Jharsuguda Engineering School, Jharsuguda

Department of Civil Engineering

Lecture Notes

on

Land Survey -II(Th-1)

(Exclusively for 6th Semester Civil Engineering Diploma Students

under SCTE&VT,Odisha,Bhubaneswar)

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LAND SURVEY - II   Dt- 15/3/22

CHAPTER-4 (SURVEY of India map series)

Open Series Map :-

i) Open series map have been introduced as per the national map Policy 2005 by Survey of India.

ii) These map series is based on transverse, merecatote projection on WGS-1984 datum.

iii) The numbering system is based on International map of the world (IMW).

Numbering system of India map :-

i) The map numbering is of the form A-12A-1.

ii) The IMW numbering system with minore modification is used up to 1°x1° / 1:250000 scale.

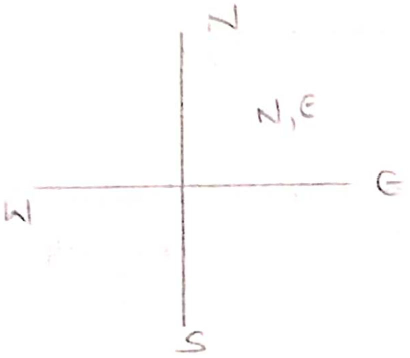
iii) Since the IMW map number for India we will always start with N' (India being in the northern hemisphere) the first letter is omitted.

iv) The next alphabet and the number of IMW map number denotes the 6°x4° region of the IMW series.

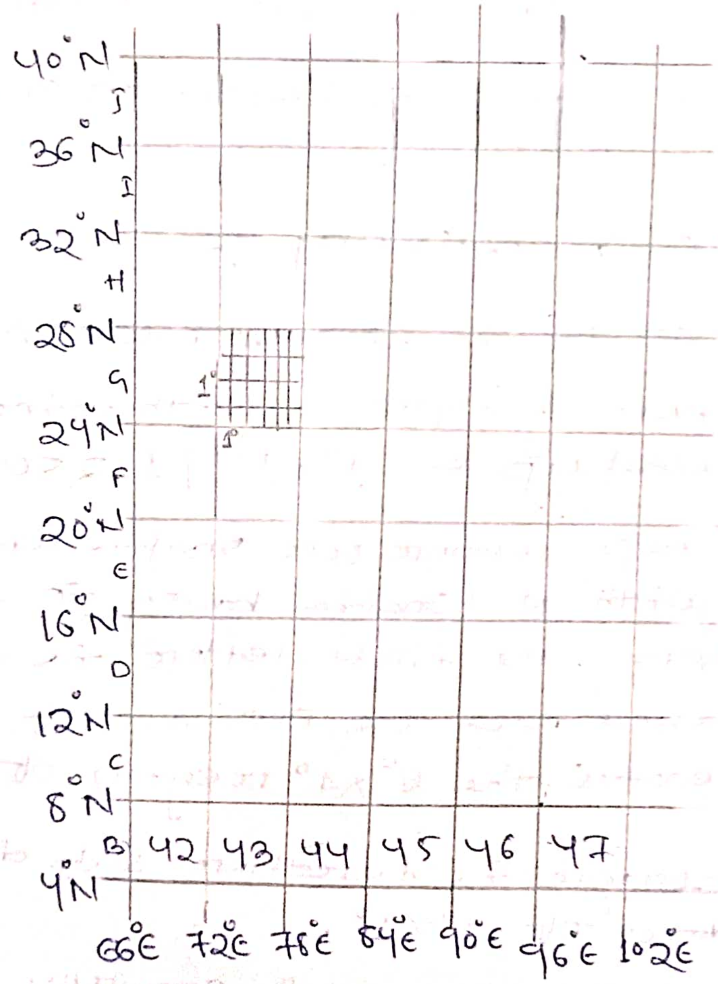
v) Each 6°x4° rectangle is furthere sub divided into 24 squares of 1°x1°.

vi) Each square is indicated serially an alphabet increasing first towards each & then towards south starting with A. So the sheet for Kalyanpure is (77.65489°E, 24.11981°N) falls with in G-43X.

vii) Each 1°x1° square is furthere devided in to 16 squares of 15'x15'. Each square is indicated serially by a numbere increasing first towards south & then towards East starting with 1. So, for the map sheet for Kalyanpure is 77°39.293'E, 24°7.187'N) falls within G-43X-12.



WGS - 1984



(1°x 1°)

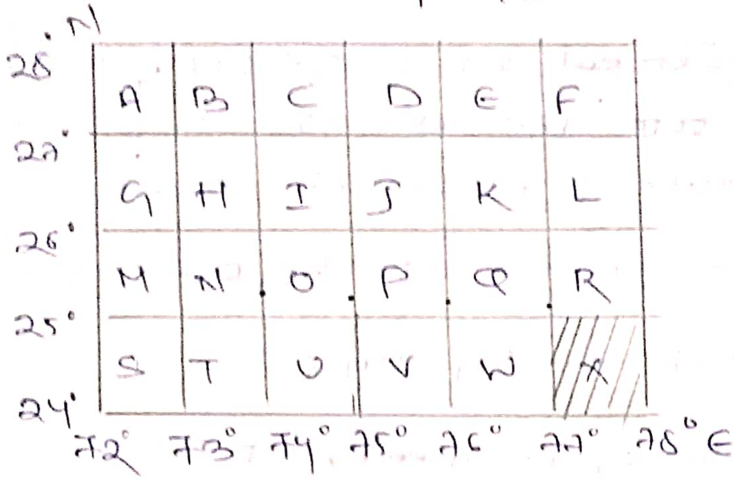
(6° x 4°)
(4, x)

4° - Longitude
6° - Latitude

Range
4°N – 40°N
66°E – 102°E

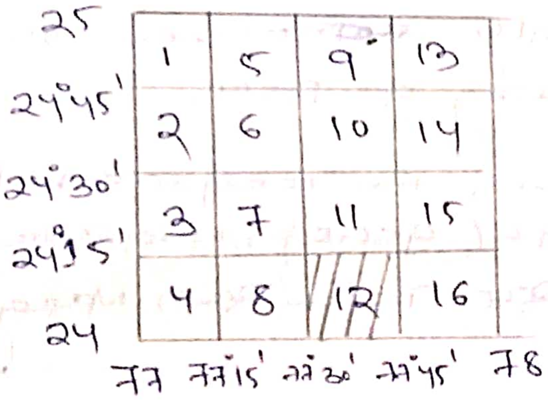
E - 77.65489°
N - 24.11981°N
G-43X

G-43X-12



(24 square)

(77°39.293' E) (24°7.187' N)



(16 square)

DEFENSE SERIES MAP (DSM):-

21/3/22

i) These are prepared on 1:250000 scale, 1:50000, 1:25000 scale for the use of defense forces of India supporting National security departments.

ii) These maps are based on WGS-1984 datum.

{WGS - World Geodetic system}

iii) They contain tools, features of map with grid, contours and other classified information without any dilution of accuracy therefore they are kept under restricted category.

iv) Survey of India is only authorized for preparation and printing of DSM.

v) For sell and distribution the responsibilities are assigned to ADGMS (GSGS), Ministry of Defense, DGIS enclave, Rao Tula Ram Marg Delhi ~~cantt~~ cantt.

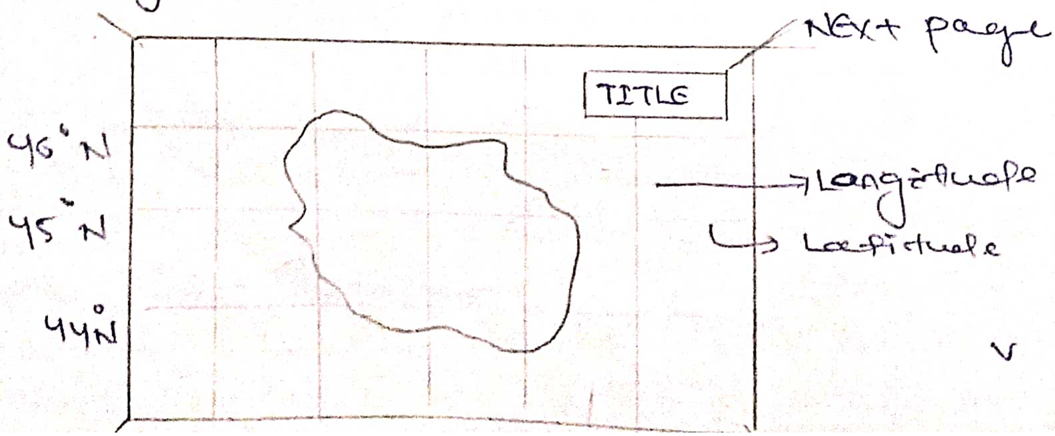
Topographic Map :-

(1) QUADRANGLE NAME :-

i) The first thing to notice on a topographic map is the title. It is found in the top right hand corner of the map.

ii) We can find similar titles on all the corners of a topographic map as well as half way betn the corners.

iii) This information is used to find the others map that may be needed.



(Q) <u>Latitude, Longitude UTM's :-</u>

UTM — Universal transverse mercator

(i) In a topographic map, there are numbers running all around the outside of the map. These numbers represent two grid system that can be used to find the exact location.

(ii) These are called latitude & longitude. The exact latitude and longitude is given at each corner of the map and are equally spaced intervals betn the corners.

(iii) UTM's are the smaller bold numbers that drawn along the border of the map.

<u>UTM Co-ordinates :-</u>

(i) UTM stands for universal transverse Mercator.

(ii) It is another grid system that can be used to find the position.

(iii) It is the most commonly used system used in military, Research and survey purposes.

(iv) The UTM system divides the surface of Earth into a grid.

(v) Each grid is identified by a number across the top called the zone number and later down the right hand side called the zone designator.

(vi) Every spot within the zone can be defined by a co-ordinate system that uses meters.

(vii) They are sometimes referred as Northing or Southing & Easting or westing.

(viii) UTM's are small bold black numbers mentioned along the edge of the map.

(ix) On a regular topomap, the dash above that number would be blue.

(x) As we go up the right hand side of the map everytime we will pass the small blue dash that is mentioned.

Map scale :-

i) Map scale represents the relationship bet^n the distance on the and corresponding distance on the ground.

ii) The scale on the topomap is found at the bottom centre of the map.

iii) The scale is represented in two different ways on a topographic map. The first is a ratio scale for eg:- 1:25000, which means 1 unit on the map represents 25,000 on ground.

iv) Below the ratio scale there is a graphic scale representing the distance in miles, feet, meters.

v) The graphic scale can be used to make first estimates of distances on the map.

vi) The space bet^n the zero and 1 mile 1 appear on the scale is the distance " must go on the map to travel 1 mile."

Contour lines :-

i) The 3 dimensional layout of the land can be shown in a topographic map using contour lines. A contour line is a line connecting points of equal elevations.

ii) On the topo map the contour lines are represented in brown lines.

iii) The contour lines represents the outline of the terrain at evenly spaced elevations.

iv) These are determined by the contour intervals. The contour interval is found below the map scale.

MAGNETIC DECLINATION

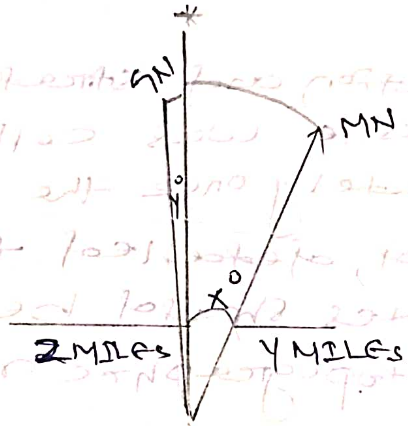
i) At the lower left hand corner of topographical maps, the magnetic declination is marked.

ii) The symbol is used in addition with a compass for navigational purpose.

iii) The centre line with the star above represents the direction of magnetic north, when using a compass, the needle always points to magnetic north.

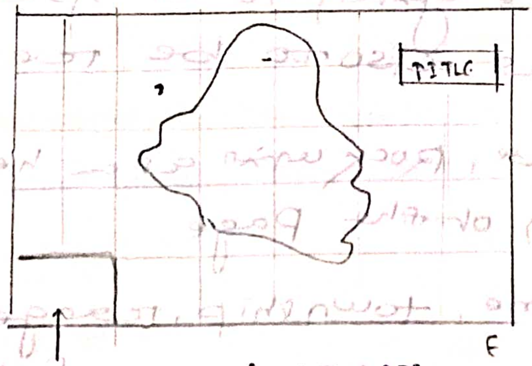
iv) The symbol tells us that for the area of the map covers. The magnetic compass needle will always point x° to the east or west of true geographic North to the left of true north line is the green north line (may be right).

v) This also tells that how much the UTM grid and zone lines are offset from true north.



MN — Magnetic North
GN — Geographic North

(Magnetic Declination Indicator)



Magnetic declination indicator

PUBLIC LAND SURVEY SYSTEM :- (PLSS)

i) The PLSS is the most often used on topographic map published in the USA & has its roots in the early surveys of north America in 1700 years.

ii) The PLSS system differs from the co-ordinate system is more descriptive and relies less on absolute measurement of the location.

iii) It is useful in that it is a good way to give a weak approximation of the location, but the main drawback is its lack of accuracy

iv) On a topo map we will find a grid with red lines & text criss-crossing the map. The lines represent the borders of various sections in a township, village and the range of that area.

Field Notes :-

i) To ensure that the location and stratigraphic unit from which a fossil was collected can be constructed accurately once the fossil is removed from the field, detailed information about the collecting sites should be recorded in field notes and on topographic map.

ii) It is helpful to record the location in the field notes in several ways in addition to the field numbers given to a specimen the following data has also to be recorded,

(a) Date, city, state, Rock unit as a header or in the margin of the page.

(b) quadrangle name, township, range section.

(c) Latitude & longitude (measured from GPS or topographic map)

(d) verbal description of site.

(v) If the topographic map is available in printed form or digital form, the site of the map is marked & the field number provided has to be indicated there for the specimen.

CH-5

PHOTOGRAMMETRY

Definition:-
It is the art and science of obtaining accurate measurement by the use of photographs for various purposes such as the construction of planimetric & topographic maps, classification of soils, interpretation of geology, acquisition of military intelligence and preparation of composite pictures of the ground.

Classification-
i) Terrestrial photogrammetry
ii) Aerial photogrammetry

Terrestrial photogrammetry:-
It is the branch of photogrammetry where photographs are taken from a fixed position on or near the ground.

Aerial photogrammetry:-
(i) It is the branch of photogrammetry where the photographs are taken by a camera mounted in an aircraft flying over the area.
(ii) Mapping from Aerial photographs is the best mapping procedure yet developed for large projects and are invaluable for military intelligence.
(iii) The major users are the civilian & military mapping agency of the government.

Vertical photographs :-

A vertical photograph is an aerial photograph made with the camera axis (optical axis) coinciding with the direction of gravity.

Tilted photograph :-

A tilted photograph is an aerial photograph made with the camera axis or optical axis unintentionally tilted from the vertical by a small amount usually less than 3°.

Oblique photograph :-

An oblique photograph is an aerial photograph taken with the camera axis directed intentionally betn the horizontal & the vertical. If the apparent horizon is shown in the photograph it is called high oblique.

If the apparent horizon is not shown in the photograph, it is said to be low oblique.

Perspective projection :-

A perspective projection is produced by straight lines radiating from a common point and passing through point on the sphere to the plane of projection. A photograph is perspective projection.

Exposure station :-

Exposure station is a point in space, in the air, occupied by the camera lens at the instant of exposure. It is the space position of the front nodal point at the instant of exposure.

Flying height :-

It is the elevation of the exposure stations above sea level or any other selected datum.

