# PHYSICS NOTES

## TOPIC: LIGHT (OPTICS)

## SUB-TOPIC 1: SPHERICAL MIRRORS
or CURVED MIRRORS

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# LIGHT

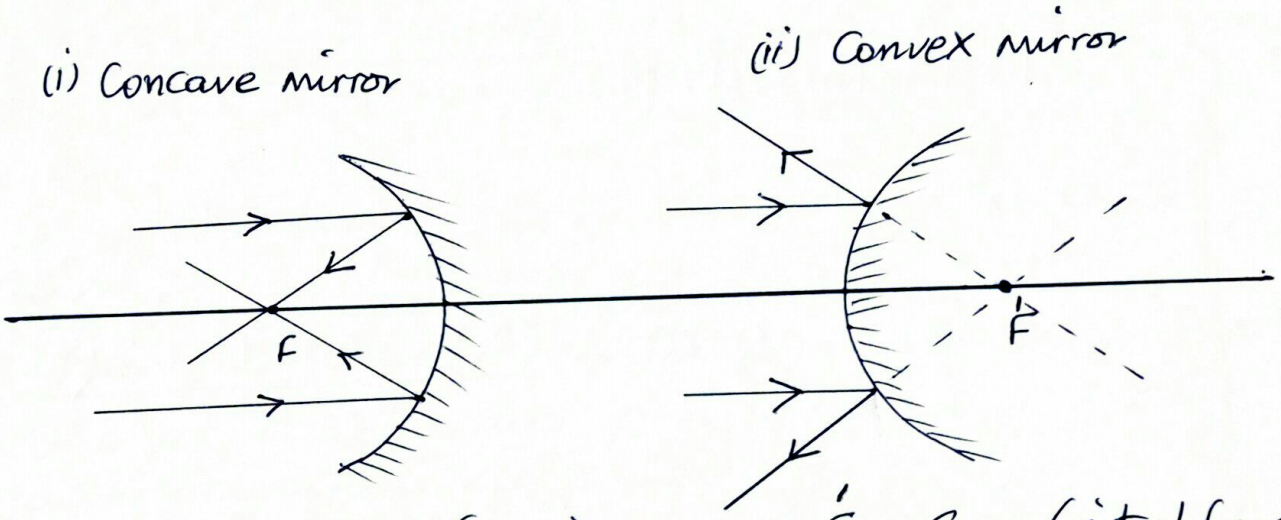
## REFLECTION OF LIGHT FROM CURVED MIRRORS (SPHERICAL MIRRORS)

Curved or spherical mirrors are obtained when a piece of transparent glass which is not straight (curved) is silvered on one side

## TYPES OF CURVED MIRRORS

(i) Concave mirror

(ii) Convex mirror




F = Focus (Real focus)

F' = Focus (virtual focus)

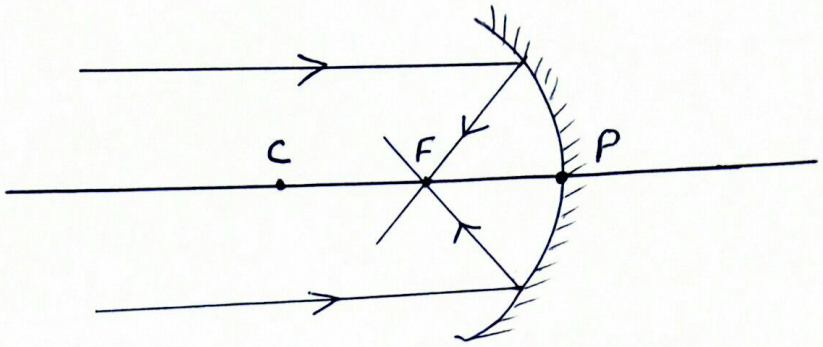
NB: Concave mirrors: Are ones which its reflecting surface curved (bend) inward.

Also are called Converging mirrors.

Convex mirrors: Are ones which its reflecting surface is curved (bend) outward or outside.

