# SCHOOL OF CIVIL AND ENVIROMENTAL ENGINEERING

# Surveying II
## CENG 2092

# Chapter 4 Photogrammetric Surveying

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2012EC (2019/20GC)
2nd Sem

# Photogrammetry

- The method of determining the shapes, sizes and position of objects using photographs.

- based on the possibility of optically projecting the terrain onto a flat surface

# Use of photogrammetry

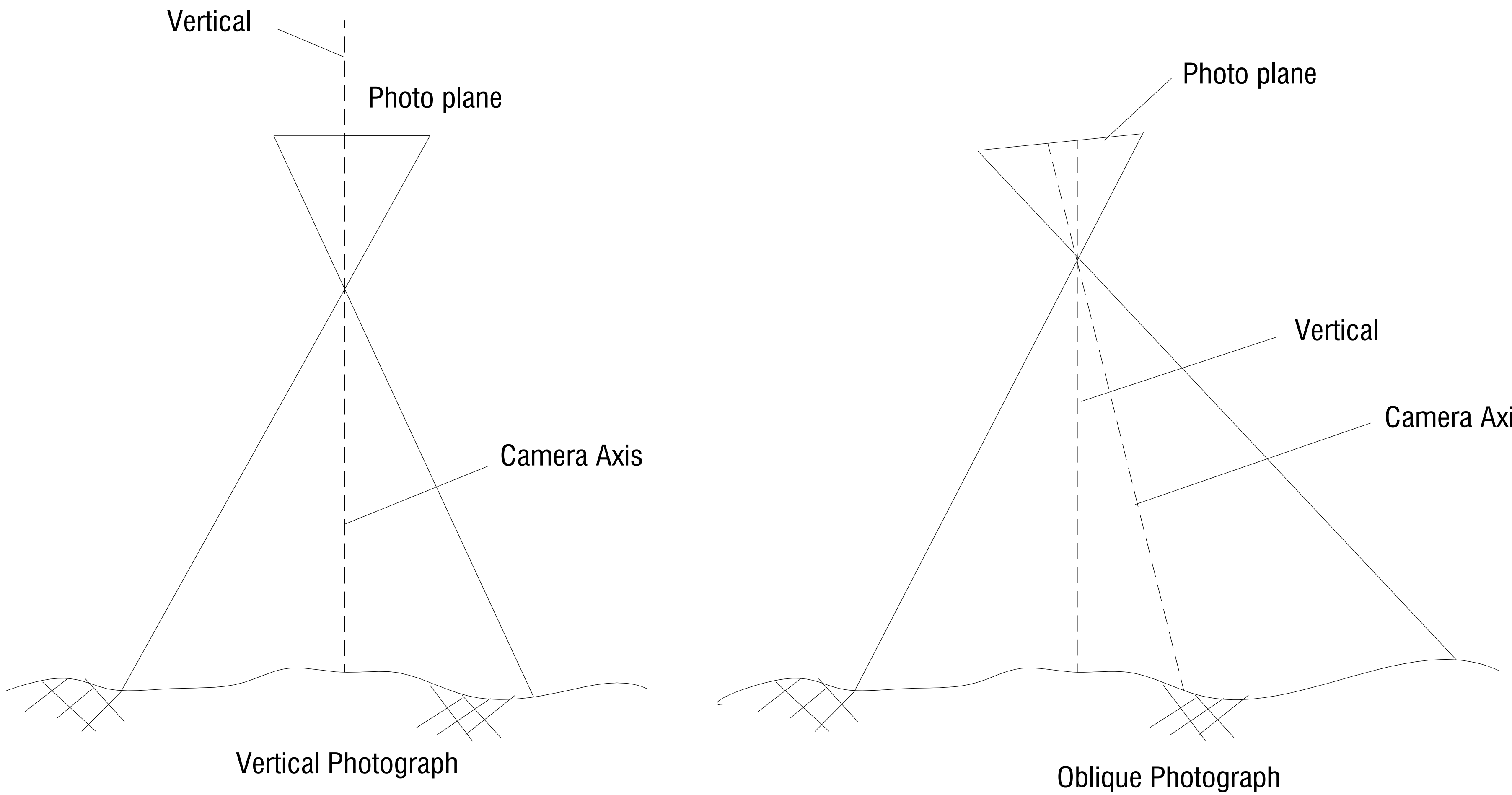
- Determining spatial information
    - Distance
    - Elevation
    - Area
    - Volume
    - Cross -section
- Construction of topographical map

# Two types photogrammetry

- **Aerial**: photograph taken from air

- **Terrestrial:** photograph taken on or near the ground

# Two types of photographs



# Vertical photograph

# Oblique photograph

# Advantage of aerial photograph

- Speed of coverage of an area
- Ease of obtaining topography in inaccessible area
- Freedom from possible omission of data in the field
- The tremendous amount of detail shown

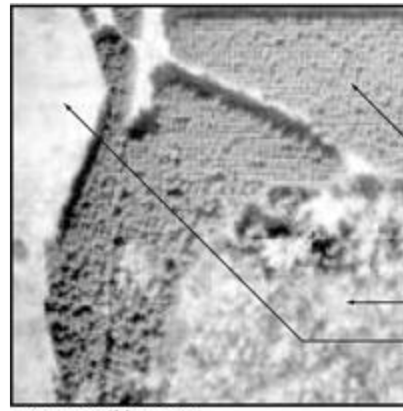
# History of photogrammetry

- 1851 --- produced the first camera
- 1858 --- aerial photograph began from balloons and measurement on photographs
- 1875 – produced the first aerial camera
- 1888 --- ground photography began
- 1901 --- introduced stereoscopic principle of measurement
- World War II gave rise to a new development of aerial photographs