Flight Line :-
It is a line drawn on a map to represent the track of the aircraft.

focal length :-
It is the distance from the front nodal point of the lense to the plane of the photograph. It is also the distance of the image plane from the rear nodal point.

Principal point :-
Principal point is a point where a perpendicular dropped from the front nodal point strikes the photograph.

Nadir point :-
Nadir point is a point where a plumb line dropped from the front nodal pierces into the photograph.

→ In the nadir point, the photograph is having placed vertically beneath the exposure stations. This point is also called photonadir or photo plumb point.

Ground nadir point :-
Ground nadir point or ground plumb point is the datum intersection with the plumb line through the front nodal point.

Tilt :-
Tilt is the vertical angle defined by the intersection of the exposure station of the optical axis with the plumb line.

$\angle KON = t = tilt$

Principal plane :-
A principal plane is the plane defined by the lens (O), the ground nadir point (N) of the principal point produced to the ground (K).

→ It is thus the vertical plane containing the optical axis (NOK or NOK).

Principal line (nk) :-

It is the line of intersection of the principal plane with the plane of the photograph.

Isocentre :-

Isocentre is a point in which the bisector of the angle of tilt meets the photograph. Oi is the bisector & i is the isocentre.

→ On a vertical photograph, the isocentre & the photo nadir point coincide with the principal point.

Swing :- (s)

Swing is the angle measured in the plane of the photograph from the positive y-axis clockwise the nadir point.

Azimuth of principal plane (Φ) :-

It is the clockwise horizontal angle measured about the ground nadir point from the ground survey north meridian to the principal plane of the photograph.

- It is the ground survey direction of the tilt (Φ).

Horizon point : (h) :-

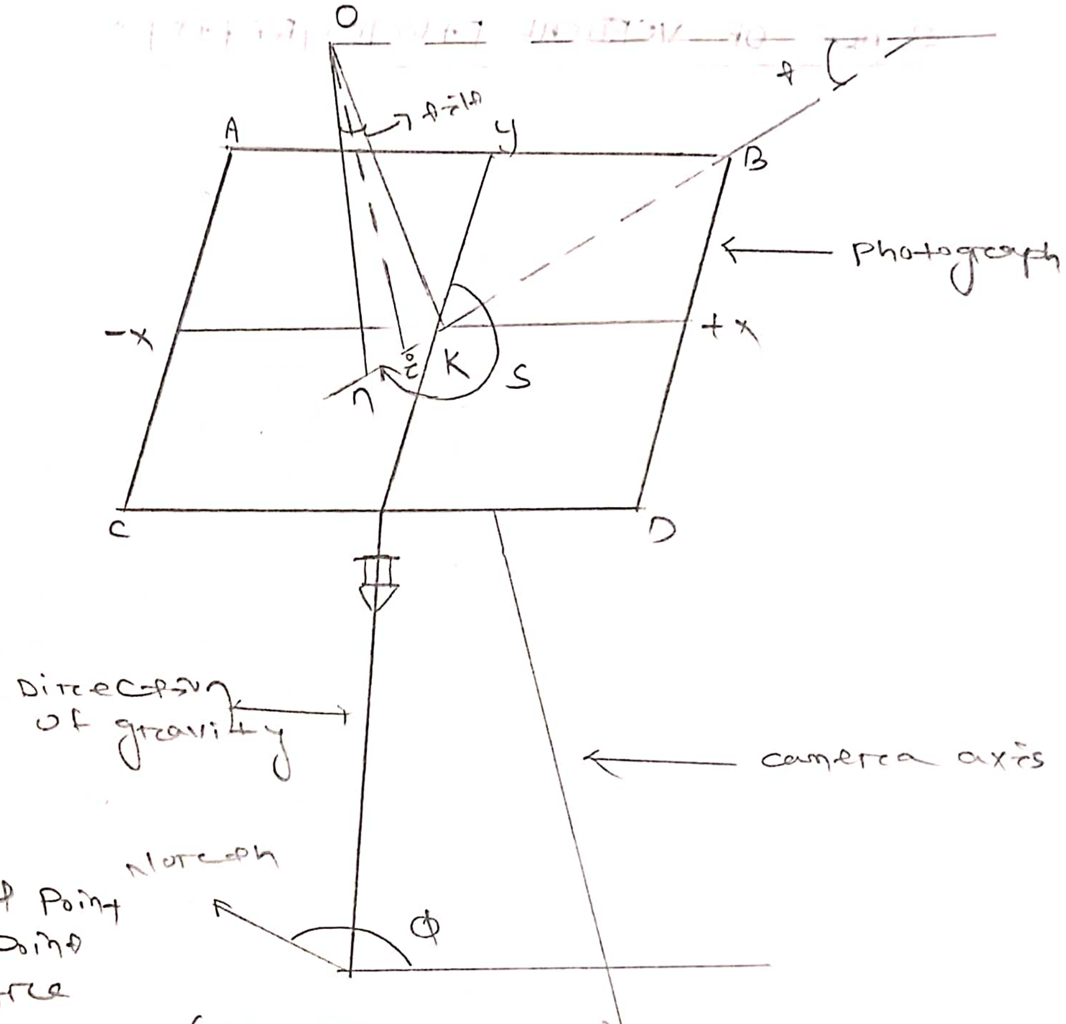
- It is the intersection of the principal line with the horizontal line through the perspective centre.

- In a near vertical or tilted photograph this point is generally outside of the photograph.

- In a high oblique photograph, it is inside the photograph.

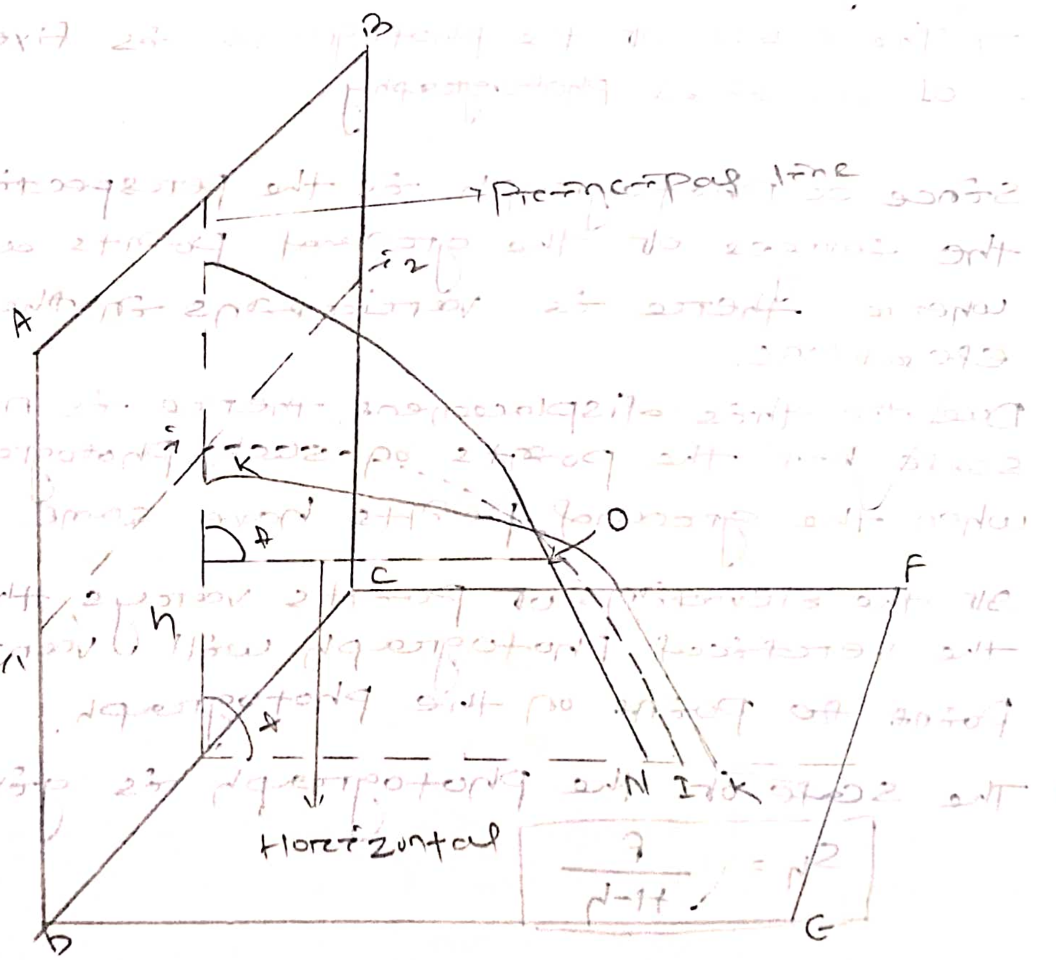
Axis of tilt :-

It is a line in the plane of photograph & is perpendicular to the principal line, at the isocentre. ($i_1 i i_2$)



K = principal point
n = nadir point
i = isocentre

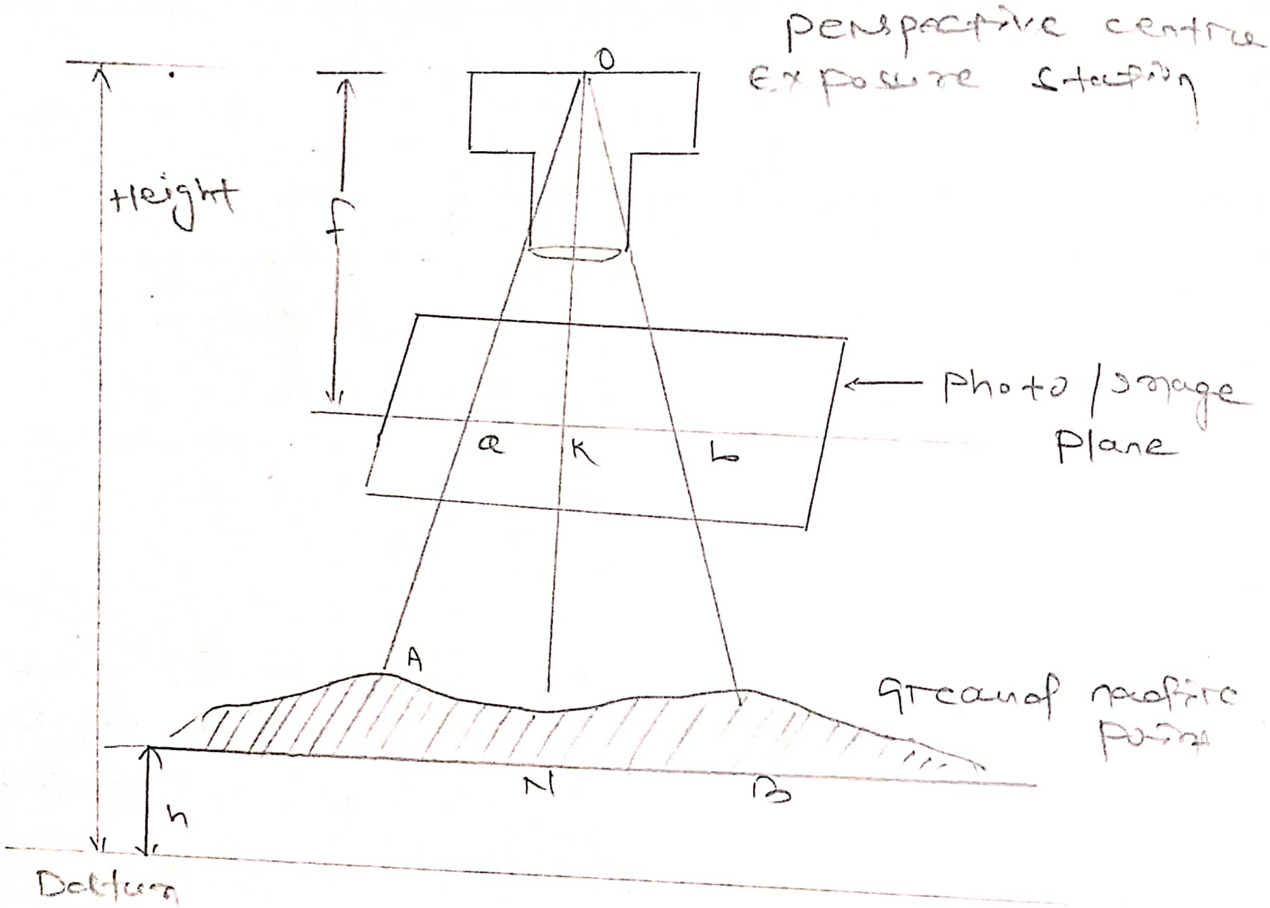
(TILTED PHOTOGRAPH)



ABCD = oblique plane or photograph -ve
CDEF = Ground horizontal plane
O = perspective line / centre

SCALE OF VERTICAL PHOTOGRAPHY :-

Dt - 29/3/22



→ Height of the exposure station or datum line.
→ The scale of the photograph is fixed, scale of vertical photography.

i) Since a photograph is the perspective projection, the images of the ground points are displaced where there is variations in the ground elevations.

ii) Due to this displacement, there is no uniform scale betn the points on such photograph except when the ground points have same elevation.

iii) If the elevations of points varys, the scale of the vertical photograph will vary from point to point on the photograph.

iv) The scale of the photograph is given by

$$S_h = \frac{f}{H-h}$$

where S_h = scale at elevation h

$$S_h = \frac{1}{\left(\frac{H-h}{F}\right)}$$ → R.F (Representative fraction)

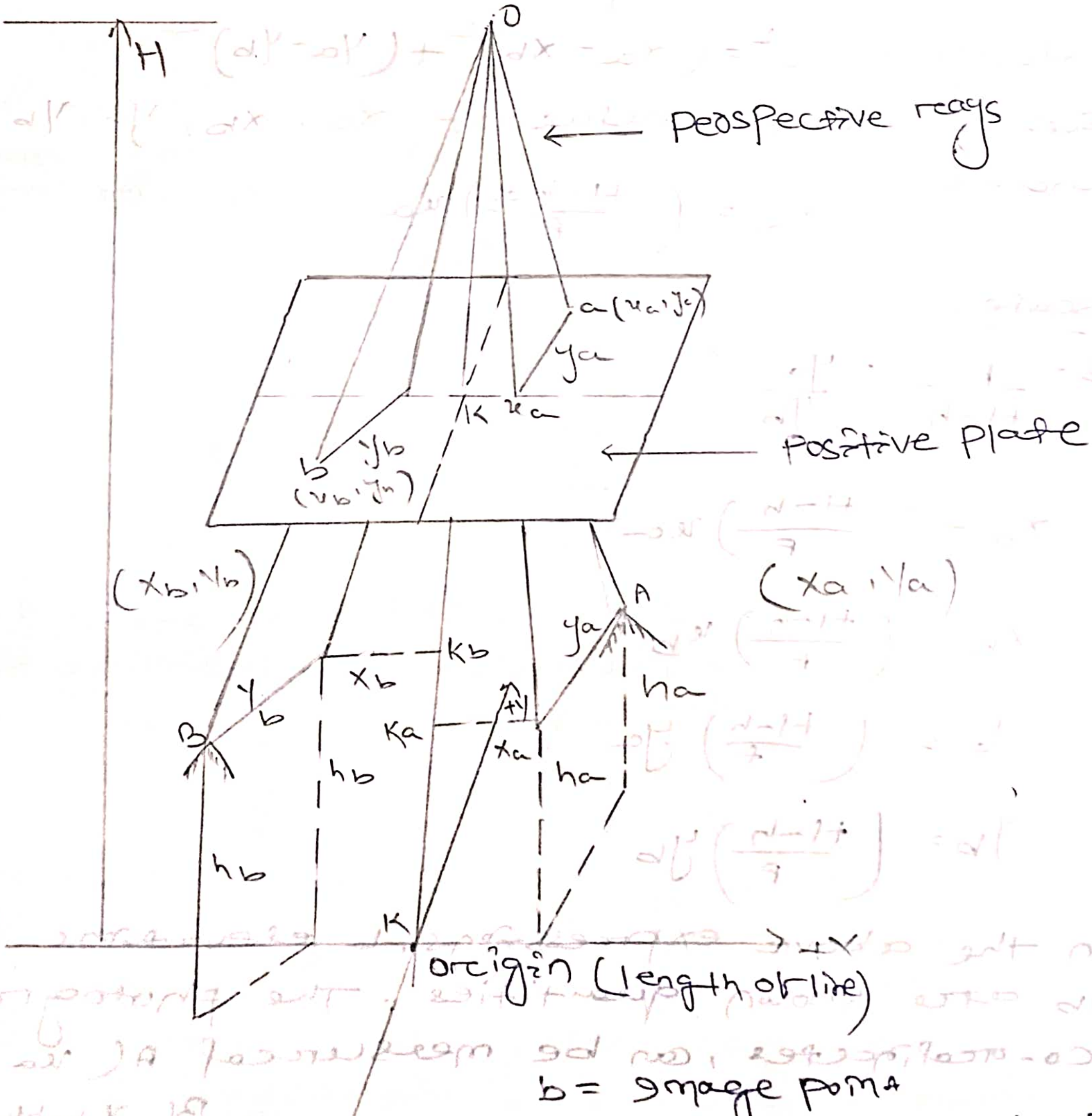
H = Flying height

AVERAGE SCALE : (Sav) :-

The average scale of a vertical photograph is that which is effective over the entire photograph is all the ground points where projected vertically downward or upward on a plane representing the average elevations of the terrain before being photographed.

