4
UNIT

# Photogrammetric Survey

## CONTENTS

## PART-1

*Basic Principles, Aerial Camera, Scale of a Vertical.*

### Questions-Answers

### Long Answer Type and Medium Answer Type Questions

**Que 4.1. What is the principle of photogrammatic survey ? Describe the types of photogrammetric survey.**

**Answer**

1. It is the science and art of obtaining accurate measurements by use of photographs, for various purposes such as the construction of planimetric and topographic maps, classification of soils, interpretation of geology, acquisition of military intelligence and the preparation of composite pictures of the ground.
2. The photographs are taken either from the air or from station on the ground.
3. Following are the two types of photogrammetry :

i. **Terrestrial Photogrammetry :** It is that branch of photogrammetry wherein photographs are taken from a fixed position on or near the ground.

ii. **Aerial Photogrammetry :** It is that branch of photogrammetry wherein the photographs are taken by a camera mounted in an aircraft flying over the area.

4. Mapping from aerial photographs is the best mapping procedure developed for large project and is invaluable for military intelligence.

**Que 4.2. Mention the different type of aerial photographs and explain each one of them.**

**Answer**

Following are the different types of aerial photographs :

**A. Terrestrial Photograph :**

1. It is the photograph taken from ground station.
2. The instrument used is phototheodolite which is a theodolite mounted on a camera with its axis horizontal or nearly horizontal.
3. The line of collimation of the telescope and the optical axis of the camera are parallel to each other.

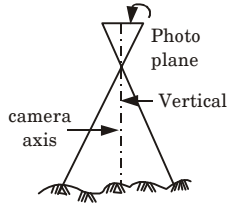



**Fig. 4.2.1.** Vertical photograph.

**B. Aerial Photograph :**

1. These are the photographs taken from overhead position with a camera board on an aeroplane, an artificial or natural satellite or a planet.
2. It can further be divided depending upon the angle between the axis of camera and the vertical axis as follows :

**i. Vertical Photograph :** It is a one, in which the optical axis of the camera is vertical or nearly vertical. A truly vertical photograph resembles a map, through a vertical photograph can be rarely obtained.

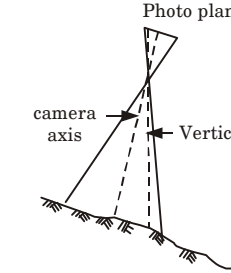
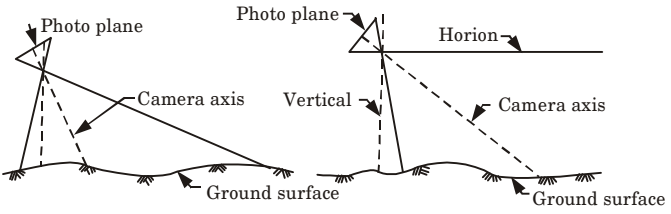



**Fig. 4.2.2.** Tilted photograph.

**ii. Tilted Photograph :** When the optical axis of the camera is unintentionally inclined to the vertical by not more than 3°, then the photograph taken is called "tilted photograph".

**iii. Oblique Photograph :** It is the photograph taken when the optical axis is intentionally inclined to the vertical at a greater angle. This is done to obtain a more familiar view of the terrain. Oblique photographs may further be divided into two categories :

- **a. Low Oblique Photographs :** Photographs which do not show the horizon.
- **b. High Oblique Photographs :** Photographs which show the horizon.




(*a*) Low-oblique photograph (*b*) High-oblique photograph

**Fig. 4.2.3.**

**iv. Convergent Photographs :**

a. These are low oblique photographs taken with two cameras exposed simultaneously at successive exposure stations.

b. The camera axes are tilted at a fixed inclination from the vertical in the direction of flight, so that forward exposure of the first station forms a stereopair with backward exposure of the next station.

**v. Trimetrogen Photographs :** These type of photographs are combination of vertical and low oblique photographs exposed simultaneously from the air station with two cameras.

**Que 4.3.** **What is aerial photogrammetry ? Write advantages and disadvantages of aerial photogrammetry.**

**OR**

**What do you understand by the term 'Aerial photography' ? Also write a short note on the factors that influence aerial photography.**

**AKTU 2017-18, Marks 07**

**Answer**

**A. Aerial Photogrammetry :** It is that branch of photogrammetry wherein the photographs are taken by a camera mounted in an aircraft flying over the area.

**B. Advantages :** Following are the advantages of aerial photogrammetry :

1. Suitable for inaccessible areas.
2. Suitable for mountainous region with less vegetation.
3. Suitable for mapping large areas, faster and economical.

**C. Disadvantages :** Following are the disadvantages of aerial photogrammetry :

1. Not suitable for dense forests and flat sands due to difficulty of identifying objects upon the photographs.
2. Not economical for survey of small areas.

**Factors :** Following are the factors that influence aerial photography :

1. **Atmospheric Conditions :** The presence of particles (smoke or dust) and molecules of gases in the atmosphere tends to reduce contrast because of scattering, therefore, the best time photography is when the sky is clear (November-February).
2. **Scale :** Ratio of *f*/*h* (*f*-focal length of the camera lens and *h*-flying height above the mean terrain). Due to variations in flying height, the scales of different photographs may vary. Scale may also vary because of the effects of tilt and relief displacements.
3. **Camera/Film/Filter Combination :** To ensure good image quality, modern distortion free cameras are used. Depending upon the requirements different lens/focal length/film/filter combinations can be used.
4. **Flight Direction :** Aerial photography is flown in strips to cover the designated area. It is advisable to keep the number of strips to minimum. The flight direction of strips is therefore kept along the length of the area.
5. **Time/ Season of Photography :** Aerial photography should be flown when the sun's elevation is 30 degrees above the horizon or three hours before and after the local noon time.

**Que 4.4.** **Differentiate between 'Aerial photography' and 'Aerial photogrammetry'.** **AKTU 2017-18, Marks 07**

**Answer**

| S. No. | Aerial Photography | Aerial Photogrammetry |
|---|---|---|
| 1. | Aerial photography is the art of taking and processing photographs. | Aerial photogrammetry is the science of making measurements from photographs. |
| 2. | The fundamental principle used by photography is line of sight. | The fundamental principle used by photogrammetry is triangulation. |

**Que 4.5.** **Describe aerial camera with the help of its neat sketch.**

**Answer**

Aerial camera consists of following three basic components :

1. **Magazine :**

i. It holds the roll of unexposed film, advances the film between exposures, holds the film in place and winds up the exposed film.

ii. The film is moved continuously past a small slit called format opening in the focal plane.