# What information can I find on an air photo?


A15183-37 (September 1955)
Chinchaga River, Alberta

**Shape**

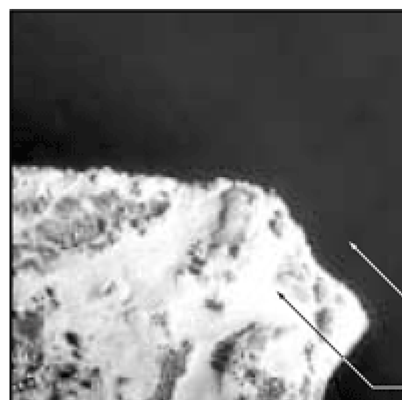



A26458-82 (May 1984)
CFB Uplands
Ottawa, Ontario

**Pattern**


A28411-345 (May 1999)
Highway 401 & Dufferin
Toronto, Ontario

**Size**




A26999-20 (August 1986)
Sandbanks Provincial Park
Picton, Ontario

**Tone/Color**

# What information …….

## Shadow


A27773-86 (July 1991)
Notre Dame Ouest & Autoroute Bonaventure
Montréal, Quebec

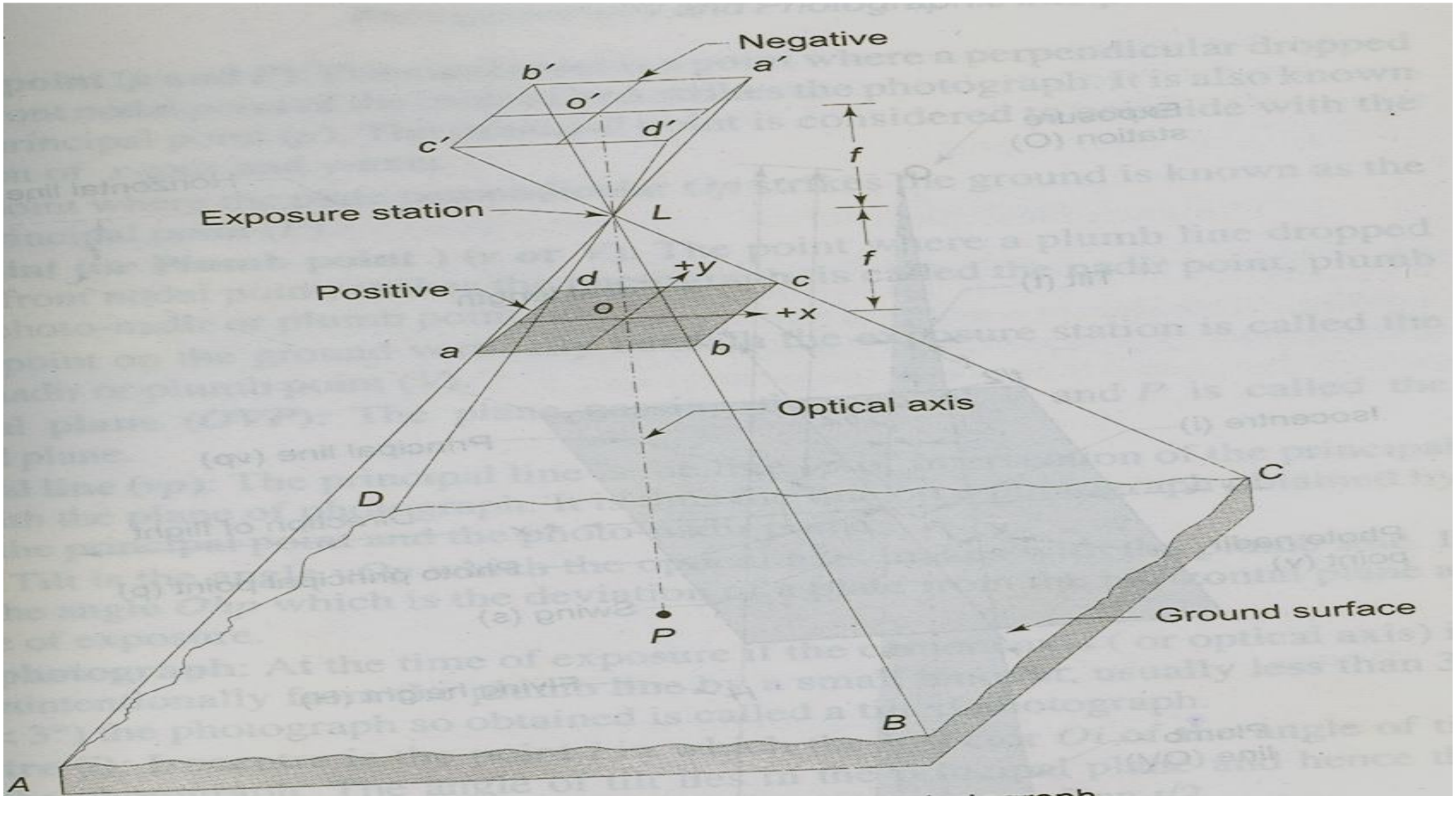
## Texture


A22288-4 (July 1971)
Lake Louise, Alberta

## Association /Site


A27949-186 (July 1993)
Esquimalt Harbour, British Columbia

# Aerial Photogrammetry



# Definition of technical terms

- **Exposure (or Air) Station (O)** is a point in the air occupied by the front nodal point of the camera lens at instant of exposure.

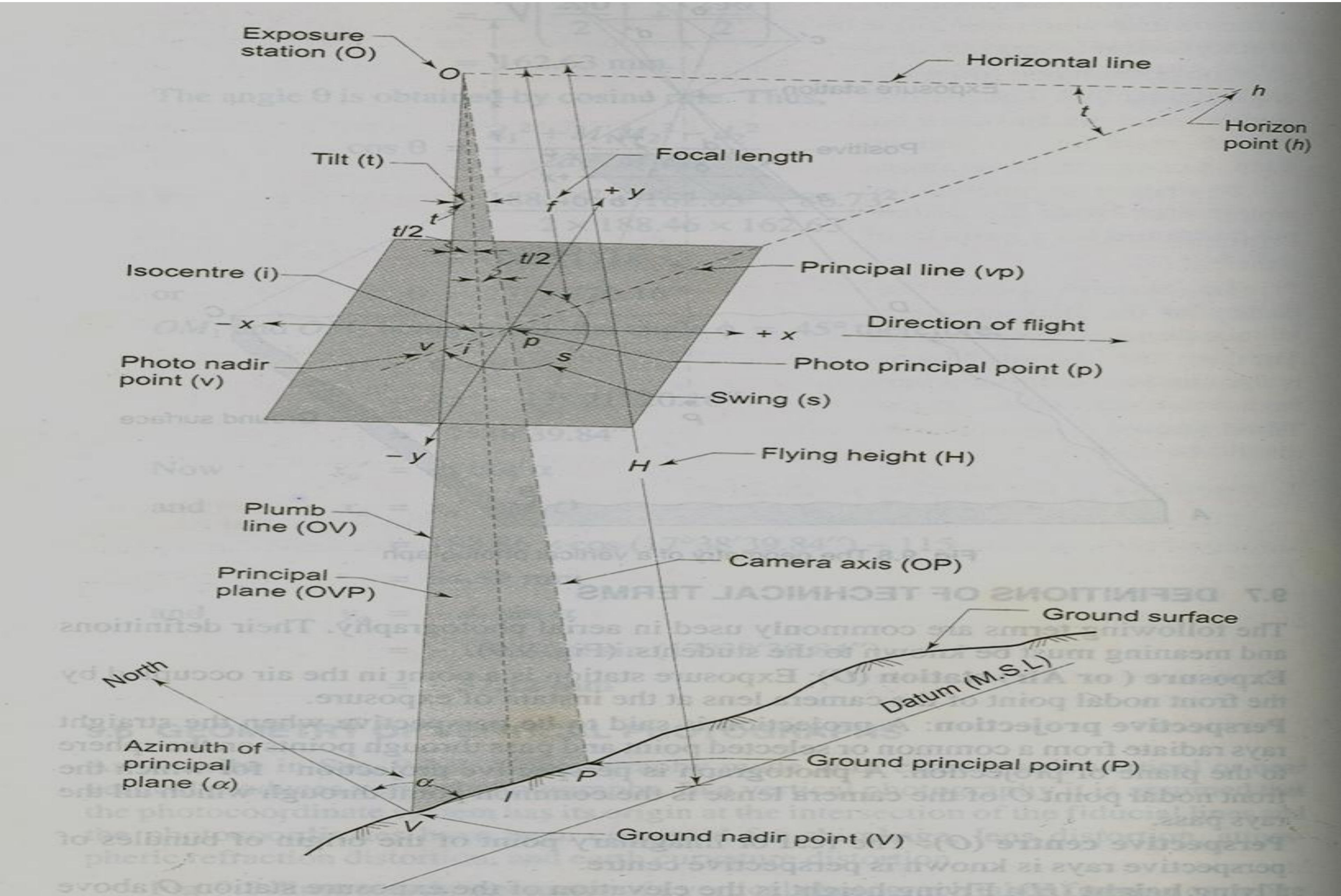
- **Perspective projection:** a projection is said to be perspective when the straight rays radiate from the common or selected point and pass thorough points on the sphere to the plane of projection.

- **Perspective Center (O):** the real or imaginary point of the origin of bundles of perspective rays is known as perspective center.

- **Flying height (H):** is the elevation of the exposure station O above mean sea level.

- **Line of flight:** a line which represents the track of an aircraft on an existing map

# Technical terms in Figure



- **Focal Length (f)**: The distance from the front nodal point of the lens to the plane of the photograph

- **Principal point (p and P):** principal point is a point where a perpendicular dropped from the front nodal point of the camera lens strikes the photograph.