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

COMPUTATION OF LENGTH OF A LINE :-



b = image point

A, B = ground / Actual point

computation of length of a line betn points of different elevations from measurements on a vertical photograph.

The length betn the 2 points A & B is given by L.

$$L = \sqrt{(Xa - Xb)^2 + (Ya - Yb)^2}$$

→ The value of Xa, Xb, Ya, Yb must be substituted with proper algebraic signs.

DETERMINATION OF HEIGHT 'H' OF LENSE FOR A VERTICAL PHOTOGRAPH :-

If the images of two points A & B having different known elevations and known length betn them appear on the photograph, the height 'H' of the exposure station can be calculated using the following steps-

(i) calculate $L^2 = (Xa - Xb)^2 + (Ya - Yb)^2$

(ii) substitute the value of Xa, Xb, Ya, Yb as under,

$$Xa = \left(\frac{H - ha}{f}\right) xa$$

Scale:-

$$S = \frac{f}{H-h} = \frac{ya}{Yb}$$

$$Xa = \left(\frac{H-h}{f}\right) xa$$

$$Xb = \left(\frac{H-h}{f}\right) xb$$

$$Ya = \left(\frac{H-h}{f}\right) ya$$

$$Yb = \left(\frac{H-h}{f}\right) yb$$

(iii) In the above expressions, L elevations ha & hb are known quantities. The photographic co-ordinates, can be measured A(xa, ya)
B(xb, yb)

only unknown quantities 'H' can be written in quadratic eqn form.

$$pH^2 + qH + r = 0$$

The value of H can also be determined by successive approximation method.

$$S = \frac{f}{H_{app} - h_{av}}$$

where,

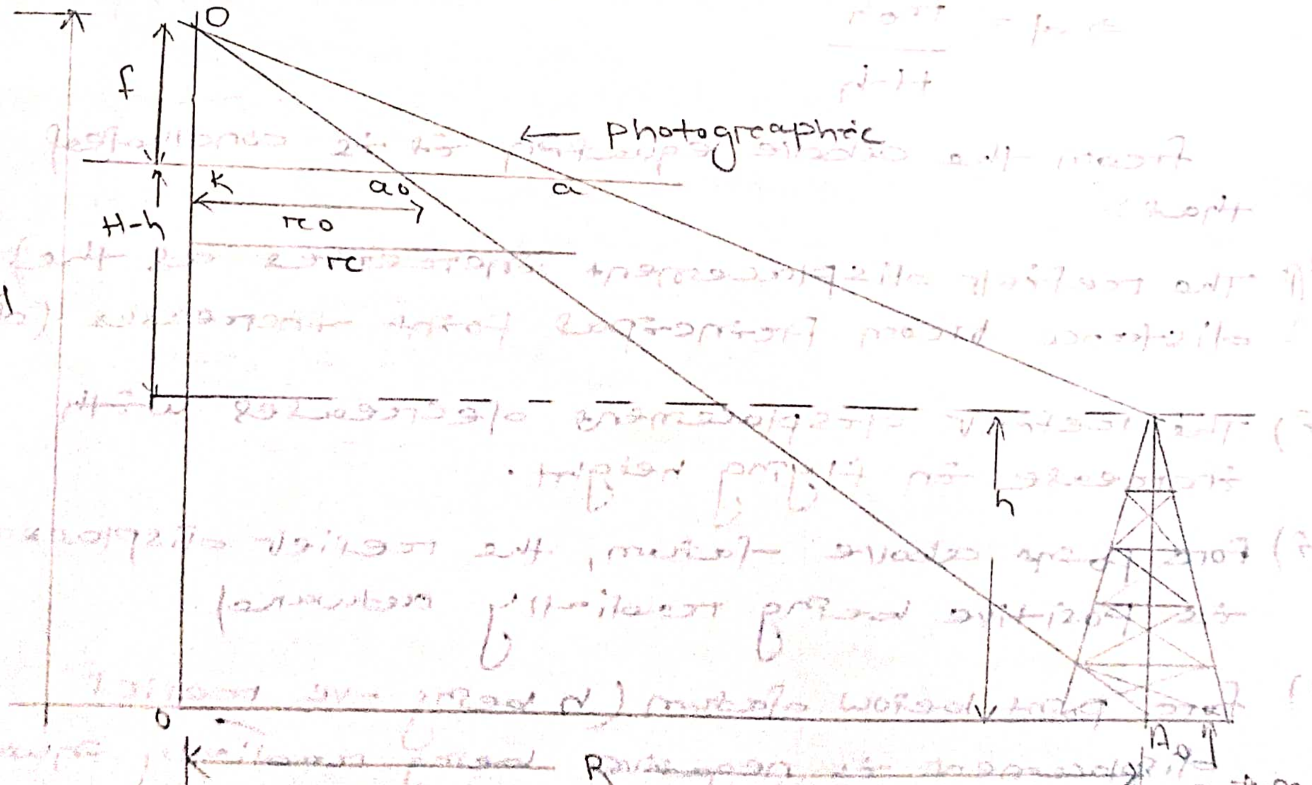
$$h_{av} = \frac{h_a + h_b}{2}$$

Dt - 30/3/22

Relief displacement

Relief / Ground Relief → unevenness / elevation of points or ground w.r.t some datum.

(i) Since the photograph is perspective view, the ground relief is shown in the perspective on the photograph. Every point on the photograph therefore is displaced from their true orthographic positions. this displacement is called Relief displacement.



(calculation of Relief Displacement)

aa_o = Relief displacement

Let r, the radial distance a from K

r_0, the radial distance a_0 from K

$R = K_0 A_0$

from similarity of triangle

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

$$\Rightarrow r = \frac{Rf}{H-h} \quad \text{---} \quad (i)$$

Again,

$$\frac{f}{H} = \frac{r_0}{R}$$

$$\Rightarrow r_0 = \frac{fR}{H} \quad \text{---} \quad (ii)$$

Relief displacement (d)

$$= r - r_0$$

$$\Rightarrow d = \frac{Rf}{H-h} - \frac{Rf}{H}$$

$$\Rightarrow d = \frac{Rfh}{H(H-h)} \quad \left(\frac{r_0 h}{H-h} = d\right)$$

$$\Rightarrow d = \frac{r_0 h}{H-h}$$

from the above equation it is concluded that:-

(i) The relief displacement increases as the distance from principal point increases. ($d \propto r_0$)

(ii) The relief displacement decreases with increase in flying height.

(iii) For point above datum, the relief displacement is positive being radially outward.

(iv) for point below datum (h being -ve) relief displacement is negative being radially inward.

(v) the relief displacement of the point below the exposure station is zero.

Height of object from Relief displacement

(i) If the scale of photograph is known, height of object can be determined as follows.

(ii) Let 'h' is the height of a tower above its base, and H be the height of exposure station above the selected datum passing through the base of the tower.

(iii) Let 't' & 'b' be the top and bottom positions of the tower on the photograph.

(iv) The radial distance are and the relief displacement can very easily be measured.

(v) If the scale 'S' of the photograph is known the height 'H' can be calculated using the following formula.

$$S = \frac{f}{H}$$

(vi) Knowing H, and measuring d and r, the height h can be calculated using the following equation.

$$h = \frac{dH}{r}$$

(Q) A vertical photograph was taken at an altitude of 1200 m above MSL. Determine the scale of photograph for terrain lying at elevations of 300 m if the focal length of camera is 15 cm.

Sol

h = 300 m

H = 1200 m

f = 15 cm

$$S = \frac{f}{H-h}$$

$$= \frac{15\text{ cm}}{1200-300\text{ m}} = \frac{1\text{ cm}}{60\text{ m}}$$

$$= \frac{0.15}{1200-300}$$

$$= \frac{1}{6000}$$

$$= 1 : 6000$$

8) A line AB 2000 m long, lying at an elevation of 500 m measures 8.65 cm on a vertical photograph for which focal length is 20 cm. Determine the scale of the photograph in an area the avg elevation of which is about 800 m.

Sol:

$h = 500$ m

$F = 20$ cm $= 0.2$ m

$$S = \frac{F}{H-h}$$

$$\Rightarrow \frac{8.65}{2000} = \frac{20}{H-500}$$

$\frac{8.65}{100} = 0.0865$

$\frac{20}{100} = 0.2$

$$= \frac{0.0865}{2000} = \frac{0.2}{H-500}$$

$\Rightarrow 0.2 \times 2000 = (H-500) \times 0.0865$

$\Rightarrow 400 = 0.0865H - 43.25$

$\Rightarrow 0.0865H - 43.25 = 400$

$\Rightarrow 0.0865H = 400 + 43.25$

$\Rightarrow 0.0865H = 443.25$

$$\Rightarrow H = \frac{443.25}{0.0865}$$

$\Rightarrow H = 5124.27 \simeq 5124$

$$S = \frac{f}{H-h}$$

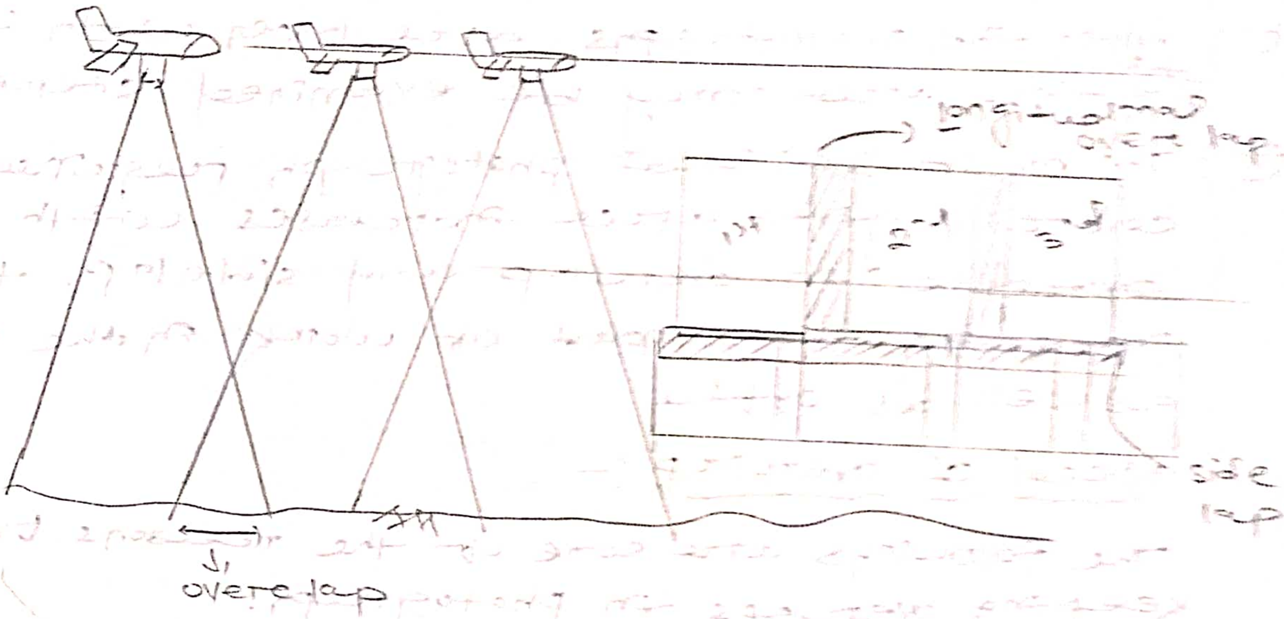
$$= \frac{0.2}{5124-800}$$

$$= \frac{0.2}{4324} = \frac{1}{21620}$$

$= 1 : 21620$ m

Dt- 6/4/22

FLIGHT PLANNING :-



(i) When vertical photographs are to be used for preparation of maps, all the methods of compilation require that the plumb points of the preceding & succeeding points are visible in each photograph.

(ii) Photographs are taken at the proper interval along each strip to give the desired overlap of photograph in the given strip.

(iii) Each strip is predetermined and their spacing is prefixed to ensure desired sidelap between adjacent strips.

Longitudinal overlap :-

(i) The overlapp of photographs in the direction of flight is called longitudinal overlapp or forward overlapp or simply overlapp.

(ii) Along a given flight line, photographs are taken at such frequency that successive photograph are to overlapp each other by 55 to 65%.

Side Lap :-

The overlapp betn adjacent flight lines is called lateral overlap or side lap. The amount of sidelap is about 15-35%..

i) When the photographs are taken with overlapp the entire area may be examined stereoscopically

ii) The no of Individual photograph required to cover a given area increases with the increase in overlap and sidelap, thus increasing the amount of work in the field as well as office.

Need of overlap :-

The followings are some of the reasons for keeping overlaps in photograph.

i) to tie the different points together accurately, it is desirable that the principle point of each print should appear on the edges of as many adjacent strips as possible.

ii) The distortion caused by the lense and by the tilt is overcome by the overlapp.

iii) In order to view the parts of photograph stereoscopically only, the overlapp portion is useful, hence the overlapp should be atleast 50%.

iv) Due to the overlapp, each portion of teritory is photographed 2 to 4 times, hence any picture distorted by excessive tilt, by or cloud shadows can be rejected without the necessity of new photograph.

v) If the flight lines are not maintained straight and parallel, the gaps betn the adjacent strip will be left, these gaps can be avoided by side lap.

Effective coverage of Photograph :-

(i) The amount of overlap & sidelap to be used in flight planning depends on the effective coverage of each photograph.

(ii) The effective coverage of each photograph depends on

a. size of the format or focal plane opening

b. focal length

c. Angular coverage of the lense

(iii) for max^n rectangular area, the rectangle must have the dimension in the direction of flight to be half of the dimension normal to the direction of flight.

Mathematically,

$$W = 2B$$

where W = distance betn the flight strips

B = width of the rectangle along the flight line (width of the overlapp)

(iv) Again for max^n area coverage W = 1.22H

where H = height of lense from ground

(v) An exposure should be taken at every 1830 m & the separation of flight strips should be 3660 m.

(vi) The above condition prevail for level terrain, vertical photographs, no crab, no drift, & constant flying height.