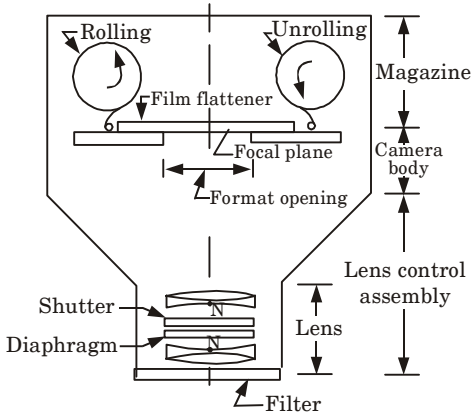



**Fig. 4.5.1.** Aerial camera.

**2. Camera Body :**

i. The camera body is the part of the camera provided at the top of the cone.

ii. Sometimes, it forms the integral part of the cone in which case they act as an integral part of preserve the interior orientation once the camera is calibrated.

**3. Lens Cone Assembly :** It has following components :

**i. Lenses :** Lenses are the most important part of an aerial camera. Lenses used in aerial cameras are compound lenses of very high quality. Lenses gather light from objects and focus on the focal plane.

**ii. Filter :** It is provided in front of the lens. It reduces effects of atmospheric haze, protects lens from dust and provides uniform light distribution over the format.

**iii. Shutter :** It controls the exposure time depending upon aircraft speed so that sharp images are obtained.

**iv. Diaphragm :** It controls the amount of light to pass through the lens by varying the size of aperture. It is normally placed in the air space between the lens elements.

**Que 4.6. Explain in detail about the characteristics of photographic images.** **AKTU 2015-16, Marks 7.5**

**OR**

**Illustrate the fundamentals of aerial photo-interpretation.** **AKTU 2015-16, Marks 10**

**Answer**

**A. Photo Interpretation :**

1. The process of studying and gathering the information required to identify the various cultural and natural features is called photo interpretation.
2. The information from an aerial photograph may be extracted by studying the characteristics of a photograph.
3. Following are the fundamentals of aerial photo interpretation :

i. Oblique photographs are easy to interpret because they depict a more familiar view.

ii. Color photographs are easy to interpret because of tonal variations present their in.

iii. Local knowledge of the area helps a lot in photo interpretation.

iv. Photo interpretation can also be arrived at by inspections or by association with familiar objects.

v. Knowledge, skill, training and experience of the interpreter coupled with imagination are very vital for interpretation.

vi. Stereopair photographs viewed stereoscopically greatly help in interpretation.

vii. Selective keys and elimination keys also greatly help in photo interpretation.

**C. Characteristics of Photograph :**

Following characteristics help the interpreter in identifying and recognizing the objects whose images appear in the aerial photographs.

**1. Shape :**

i. This refers to the general form, configuration, or outline of individual objects.

ii. In the case of stereographic photographs, the height of the object also defines its shape.

iii. Therefore, to facilitate easy recognition objects in profile, the interpreter must use stereographic photographs under stereoscope.

iv. The top view of the objects in vertical photography is quite unfamiliar and difficult to interpret, and one requires special training to acquire expertise in studying top views.

**2. Size :**

i. It is one of the most important and useful clues to identify the objects.

ii. By measuring an unknown object interpreter can arrive at more accurate identification.

iii. The size of objects on photographs must be considered in the context of the scale.

iv. For example, an irrigation ditch and antitank ditch images look alike but differ in size.

**3. Shadows :**

i. These are important for two opposing reasons :
   a. The shape or outline of a shadow affords the profile view of the objects which aids the interpretation; and
   b. Objects within shadows reflect little light and difficult to discern on photographs. This hinders interpretation.

ii. As an example for the first, shadows cast by towers, bridges, and certain species of trees can aid interpretation.

**4. Pattern :**

i. This relates to the spatial arrangement of objects.

ii. The repetition of certain general forms is characteristics of many natural and man-made objects.

iii. This is what constitutes a pattern that aids recognition.

iv. For example, the ordered spatial arrangement of trees in an orchard is distinctly different from that of groups of trees in a forest.

**5. Tone (or Hue) :**

i. This refers to the relative brightness or colour of objects on photographs.

ii. In aerial photographs which are generally in black and white, the objects are observed in tones of grey.

iii. The tones of photographic images are influenced by many factors.

iv. It may be clearly understood by the interpreter that a body of water may appear on a photograph in tone ranging from white to black.

v. Lighter-toned areas are topographically higher and drier while darker toned areas are lower and wetter.

**6. Texture :**

i. The texture in aerial photograph is created by tonal repetitions in group of objects too small to be discerned.

ii. As the scale of the photograph is reduced, the texture of the object or area becomes progressively finer.

iii. An example would be the smooth texture of green grass as contrasted with the rough texture of green tree crowns on medium scale aerial photographs.

**7. Site :** This refers to topographic or geographic locations and is particularly valuable in the identification of types of vegetation.

**8. Association :** This refers to the occurrence of certain features in relation to others. For example, a Ferris wheel, which might be difficult to identify if standing in a field near a barn, would be easily identified if it is in an amusement park.

**Que 4.7.** **How will you determine the scale of an aerial photograph ? What do you understand by the terms 'datum scale' and 'average scale' ?**

**OR**

**Derive an expression for the scale of vertical photograph.**

**AKTU 2016-17, Marks 05**

**Answer**

**A. Scale of Aerial Photograph :**

1. Scale of a vertical photograph = $\frac{\text{Distance on photo}}{\text{Corresponding distance on ground}}$

2. In the case of a map, the scale is uniform for the entire map because a map is an orthographic projection, whereas in case of a photograph the scale varies due to variation in elevation of a terrain because a photograph is a perspective projection.

**i. Flat Terrain :** The Fig. 4.7.1 shows a flat terrain $AB$ height $h$ above datum.

$$\text{Scale, } S = \frac{ab}{AB}$$

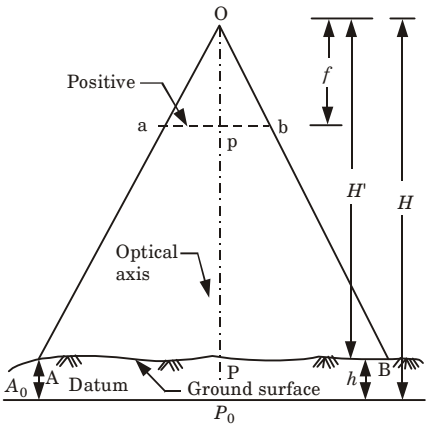



**Fig. 4.7.1.** A vertical photograph taken over flat terrian.

From similar triangles $Oap$ and $OAP$,

$$\frac{ab/2}{AB/2} = \frac{Op}{OP}$$

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

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

**ii. Variable Terrain :** Fig. 4.6.2 shows the vertical photograph of a terrain, in which the elevation is not constant. As per formula $S = \frac{f}{H - h}$, the scale increases with increase in elevation. Consider two points $A$ and $B$, $h_A$ and $h_B$ above datum respectively.