- **Nadir point (plumb point)(v or V) :** The point where a plumb line dropped from the front nodal point, strikes the photograph

- **Principal line (vp) :** is the line of intersection of the principal plane with the plane of photograph.

- **Tilt (t):** Tilt is the angle $\nu Op$ which the optical axis makes with the plumb line.

- **Tilted photograph** : At the time of exposure if the camera axis (or optical axis) is tilted intentionally from the plumb line by a small amount usually less than $3^\circ$

- **Isocenter (i):** is the point i in which the bisector Oi of the angle of tilt meets the photograph.

- **Swing(s)**: The horizontal angle measured clockwise in the plane of the photograph from the positive y-axis to the plumb point is known as the swing.

- **Azimuth of the principal plane** (∝) : is the clockwise horizontal angle ∝ measured about the ground-nadir point from the ground survey north meridian to the principal plane of the photograph.

- **Horizon Point (h):** the point of intersection of the principal line vip produced with the horizontal line Oh through the exposure station O, is known as the horizon point.

# Scale of a vertical photograph—flat area

$$S = \frac{ab}{AB}$$

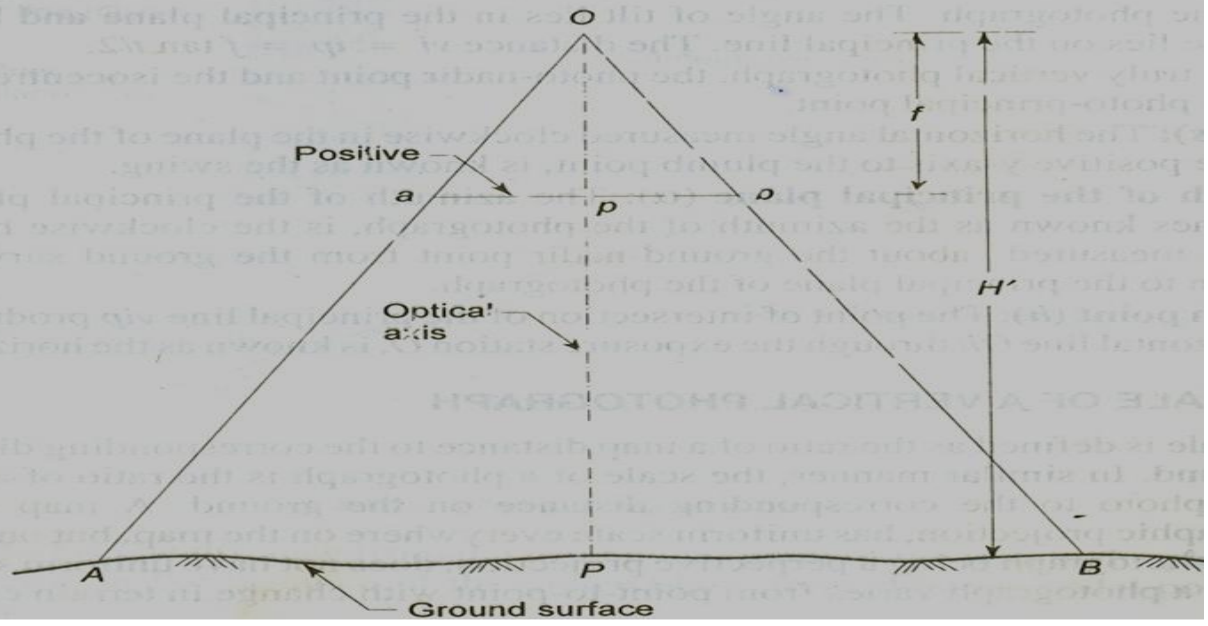
From the similar $\Delta^s$ $Oab$ and $OAB$, we get:

$$\frac{ab}{AB} = \frac{Op}{OP} = \frac{f}{H'}$$

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

Where $f$ = focal length of the aerial camera

$H'$ = flying height above the ground



# Image Displacement

Consider similar triangle vbO & EBO

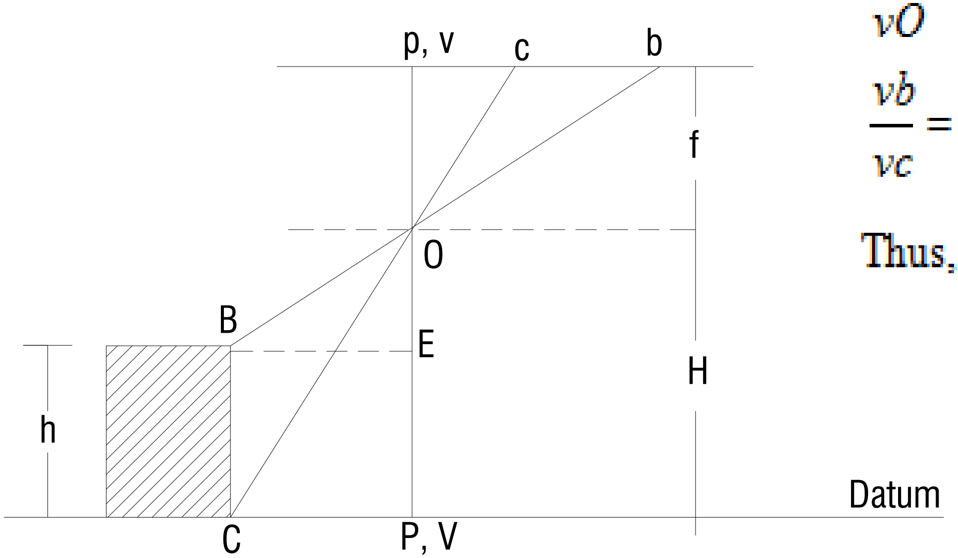
$$\frac{vb}{vO} = \frac{EB}{EO} \Leftrightarrow \frac{vb}{f} = \frac{EB}{H-h}$$

