solids and attached nutrients. GIS provide options for wetland mapping and design projects for wetland conservation quickly with the help of GIS. Integration with Remote Sensing data helps

to complete wetland mapping on various scale. We can create a wetland digital data bank with spices information using GIS.

20. **GIS Applications in Geology:** Geologists use GIS in a various applications. The GIS is used to study geologic features, analyse soils and strata, assess seismic information, and or create three dimensional (3D) displays of geographic features. GIS can be also used to analyse rock information characteristics and identifying the best dam site location.
21. **Detection of Coal Mine Fires:** GIS technology is applied in the area of safe production of coal mine. Coal mine have developed an information management system, the administrators can monitor the safe production of coal mine and at the same time improve the abilities to make decisions. Fire happens frequently in coal mines. So it can assessed spontaneous combustion risk using GIS tools.(Kun Fang, GIS Network Analysis in Rescue of Coal Mine)