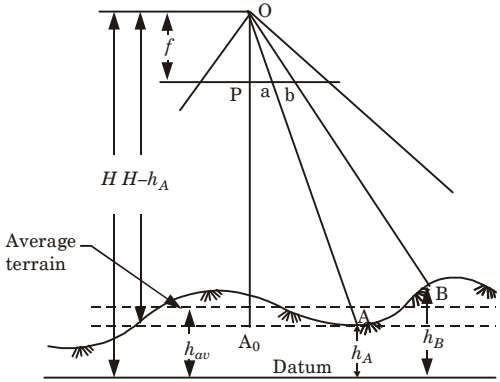



**Fig. 4.7.2.** Vertical photograph taken over variable terrain.

$$S_A = \frac{f}{H - h_A}$$

and, $$S_B = \frac{f}{H - h_B}$$

**B. Average Scale :**

1. For a variable terrain it is often convenient to express average scale of the photograph. If elevation of points $A$, $B$, $C$, $D$..... is $h_A$, $h_B$, $h_C$, $h_D$ ....

then $$h_{av} = \frac{1}{n}(h_A + h_B + h_C + h_D + ....)$$

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

2. Average scale of a terrain can also be obtained by determining scale of different points and taking their average.

$$S_{av} = \frac{1}{n}(S_A + S_B + S_C + S_D + .....)$$

**C. Datum Scale ($S_D$) :**

1. The datum scale of a vertical photograph is the scale that would be, if all the ground points were projected downwards on the datum.

2. From Fig. 4.7.1, $$S_D = \frac{ap}{A_0P_0} = \frac{f}{H}$$

**Que 4.8.** **Discuss the method of determination of ground co-ordinates and distance between two points on ground.**

**OR**

**Derive an expression for the scale of a vertical photograph. Explain how the ground coordinates and the distances can be obtained from a vertical photograph.** **AKTU 2016-17, Marks 05**

**Answer**

**A. Scale of Vertical Photograph :** Refer Q. 4.7, Page 4–9B, Unit-4.

**B. Coordinate and Distances of Vertical Photograph :**

1. Let photo co-ordinates of a point be $(x, y)$ and ground co-ordinates of corresponding point $(X, Y)$ then from scale of a photograph

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

where, $H$ = Flying height

$h$ = Elevation of the point.

Then, $$X = x \frac{H - h}{f} = \frac{x}{S}$$

2. If there are two points $A$ and $B$ on the ground with elevations $h_A$ and $h_B$ then their ground co-ordinates are :

$$X_A = x_A \frac{H - h_A}{f} = \frac{x_A}{S_A} \text{ and } Y_A = y_A \frac{H - h_A}{f} = \frac{y_A}{S_A}$$

$$X_B = x_B \frac{H - h_B}{f} = \frac{x_B}{S_B} \text{ and } Y_B = y_B \frac{H - h_B}{f} = \frac{y_B}{S_B}$$

3. Distance between two points by co-ordinate geometry,

$$D = \sqrt{(X_A - X_B)^2 + (Y_A - Y_B)^2}$$

## PART-2

*Relief displacement of a Vertical Photograph, Height of Object from Relief Displacement.*

**Questions-Answers**

**Long Answer Type and Medium Answer Type Questions**

**Que 4.9.** **Explain relief displacement on a vertical photograph. Derive an expression for its determination. Also derive an expression for determining scale of a vertical photograph.**

**OR**

**Explain, what is relief displacement and how is it calculated ?**

**AKTU 2014-15, Marks 05**

**OR**

**Define relief. Derive an expression for the displacement due to ground relief.**

**AKTU 2016-17, Marks 10**

**Answer**

**A. Relief Displacement :**

i. Relief displacement occurs when the point being photographed is not at an elevation of the mean datum.

ii. The distance on a photograph, from the image of any ground point to its fictitious image projected to a datum plane is the image displacement caused by topographic relief and is known as relief displacement.

**B. Derivation :**

1. Fig. 4.9.1 shows a vertical photograph taken from a height $H$ above datum.

2. The image of ground point $A_0$, whose elevation is $h_1$, is '$a$' on the photograph and that of its projection on the datum plane $A_1$ is $a_1$, thus $aa_1$ is the relief displacement of point $A$ due to its elevation $h_1$. Similarly the relief displacement of point $A_2$ is $aa_2$ on the photograph.

3. Let,
   $r_0$ = Radial distance of '$a$' from principal point '$p$'
   $r_1$ = Radial distance of '$a_1$' from principal point '$p$'
   $r_2$ = Radial distance of '$a_2$' from principal point '$p$'
   $R$ = Ground distance $A_0P_0$.

4. From similar triangles $a_1pO$ and $A_1P_1O$,

$$\frac{f}{H} = \frac{r_1}{R}$$
$$fR = r_1H = a_1 \quad \text{...(4.9.1)}$$

5. From similar triangles $apO$ and $A_0P_0O$,

$$\frac{f}{H - h_1} = \frac{r_0}{R}$$
$$fR = r_0 (H - h_1) \quad \text{...(4.9.2)}$$

6. From eq. (4.9.1) and eq. (4.9.2), we get

$$r_1 H = r_0 (H - h_1) \quad \text{...(4.9.3)}$$

or
$$r_0 = r_1 \frac{H}{H - h_1} \quad \text{...(4.9.4)}$$

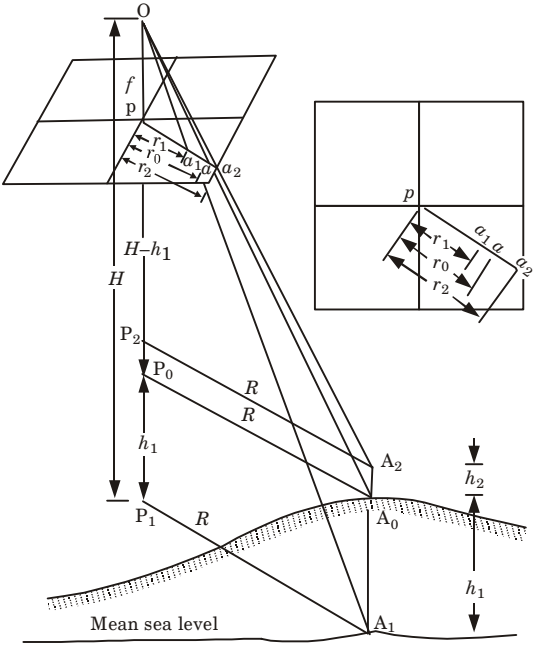



**Fig. 4.9.1.** Topographic relief displacement.

7. Relief displacement of ground point $A_0$,

$$d = aa_1$$
$$d = pa_0 - pa_1 = r_0 - r_1$$
$$= r_1\left(\frac{H}{H - h_1}\right) - r_1 = r_1\left[\frac{H}{H - h_1} - 1\right] = \frac{r_1 h_1}{H - h_1}$$
...(4.9.5)

8. From similar triangles $a_2 pO$ and $A_2 P_2 O$,

$$\frac{f}{H - h_1 - h_2} = \frac{r_2}{R}$$
$$fR = r_2 (H - h_1 - h_2) \quad \text{...(4.9.6)}$$