Also from similar triangles vcO & VCO

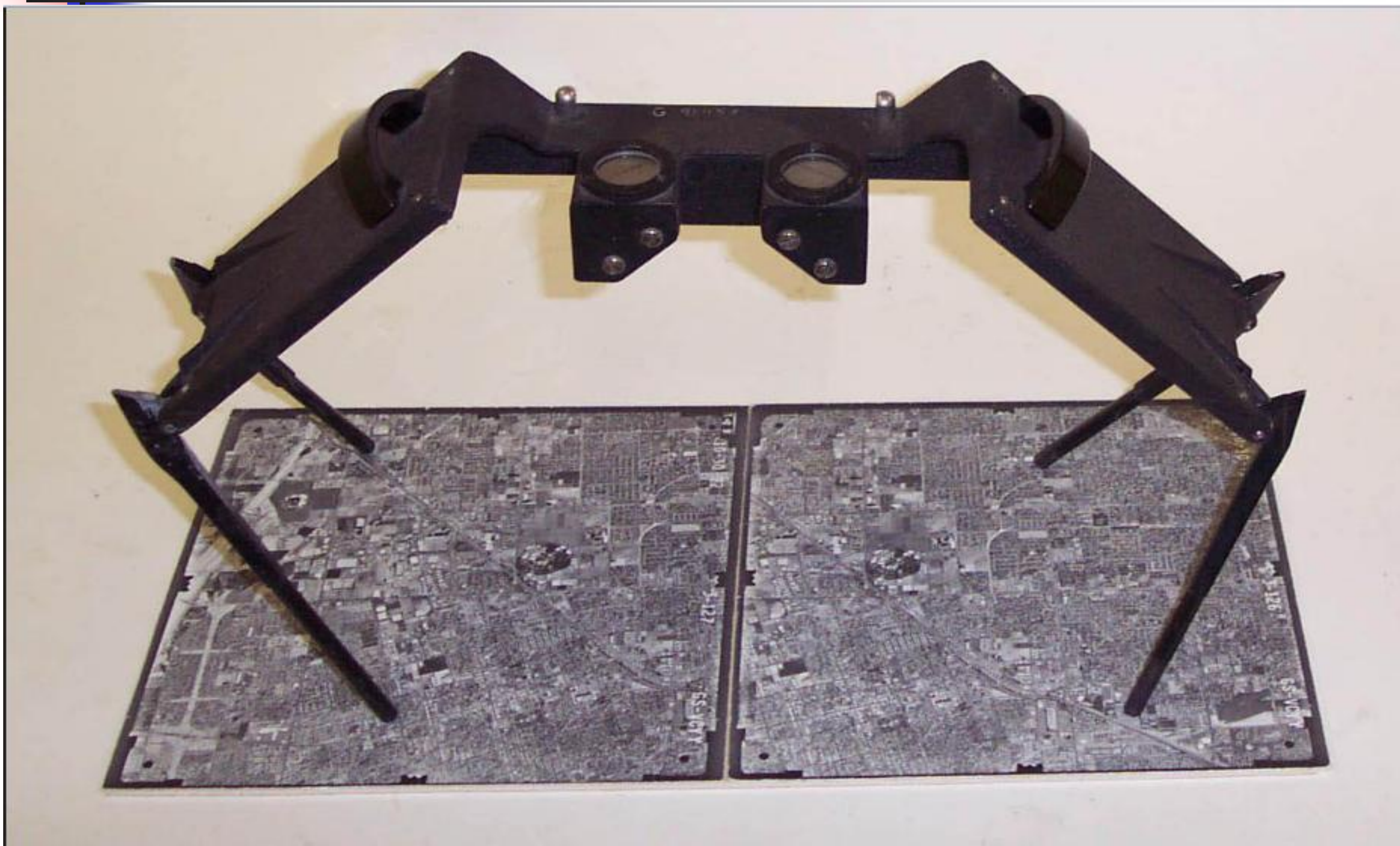
$$\frac{vc}{vO} = \frac{VC}{VO} \Leftrightarrow \frac{vc}{f} = \frac{VC}{H} = \frac{EB}{H}$$

$$\frac{vb}{vc} = \frac{H}{H-h} = \frac{vb}{vb-bc} \Rightarrow \frac{vb}{bc} = \frac{H}{h} \Rightarrow bc = \frac{h}{H} vb$$

Thus, the distortion due to height $BC = bc = \dfrac{h}{H} vb$

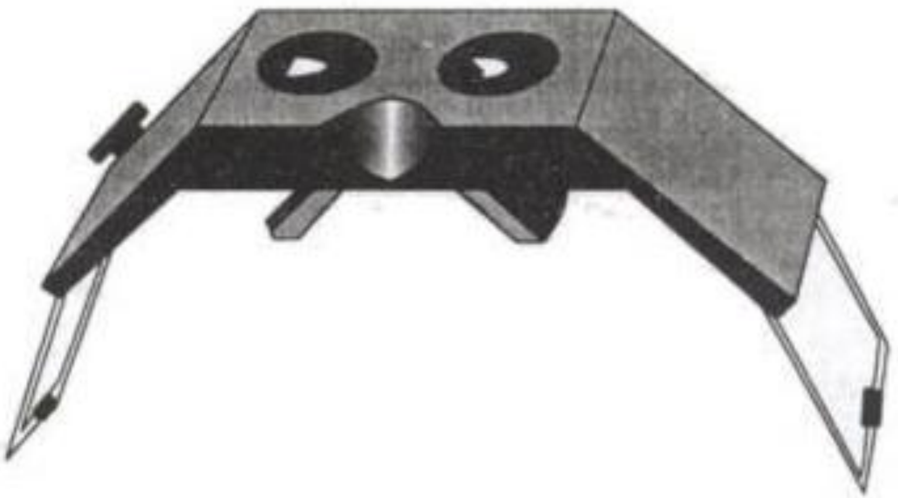


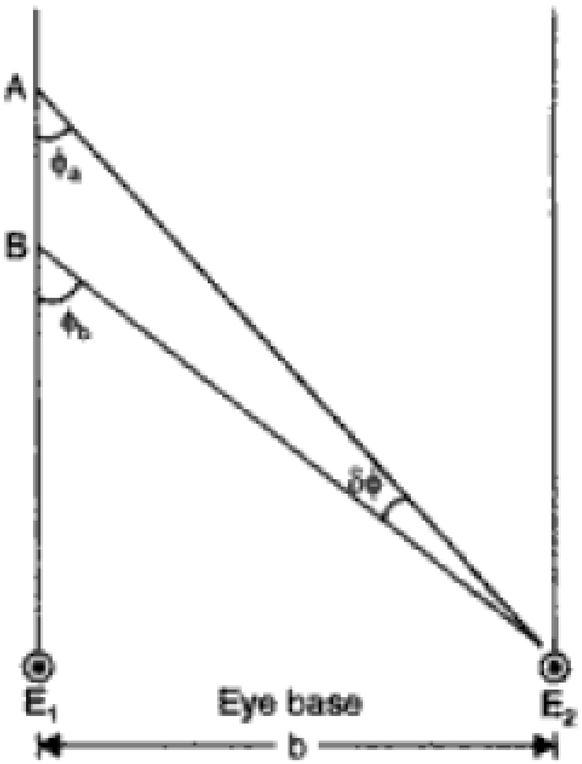
# Mirror Stereoscope



# Stereoscopic Vision

- Overlapping photographs → 3D view





# The impression of depth is caused by:

- Relative apparent size of near and far objects
- Effects of light and shade
- Viewing of an object simultaneously by two eyes which is separated in space → principle of stereoscopic vision

# Parallax

- The algebraic difference of the distances of two images of a ground point from their perspective principal point, measured parallel to the air base.

- Parallax heighting is the process of finding the height of objects from stereo-pair of photographs that have no tilt and are taken from the same flying height.