Also are called diverging mirrors

# TERMINOLOGIES USED IN SPHERICAL MIRRORS




1. Centre of curvature (C):- is the central point of a sphere of which a mirror is a part.
2. Mirror pole (P):- is the central point of the reflecting surface of a spherical mirror
3. Principal axis (PA):- is unlimitted line joining the focus and the pole of the mirror.
   or
   is unlimitted straight line joining the centre of curvature and the pole of a spherical mirror.
4. Principal focus (F): is the point on the principal axis at which rays parallel and very close to the principal axis converge or appear to diverge from after reflection.
5. Principal focus of a concave mirror: is the point on the principal axis at which rays parallel and very close to the principal axis converge after reflection.
6. Principal focus of a Convex mirror: is the point on a principal axis at which rays parallel and very close to the principal axis appear to diverge from after reflection.
7. Radius of Curvature (r): is the distance between centre of curvature and mirror pole
   or
   is the radius of a sphere of which the mirror is a part.

8. Focal Length (F): is the distance between the principal focus and the mirror pole.

9. Aparture: is the width of a spherical mirror.
Or
is the effective diameter of a Curved mirror.

10. Focal plane: is the plane perpendicular to the principal axis and passes through the principal focus

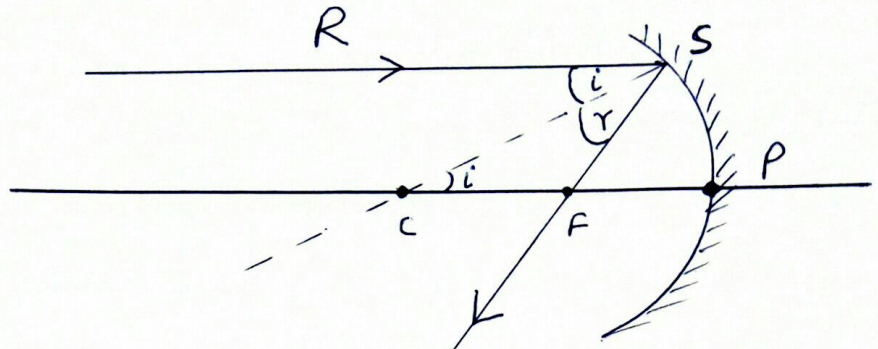
11. Real image: This is an image which can be formed/focused onto a screen or is formed by actual rays of light.

12. Virtual image: This is an image which cannot be focused onto a screen or is formed by intersecting imaginary (apparent) rays of light.

DIFFERENCES BETWEEN REAL AND VIRTUAL IMAGE

| REAL IMAGE | VIRTUAL IMAGE |
|---|---|
| (i) A real image is formed due to actual intersection of the reflected rays | (i) A virtual image is formed when the reflected rays meet if they are produced backwards (apparent intersection of the reflected rays). |
| (ii) A real image can be obtained on a screen | (ii) A virtual image cannot be obtained on a screen |
| (iii) A real image is inverted with respect to the object. Eg: The image of a distance object formed by a concave mirror | (iii) A virtual image is erect with respect to the object. Eg. The image of an object formed by plane mirror or by Convex mirror. |

Qn:




Show that $f = \frac{r}{2}$ ie $PF = \frac{PC}{2}$

Ans:

$F\hat{C}S = i$ (Alternate interior angles)

$\Delta CFS$ is isosceles $(i = r)$

If RS is very close to CP; $S \simeq P$

Thus; $CF = FS = FP$, $CP = 2FP$

$r = 2f$

$$\therefore \boxed{f = \frac{r}{2}}$$

## FORMATION OF IMAGES

The following guidelines help to state the properties of images formed in a spherical mirrors:-

(i) On which side of the mirror is the image formed?

Ans: (a) Infront/left/against incident-rays

(b) Behind/right/Same direction to incident-rays

(ii) How far from the mirror is the image formed?

Ans:
— cm away from the mirror.

(iii) How large is the image compared to the object?

Ans: Linear magnification (M):
the same size ($M=1$); enlarged/magnified ($M>1$),
Diminished/Smaller than ($M<1$).