9. From eq. (4.9.2) and eq. (4.9.6), we get

$$fR = r_0 (H - h_1) = r_2 (H - h_1 - h_2)$$

$$r_0 = r_2 \frac{H - h_1 - h_2}{H - h_1} \qquad ...(4.9.7)$$

10. Relief displacement of point $A_2$,

$$d = r_2 - r_0 = r_2 - r_2 \frac{H - h_1 - h_2}{H - h_1}$$

$$= r_2 \left[ 1 - \frac{H - h_1 - h_2}{H - h_1} \right] = \frac{r_2 h_2}{H - h_1} \qquad ...(4.9.8)$$

**Que 4.10. How do you determine the height of object from relief displacement ?**

**Answer**

1. If the scale of the photograph is known, the height of any object, such as a tower *TB* shown in Fig. 4.10.1 can be determined by following equation :

$$d = \frac{rh}{H} \qquad ...(4.10.1)$$

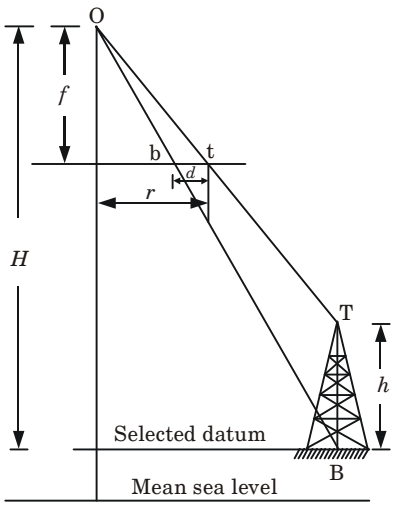



**Fig. 4.10.1.** Height of a tower from relief displacement.

2. Let $h$ be the height of the tower above its exposure station above the selected datum passing through the base of the tower.
3. Let $t$ and $b$ be the top and bottom positions of the tower on the photograph.
4. The radial distance $r$ and the relief displacement can very easily be measured.
5. If the scale $S$ of the photograph is known, the height $H$ can be calculated from the relation

$$S = \frac{f}{H} \quad ...(4.10.2)$$

6. Knowing $H$, and measuring $d$ and $r$, the height $h$ is calculated from eq. (4.10.1). Thus,

$$h = \frac{dH}{r} \quad ...(4.10.3)$$

where $h$ is the height of the tower above the selected datum with reference to which $H$ has been computed.

7. Incidentally, if the elevation of the bottom of the tower is known, the height of flight above mean sea level can be known.

**Que 4.11.** **The distance from the principal point to an image on a photograph is 6.44 cm and the elevation of the object above datum is 250 m, what is the relief displacement of the point is datum is 1/10000 and focal length is 20 cm.** **AKTU 2014-15, Marks 05**

**Answer**

**Given :** Elevation of the object, $h_1 = 250$ m
Distance between principal point to image on photograph, $r_1 = 6.44$ cm
Scale, $S = 1 : 10{,}000$, Focal length, $f = 20$ cm
**To Find :** Relief displacement.

1. Scale of photograph is given by,

$$S = \frac{1}{10{,}000} = \frac{f}{H} = \frac{20/100}{H}$$

or $$H = \frac{20}{100} \times 10{,}000 = 2{,}000 \text{ m above datum.}$$

2. Relief displacement $= \frac{r_1 h_1}{H - h_1} = \frac{6.44 \times 250}{2000 - 250} = 0.92$ cm

**Que 4.12.** **A tower was photographed from an elevation of 800 m above msl. The radial distance of top and bottom of the tower from the principal point is 121.3 mm and 90.7 mm respectively. If the bottom of tower has elevation of 280 m determine the height of the tower above its bottom.**

**Answer**

**Given :** $H = 800$ m, $r_2 = 121.3$ mm, $r_0 = 90.7$ mm, $h_1 = 280$ m
**To Find :** Height of the tower above its bottom, $h_2$.

1. Relief displacement, $d = r_2 - r_0 = 121.3 - 90.7 = 30.6$ mm

2. Relief displacement is given by,

$$d = \frac{r_2 h_2}{H - h_1}$$

$$30.6 = \frac{121.3 \times h_2}{800 - 280} = \frac{121.3 \times h_2}{520}$$

Height of tower above its bottom,

$$h_2 = \frac{30.6 \times 520}{121.3} = 131.179 \text{ m.}$$

## PART-3

*Flight Planning for Aerial Photography, Selection of Altitude, Interval between Exposures, Crab and Drift.*

### Questions-Answers

**Long Answer Type and Medium Answer Type Questions**

**Que 4.13. Explain briefly the aspects of flight planning for an aerial survey and obtain an expression for the number of photographs required for a given area of length and width for such a survey.**

**Answer**

**A. Flight Planning :**

1. Flight planning consists of the following information :

i. The area to be surveyed.

ii. Focal length of the camera.

iii. Scale of the photograph.

iv. Longitudinal and side overlap.

v. Approximate ground speed of the aircraft in stable air.

2. The above information is required to find the altitude of the aircraft above datum, time interval between the exposures, the area covered by each photograph, number of photographs, number of strips and air base.

3. To cover the entire terrain to be surveyed, the sufficient photographs with suitable overlap should be taken.

**B. Expression :**

1. Let, Ground length to be surveyed = $L$
Ground width to be surveyed = $W$
Length of photograph = $l$

Width of photograph = $w$
Scale of photograph = $S$
End or longitudinal overlap = $l_e$
Side overlap = $l_s$

2. Net ground length covered by each photograph = $lS(1 - l_e)$
3. Net ground width covered by each photograph = $wS(1 - l_s)$
4. Number of exposures per flight line ($N_1$) = $\frac{L}{lS(1-l_e)} + 1$
5. Number of flight lines ($N_2$) = $\frac{W}{wS(1-l_s)} + 1$.
6. Number of photographs required = $N_1 \times N_2$
7. Required number of photographs can also be worked out on the basis of net area covered by each photograph and area to be surveyed.

Area to be surveyed = $LW$

8. Net area covered by each photograph = $lS(1 - l_e) \times wS\,(1 - l_s)$
$= lwS^2\,(1 - l_e)\,(1 - l_s)$
9. Number of photographs required = $\frac{WL}{wlS^2(1-l_e)\,(1-l_s)}$
10. Number of photographs required on area basis will be lesser than that required on the basis of number of exposures per flight line × number of flight lines.

**Que 4.14.** **Write a short note on :**

**i. Interval between exposures.**
**ii. Selection of flying altitude.**

**Answer**

**i. Interval Between Exposures :**

1. The time interval between the exposures can be calculated if the ground speed of the airplane and the ground distance along the direction of flight between exposures are known.
2. Let V = Ground speed of the airplane (km/hour).

Ground distance covered by each photograph in the direction of flight in km,

$L = (1 - le)\,Sl$

Time interval between the exposures, $T = \frac{3600L}{\mathrm{V}}$

3. The exposures are regulated by measuring the time required for the image of a ground point to pass between two lines on a ground-glass plate of the view-finder.

4. Usually, however, the interval is not calculated, but the camera is tripped automatically by synchronizing the speed of a moving grid in the view-finder with the speed of the passage of images across a screen.