SELECTION OF ULTITUDE :-

The selection of height above ground depends on the accuracy of the process to be used & the contour interval desired.

Mathematically,

flying height = contour interval × C-factor

The value of C-factor vary from 500 to 1500 & depends on the condition of surrounding the entire map compilation operation.

Number of photographs necessary to cover a given area :-

The no of photograph (N) $= \frac{A}{a}$

Where A = Total area to be photograph

a = Net ground area covered by each photograph

$A = L \times W$

Where, L = Net ground distance corresponding to l.

W = Net ground distance corresponding to w.

where,

l = Length of the photograph in the direction of flight.

w = Width of the photograph normal to the direction of flight.

Interval betn exposure :-

$$T = \frac{3600L}{V}$$

Where,

T = time interval betn the exposure

L = ground distance covered by each photograph in the direction of flight which is,

$$L = (1 - P_l) S_l$$

V = ground speed of the aeroplane (km/h)

P_l = % overlapp in successive photographs in the direction of flight

S = scale of the photograph

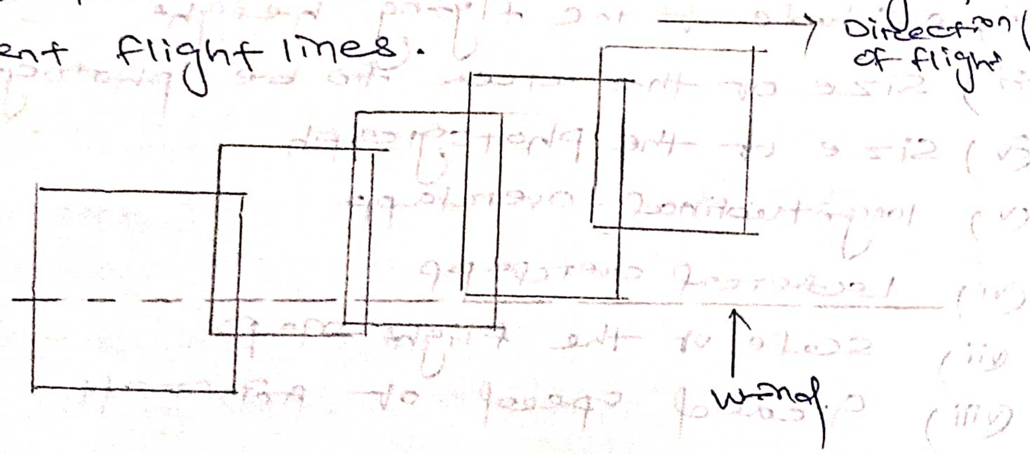
Dt- 8/4/22

DRIFT :-

(i) Drift is caused by the failure of the photograph to stay on the predetermined flight line.

(ii) If the aircraft is set on its course by compass without allowing for wind velocity, it will drift from its course.

(iii) If the drifting from the predetermined flight line is excessive, reflights will have to be made because of serious gaping betn adjacent flight lines.



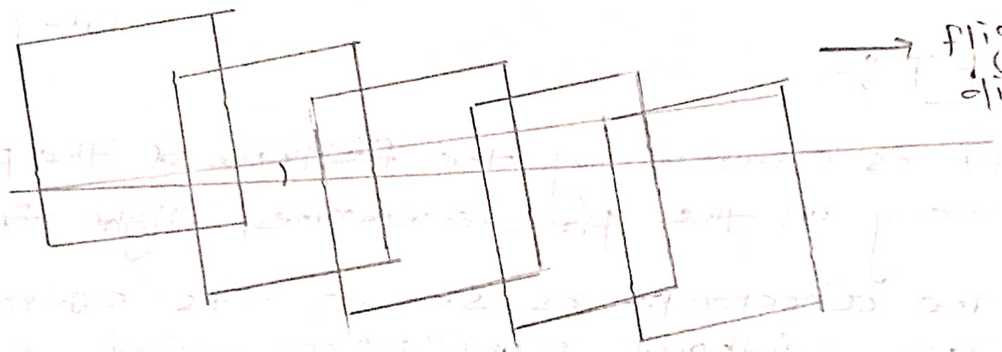
CRAB :-

(i) It is a term used to designate the angle formed by the flight line and the edge of the photograph in the direction of flight.

(ii) At the instant of exposure, if the focal plane of the camera is not square to the direction of flight, the crab is caused in the photograph.

iii) The arrangements are always made to rotate the camera about the vertical axis of the camera mount.

iv) Crabbing should be eliminated since it reduces the effective coverage of the photograph.



COMPUTATION OF FLIGHT PLAN :-

For the computation of flight plan, the following data is required.

i) focal length of camera lens
ii) Altitude of the flying height
iii) size of the area to be photographed
iv) size of the photograph
v) longitudinal overlapp
vi) Lateral overlapp
vii) scale of the flight map
viii) Ground speed of Aircraft.

(Q) The scale of an aerial photograph is 1cm = 100m. The photograph size is 20cm x 20cm. Determine the no. of photographs required to cover an area of 100 sq km. If the longitudinal lap is 60%, and side lap is 30%..

Sol^n Given data,

$l = 20$ cm

$w = 20$ cm

$P_l = 0.6$

$P_w = 0.3$

$S = \frac{H\ (m)}{f\ (cm)}$

$L = (1 - P_l) S l$

$= (1 - 0.6) \times 100 \times 20$

$= 800 = 0.8$ m

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

$= (1 - 0.3) \times 100 \times 20$

$= 1400 = 1.4$ m

$a = L \times W = 0.8 \times 1.4$

$= 1.12$

$N = \frac{A}{a} = \frac{100}{1.12} = 89.28 \simeq 90$

STEREOSCOPIC VISION :-

(i) The depth perception is the mental process of determining the relative distance of objects from the observer from the impressions received by the eyes.

(ii) Due to the binocular vision, the observer is able to perceive the spatial relations that is the 3-D field of view.

(iii) The impressions of depth is caused mainly by 3 reasons

a. The relative apparent size of near and far objects.

b. Effect of shade & light

c. viewing an object simultaneously by two eyes separated by a space.

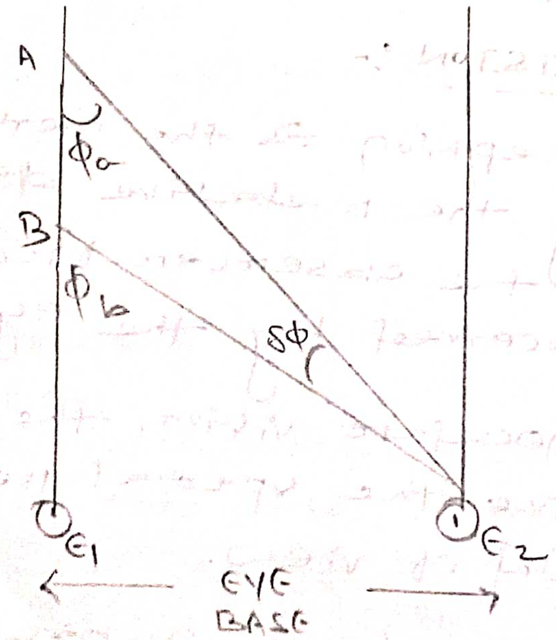
iv) Out of these three the third one is very important because each eyes views an object from slightly different position & by a psychological process the two separate images combined together in the brain to see in the third dimension.

PARALLAX :-

i) In the normal binocular vision, the apparent movement of a point viewed from one eye and then with another eye is called parallax.

ii) Since an object is viewed simultaneously by the two eyes, the two rays of vision converge at an angle upon the object view.

iii) The angle of parallax or the parallactic angle is the angle of convergence of the two rays of vision.



Let A & B are the two objects in field of view & are being viewed by the two eyes represented by the positions E_1 & E_2 separated by the eye base.

The angle $\angle E_1AE_2 = \phi_a$ is the angle of parallax of object A.

$\angle E_1BE_2 = \phi_b$ is the angle of parallax of object B.

The object 'B' for which the parallactic angle is greater will be judged by the nearer to the observer than object A, for which parallactic angle ϕa is smaller.

The measure of the distance BA is evidently provided by the difference in parallactic angle of A & B, so it $\phi_b - \phi_a = \delta\phi$ is called differential parallax.

STEREOSCOPIC FUSION :-

(i) The principle of stereoscopic vision can be applied to photogrammetry.

(ii) If a pair of photographs is taken of an object from two slightly different locations of the camera & then viewed by an apparatus which ensures that the left eye sees only the left side of the photograph & the right eye is directed to see the right side picture, the two separate images of object will fuse together in the brain to provide the observer with a spatial impressions. This is known as stereoscopic fusion & the pair of two such photographs is called stereopair.

(iii) Two devices are used to view the stereopairs

(a) Stereoscope

(b) Anaglyph

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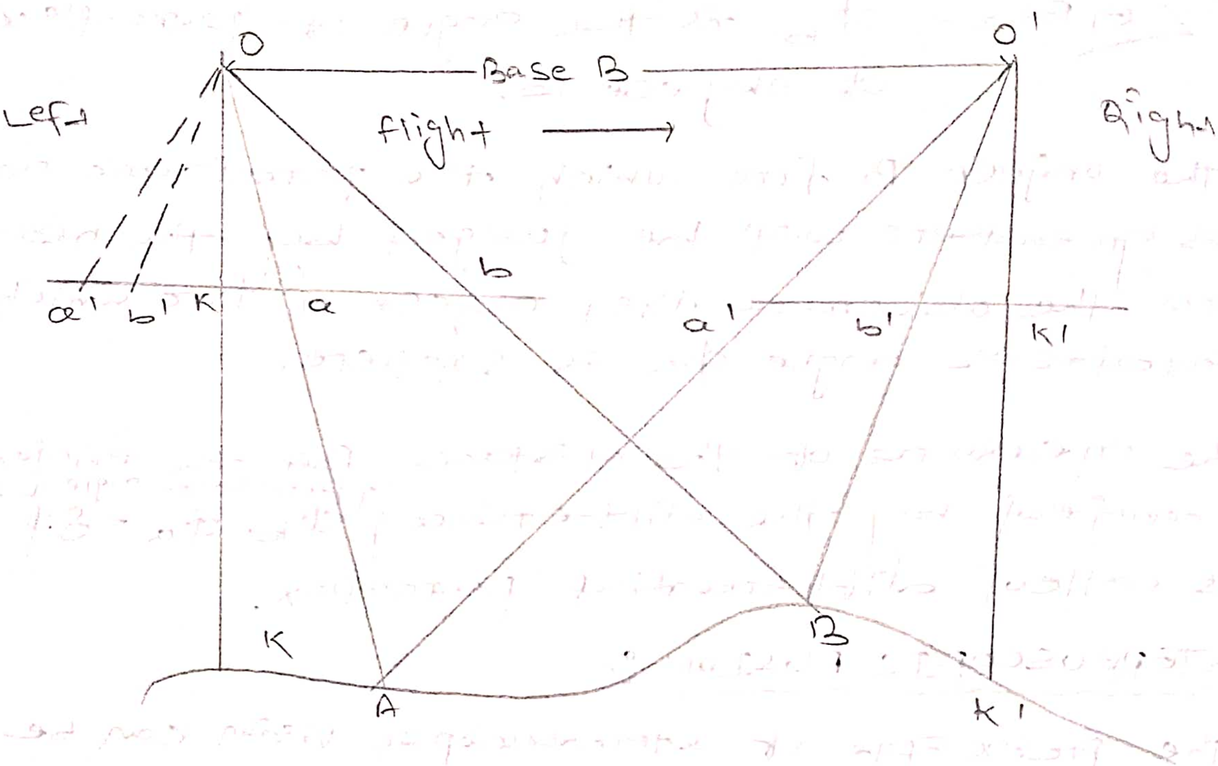
PARALLAX EQUATION :-

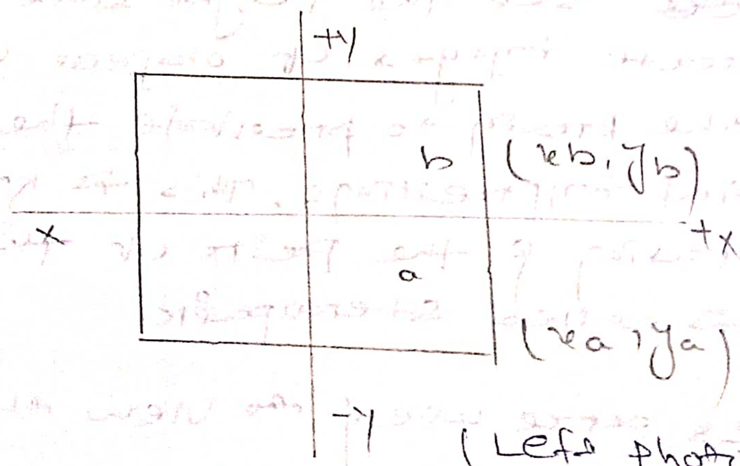


The Parallax of the higher point is more than Parallax of the lower point.

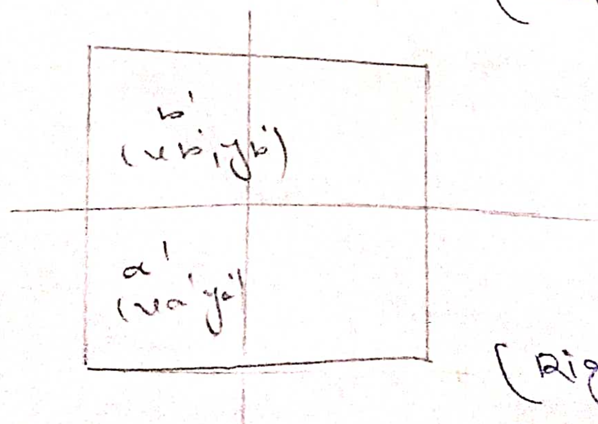
$bb' > aa'$

Parallax of $A = aa'$

Parallax of $B = bb'$



(Left photograph)



(Right photograph)

$P_a = x_a - x_a'$

$y_a - y_a'$

$P_b = x_b - x_b'$

$y_b - y_b'$

$(x_a, y_a)\ (x_a', y_a')$ stereopoint of A.

$(x_b, y_b)\ (x_b', y_b')$ stereopoint of b.

$(x_a, y_a)(x_a', y_a')(x_b, y_b)\ (x_b', y_b')$, these are called stereopairs.

The point to point difference in parallax exhibited betn points on a stereopair image makes possible the viewing of the photographs stereoscopically to gain an impression of a contineous 3-D image of the terrain.

Ideal conditions for obtaining aerial stereoscopic views of the ground surface :-

i) The photographs are taken with sufficient overlapp.

ii) The elevations of the camera positions remain the same for the two exposures.

iii) The camera axis is vertical so that the picture planes lie in the same horizontal plane.

Parallax equation for determining elevations and ground co-ordinates of a point :-

$$H - h = \frac{BF}{P}$$

← parallel eqn for the elevation of a point

B = Air Base

H = flying height

f = focal length

Ground co-ordinates,

$$X = \frac{B}{p} x , \quad Y = \frac{B}{p} y$$

(X, Y) - Ground co-ordinates of the point

(x, y) - co-ordinates of image point

Difference in Elevation by stereoscopic parallax:

$$\Delta h = \frac{\Delta p}{P_1 (P_1 + \Delta p)} \cdot BF$$

$\Delta p = P_2 - P_1$

Mean principle base :-

$$b_m = \frac{b + b'}{2}$$

where b = principle base of left photograph
b' = principle base of right photograph

Principle Base :-

The distance betn the principal point of a photograph & the position of transferred principle point of its next photograph obtained complete fusion to stereoscopic is called principle base.