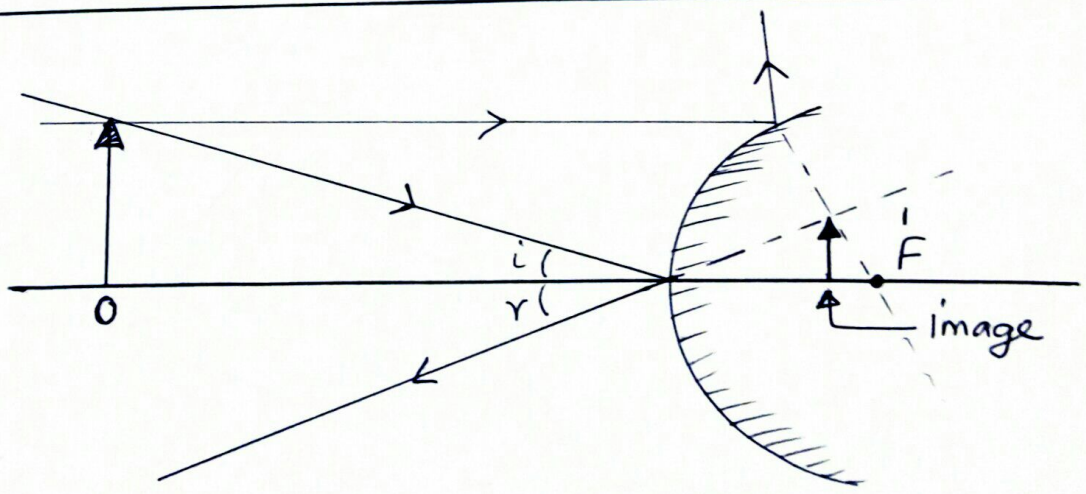
(iv) In which way up is the image situated at the principal axis (PA)?

Ans:
Erect/upright; Inverted/upside down turned or Laterally inverted.

(v) What is the nature of the image?

Ans:
(a) Real
(b) Virtual/ideal

## IMAGES FORMED IN CONVEX MIRRORS:



The image is:

(i) Behind the mirror

(ii) Between F and P

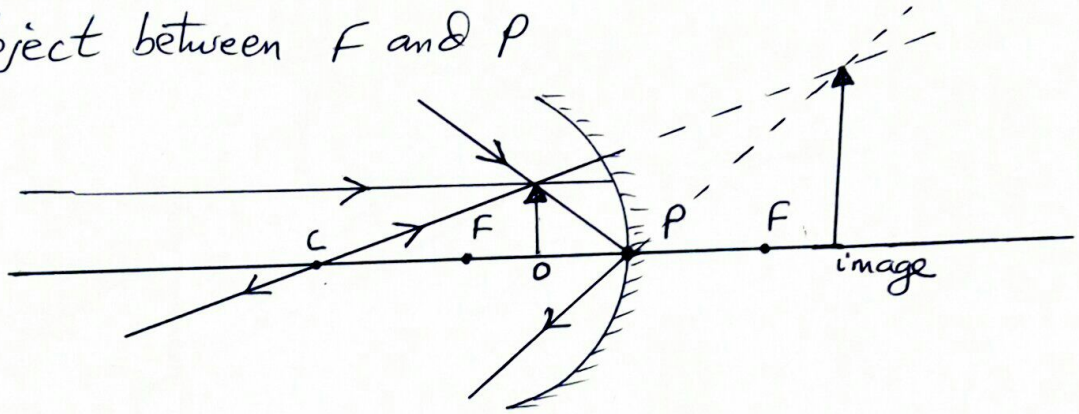
(iii) Diminished/smaller than

(iv) Upright/erect

(v) Virtual/ideal

## IMAGES FORMED BY CONCAVE MIRRORS

(a) Object between F and P




The image is

i. Behind the mirror

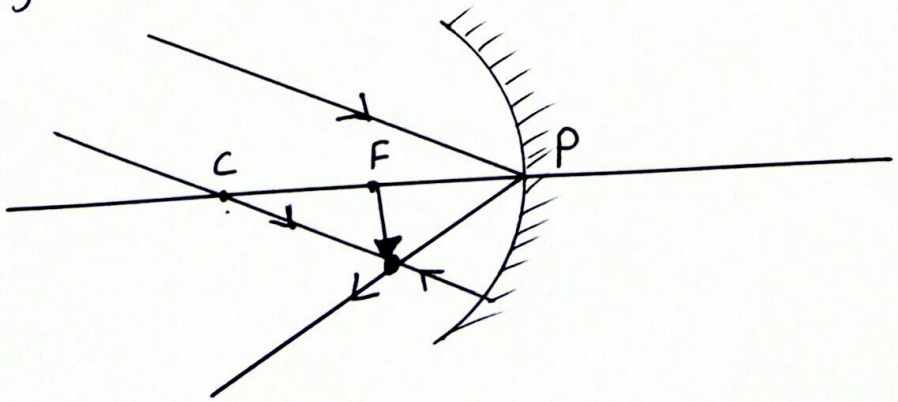
ii. Beyond F

iii. Enlarged/Magnified

iv. Upright/Erect

v. Virtual/ideal

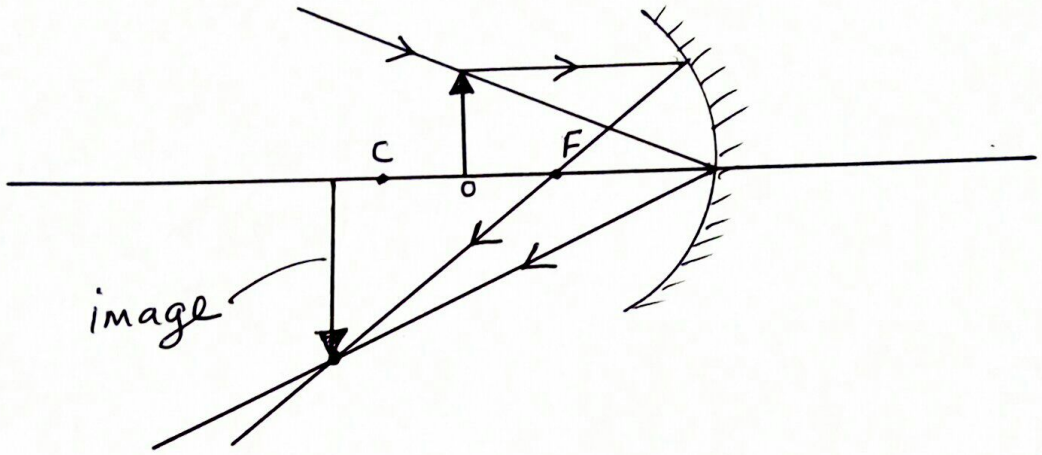
(b) Object at infinity



The image is :-

i. Infront the mirror
ii. At F
iii. Inverted
iv. Diminished
v. Real

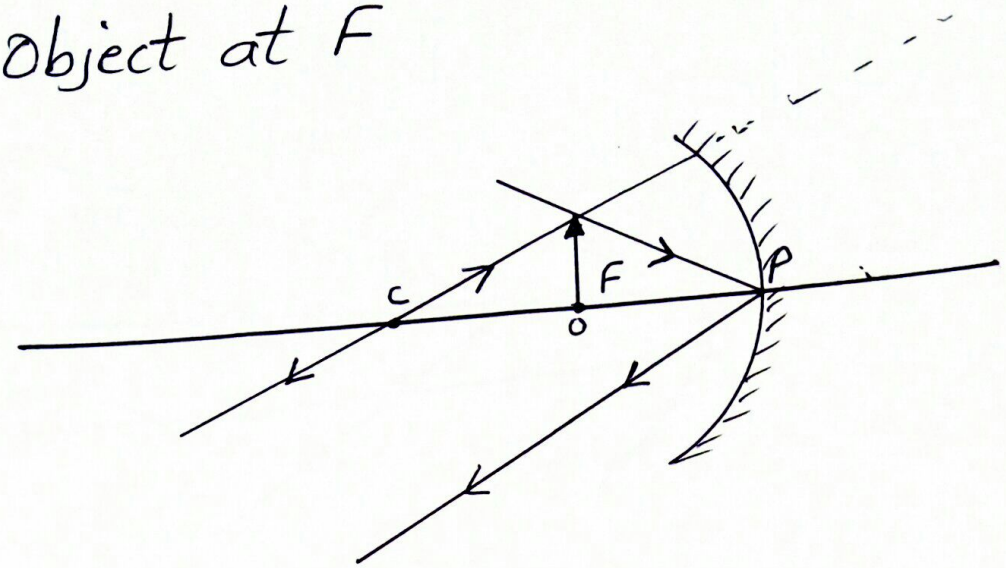
(c) Object between C and F




The image is :-

i. Infront of the mirror
ii. Beyond C
iii. Enlarged / Magnified
iv. Inverted
v. Real