**ii. Selection of Flying Altitude :**

1. The selection of height above ground depends upon the accuracy of the process to be used and the contour interval desired.
2. Several inter-related factors which affect the selection of flying height, such as desired scale, relief displacement, and tilt.
3. Since vertical accuracy in a topographic map is the limiting factor in the photogrammetric process, the flying height is often related to the contour interval of the finished map.
4. The process is rated by its *C*-factor which is the number by which the contour interval is multiplied to obtain the maximum height about the ground.

   Thus, Flying height = (Contour interval) × (*C* factor)
5. *C*-factor for various processors varies from 500 to 1500, and depends upon the conditions surrounding the entire map-compilation operation.

**Que 4.15.** **Explain with reference to aerial photographs, what is meant by end overlap and side overlap and why they are provided ?**

**OR**

**Why overlapping is required in aerial photography ? Also explain crab and drift.**

**OR**

**Why overlapping is necessary ?** **AKTU 2014-15, Marks 05**

**Answer**

**A. Overlap :** To ensure a complete coverage of the area to be surveyed, there should be some overlap of the area covered by each aerial photograph. Following are the two types of overlap :

**1. End or Longitudinal or Forward Overlap :** It is the overlap in photographs in the direction of flight. It is kept 55 % to 65 %.

**2. Side Overlap :**

i. It is the overlap in photograph in a direction perpendicular to the line of flight. It is kept 25 % to 35 %.

ii. It is the overlap between photographs of two adjacent flight strips. It is also called "lateral overlap".

**B. Requirements of Overlapping :**

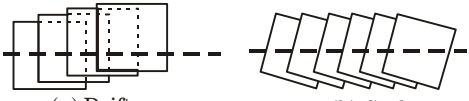
1. It is required to orient prints so as to form a continuous flight strip.
2. The central portion of the print is always less distorted than the outer edges. Since, due to the overlap, the same area is photographed twice or

thrice, the highly distorted outer portion of the photograph can therefore be discarded.

3. For a stereoscopic vision only the overlapped portion is useful.
4. If a proper side overlap is provided, there will be no possibility of gaps left because of the deviation of the aircraft from the flight line.

**C. Drift :** It is shifting of aircraft from its planned flight lines often caused due to strong winds (while taking photographs).

**D. Crab :** When the camera mounted abroad an aircraft is not square with the direction of flight at the time of exposure, the photograph taken will be oblique with the direction of flight.



(a) Drift (b) Crab

**Fig. 4.15.1.**

**Que 4.16. An area 30 km in the north south direction and 24 km in the east west direction is to be photographed with a lens having 30 cm focal length. The photograph size is 20 cm × 20 cm. The average scale is 1 : 12000 effective at an elevation of 400 m above datum. Longitudinal and side lap are 60 % and 30 % respectively. The two other flight lines are to coincide with east and west boundaries of the area. Determine flying altitude, number of flights lines, number of photographs per flight line and total number of photographs required.**

**Answer**

**Given :** Photograph size = 20 cm × 20 cm, Scale = 1 : 12000
Elevation = 400 m, Longitudinal lap, = 60 %, Side lap, = 30 %
Focal length, $f$ = 30 cm
**To Find :** Flying altitude, number of flights lines, number of photographs per flight lines, total number of photographs.

1. Flying altitude, $\frac{H}{f} = \frac{1}{S}$

$$H = 12000 \times 0.30 = 3600 \text{ m}$$

2. Theoretical ground spacing of flight lines,

$$W = (1 - l_s)\, Sw$$
$$= (1 - 0.30) \times 12000 \times 0.20 = 1680 \text{ m}$$

3. Number of flight lines required,

$$N_2 = \frac{L_2}{W} + 1 = \frac{24 \times 10^3}{1680} + 1 = 15.28 \approx 16$$

4. Actual spacing of flight lines,

$$= \frac{24 \times 10^3}{16} = 1500 \text{ m}$$

5. Ground distance between exposure,
$$L = (1 - l_e)\, Sl$$
$$= (1 - 0.60) \times 12000 \times 0.20 = 960 \text{ m}$$
6. Number of photographs per flight line,
$$N_1 = \frac{30 \times 10^3}{960} + 1 = 32.25 \approx 33$$
7. Total number of photographs required
$$= N_1 \times N_2 = 33 \times 16 = 528$$

**Que 4.17.** **The scale of an aerial photograph is 1 cm = 160 m and the size of photography is 20 cm × 20 cm. If the longitudinal lap is 65 % and side lap is 35 %, determine the number of photographs, required to cover an area 348 sq km.** **AKTU 2014-15, Marks 15**

**Answer**

**Given :** Size of photograph, $l \times w = 20 \text{ cm} \times 20 \text{ cm}$
Longitudinal overlap, $le = 65\ \%$, Side overlap, $ls = 35\ \%$
Total area covered, $A = 348 \text{ km}^2$
**To find :** Number of photograph.

1. Scale of photograph, $S = \frac{160 \times 100}{1} = 16000 : 1$
2. Number of photographs per flight lines,
$$N_1 = \frac{L}{l \times S(1 - l_e)} + 1$$
$$L = \sqrt{348} = 18.65 \text{ km}$$
$$N_1 = \frac{18.65 \times 10^3}{0.20 \times 16000 \times (1 - 0.65)} + 1$$
$$= 17.65 \approx 18$$
3. Number of flight lines, $N_2 = \frac{W}{wS(1 - l_s)} + 1$
$$= \frac{18.65 \times 10^3}{0.20 \times 16000 \times (1 - 0.35)} + 1$$
$$N_2 = 9.96 \approx 10$$
4. Total number of photograph required $= N_1 \times N_2 = 18 \times 10 = 180$

**Que 4.18.** **A line *PQ* appears to be 10.16 cm on a photograph for which the focal length is 16 cm. The corresponding line measure 2.54 cm on a map which to be a scale 1/50,000. The terrain has an**

**average elevation of 200 m above msl. Calculate the flying altitude of the aircraft above mean sea level.**

**Answer**

**Given :** Length of line $PQ$ on photograph = 10.16 cm
Length of line $PQ$ on map = 2.54 cm, Focal length, $f$ = 16 cm
Scale of map, $S_m$ = 1/50000, Average elevation of terrain, $h_1$ = 200 m
**To Find :** Flying altitude.