# Determination of height of object

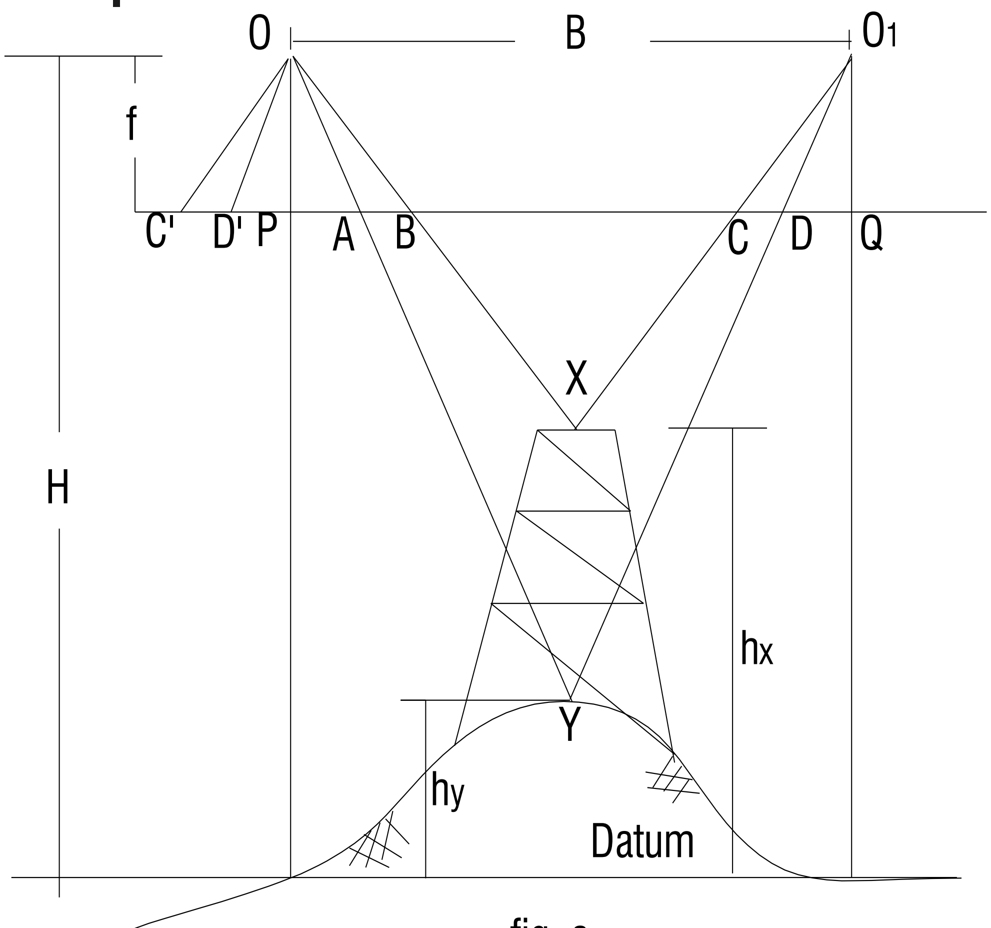



fig. a

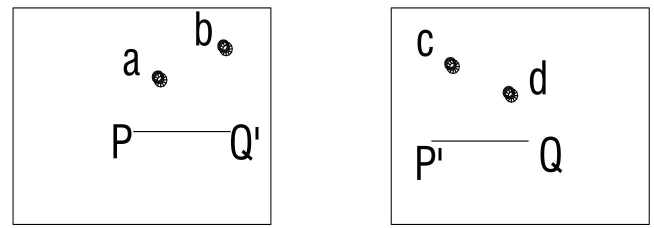



fig. b

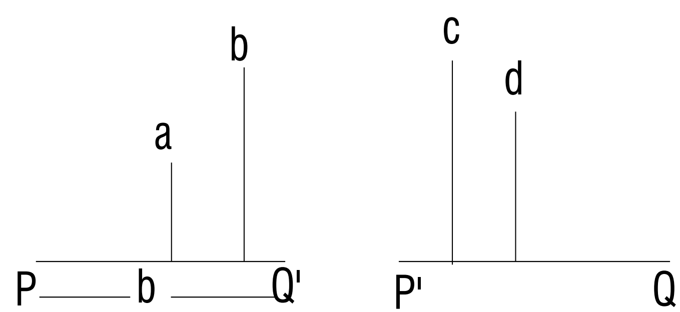



fig. c

- The parallax of X has magnitude of PB – (-CQ) when distances are measured positive to the right. Parallax of Y is PA – (-DQ).

Triangles OD'A and YOO$_1$ are similar:

$$\frac{OO_1}{D'A} = \frac{H - h_y}{f}$$

Triangles OD'A and XO$_1$O are similar:

$$\frac{OO_1}{C'B} = \frac{H - h_x}{f}$$

$$\Rightarrow D'A = P_y = \frac{fB}{H - h_y} \text{ (Parallax of Y)}$$

$$\Rightarrow C'B = P_x = \frac{fB}{H - h_x} \text{ (Parallax of X)}$$

In general, $P = \dfrac{fB}{H - h} = Parallax = Scale * B$

$$\Delta p = Px - Py$$

$$hx = H - \frac{Bf}{Px}$$

$$hy = H - \frac{Bf}{Py}$$

$$\Delta h = Bf \frac{(Px - Py)}{PxPy}$$

$$\Delta h = \frac{Bf\,\Delta P}{Py(Py + \Delta P)}$$

Let Px - Py = dP

$$dP = fB\left[\frac{1}{H-hx} - \frac{1}{H-hy}\right]$$

$$= fB\left[\frac{hx-hy}{(H-hx)(H-hy)}\right] \text{, hx - hy = dh}$$

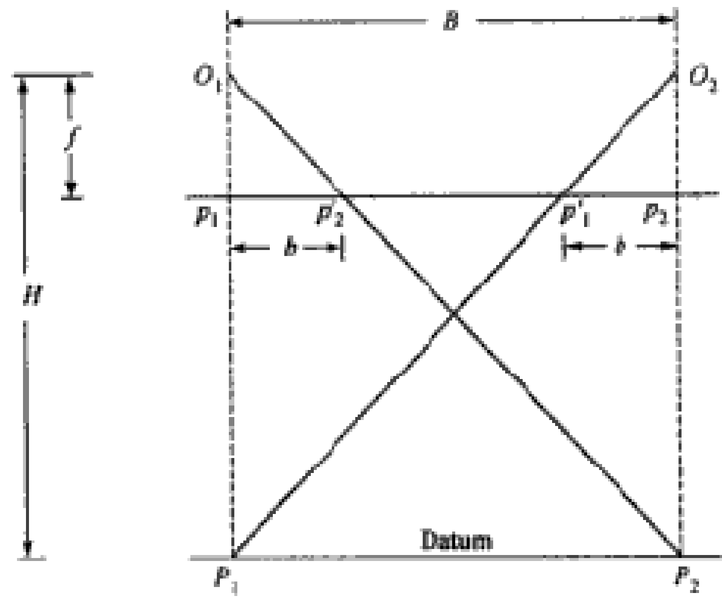
$$= Px\frac{dh}{H-hy}$$

$$dh = dp\left[\frac{H-hy}{Px}\right] \text{ = difference in level between X and Y}$$