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Q) A photogrammetric survey is carried out to a scale of 1:20,000. A camera with a wide angle lens of f = 150 mm was used with 23 cm × 23 cm plate size for a net 60% overlap along the line of flight. Find the error in height given by an error of 0.1 mm in measuring the parallax of the point.

Sol) Given data,

$S = \frac{1}{20,000}$

1m = 1000 mm

$1mm = \frac{1}{1000} m$

f = 150 mm

Photo size = (23 × 23) cm

$S = \frac{f}{H-h} = \frac{150}{H-0}$

$S = \frac{150}{H}$

$\Rightarrow H = \frac{150}{S}$

$= \frac{0.15}{1/20,000}$

= 3000 m

H = 3000 m

$B = (1 - P_L) \times L \times S$

$= (1-0.6) \times 23 \times 10^{-3} \times 20,000$

= 184 m

$\delta F = 184 \times 0.15$

= 27.6 m

Therefore

$$\Delta h = \frac{(H-h)^2 \cdot \Delta P}{BF}$$

$$= \frac{(3000-0)^2 \times \Delta P}{276}$$

$$= \frac{(3000)^2 \times 0.1}{276}$$

$= 3.26$ m.

Q) In a pair of overlapping vertical photographs, the mean distance betn 2 principle point both of which lie on the datum is 6.375 cm, At the time of photography the aircraft was 600 m above the datum. The camera has a focal length of 150 mm in the common overlapp, a tall chimney 120m high with its base in the datum surface is observed. Determine the difference of parallax fore top & buttom of chimney.

Sol
Given data,

$f = 150$ mm $= 0.15$ m

$H = 600$ m

$b = 6.375$ cm

$h = 0$

$$H - h = \frac{BF}{P}$$

$$\Rightarrow p = \frac{BF}{H-h}$$

$$S = \frac{F}{H} = \frac{0.15}{600} = \frac{1}{4000}$$

$B = ?$

$$\frac{H}{F} = \frac{B}{b}$$

$$\Rightarrow B = \frac{H \times b}{F}$$

$$= \frac{600 \times 0.06375}{0.15}$$

$$= 255$$

$$P = \frac{BF}{H-h}$$

$$P_{top} = \frac{255 \times 150}{600-120}$$

$$= 79.68 \text{ mm}$$

$$P_{bottom} = \frac{255 \times 150}{(600-0)}$$

$$= 63.75 \text{ mm}$$

$$\Delta p = 79.68 - 63.75$$

$$= 15.93 \text{ mm}$$

Ground control for Photograph :-

(i) The ground control is essential for establishing the position & orientation of is photograph in space relative to the ground.

(ii) The extend of ground control required is determine by scale of the map, the navigation control & the cartographical process by which maps will be produced.

(iii) The ground survey for establishing the control is divided into 2 types:-

a) Basic control

b) Photo control

- The basic control consist in establishing the basic network of triangulating stations, traverse station, Azimuth marks, Bench marks etc.

- The photo control consists in establishing the horizontal position or elevation of images of some of the identified points on the photograph with respect to basic control.

- Each of these controls introduces horizontal control as well as vertical control that is known as basic horizontal control, basic vertical control, horizontal photo control & vertical photo control respectively.

- The Elevation of a vertical photo control point is determined by carrying a line of levels from a basic control Bench mark to the point & then carrying to the original bench mark or to a second benchmark for checking

- The horizontal photo control points are located with respect to the basic control by 3rd order or 4th order triangulation, 3rd order traversing, 3stadia traversing, trigonometry traversing etc.

- vertical photo control may be established by 3rd order levelling, fly leveling, transit stadia leveling etc.

- The photo control can be established by 2 method
  - (a) post marking method
  - (b) pre marking method

- In the post marking method, the photo control points are selected after the aerial photography. The advantages of there method is in positive identification and favourable location of point.

- In the pre marking method, the photo control points are selected on the ground first & then included in the photograph. The marked points on the ground can be identified on subsequent photograph.

Radial Line Method of Plotting:- (Arundel's Method)

The radial line plotting called as photo triangulation is the most accurate means of plotting a planimetric map from aerial photographs without the use of expensive instruments.

- This method is based on the following perspective properties of a vertical or nearly vertical photograph.

(a) The displacement in a photograph due to ground relief & tilt are width in the limit of graphical measurement radial from the principle point of the photograph.

(b) The images near the principle point are nearly free from errors of tilt & they are shown in their 2 orthographic positions regardless of ground relief.

- The position of a point included in properly overlapping photograph may be located on the map where 3 rays from 3 known points intersect.

Principle of Radial line resection & intersection:-

This principle can be expressed in the following 2 problems-

(a) To locate the principle point of photograph on a map.

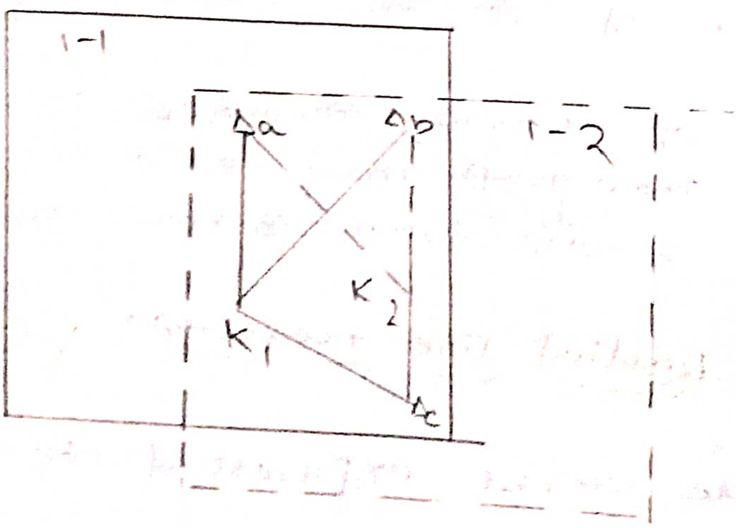
(b) To transfer images, photograph in a map.

To locate the principle point of the photograph on a map :-

- A map represents the 2 horizontal position of all points at the map scale which is uniform.
- The map position of principle point of vertical photograph can be located either by 3 point resection or by 2 point resection.

Map position of principle point by three point resection :-

Let a, b, c be the 3 photo control points appearing in both the photographs & A, B & C these are map position already known by ground survey. It is required to know the map position of the principle point K_1 & K_2 by 3 point resection.



(Photographs)

a, b, c – Photo control point of the overlap portion

DTM / DEM :-

DTM - Digital terrain Model.
DEM - Digital Elevation Model

~~terrain~~ - profile of the ground

ortho image generation / ortho photo
↓
Perfectly vertical photograph

GPS

Global Positioning system

→ Developed by DoD, USA in 1970s.
DoD – Department of Defence

→ It was actually NAVstar GPS.
↓
Navigational system of Time & Ranging
Global positioning system.

→ Constellation of 24 satellites in 6 orbits around the Earth.

→ Orbital distance is 20,200 KM.

Defination of GPS:-

(i) The GPS or Global positioning system made up of a network of 24 satellites placed into the orbit by the U.S.A department of defence.

(ii) It was originally intended for military application but later the government made the system availa[ble] civilian use.

(iii) GPS works in any weather conditions, anywhere in the world, 24 hours a day & there are no subscription fee or setup changes to use GPS.

(iv) It is a satellites based Navigational system consisting of a network of 24 orbi satellites that are at elevation of 20,200 KM in space & in 6 different orbital parts. The satellites are constantly moving, making to complete orbits around the Earth in 24 hours that means 2.6 KM/sec.

(v) GPS originally was navstar GPS is a satellite based radio navigation system by united state govt & operated by united

State space force (USF).

(ii) It is one of the global navigation satellite system (GNSS) that provides geolocation & time information to a GPS receiver anywhere on or near the earth where there is an unobstructed line of sight to four or more GPS satellites.

(iii) The GPS project was started by U.S Department of Defence & the full constellation of 24 satellites where operational in 1993.

Dilution of Precision :-

i) DOP is a value that shows the degree of degradation of the GPS positioning accuracy. The smaller is the value, the higher the position accuracy is.

ii) The value depend upon the position of GPS satellite track for positioning.

iii) If the track satellite spread evenly over the earth, the positioning accuracy would become higher.

GPS segments / components of GPS / working principle of GPS :-

GPS consist of 3 major segments.

(1) Space segment

(2) Control segment

(3) User segment

→ The control segment maintains the integrity of both the satellite & the data they transmit.

→ The space segment is composed of the constellation of satellites as a whole that are currently in orbit, including operational, backup & inoperable units.

→ The user segment is simply all the end users who have purchased any one of the variety of commercially available receivers.

1. Space segment :-

(i) The space segment consist of the complete constellation of orbiting Navstar GPS satellite.

(ii) The current satellite are manufactured by Rockwell International & cost approximately 40 million each.

(iii) To date the complete system has cost approximately 10 billion. Each satellite ways 900 kg is about 5 metre wide with the solar panels fully extended. There were 11 block-I prototype satellites launched followed by 24 block-II to production units.

(iv) The satellites are located in 6 orbits at 20,200 km altitude.

(v) Each of these 6 orbits is inclined 55 degree of from the equator & is spaced 60° apart with 4 satellites located in each orbit.

(vi) The orbital period is 12 hours that means is satellites completes to full orbits is 24 hour day.

(vii) The space segment is the constellation of satellites from which user make ranging measurements.

(viii) The SVs transmit a PRN-coded signal from which ranging measurements are made.

(ix) This concept makes the GPS a passing system for the user with signal only b transmitted & the user passively receiving the signals.

(x) The SVs send radio signal from space. The fact of the satellites is to receive & store data uploaded by the control segment.

(xi) The signals that are broadcasted by the satellites vehicles are used to determine position, velocity and time.

(xii) Maintain accurate time by means of onboard atomic clocks & transmit information & signals to users on two L-Band frequencies.

(xiii) Fully operational capability was declared on 17th July 1995.

(xiv) Currently 12 out of these satellite are redesign as a part of GPS modernization programme.

GPS satellite detail -

Name - Navstar

Galaxy - consists of 24 satellites

Manufacturer - Rockwell International

Altitude - 20,200 km

weight - 845 kg

Number of orbits - 6

" " Satellite per orbit - 4

Orbital Inclination - 55° to equatorial plane

orbital spacing - 60°

" period - 12 hours

Planed life span - 7.5 years

2. Control segment :-

(i) The control segment (ground-based) of GPS consist of master control station (MCS) located at falcon airbase in colorado springs, colorado & four unmanned monitor stations located strategically around the world, such as Hawaii monitor system (HMS), as Ascension monitor station, Diego garcia monitor station, Kwajalein monitor station

(ii) In addition the airforce maintains three primary ground antennas located more or less equidistant around the equator. Observation & controlling the satellite system is regularly.

(iii) To check the satellite functions & its accurate position in space.

(iv) To determine the time of GPS.

(v) update periodically navigation messages for each satellite.

(vi) In the event of some catastrophic failure, there are 2 also backup master control station one located in Sunny vale, California & at the other in Rockville, maryland.

(vii) The unmanned monitor stations passively track all the GPS satellites visible to them at a given moment, collecting signals data from each. This information is then passed to MCS at colorado Springs via the secure of DSCS (Defense Satellite communication system) where the satellite position (ephemeris) & clock timing data are estimated and predicted.

(viii) The MCS than periodically sends the corrected position & clock timing data to the appropriate ground antennach which the upload those data to each of the satellite. finally the satellite use that corrected information in them data transmission down to the end users.

3. USER SEGMENT :- Dt - 18/4/22

(i) The information that comes from space and sent to satellites is the most important part of GPS & this is done by the user segment, through the GPS receiver.

(ii) To collect and store the information that has come from space & satellites are required.

(iii) The user segment consist of the GPS receivers & the user community.

(iv) The GPS receivers convert the SV signals into position, velocity & time estimates. 4 satellites are required to compute the 4 dimensions like latitude, longitude, altitude & time.

(v) The user receiving equipment comprises the user segment. Each set of equipment is typically refere to as a GPS receivere which processes the L-Band signals transmitted from the satellites to determine position, velocity & time.

(vi) Navigation receivers are made for aircrafts, ships & ground vehicles & for hand carrying by individuals.

(vii) Time & frequency dissemination, based on the precise clocks onboard SV's and ~~cont~~ controlled by the monitor station is another use of GPS. Astronomical observatory, ~~tel~~ telecommunication facilities & laboratory standards can be set to precise time signals & controlled to accurate frequencies by special purpose of GPS receivere.

Working functions of GPS :-

Generally the functions of GPS are completed in five steps –

(1) Triangulating from satellite
(2) Measuring distance from a satellite
(3) Getting perfect timing
(4) Knowing where a satellite is in space
(5) Correcting the errors

1.

(i) The GPS operation based on the concept of ranging & trilateration from a group of satellite, which attached precise reference point.

(ii) Each satellite broadcast a navigation message which contains the following information.

(a) A pseudo random code called coarse acquisition (CA code), which contain orbital information about the entire satellite constellation (ALMANAC)

(b) Details of individual satellites position (eph that includes information used to correct the orbital data of satellite caused by small dis-

(iii) The GPS system time derived from an atomic clock install on the satellite, with clock correct parameters the correction of satellite time due to difference betn UTC & GPS time & the delays caused by the signal travelling through the ionosphere

(iv) A GPS health message that is use to exclude unhealthy satellite from the position solution.

(v) The GPS receivere in the aircrafts takes 12.5 minute to recieve all the data frames in the navigational message. Once obtain the reciver starts to match its satellites CA code with an identical copy of the code contain in the receiver. By shifting its copy of the satellites code, in a matching process & by comparing the shift with the internal clock the receiver can calculate how long it took the signals to travel from the satellite to the receiver.

(vi) In trilateration process, the receiver determines its position by using the calculated pseudo range & the satellite (position) information that has been supplied by the satellites.

(viii) If only satellite is visible, position location is impossible as the receivere location can be anywhere on the surface of the earth with the satellite as its centre.

(ix) With atleast 4 satellites visible, and their alignment is good, the 4 spheres will intersect at only one point in space so, the recieven position can be accurately fixed in 3 dimensions.

(x) Altitude reciever from GPS position are called as geodetic altitude & where not initially used for aircraft navigation.

(xi) As GPS satellites provide very accurate time reference as well as precise 3D position, they can also calculate & provide accurate speed data.

2. Measuring distance from a satellite :-

- Distances are calculated on GPS is based on signals of a satellite ranging.
- Distance . D = speed of the satellite ranging (3×10^8 m/sec × time)

where time = $t_2 - t_1$

t_1 = sending time
t_2 = receiving time

3. Getting perfect Timing :-

- If the travel time measured to the radio signals are the basic of GPS then the stopwatch are very working instrument in this case to stop.
- If their time is stopped for 1000 of a second, then it will wrong out 200 miles.

- In terms of satellite, timing is perfect because the atomic clock is the compulsory elements of the satellite system.
- The key to accurate scheduling is to measure the distance to an extra satellite.
- ~~Knowing a~~

4. Knowing where a satellite is in space :-
- We know that the exact position of satellite for which we can use that satellite as a reference point, but how accurately their position is the matter of concern.

5. Correcting the Errors :-
- In reality, there are a lot of things which can disrupt the GPS signals. To get the accurate results, these errors are likely to be corrected.

- The relative position of satellite in space give rise to the errors.

Signals of GPS :-

- GPS system sends their information through microwave signal.
- Signal systems are as below -

Pseudo Random code (PRC) :-

- It is the prime part of GPS.
- It is a complicated of digital number or complicated sequence of on & off pulse.
- There are 2 types of PRC signals.

(i) C/A code :-

- It contains L_1 signals.
- It repeats every 1023 bits & modulates at rate of 1 megahz
- C/A code is the basis of civilians GPS users.