1. $$\frac{\text{Photo scale}}{\text{Map scale}} = \frac{\text{Photo distance of line } PQ}{\text{Map distance of line } PQ}$$

*i.e.,* $$\frac{S_p}{\frac{1}{50000}} = \frac{10.16}{2.54}$$

$$S_p = \frac{1}{12500} \quad \text{...(4.18.1)}$$

2. $$\text{Photo scale} = \frac{f}{H - h_1} = \frac{0.16}{H - 200} \quad \text{...(4.18.2)}$$

3. From equations (4.18.1) and (4.18.2), we get

$$\frac{0.16}{H - 200} = \frac{1}{12500}$$

Flying altitude, $H$ = 2200 m

**Que 4.19.** **Two consecutive photographs were taken with a camera of focal length 37.5 cm, at a height of 7200 m. The overlap was exactly half and the prints were 22.5 cm × 22.5 cm. The height was same for both the exposures and the aircraft flew on even peel with no drift. The ground was flat at approx 2500 m above msl. Determine the scale of the photograph and the length of the airbase.**

**AKTU 2016-17, Marks 05**

**Answer**

**Given :** Focal length of camera, $f$ = 37.5 cm
Height of aircraft, $H$ = 7200 m
Height of the ground above mean sea level, = 2500 m
Size of print = 22.5 cm × 22.5 cm
**To Find :** Scale of photograph and length of airbase.

1. Scale of photograph, $S = \frac{f}{H - h} = \frac{37.5 \text{ cm}}{(7200 - 2500)\text{m}} = \frac{1}{125.33}$

Thus, the scale of the photographs is 1 cm = 125.33 m

2. The actual ground length covered by each photograph,

$$L = (1 - l_e) \times S \times l$$
$$= (1 - 0.5) \times 125.33 \times 22.5 = 1410 \text{ m}$$

Hence length of airbase, $L = 1410$ m

**Que 4.20. A flooded area is covered by 140 dots on a 25 dot/cm$^2$ grid on a 1:25000 vertical aerial photography. Find the ground area flooded.** **AKTU 2017-18, Marks 07**

**Answer**

**Given :** Number of dots covered for flooded area = 140 dots
Number of dots per cm$^2$ = 25 dots
Scale of photograph = 1 : 25000
**To Find :** Ground area of flood.

1. Ground area shows by one dot

$$= \frac{1 \text{ cm}^2}{25 \text{ dots}} \times 25000^2 = 25{,}000{,}000 \text{ cm}^2 = 0.25 \text{ ha/dot}$$

2. Total ground area = 140 dots × 0.25 ha/dot = 35 ha

## PART-4

*Stereoscope and Stereoscope Views.*

### Questions-Answers

**Long Answer Type and Medium Answer Type Questions**

**Que 4.21. Describe the stereoscope with its functions and types.**

**OR**

**Describe the mirror stereoscope with neat sketch.**

**AKTU 2014-15, Marks 05**

**Answer**

**A. Stereoscope :** It is an instrument used for viewing stereopair in photogrammetric surveying or aerial surveying is called as stereoscope.

**B. Function of Stereoscope :**

1. A stereoscope is used to accommodate the wide separation of the individual photograph of the stereopair to the fixed length of the eye base.
2. It is also used to magnify the depth of perception.

## C. Types of Stereoscope :

Following are the types of stereoscope which are generally used into practice of aerial surveying :

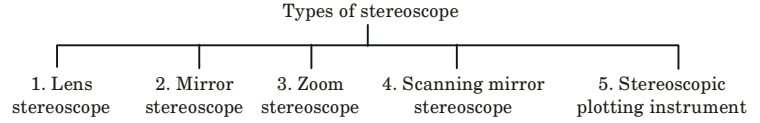



**Fig. 4.21.1.**

### 1. Lens Stereoscope :

i. This type of stereoscope consists of magnifying lens at a place of mirror for each eye.

ii. In case of lense stereoscope, the two lenses are mounted on an assembly in such way that distance between them is equal to the average eye base or interpupillary distance of the human eyes. However minor adjustment is done for the separation of these two lenses according to the user.

iii. The distance between the nodal points of the lens and the photograph is always proportionate to the focal length of the lens being used in the stereoscope.

iv. Lense stereoscope causes more strain to the eyes but lense stereoscope is small in size and compact and hence can be conveniently handled and used in the field of aerial survey.

v. Since lenses have the magnifying effect, the heights of an object can be seen larger than the actual height of an object.

### 2. Mirror Stereoscope :

i. This type of stereoscope consists of four mirrors, two mirror say $m_1$ and $m_2$ are small eye piece mirror and other two say $M_1$ and $M_2$ are larger wing mirror as shown in Fig. 4.21.2. These four mirrors are situated at an orientation of 45° with the plane of the photographs.

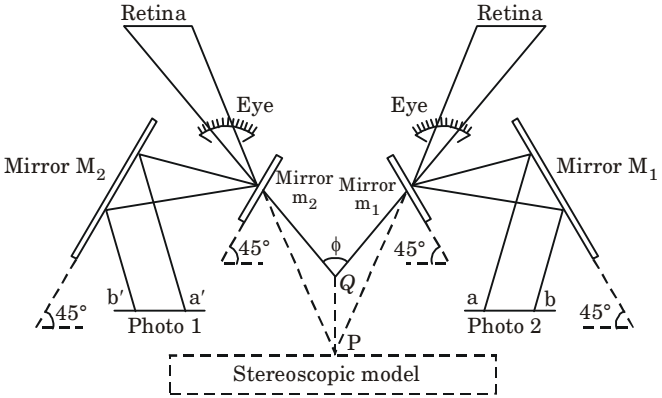



**Fig. 4.21.2.** Optical diagram of mirror stereoscope.

ii. The photographs to be viewed are placed at a certain distance from the wing mirror $M_1$ and $M_2$ and light reaches to the eyes exactly as it would come from the actual terrain.

iii. Mirror stereoscope completely separate the photographs for viewing and the whole overlap area can be seen stereoscopically without any slip of photographs, is the greatest advantages of mirror stereoscope.

iv. It is not handy and portable due to its large size.

**Que 4.22. Explain the working of mirror stereoscope.**

**Answer**

1. The mirror stereoscope, shown diagrammatically in Fig. 4.22.1(b), consists of a pair of small eye-piece mirrors $m$ and $m'$, and a pair of larger wing mirrors, $M$ and $M'$, each of which is oriented at 45° with the plane of the photographs.
2. Fig. 4.22.1(a) shows a nail mounted on a block of timber, and is being photographed by two camera positions.

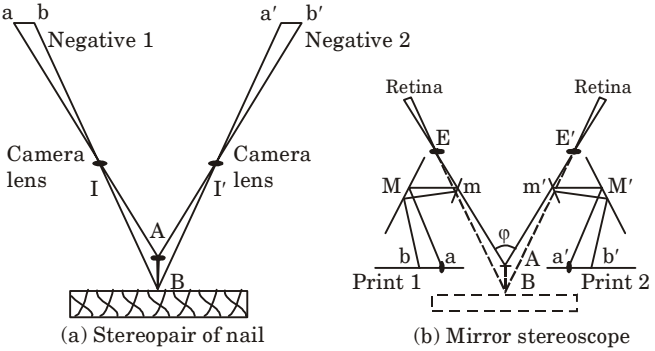



**Fig. 4.22.1.** Principle of mirror stereoscope.

3. The camera lens is placed first in the position of left eye and then in the position of right eye and separate photograph is taken in each position.
4. It will be noted that the head of the nail is to the left in the left film and to the right in the right film. $ab$ and $a'b'$ are the images of the nail $AB$ in the two films.
5. Contact prints from these negatives are placed in the mirror stereoscope as shown in Fig. 4.22.1(b), where only images of the nail are drawn.
6. The four mirrors transfer the light to the eyes exactly (except for accommodation) as if it had come from nail as shown by dotted line.
7. The convergence and retinal disparity are sufficient for the observer to see the nail in three dimensions.
8. The total distance $b\,M\,m\,E$ *or* $b'\,M'\,m'\,E'$, from the eye to the plane of the photographs varies 30 cm to 45 cm, in order that the unaided eye may comfortably view the photographs.