$$dh = dp\frac{H}{Px} \text{ Ignoring hy, since hy << H}$$

$$dh = dpH\left[\frac{H-hx}{fB}\right] \text{ Ignoring hx}$$

$$dh = dp\frac{H^2}{fB}$$




$$p1p2' = b1 \qquad bm = \frac{b1+b2}{2}$$

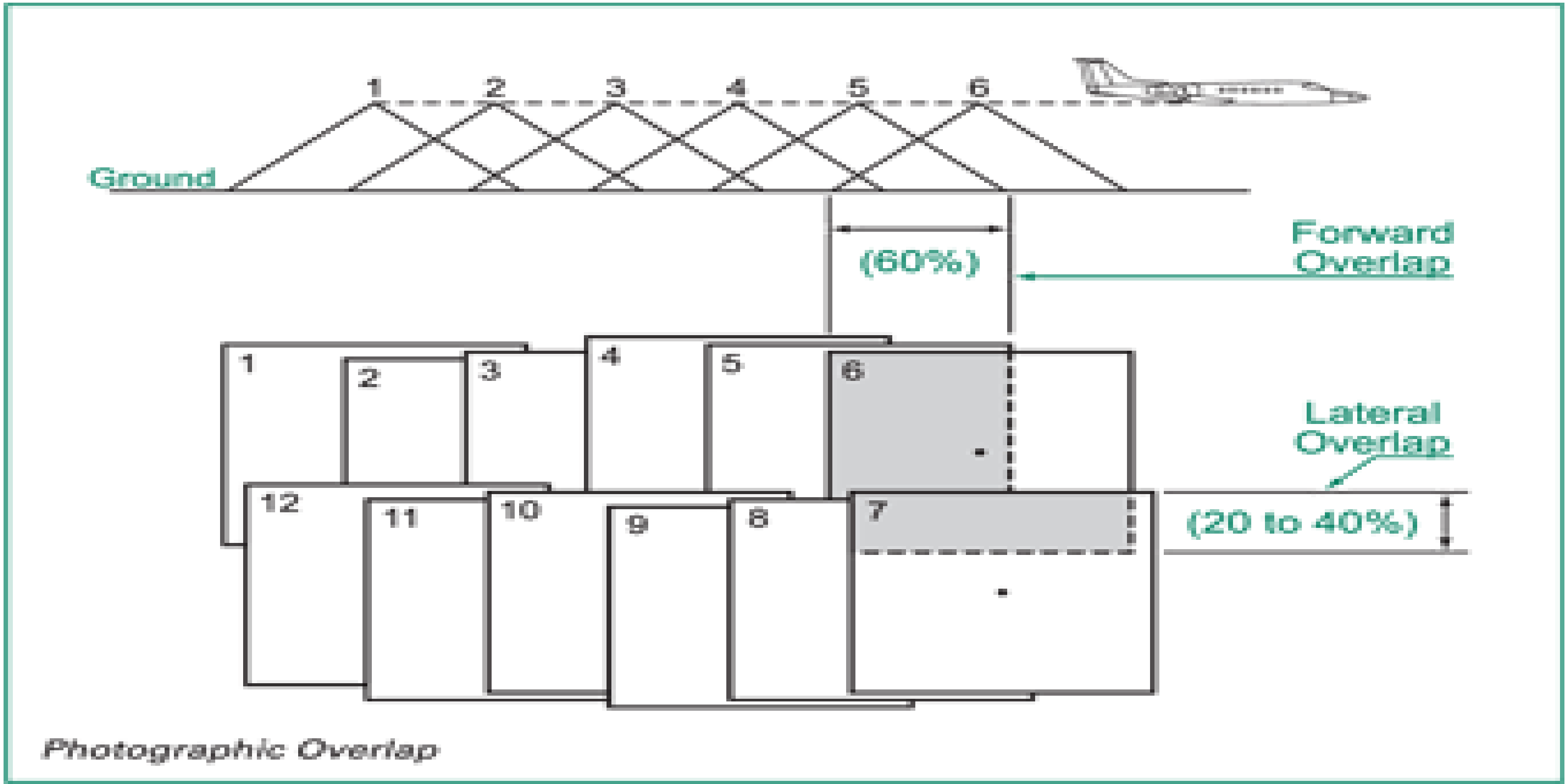
$$p1'p2 = b2$$

$$\frac{f}{H} = \frac{bm}{B} \rightarrow fB = Hbm$$

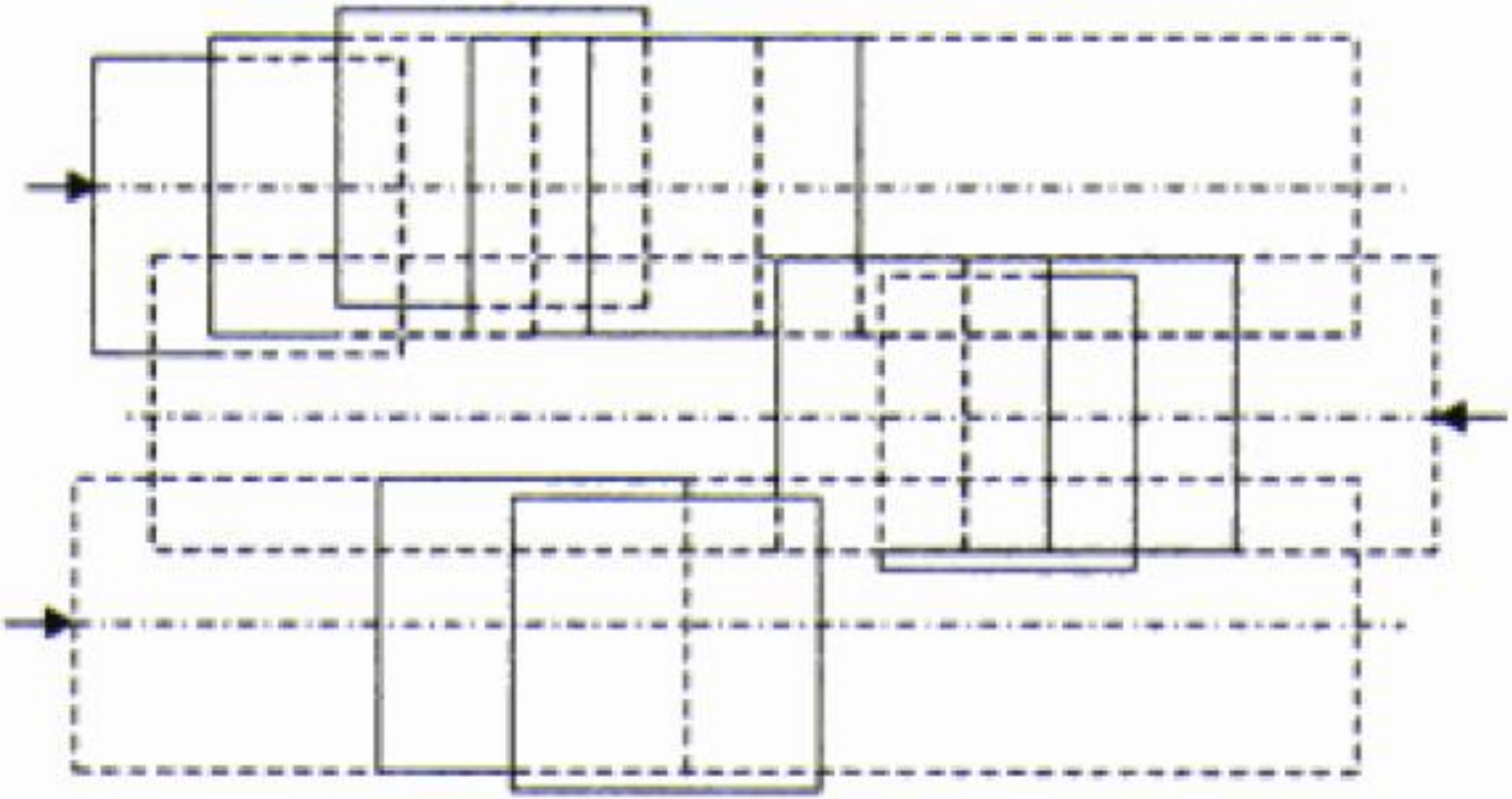
If hy = 0, Py = bm $\quad \Delta h = \dfrac{Hbm\Delta P}{bm(bm+\Delta P)} \qquad dh = \dfrac{dpH}{bm+dp}$

# Flight Planning

- In order to obtain stereo pairs, every part of the ground to be surveyed must be photographed at least twice.