(ii) Precise code :-

- It is more complicated than C/A code.
- It can modulate both L_1 & L_2 carriers signals at a rate of 10 mhz.
- It is used for military purpose.
- There are 2 types of signals L_1 & L_2

L_1 signals -

L_1 carries 1575.42 mhz & both the status message and a pseudo random code for timing.

L_2 signals -

- It carries 1227.6 mhz.
- It used for more precise military pseudo random code.

Errors in GPS signals :-

There are a number of sources of errors that the GPS measurements.

1. Satellite clock error :-

(i) The satellite contains atomic clocks that control all the onboard time operation including broadcast & signal generation.

(ii) All though this clock are highly stable, the clock correction fields in the navigation data message are sized such that the deviation bet^n the SV time & GPS time may be as large as one microsecond.

- The correction parameters are implemented by the receiver using a second order polynomial.
- Since these parameters are computed using a curve-fit to predicted estimate of the actual satellite clock error.

- These residual clock error results in ranging errors that typically vary from point 0.3 to 4 m depending upon the time of satellite & age of broadcast data.

- Range errors due to residual clock errors are generally the smallest following a control segment uploads to a satellite & they slowly degrade over time until the next upload.

- Errors were obtained to be statistically independent from satellite to satellite with significant correlation over time.

2. Ephemeris error -

- Estimates of ephemeris data for all the satellites are computed & uplinked to the satellites with other navigation data messages for rebroadcast to user.

- Ephemeris errors are generally smallest in the radial direction (from satellite towards the centre of earth).

- The components of ephemeris errors in the along-track (instantaneous direction of travel of the satellite) & cross track (perpendicular to along-track) directions are much larger.

- Along-track & cross-track components are more difficult for the control segment to observe through its monitor on the surface of earth.

- The user does not experience large measurement errors due to the largest ephemeris errors components for the same region.

3. Relativistic Effects :-

- The need for special relativity corrections arise any time signal source or the signal receiver is moving with respect to the chosen isotropic light speed.

- The need for general relativistic corrections arises anytime the signal sources & the signal receivers are located at different gravitational potentials.
- The satellite clock is affected by both SR & GR.
- In order to compensate both these effects, the satellite clock frequency is adjusted to 10.22999999543 Mhz prior to launch.

- Due to rotation of earth, during the time of signal transmission a relativistic error is introduced called as Sagnac Effect.

- Correction for sagnac effect are often refer to as earth rotation corrections. If left uncorrected, the sagnac effect can lead to position error on the order of 30 m.

4. Atmospheric Errors :-
- It includes ionospheric effects & tropospheric village.
- The ionosphere is a dispersive medium located primarily in the region of atmosphere betn 70 to 1000 km above Earth surface. within this region the UV rays ~~~~~~~~ the UV rays from sun ionized a portion of ~~~~~~~~ gas molecules and release free electrons.
These free electrons influence the electromagnetic wave propagation including GPS satellite signal broadcast

- The troposphere is the lower part of [illegible] is non dispersive for frequencies up to ≈ 15 GHz.
- With in this medium the phase & group velocities associated with the GPS carrier & signal information on both L_1 & L_2 are equally delayed with respect to free space propagation.
- This delay is the function of tropospheric refractive index which depends on local temp, pressure & relative humidity.

- Receiver noise & resolution
- Multipath & shadowing effect
- User equipment biases
- Satellite Bises
- Pseudo range error budgets

Date - 20/4/22

- **Multipath and shadowing effect :-**

Multipath errors varies significantly magnitude depending on the environment within which the receiver is located, the satellite elevation angle receiver signal processing antenna gain pattern & signal characteristics.

Hardware Biases :-

The timing bias betⁿ L_1 & L_2 signals is inconsequential for most dual frequencies users since the broadcast clock corrections compensate from the bias under the presumption that the user is combining L_1 & L_2 pseudorange measurements via the ionospheric free pseudo range equation.

- User Equipment Biases :-

It is introduced by the receiver hardware because there relatively small in comparison to other error sources, hence ignored.

- for many application the common delay does not affect performance since it does not influence positioning accuracy, but rather directly appears only in the least square estimate of the receiver clock bias.

- Pseudo range error budgets :-

These budgets are intended to solve as guideline for position error analysis.

Application / uses of GPS :-

- Receiver noise & resolution :-

Measurement errors are also induced by the receiver tracking loose. The sources of these errors include factal noise & the effects of reference interference.

- Receiver noise & resolution errors affect carrier phase measurements.

The GPS provides critical capabilities to military civilian & commercial users around the world.

1. GPS & satellite image
2. Road traffic and longestion
3. Defence applications.
4. Accidental purpose
5. Idea on tectonics
6. used in terrorism
7. used in minings
8. used in climatology
9. GPS used in tourism
10. Navigational use
11. Disaster relief
12. fleet tracking
13. Robotics
14. Surveying
15. Automated vehicles
16. Agriculture
17. Tracking of oil leaks.
18. Astronomy
19. Topography mapping
20. forecasting
21. urban planning
22. cartography

Names of the Satellite (GNSS) –

1. GPS (USA)
2. Global'naya Navigatsionnaya Sputnikovaya Sistema
3. Galileo (EU)
4. Beidou (China)
5. NavIC (India) - Navigation with Indian constellation
6. QZSS (Quazi zenith satellite system)
7. DORIS (France)

DGPS (Differential Global Positioning System) :–

- It is an enhancement to global positioning system which provides improved location accuracy, in the range of operations of each system from 15 m nominal GPS accuracy to about 1 to 3 cm in case of based best implementation.
- DGPS use fixed reference location, Earth to calculate positioning errors transmitted by the satellite view.

Dt:- 21/4/22

GPS	DGPS
(i) Only one stand GPS receiver is used.	(i) Two rover and stationary receiver are used.
(ii) Accuracy is 10 to 15 m	(ii) Accuracy is 10 cm.
(iii) The range of the instrument is global.	(iii) The range of the instrument is local (within 100 km).
(iv) The cost is affordable	(iv) The cost is expensive.
(v) The frequency range vary from 1.1 to 1.5 GHz	(v) The frequency varies as per the agency.
(vi) The factors that are affecting the accuracy is selective availability, satellite timing, atmospheric conditions, ionosphere, troposphere & multipath.	(vi) The factors affecting the accuracy are the distance betn the transmitter & atmosphere, ionosphere, troposphere & multipath.
(vii) The time co-ordinate use is WGS - 84.	(vii) The time co-ordinate used is local co-ordinate system.

Differential positioning :-

- Differential or relative positioning requires atleast 2 receivers setup at 2 different stations.
- One receiver is placed at well defined position or known position called reference station or base station & the 2nd receiver is placed at an unknown station whose value to be determined.
- The 2nd receiver is called the rover receiver or the navigation.
- Both the receiver simultaneously are set to collect the satellite data to determine the coordinate differences.
- The process involves the measurement of differences in ranges betn the satellite & 2 or more ground observing points.
- Both the reference & rover receivers ~~transmit~~ & appear data simultaneous for later data computation called post processing or in real time the reference receiver transmits the differential data to the rover receiver for real time computation of position.
- The basic principle of differential positioning is that the absolute positioning errors at the 2 receiver point will be approximately the same for a given instant of time.
- The resultant accuracy for a given instant of time.
- The resultant accuracy of these co-ordinate differences is at the meter level for loaded & at centimetre level for carrier phase observations & phase observation.

- GPS BASELINE :-
- The GPS receiver used for surveying are more complex & expensive than those used for navigation.
- Survey grade GPS receivers used dual frequency (L_1 & L_2) broadcast by the GPS satellites.

- The survey grade receiver usually have a separate high quality antenna.

- The GPS baseline uses two survey quality GPS receiver with one at each end of the line to be measured.

- They collect the data from the same GPS satellite at the same time.

- The duration of these simultaneous observation varies with the length of the line & the accuracy needed but is typically an hour or more.

- When the data from both this points is later combined, the difference in position (latitude, longitude & height) betn the 2 point is calculated with the help of post processing software.

- Although a single base line from a known position is enough to give the position of the other end of the base line, additional GPS base lines to other points are often measured to give a check on the results & estimate of uncertainty of the calculated position.

GENERAL FIELD SURVEY PROCEDURE VISION AN THE DGPS:-

This procedure should be followed for static, kinematic, real time & real time & post processed data collection.

(i) Antenna setup :-
All the tribrachs for mounting the antennas should be calibrated and adjusted both optical P and standard plumb bob must be used to minimize centering errors.

- The reference line marked on the antenna should be oriented towards the north direction with the help of magnetic compass.

(ii) Receiver setup :-

- All the GPS receivers have to be setup in accordance with the manufacturer instruction prior to any observation.

- Base station, antennas should be mounted on tripod and kinematic rover receivers & its antenna should be mounted on range polls.

- For kinematic observation in RTK (Real time kinematic) method, a radio modem for transmitting of real time correction have to be setup along the base station and rover receiver.

- Modern GPS receiver are having separate data controller to record, co-ordinate & process all GPS data & they have the facility of bluetooth, wireless or wired connection.

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(iii) Height of Instrument :-

- These refers to the correct vertical height of the GPS antenna above the reference datum.

- The height measurement is made to a fixed point on the antenna mounting device from which the calibrated distance to the antenna phase centre can be added.

- HI measurement should be done both before & after each observation session.

- HI measurement should be made to the nearest mm in metric units.

- It should be noted that whether the HI is measured vertical or diagonal.

- All the GPS receiver will have specific antenna height measuring guidance with their instrument operating manual.

field observation recording procedure :-

field recording long sheets, log forms or fully text input data collectors have to be completed for each station and session. The following typical data can be included on the field logging records.

1. Date & weather conditions
2. Station & Designation
3. station file number
4. Time of starting and ending of observation session
5. Receiver, antenna, controller, model and serial number
6. Antenna height vertical or diagonal
7. space vehicle designations of satellite observe during the session.
8. sketch of the station location.
9. Approximate geodetic location & elevation.
10. Problems, encountered.

field calibration and initialization

- for kinematic surveys it is necessary to calibrate the best station to know local co-ordinate point & reference datum.
- An initialization process may also be required for some type of kinematic surveys.
- The calibration procedure should be noted on the log.

field processing & verification :-

GPS data processing & verification have to be done in the field itself as far as possible to identify any problems that can be corrected before returning from the field.

Survey sessions :-

- The survey sessions refers to a single period of observation.

- Sessions and station designation are denoted by the original manufacture of the receiver.

- The station and session designation should be co-related with the entries on the log forms so that there will not be any doubt during base line processing.

- In addition for best processing, the following points should also be noted.

1. Satellite visibility for each station.
2. Name of the person designated to each station
3. Project sketch.
4. Site reconnaissance data for station.
5. Explicit instruction on which each session to begin and end and follow up session.
6. Providing observer's data log sheets for each occupied station.

Office procedure after Data collection :- 1/22

The survey data should be systematically catalog and archived begin observation session on at the end of working day.

Many problem can be identified

Some of the typical field office procedure as follows -

1. Transfer of data from receiver to the computer
2. data verification & back up.
- Preliminary computation of base line.
- Preliminary quality control procedure.
- compared & control of survey parties for repeated observation session.
- Supervise calibration & testing of field equipment
- Go through the operators manual & download the data.
- Delete the files from the receiver memory when the data download procedure has been verified.
- download the data to the computer & make backup copies.
- Store backup copies separately

Post Processing of differential GPS data :-

The flow of process used when reducing GPS base lines are follows :-

1. Create a new project
- download the baseline data from receiver and data collection.
- download precise ephemeris data.

- Process all based lines.
- review inspect and evaluate adequacy of baseline reduction results.
- Make changes & rejected / Rejects.
- Reprocess the base line and reevaluating the results.
- Designate independent & trivial base lines.
- Review look closer & adjust base line network

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Differential Reduction Technique :-

These are 3 methods of differential reduction technique - (1) single Differencing
(2) Double Differencing
(3) Triple Differencing

1. Single Differencing Betn Receivers :-

It is the process of single differencing the mathematical model for pseudo range or carrier phase observable measurements betn the receivers and will eliminate the satellite clock errors and large amount of satellite orbit and atmospheric delays.

Single Differencing Betn Satellites :-

It can be done at each individual receiver during observations as a prerequisite to double differencing & in order to eliminate receiver clock errors.

Single Differencing Betn Epochs :-

Single differencing, the mathematical model betn epochs takes advantage of doppler shift or apparent change in the frequency of the satellite signal by the relative motion of the transmitter & receiver. It is generally done to eliminate cycle ambiguities.

- There are 3 forms of single differencing techniques betn the epochs.

(i) Intermittently integrated doppler (IID)
(ii) Consecutive doppler counts (CDC)
(iii) Continuously integrated doppler (CID)

2. Double Differencing :-

- It is the differencing of two single differences.
- It eliminates clock errors.
- There are 2 general methods of double differencing technique
- Receiver time
- Receiver satellite

Receiver time double differencing :-

- It uses a change from one epoch to the next in betn the receiver single differences for the same satellite.
- It eliminates satellite dependent integer cycle ambiguities and simplifies editing of cycle sleeps.

• Receiver satellite double differencing -

These technique uses a pair of receivers recording different satellite observations during a survey session & then differencing the observations betn the two satellites.

3 Triple Differencing :-

• There is a single type of triple differencing procedure namely receiver satellite time (epoch)

- When used in conjuction with carrier beat phase measurement, it eliminates initial cycle ambiguity.

- In this case the data are automatically edited by the software to detect any data that can not be solved.

- This feature is advantageous to the user because of the reduction in the editing of data required.

Base Line Processing :-

The steps for baseline processing are as follows:-

(i) Downloading GPS data:-

- In this process the observation data is transferred from the GPS data collector to the personal computer for processing.

(ii) Preprocessing.

Once observation data has been downloaded, preprocessing of data can be completed. It depends upon the type of GPS data collected. (Static, rapid static & kinematic).

(iii) Ephimeris data:-

Retrieval (extraction) of post processed ephemerides may be required depending on the solution and type of survey being conducted.

(iv) Base line solution :-

Carrier phase Baseline processing is fairly automatic process on almost all commercial software packages if all observed baseline are processed any dependent baselines should be removed so that they will not be used in subsequent network adjustment.

Standard GPS data formats :-

Most widely used standard formats of GPS data are as follows :

(i) RINEX (Receiver Independent exchange)

(ii) RTCM SC-104. (Radio Technical commission for maritime services study committe)

(iii) NMEA (National Marine electronics Association)

LATENCY :-

- In differential positioning, it takes some time for the base station to calculate corrections & it takes some time for it to put the data in the packets of correct format & transmit them.
- The time it takes to transmit the data from the base station to the rover station is called latency time.
- It can be as ~~little~~ little as 1/4 sec to 2 sec.

Geographical Information System (GIS) Dt- 4/5/22

- computer based system in which data about position, location can be shown in the map format / pictorial format a lap with idea of properties of that location.

Defination of GIS :-

i) A GIS is a specific information system applied to geographic data and is mainly referred to as a system of hardware, software & procedures, designed to support the capture, management, manipulation, analysis, modelling & display of spatially reference data for solving complex planning & management problems.

ii) GIS is a powerful computerised information system for spatial data referenced by the geographic co-ordinate

iii) GIS is any manual or computer based set of procedures used to store & manipulate geographically referenced data.

Components of GIS :-

(1) computer Hardware
(2) Software
(3) spatially / Geographically referenced data
(4) Personnel's involved

1. Computer Hardware :-

The hardware component of GIS include
(1) Procesor
(2) Monitor
(3) input devices like keyboard, mouse, digitizer, scanner.
(4) storage devices like floppy, floppy disk, CD's, Hard disk.
- output devices like monitor, printer, plotter.