9. The angle φ is determined by the separation of photographs that gives the most eye comfort, and is compatible with the distance $bMmE$.
10. If this distance is to be reduced, a pair of magnifying lense is placed at $E$ and $E'$. Each magnifier has a focal length slightly smaller than the distance $bMmE$.

**Que 4.23.** **What do you understand by stereopairs ? Vertical photographs were taken from height of 3048 m, the focal length of the camera lens being 15.24 cm. If prints were 22.86 × 22.86 cm and the overlap is 60 %, what is the length of airbase and what is the scale of photographs ?**

**Answer**

**A. Stereopairs :**

1. The two consecutive overlapping photographs taken from adjacent positions during a flight are called stereopair and these can only be viewed through a stereoscope.
2. A number of stereopairs are used to compile a controlled or photogrammetric map.
3. When a stereopair is viewed through a stereoscope the picture seen is the same as viewed by an aircraft camera.

**B. Numerical :**

**Given :** Height at which the photograph were taken, $H = 3048$ m
Focal length of the camera, $f = 15.24$ cm
Size of photograph = 22.86 × 22.86 cm, Overlap = 60 %
**To Find :** Length of airbase, scale of photographs.

1. Assume height of the ground above the mean sea level, $h = 250$ m
2. Scale of the photograph is given by, $S = \dfrac{f}{H - h}$

$$S = \frac{15.24}{3048 - 250} = \frac{1}{183.60} \text{ or } 1 \text{ cm} = 183.60 \text{ m}$$

3. The actual ground length covered by each photograph or air base,
$L = (1 - l_e)\, Sl = (1 - 0.6) \times 183.60 \times 22.86$
Length of airbase, $L = 1678.83$ m

## PART-5

*Parallax Equations.*

**Questions-Answers**

**Long Answer Type and Medium Answer Type Questions**

**Que 4.24. Describe the construction and working of a parallax bar with the help of a neat sketch.**

**OR**

**Describe the parallax bar with neat sketch.**

**AKTU 2014-15, Marks 05**

**Answer**

**A. Construction of Parallax Bar :**

1. It is used to measure the parallax difference between two points. The difference in parallax of two points is called parallax difference.

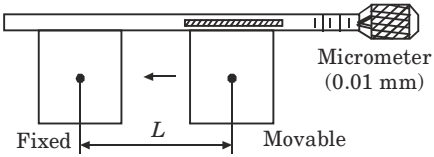



**Fig. 4.24.1.** Parallax bar.

2. Parallax is the displacement in the image of an object caused by a shift in the point of observation *i.e.*, successive exposures during a flight. It is also called stereoscopic parallax or $x$-parallax.
3. The instrument as shown in Fig. 4.24.1 consists of two plates of transparent materials attached to a bar.
4. The left plate is fixed and the right one movable with the help of a micrometer screw.
5. The total movement possible being 25 mm, which can be read nearest to 0.01 mm. Each plot contains a tiny dot in the centre.
6. The stereopair is viewed under a stereoscope and the parallax bar is placed on the photographs.

**B. Working :**

1. Let it be required to measure the parallax difference between two points $A$ and $C$ whose image appear on both the photographs at $(a, c)$ and $(a', c')$ respectively.
2. The left mark of the parallax bar is placed over $a$ and the parallax bar is so oriented that it is parallel to the flight line.
3. Move the right mark and make the fused dot to touch the ground point. Take the micrometer reading.
4. Shift the bar bodily, put the left mark over the image $c$ and move the right mark so that the fused marks again rests on the ground.
5. Note the micrometer reading. The difference between the two readings gives the value $\Delta p$.

6. Thus in Fig. 4.24.2 when point $a$ is fused, the separation of the marks is lesser and the point is higher as is clear from the two intersecting rays $OaA$ and $O'a'A$ in the lower part of the diagram.

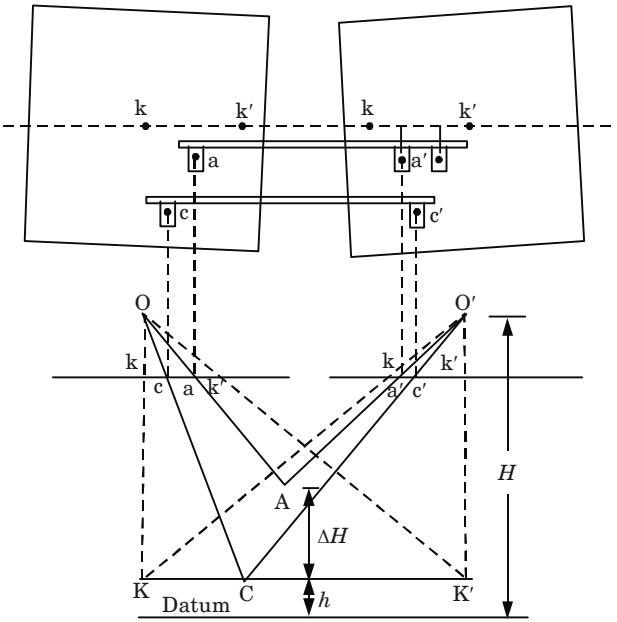



**Fig. 4.24.2.** Principle of a parallax bar.

7. Similarly, when $c$ is fused, the separation of the marks is increased, and the point of lower as is clear from the two intersecting rays $OcC$ and $O'c'C$.

8. The difference in elevation is then found by,

$$\Delta H = \frac{(H-h)^2\,\Delta p}{(H-h)\Delta p + b_m\,H}$$

where, $b_m$ is the mean principal base.

**Que 4.25. Derive the parallax equation for determining the evaluation of a point.**

**OR**

**Establish parallel equation for determining elevation of a point from a stereopair.**

**Answer**

1. Fig. 4.25.1 shows the two images of a point $A$ as $a$ when the aircraft is at position $O_1$ and as $a'$ when the aircraft is at $O_2$.