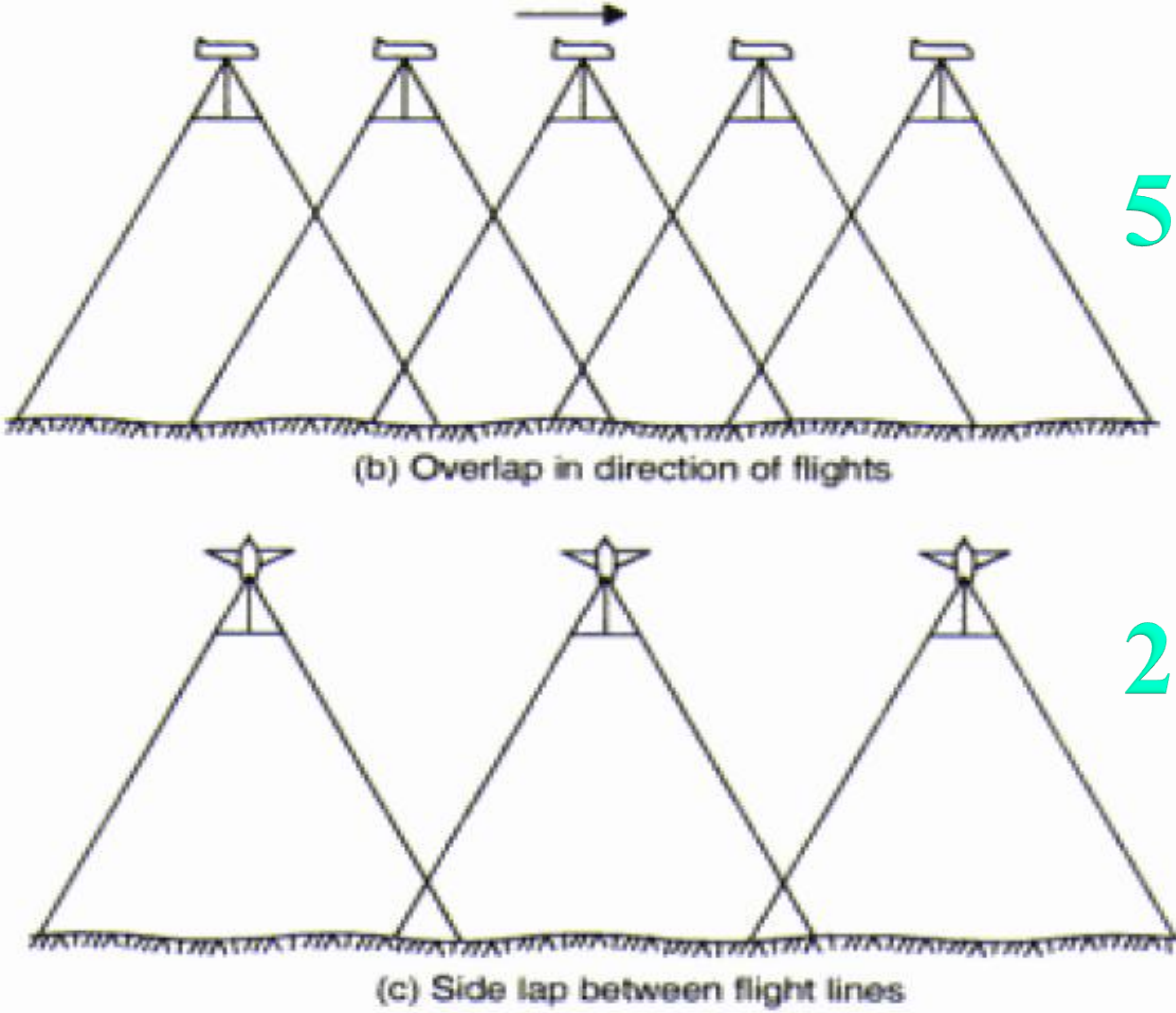


# Flight lines



(a) Flight lines

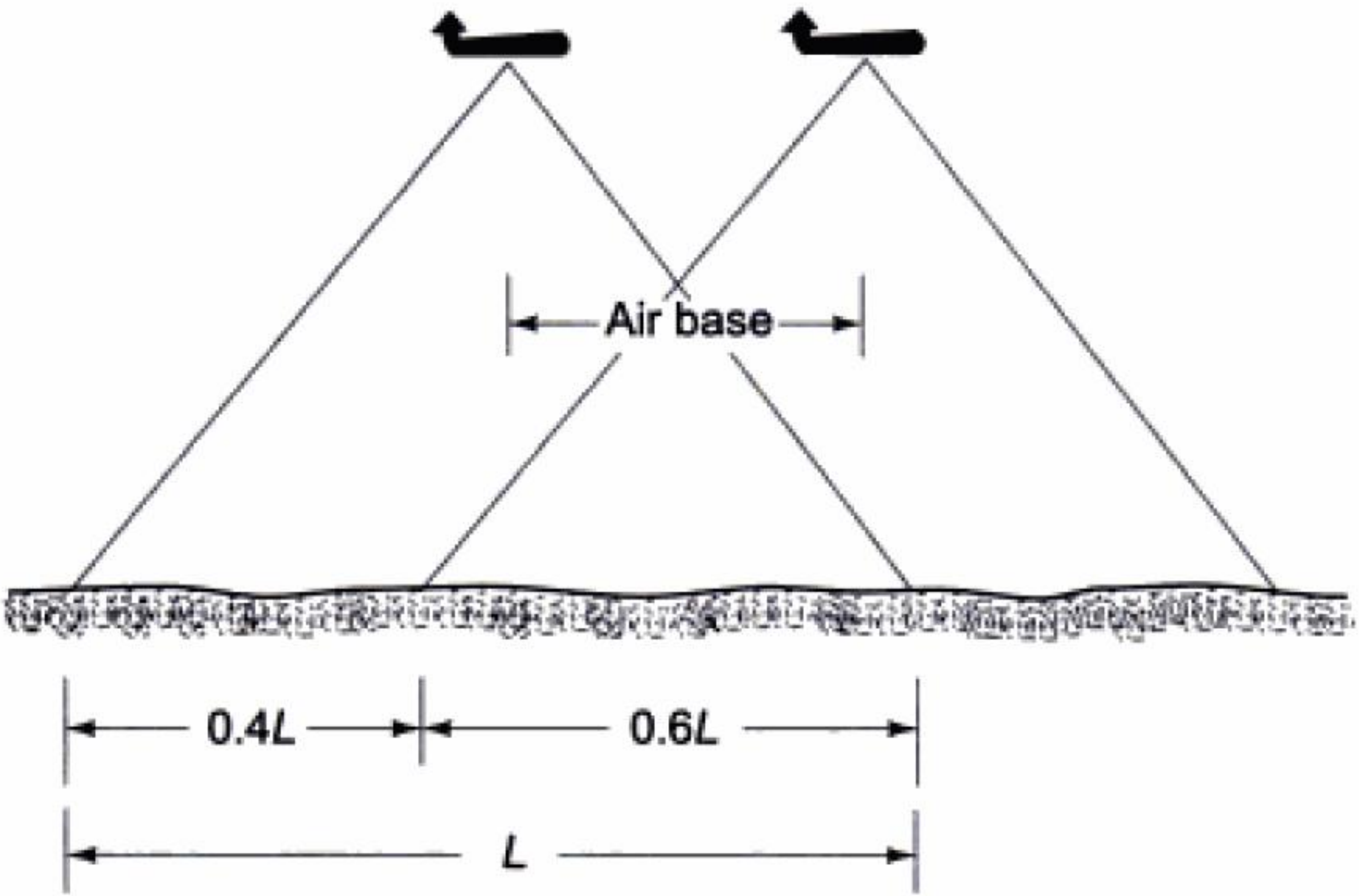
# Over lap and side lap




55 -65%

20 -40%

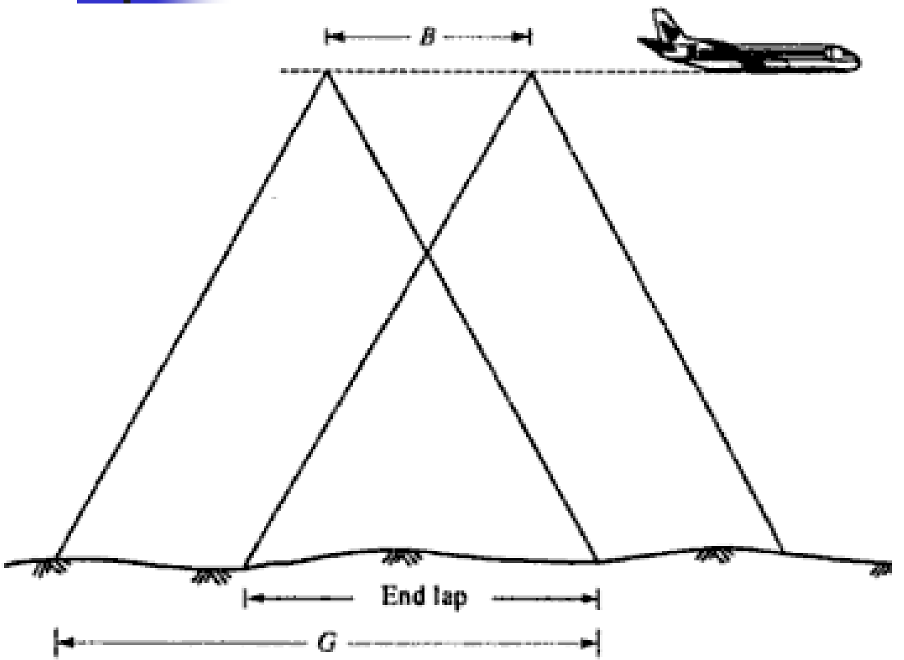
# Air Base

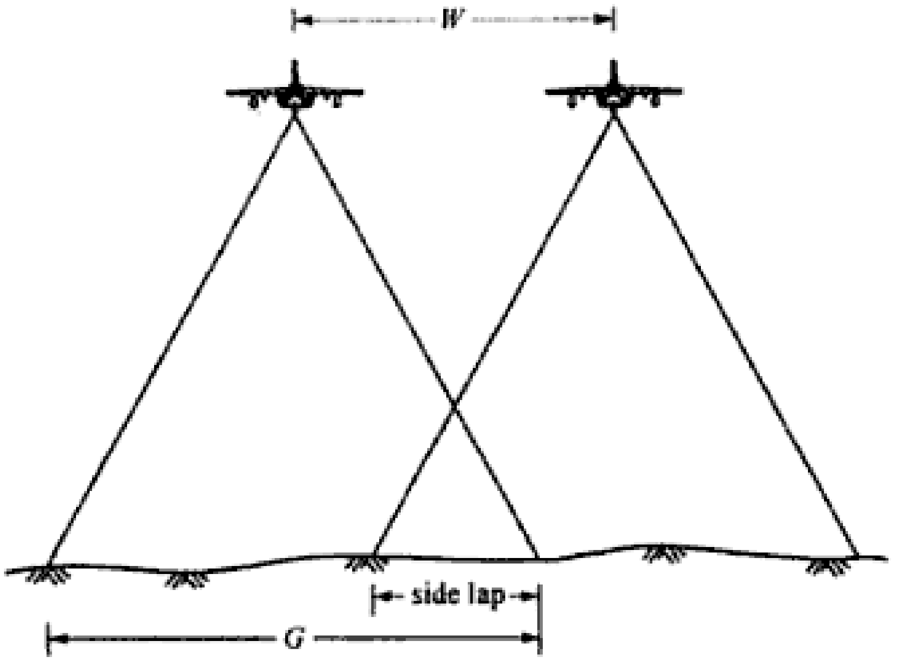


# Photograph Required

- Lp = length of the photograph in cms in the direction of flight
- Lg = Net ground distance corresponding to Lp
- Wp = width of photograph in cms at right angles to the direction of flight
- Wg = Net ground distance corresponding to Wp
- OL = %longitudinal overlap
- Ow = % of side overlap
- S = scale of photograph
- Ap = Net area of the ground in each photograph
- Ag = Total area land to be photographed
- N = Numbers of photographs required

# Overlaps Formula




$$E_{\%} = \left(\frac{G-B}{G}\right)100$$

$$S_{\%} = \left(\frac{G-W}{G}\right)100$$

# Total Number of photograph

Then $$Lg = SLp(1 - O_L)$$
$$Wg = SWp(1 - Ow)$$

Theoretical spacing of flight strips = $W_G$

Theoretical No of strips, $K = \dfrac{width\ of\ the\ area}{W_G}$

Actual Number of strips= K+1 (one strip being added to cover the sides)

Theoretical no of photographs per strips, $M = \dfrac{length\ of\ the\ area}{Lg}$

Actual no of photograph per strip, = M+1

Actual no of photographs for complete coverage of the area = N = (K+1)(M+1)

**Interval between Exposures**

$= \dfrac{3600Lg}{V}$ Where V = speed of the aircraft in Km/hr, Lg = distance traveled by the airplane between exposures

**Example 1:** **In pair of overlapping vertical photographs the mean distances between two principal points lying on the datum is 6.385 cm. the flying height of the aircraft at the time of photography, was 580 m above datum. Determine the difference of parallel for top and bottom of a tower of height 115 m having base in the datum surface. The focal length of the camera is 150 mm.