(2) Software :-

Some of the GIS software include -

(i) ARCINFO (developed by ESRI, USA)
(ii) ARCVIEW (" " " ")
(iii) AutoCAD Map (developed by Autodesk
(iv) MAPINFO (developed by MAPINFO corporation
(v) SPANS (PCI Geomatics CANADA)
(vi) ISRO GIS (INDIA)
(vii) GISNIC (NIC, INDIA)
(viii) GRAM ++ (IIT BOMBAY)

(3) Spatially / Geographically referenced data :-

(i) The spatially referenced data are the data which describes the entities & events of the real world in terms of their position or location, attributes & the spatial relationship with each other.

(ii) Every spatial entity has a specific position or location as it pertains to some space in the real world, so without having knowledge regarding location, we can't identify the entity or event.

(iii) The characteristics related to the location are called attributes. The attributes may be spatial or non spatial.

(iv) Every spatial entity has a geometric relationship with other spatial entities or events. For better analysis of spatial data, the understanding of this relationship is necessary. This relationship is called Topology. This may include adjacency, containment & connectivity.

(4) Personnel's involved :-

A GIS is useless without the people who design, Programme & maintain it, supply it with data & interpret its results.

Data Structure in GIS :-

The spatially referenced data has two components
(1) Spatial components
(2) Attribute component

The organisation of this data can be studied under two heading.

Spatial data Model –
1. Raster Model
2. Vector Model

Attribute data Model –
There are 3 classical ways of representing attribute data.
1. Hierarchical Model
2. Network Model
3. Relational Model

Raster Model :-

It is an explicit representation of spatial component of data in which a set of cells is located by coordinates & each cell is independently addressed with the value of an attribute. It is the representation of spatial component of data in terms of grids or pixels.

Vector Model :-

It is an explicit representation of spatial component of data in which the 3 main geographical entities such as point, line & polygon are used to describe spatial entities or events.

- The spatial features or events are represented in terms of either point or line or polygon.

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Hierarchical Model :-

This model assumes that each part of the hierarchy can be reached using a key that fully describes the data structure. This model are good for data retrieval.

Network Model :-

In network model, an entity can have multiple parents as well as multiple child relationship. It is very useful in case where much more gre is required. Particularly in data structures, for graphic features where adjacent items in a map or figure need to be linked together even though the actual data about the coordinates may be written in very different parts of the data base.

Relational Model :-

The relational data base model is the simplest form that stores no pointers & has no hierarchy of the data fields within a record

functionalities of GIS :-

The GIS software along with other elements occure a variety of tools and functionalities for performing a wide range of desired data input, storage & editing, manipulation, analysis & presentation related activities, which can be group under 4 major module -

(1) Data input, modeling, storage module.
(2) Data retrieval, editing, manipulation & management module.
(3) Analysis module
(4) Presentation of output generation module.

Applications of GIS :-

Some measured applications of GIS can be defined as follows :-

(1) Socio economic / Government :-

- health infrastructure planning
- Local Govt
- transport planning
- service planning
- urban management

(2) Defence agencies :-
- Target site identification
- Tactical support planning
- Mobile command modeling
- intelligence data integration
- commerce &

Commerce & business :-
- Market
- insurance
- fleet management
- direct marketing
- target marketing
- Retail site location

Utilities :-
- Network management
- service provision
- telecommunication
- emergency repairs

Environmental Management :-

1. Landfill site selection
2. Land use analysis
3. site suitability analysis
4. pollution monitoring
5. natural hazard assessment
6. disaster management
7. Environmental impact assessment

Basics of scale / Maps :-

- Scale - Ratio betn the Map distance / ground distance surface of earth
- Map - The pictorial form of the surface of earth on a sheet is called as map.
- Map Projection :-

{Spatial - It is related to location}

- Classification of Map :-

(1) Physical Map - physical characteristics of the map
(2) Topographic Maps - ground features of the map
(3) Road maps - It shows the various Roads
(4) Political Maps - Political boundaries of state, country, district etc.

(5) Economic & Resources Map -
(6) Thematic Map / Reference Map - The map is prepared on a particular theme / Population
(IMP)

Introduction :-
Geodesy is the science concerned with the study of the shape & size of the earth in the geometrical sense, & the study of certain pysical phenomena, such as gravity, seeking explanation of fine irregularities in the earth's space. The subject is intimately linked with surveying & mapping.

Types of Map :-
Maps are made for a variety of users. Geographers, military personnel, economists, planners, civil engineers, architects, aire & marine navigators & a host of other users use map. The earth features are numerous, & hence it is not possible to represent all of them on one map. They are drawn on various scales to suit various requirements. Maps can be mainly classified into 4 categories as discussed below -

(1) Cadastral Maps
(2) Topographic Maps
(3) Thematic Maps
(4) Remotely sensed Images

1. Cadastral Maps-
- Cadastral maps are used to demarcate the boundaries of fields & buildings & for registering the ownership of landed properties.
- Cadastral maps have the location of property-ownership lines.
- They are prepared & compiled by government agencies & are used for revenue & tax purposes.

2. Topographic Maps-
- Topographic maps show the shape & elevation of terrain. Topographic maps are used for designing gardens & parks, building roads & pipes, planning hiking routes. Examples for topographic maps are flood control maps & engineering maps.

3. Thematic Maps-

A thematic map shows information about a special topic, which is superimposed on a base map.

- Types of thematic maps include geologic, forestry, soil, land use & historical.

4. Remotely sensed images-

Remote sensed images are geographic information gathered by means of a sensor. The common remote sensing images include aerial photographs, radar images & satellite images.

- Scale of a Map :-

- A Map scale provides the map viewer a ratio betn the size of the features on the map & the size of the features on the ground. The orientation of a map shows the way that the map is aligned relative to the Earth's surface.

- Map are always oriented with the north (normally true north) at the top.

- One should know the differences betn Northing, Southing, Easting & westing & be able to locate these orientations on a map.

- The relation betn the map distance & the ground distance is called a scale, & is defined as the proportion betn a distance on the map and the corresponding distance on the ground.

- To make a map useful, cartographers establish & indicate a consistent relationship betn size on the map & size in real life. This relationship is the map scale.

- Map scale is the basis of drawing maps. It enables us to represent the features of the ground on a map of convenient size.

- The 'Survey of India' has started publishing maps on the scales of 1:25,000, 1:50,000, 1:2,50,000, 1:10,00,000 etc. It may be helpful to categorize the scale as below:-

Large scale - 1:50,000 & larger
Medium scale - 1:50,000 to 1:2,50,000
Small scale - smaller than 1:2,50,000

- Representing the scale of a Map:-

The scale of a map can be represented by using a bar scale, a representive fraction, or a text scale.

Bar scale - A bar scale shows a graphic represen-tation, where you can actually measure the distance on the map & then compare it to the bar scale.

Representative fraction - A representative fraction gives the map viewer a number scale represented by a fraction. An example of a representative fraction would be 1:24,000.

Textual scale - A text scale actually describes the scale in words, for example, 1,00,000 cm equals one kilometre & a text scale on the map for a representative fraction of 1:1,00,000 would look like, 1 cm on the map equals to 1 km on the ground, or 1 cm equals 1 km.

- USES OF MAPS -

A map defines the following:-

Position (Location) - A map gives the location or position of places or features. The positions are usually given by the co-ordinates of the place, either in the cartesian co-ordinates (x, y) in metere, or in geographic coordinates (latitude & longitude) in degrees, minutes & seconds.

Spatial Relationships - A map gives the spatial relationship betn features. for examples, which district is the neighbour of another district? on which side dr the road is the river? Is there a dam on the town? where is the nearest railway station?

Distance Direction, Area - One can determine a lot of information from a map such as distances, directions & areas. In determining distances & areas, the scale of the map has to be taken into consideration.

- Characteristics of Maps-

Ans The characteristics of maps are:-

1. All maps are concerned with 2 primary elements location & attributes.
2. All maps are reductions of the reality - scale.
3. All maps are transformations of space - map projections & co-ordinate systems.
4. All maps are abstractions of reality - generalization & its components.
5. All maps use signs & symbolism - cartographic symbolization.
6. All maps are static & dependent upon the stability of the data.

- Map Projection :-

- Map projection is the method by which the curved surface of the earth, or a part of it, is represented on a flat surface on a certain scale by making parallels & meridians. In other words, transformation geographical coordinates to a plane grid coordinate system is referred to as map projection.
- Globes & maps of the world generally show lines of latitude & longitude, also known as parallels and meridians, that cross each other on the surface of the earth. This is called a graticule. Thus map projection may be defined as the preparation of the graticule on a flat surface.
- Mathematical formulae are used to construct a graticule on a map, corresponding to the intersecting graticule & meridian of the earth

- AN IDEAL MAP PROJECTION-

An ideal map projection represents the meridians and the parallels in the same way on a globe. The global network of meridians & the parallels has the following characteristics :-

(1) The equator divides the globe into 2 halves, the northern hemisphere & the southern hemisphere.

2. The equator is the only great circle ~~in length~~ line of latitude. All other lines of latitude are shorter than the equator and are not great circles.

3. Each meridian is one half a great circle in length. It is the shortest ~~route~~ line betn the two poles.

4. All meridians converge at the north & south polar points.

5. The parallels and the meridians intersect at right angles.

- Projection characteristics:-

An issue with all projections is that they have to distort or change in some way the representation of shape, area, direction, or distance of land features or graticule in one way or another, in order to flatten the globe to a piece of paper.

Features of various projection:-

Shape -

Map projections that represent the true or correct shape of the earth's features are called conformal projections. Usually, these map projections can only show small areas of the earth's surface at one time.

Area:-

Other projections, called 'equal area' projections, are drawn so that they illustrate the same representation of the area of ~~a~~ features.

Distance:-

Equidistant maps, or maps that keep the correct representation of actual distance on the earth are very important to travellers. An example of an equidistant map projection is a 'polar (meaning at the north or south pole) azimuthal equidistant projection.

Direction:-

Another feature of map projection is direction. The shortest distance betn two points is a straight line, except globe. A straight line on a globe is actually curved due to the spherical shape of the globe, & is called a great circle.

• Different Map Projection :-

There are many types of map projections. There are different criteria considered for the classification, they are map projections according to the developable surface, map projections according to the method of deviation (source of light) & the map projection according to the global properties.

- The map projections according to the projection surface are classified as:

1. Conic projection
2. Cylindrical Projection
3. Planar or azimuthal projection

• The Universal Transverse Mercator-

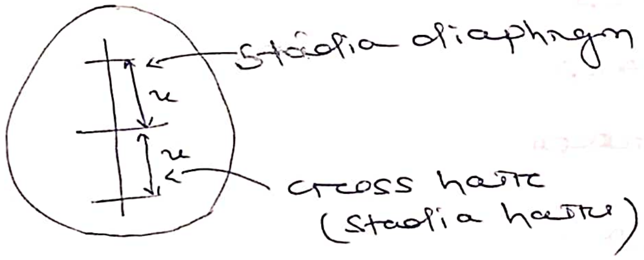
This projection is used to define horizontal positions worldwide by dividing the surface of the earth into 6 degree zones, each mapped by the transverse Mercator projection with a central meridian in the centre of the zone. Universal transverse mercator (UTM) zone numbers designate 6 degree longitudinal strips extending from 80 degrees south latitude to 84 degrees North latitude.

Dt-19/5/22

TACHEOMETRY

Tacheometry is the process of measuring horizontal & vertical distance betn any two points on earth by using angular measurement.

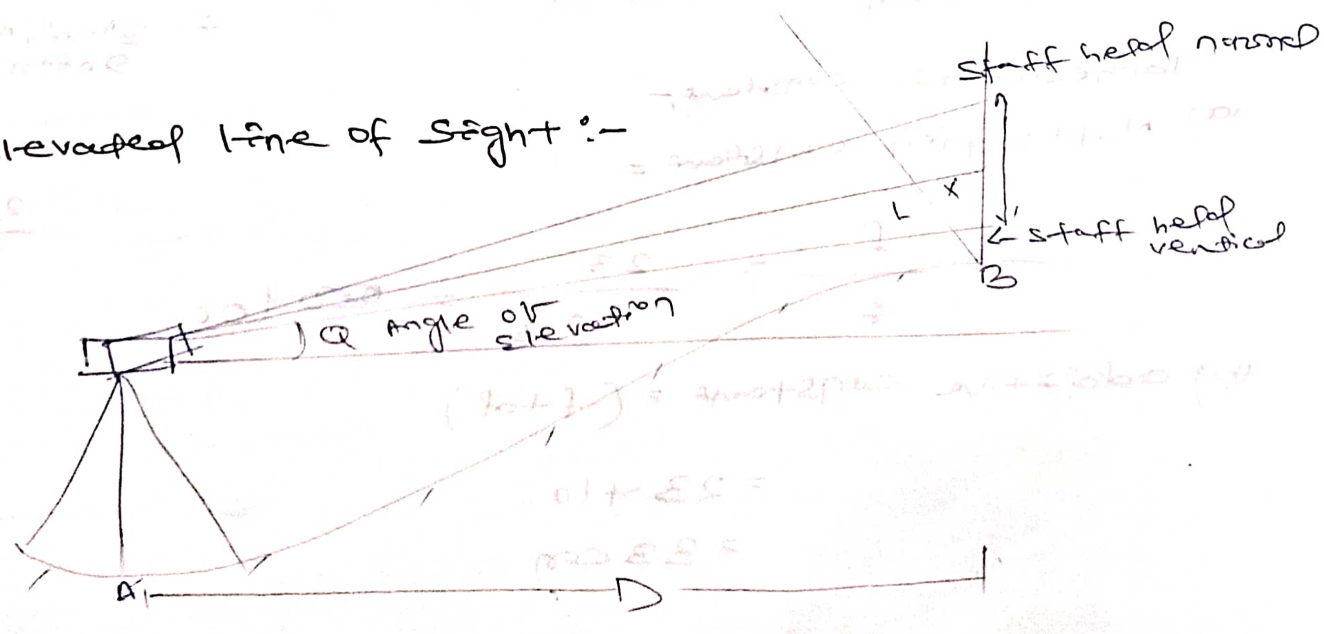
Instruments used - Tacheometer
↳ Theodolite with an anallactic lens.



x & x = constant

Depressed line of sight-

Elevated line of sight :-



1) Additive constant (f+d). f = focal length of lens

2) Multiplying constant ($\frac{f}{i}$)

d = Distance betn focus & image

i = stadia intercept / interval

| anallactic lens - additive constant = 0 |

Distance formula :-

$$D = As + B$$

B = additive constant

A = Multiply constant

S = Staff intercept

Distance eqn formula :-

$$D = (f/i)\, s + (f+d)$$

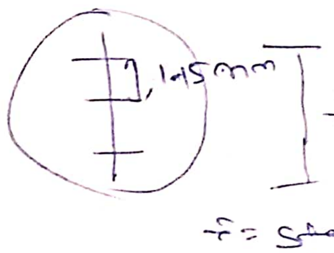
Q) A tacheometer has a diaphragm with 3 cross hairs spaced at distance of 1.15 mm. The focal length of the object glass is 23 cm & the distance from the object glass to the trunnion axis is 10 cm. calculate the tacheometry constant.