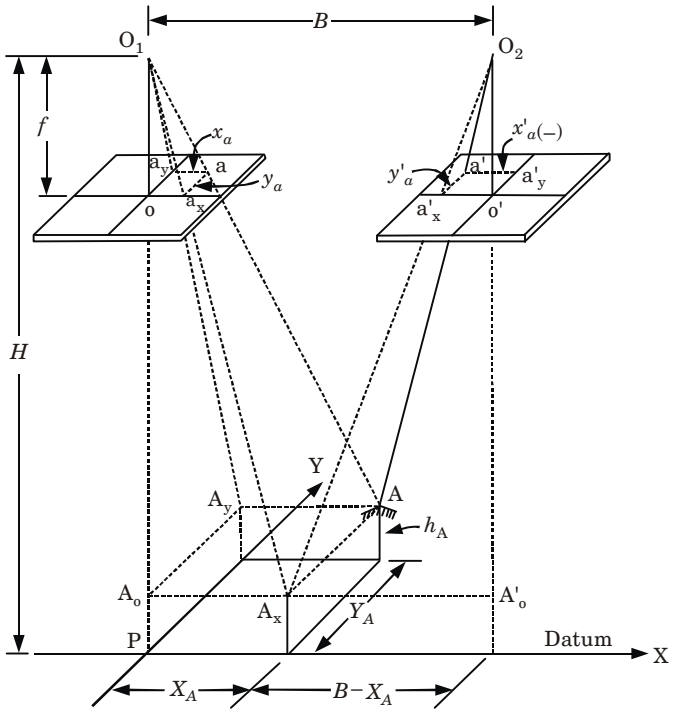



**Fig. 4.25.1.** Parallax relationship.

2. There is obviously a shift in the image because the image $a$ is to the right of principal point whereas the image $a'$ is to the left of principal point.
3. Co-ordinates of the point image $a$ are $(x_a, y_a)$ and that of $a'$ are $(x'_a, y'_a)$, while that of ground point $A$ these are $(X_A, Y_A)$.
4. From similar triangles $O_1oa_y$ and $O_1A_oA_y$, we get

$$\text{or} \qquad \frac{Y_A}{H - h_A} = \frac{y_a}{f}$$

$$Y_A = \frac{y_a}{f}(H - h_A) \qquad \text{...(4.25.1)}$$

5. From the similar triangles $O_1oa_x$ and $O_1A_oA_x$, yield

$$\frac{X_A}{H - h_A} = \frac{x_a}{f}$$

$$\text{or} \qquad X_A = \frac{x_a}{f}(H - h_A) \qquad \text{...(4.25.2)}$$

6. Also, from similar triangles $O_2o'a'_x$ and $O_2A'_oA_x$,

$$\frac{B - X_A}{H - h_A} = \frac{-x_a}{f}$$

or $$X_A = B + \frac{x'_a}{f}\ (H - h_A) \quad ...(4.25.3)$$

7. From eq. (4.25.2) and (4.25.3), we get

$$h_A = H - \frac{Bf}{x_a - x'_a} \quad ...(4.25.4)$$

8. Substituting $P_a$ for $x - x'_a$ into eq. (4.25.4), we get

$$h_A = H - \frac{Bf}{P_a} \quad ...(4.25.5)$$

where, $P_a$ = Parallax of the point $A$.

9. Now substituting eq. (4.25.5) into eq. (4.25.2) and eq. (4.25.1) and reducing, we get

$$X_A = B\frac{x_a}{P_a} \quad ...(4.25.6)$$

$$Y_A = B\frac{y_a}{P_a} \quad ...(4.25.7)$$

Eq. (4.25.5), (4.25.6) and (4.25.7) are commonly called parallax equations.

## PART-6

*Introduction to Digital Photogrammetry.*

### Questions-Answers

### Long Answer Type and Medium Answer Type Questions

**Que 4.26. Describe the digital photogrammetry. What are the uses of digital photogrammetry ?**

**Answer**

**A. Digital Photogrammetry :**

1. The digital or soft extension of the conventional hard copy photogrammetry is called as digital photogrammetry.
2. In case of digital photogrammetry, there is use of digital images without using the conventional photographic images. Digital images can be obtained by using the satellite images or by scanning aerial photos of high resolution.

3. In general, digital photogrammetry is the art of using computers so as to obtain the measurements of objects in a photograph. It consists of analyzing one or more existing photographs or videos with photogrammetric software to determine spatial relationships.
4. Some of the projects require only 2D *i.e.*, two dimensional measurements such as the height of a building or width of a river and these measurements can be taken from a single photographs.
5. For 3D *i.e.*, three dimension measurements, the process involves a 3D models from two or more photographs.

**B. Uses of Digital Photogrammetry :** Following are the various of digital photogrammetry :

1. It is used in digital terrain modeling.
2. It gives appropriate display and measurements.
3. It is used for two-dimensional and three-dimensional flood plain mapping.
4. It can also be used for stream mapping.
5. It can produce superior quality planimetric and topographic data.
6. It can also be used for highway mapping and data compilation.

## VERY IMPORTANT QUESTIONS

***Following questions are very important. These questions may be asked in your SESSIONALS as well as UNIVERSITY EXAMINATION.***

**Q. 1. What do you understand by the term 'Aerial photography' ? Also write a short note on the factors that influence aerial photography.**

**Ans.** Refer Q. 4.3, Unit-4.

**Q. 2. Differentiate between 'Aerial photography' and 'Aerial photogrammetry'.**

**Ans.** Refer Q. 4.4, Unit-4.

**Q. 3. Derive an expression for the scale of vertical photograph.**

**Ans.** Refer Q. 4.7, Unit-4.

**Q. 4. Derive an expression for the scale of a vertical photograph. Explain how the ground coordinates and the distances can be obtained from a vertical photograph.**

**Ans.** Refer Q. 4.8, Unit-4.

**Q. 5. Define relief. Derive an expression for the displacement due to ground relief.**

**Ans.** Refer Q. 4.9, Unit-4.

**Q. 6. The distance from the principal point to an image on a photograph is 6.44 cm and the elevation of the object above datum is 250 m, what is the relief displacement of the point is datum is 1/10000 and focal length is 20 cm.**

**Ans.** Refer Q. 4.11, Unit-4.

**Q. 7. Why overlapping is necessary ?**

**Ans.** Refer Q. 4.15, Unit-4.

**Q. 8. The scale of an aerial photograph is 1 cm = 160 m and the size of photography is 20 cm × 20 cm. If the longitudinal lap is 65 % and side lap is 35 %, determine the number of photographs, required to cover an area 348 sq km.**

**Ans.** Refer Q. 4.17, Unit-4.

**Q. 9. Two consecutive photographs were taken with a camera of focal length 37.5 cm, at a height of 7200 m. The overlap was exactly half and the prints were 22.5 cm × 22.5 cm. The height was same for both the exposures and the aircraft flew on even peel with no drift. The ground was flat at approx 2500 m above msl. Determine the scale of the photograph and the length of the airbase.**

**Ans.** Refer Q. 4.19, Unit-4.

**Q. 10. Describe the mirror stereoscope with neat sketch.**

**Ans.** Refer Q. 4.21, Unit-4.

**Q. 11. Describe the parallax bar with neat sketch.**

**Ans.** Refer Q. 4.24, Unit-4.

**Q. 12. Explain in detail about the characteristics of photographic images.**

**Ans.** Refer Q. 4.6, Unit-4.