**

**Solution:**

**$B = (b/f)H = (6.385X580/15) = 246.89$ m**

**Parallax is given by :**

**$P = (Bf)/(H – h)$**

**For the bottom of the tower, $h = 0$. Hence**

**$P_T = (246.89x150/(580-115) = 79.64$ mm**

**$P_B = (246.89x150/580) = 63.85$ mm**

**The difference of parallax is given by**

**$\Delta p = P_T – P_B = 79.64 – 63.85 = 15.79$ mm**

**The result can be checked**

**$\Delta h = h_T – h_B = (H \Delta p)/(bm + \Delta p)$**

**$= (580x15.79)/(63.85 + 15.79) = 115$ m ( the given value)**

**Example 2: An area 40 km in the north-south direction and 36 km in the east-west direction, it to be photogrammetrically surveyed. For this, aerial photography is to be made with the following data:**

| | | |
|---|---|---|
| **i)** | **Photograph size** | **= 20 cm x 20 cm** |
| **ii)** | **Average scale of photographs** | **= 1:15000** |
| **iii)** | **Averaged elevation of the terrain (h)** | **= 450 m** |
| **iv)** | **End lap** | **= 60%** |
| **v)** | **Side lap** | **= 30%** |
| **vi)** | **Ground speed of the aircraft** | **= 220km/hr** |
| **vii)** | **Focal length of the camera** | **= 30 cm** |

**Calculate the following data:**

**a) Flying height of the aircraft**
**b) Number of photographs in each flight (i.e. strip)**
**c) Number of flights (i.e. strips)**
**d) Total Number of photographs**
**e) Spacing of flight lines**
**f) Ground distance between exposures**
**g) Exposure interval**

# Solution

Given that

- S = 1/15000
- f = 30 cm
- Lp = 20 cm
- Wp = 20 cm
- Lo = 40 km
- Wo = 36 km
- H = 450 m
- E = 60%
- S = 30%

**a)** $S = f/(H - h) \rightarrow H = (f/S) + h = 4950$ m

**b)** Number of photograph for each flight / Strip

$N_1 = (L_o/L) + 1$

$L = L_p(1-E)/S = 20(1-0.6)x15000/100 = 1200$ m

$N_1 = (40x1000/1200) + 1 = 34.3 = 35$

**c)** Number of flights or strips

$N_2 = (Wo/W) + 1$

$W = L_p(1\text{-Side lap})/S = 20(1-0.3)x15000/100 = 2100$ m

$N_2 = (30x1000/2100) + 1 = 18.1 = 19$

**d)** Total number of photographs

$N = N_1 \times N_2 = 35x19 = 665$

**e)** Spacing between flights $d = (W_o/(N_2-1)) = 2000$ m

**f)** Ground distance between exposure is $L = 1200$ m

**g)** Exposure interval

$t = L/V = (1200x3600/(220x1000)) = 19.6$ sec