Sol Given data,

f = 23 cm

i = 2×1.15 = 2.3

d = 10 cm



i = stadia interval

Tacheometric constant -

(a) Multiplying constant =

$$\frac{f}{i} = \frac{23}{0.23} = 100$$

$\frac{2.3}{10} = 0.23$

(b) additive constant = (f+d)

= 23 + 10

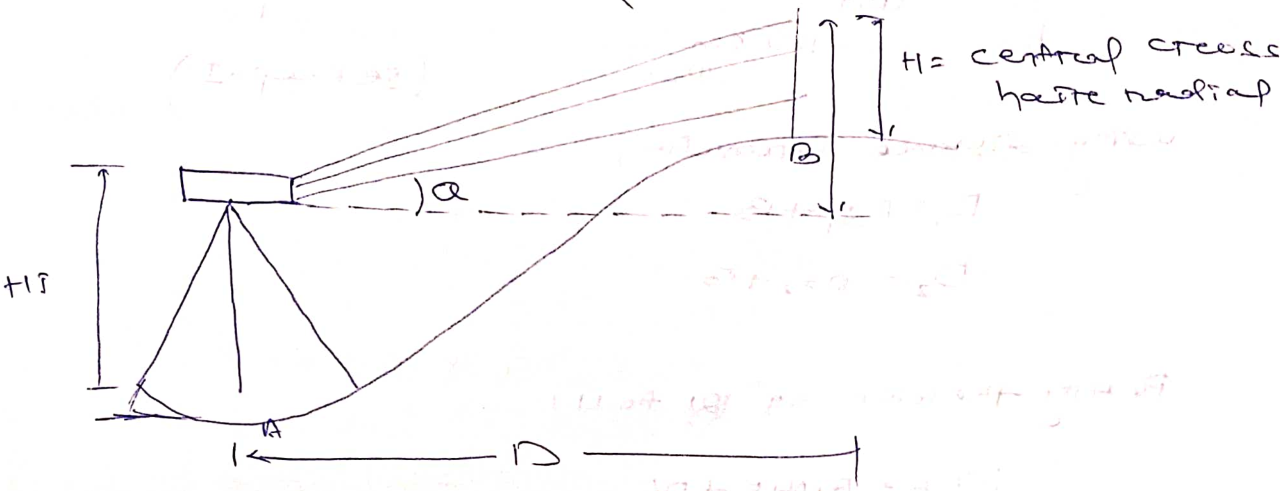
= 33 cm

• Distance of elevation for inclined line of sight

$$d = AS\cos^2\theta + B\cos\theta$$

Elevation formula,

$$V = AS\frac{\sin 2\theta}{2} + B\sin\theta$$



Dt - 20/5/22

(Q) A staff was held vertically at a distance of 46.2m & 117.6 m from the centre of a theodolite fitted with stadia hairs at the staff intercepts with the telescope horizontal where 0.45 m & 1.15 m respectively. The instrument was then set over station P of RL 150 m, the HI be 1.38 m, the stadia hair readings on a staff held vertically at a station where 1.2m, 1.93m & 2.65 m respectively while the vertical angle was 9°30'. find the distance PQ & RL of Q.

Sol^n Given data

$HI = 1.38$ m

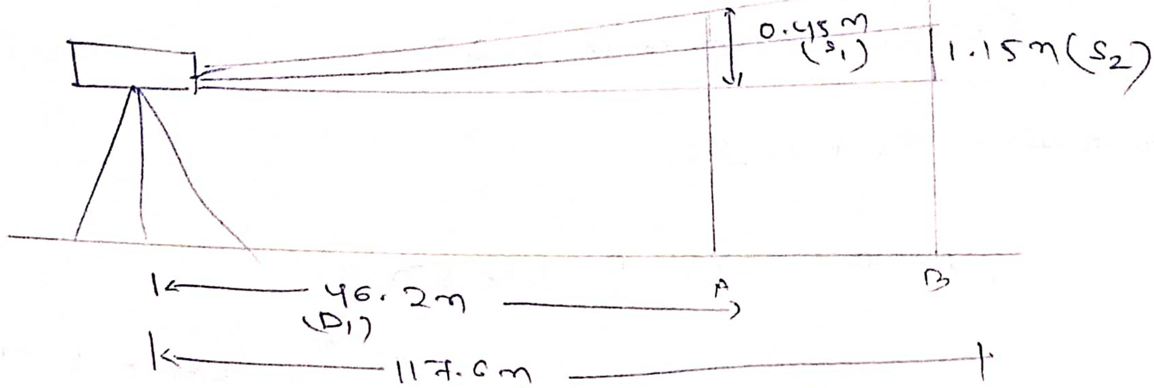
$\theta = 9°30'$

$S_1 = 1.2$m

$S_2 = 1.93$

$S_3 = 2.65$ m

$S = 0.73$ m



(setup-I)

using distance formula,

$D_1 = AS_1 + B$

$D_2 = AS_2 + B$

Putting the value eqn (2) to (1)

$117.6 = A \cdot 0.45 + B$
$46.2 = A \cdot 1.15 + B$
(−) (−) (−)

$71.4 = A\ 0.7$

$A = \frac{71.4}{0.7} = 102$

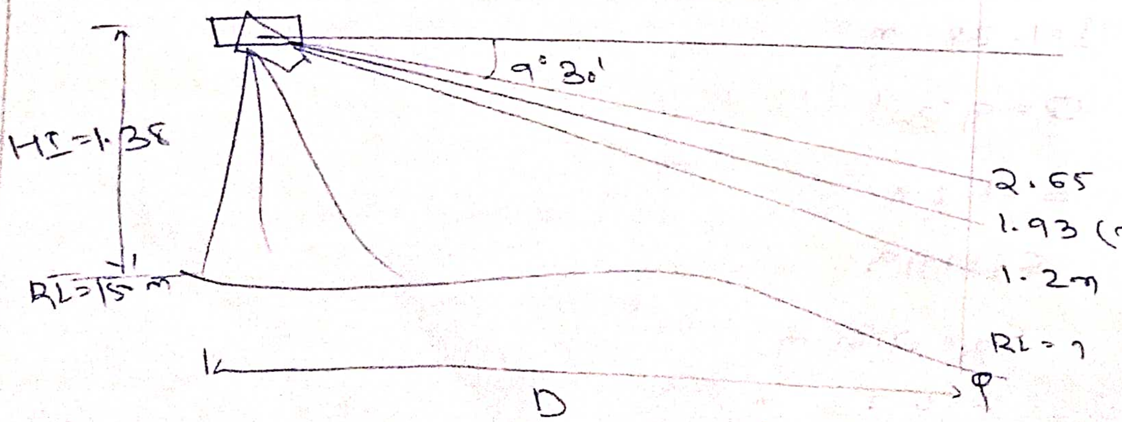
$D_1 = AS_1 + B$

$46.2 = 102 \times 0.45 + B$

$= 46.2 = 45.9 + B$

$\Rightarrow B = 46.2 - 45.9$

$B = 0.3$



Setup-II

Staff intercept $S = US - LS$

$= 2.65 - 1.2 = 1.45$

Distance formula,

$D = AS\cos^2\theta + B\cos\theta$

$\Rightarrow PQ = 102 \times 1.45 \times \cos(9°20')^2 + 0.3 \times \cos(9°20')$

$= 144.16$ m

Elevation formula,

$V = AS \dfrac{\sin 2\theta}{2} + B\sin\theta$

$= 102 \times 1.45 \times \dfrac{\sin(2 \times 9°20')}{2} + 0.3 \times \sin(9°30')$

$= 24.125$ m

$RL_Q = RL_P + HI - V - h$

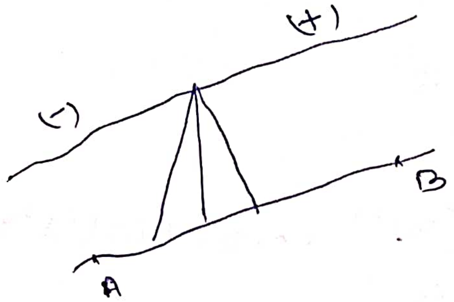
$= 150 + 1.38 - 24.125 - 1.93$

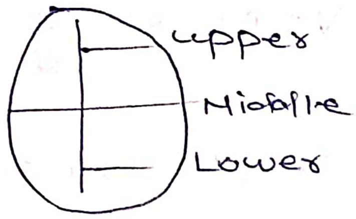
$= 125.325$ m (Ans)

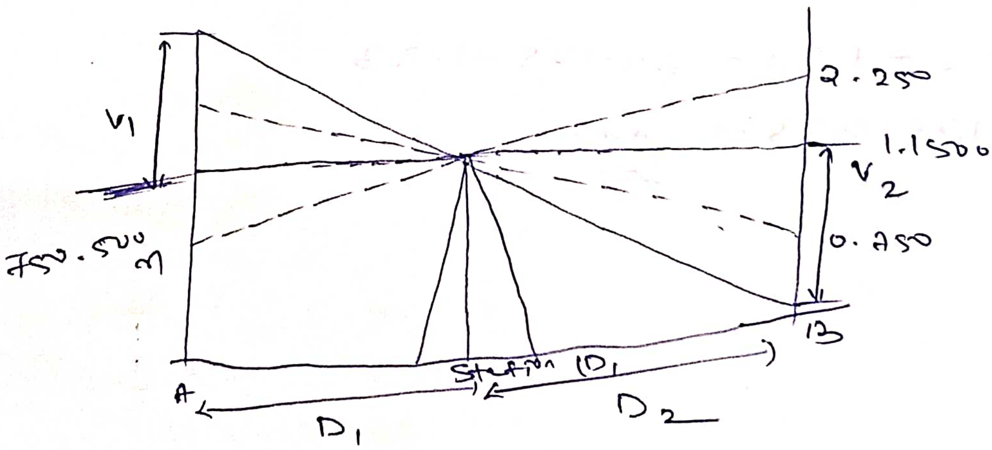
IMP Question

Instrument Station	Staff Station	Vertical Angle	Hair Readings	Remarks
A	BM	$-5°20'$	1.150, 1.800, 2.450	RL of
B	B	$+8°12'$	0.750, 1.500, 2.250	BM = 750.500 m

Solution – Calculate the horizontal distance AB & RL of B.







$S_1 = 2.450 - 1.150 = 1.3\ m$

$S_2 = 2.250 - 0.750 = 1.5\ m$

$D = KS\cos^2\varphi + c\cos\varphi$

$D = D_1 + D_2$

$V = KS\dfrac{\sin 2\theta}{2} + c\sin\varphi$

$D_1 = KS_1 \cos^2\alpha + C\cos\varphi$

$= 100 \times 1.3 \times \cos(-5^\circ 20')^2 + 0 \cos(-5^\circ 20')$

$= 128.87$ m

$D_2 = 100 \times 1.5 \times \cos(8^\circ 12')^2 + 0 \cos(8^\circ 12')$

$= 146.94$ m

$D = 128.87 + 146.94$

$= 275.81$ m

$V_1 = 100 \times 1.3 \times \frac{\sin(2 \times -5^\circ 20')}{2} + 0 \sin(-5^\circ 20')$

$= 12.03$ m

$V_2 = 100 \times 1.5 \times \frac{\sin(2 \times 8^\circ 12')}{2} + 0 \sin(8^\circ 12')$

$= 21.17$ m

RL of horizontal line $= BM + h + V_1$

$= 750.500 + 1.800 + 12.03$

$= 764.33$ m

RL of B

$= h + V_2 - h$

$= 764.34 + 21.17 - 1.500$

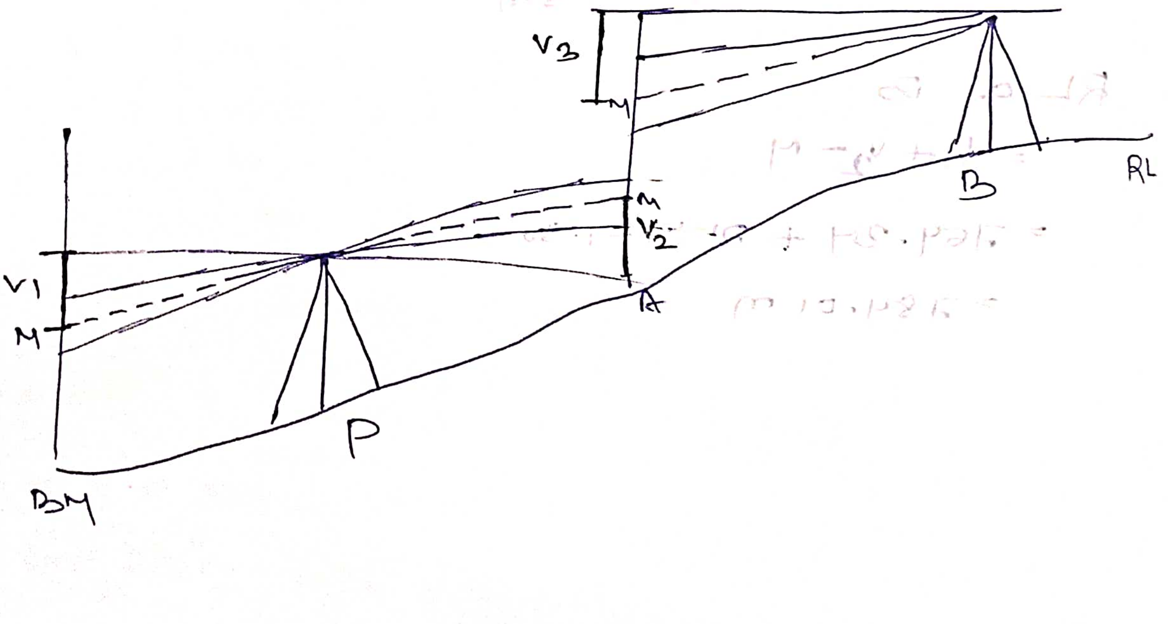
$= 784.01$ m

(Q) The following observation were take with a tacheometer fitted with an anallatic lens, the staff being held vertically. The constant of the tacheometer is 100.

Inst station	Height of instrument	Staff station	vertical angle	Staff readings (m)	Remarks
P	1.255	BM	−4°20′	1.325, 1.825, 2.325	RL of BM = 255.?
P	1.255	A	+6°30′	0.850, 1.600, 2.350	
B	1.450	A	−7°24′	1.715, 2.315, 2.915	

Calculate the RL of B & the distance betn A & B.

Sol



$S_1 = 2.325 - 1.325 = 1\ m$

$S_2 = 2.350 - 0.850 = 1.5\ m$

$S_3 = 2.915 - 1.715 = 1.2\ m$

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

$V = KS\dfrac{\sin 2\theta}{2} + C\cos\theta$

$D_1 = KS_1\cos(4^\circ 20')^2 + 0 \times \cos(4^\circ 20')$

$= 100 \times 1 \times \cos(4^\circ 20')^2 + 0 \times \cos(4^\circ 20')$

$= 99.42\ m$

$D_2 = 100 \times 1.5 \times \cos(6^\circ 30')^2 + 0 \times \cos(6^\circ 30')$

$= 148.07\ m$

$D_3 = 100 \times 1.2 \times \cos(7^\circ 24')^2 + 0 \times \cos(7^\circ 24')$

$= 118.009\ m$

$V_1 = 100 \times 1 \times \dfrac{\sin(2 \times 4^\circ 20')}{2} + 0 \times \sin(4^\circ 20')$

$= 7.534\ m$

$V_2 = 100 \times 1.5 \times \dfrac{\sin(2 \times 6^\circ 30')}{2} + 0 \times \sin(6^\circ 30')$

$= 16.87\ m$

$V_3 = 100 \times 1.2 \times \dfrac{\sin(2 \times 7^\circ 24')}{2} + \sin(7^\circ 24')$

$= 15.32\ m$

RL of horizontal line

$= BM + h + V_1$

$= 255.75 + 1.825 + 7.53$

$= 265.105\ m$

$= 278.01 - 1.450$ (412)

$= 276.56\ m$

RL of A

$= 265.105 + 16.87 - 1.600$ (V_2, M)

$= 280.375\ m$

RL of B

$= 280.375 + 15.32 + 2.315 = 278.04\ m$ (V_3, M)