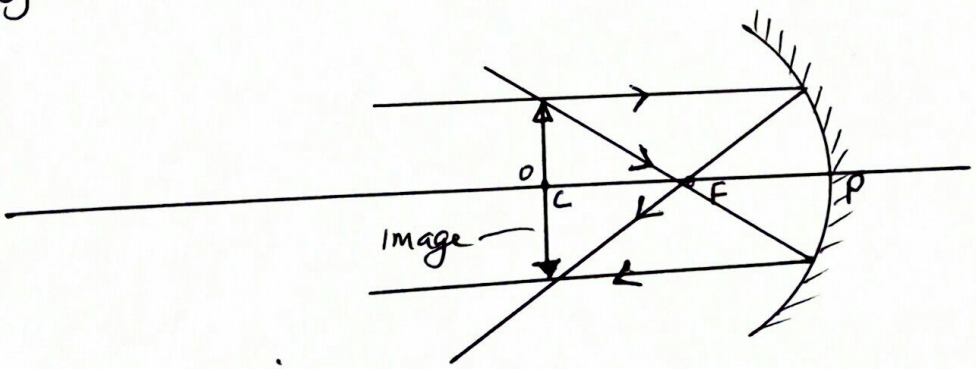
(d) Object at F




The image is:-

i. infinity
ii. Infront the mirror
iii. Enlarged / Magnified
iv. Inverted
v. Real

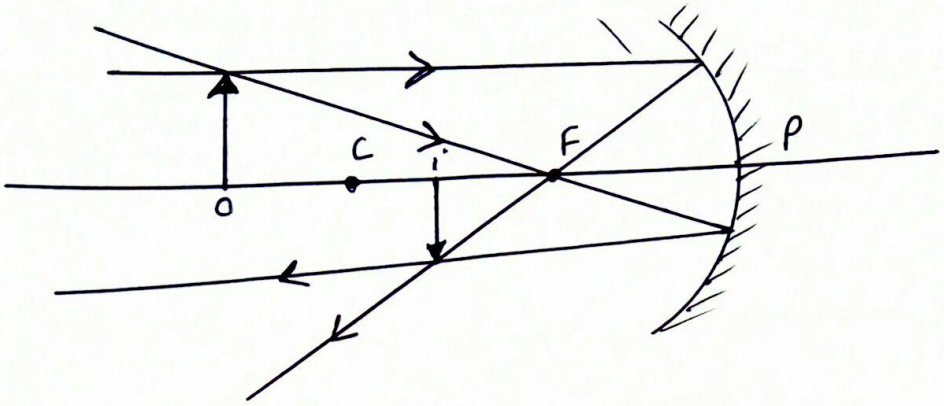
(e) Object at C




The image is:-

i. At C
ii. Infront the mirror
iii. The same size as the object
iv. Inverted
v. Real

(f) Object beyond C




The image is:-

i. Infront/left the mirror
ii. Between C and F
iii. Diminished
iv. Inverted
v. Real

# SIGN CONVENTION

Sign convention is the mathematical description of properties of images formed in optical instruments in relation to nature and geometry.

Note; (i) All distances are measured from the mirror pole to the image or object

(ii) The P.A is a line onto which images and objects are erected.

## TYPES OF SIGN CONVENTIONS

There are two types of sign conventions namely:-

1. REAL-IS POSITIVE (R.P) in this convention:

(a) Image distances and object distances are positive
(b) Real foci are positive
(c) Virtual foci are negative
(d) Virtual image take negative distances

2. NEW CARTESIAN (GEOMETRICAL CONVENTION)

(a) It considers the origin of the X-y plane as the reference point or as the mirror pole
(b) All distances measured left/against i-rays are negative
(c) All distances measured right/same direction to i-rays are positive.

## SYMBOLS USED IN MIRRORS

$f$ = focal length; $r$ = radius of curvature; $u$ = object distance; $v$ = image distance; $M$ = Linear magnification; $h_o$ = height/size of object; $h_i$ = height/size of image.

## MIRROR FORMULAE

1. Power formula: $\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$

2. Magnification formula: $M = \frac{v}{u} = \frac{h_i}{h_o}$

### Examples

1. A object is placed 30cm away from a convex mirror of focal length 12cm. Find the position, nature and magnification of the image formed.

Solution:

| REAL-IS POSITIVE (R.P) | NEW CARTESIAN (N.C) |
|---|---|
| $u = +30$cm (real) | $u = -30$cm (left) |
| $f = -12$cm (virtual focus) | $f = +12$cm (right) |
| $v = ?$ | $v = ?$ |
| From: $\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$ | From: $\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$ |
| $\frac{1}{-12} = \frac{1}{v} + \frac{1}{+30}$ | $\frac{1}{+12} = \frac{1}{v} + \frac{1}{-30}$; $\frac{1}{v} = \frac{1}{12} + \frac{1}{30}$ |
| $\frac{1}{v} = -\frac{1}{12} - \frac{1}{30} = \frac{-5-2}{60}$ | $v = \frac{60}{7} = +8.57$cm (right) |
| $v = \frac{60}{-7} = -8.57$cm (virtual) | |

But;

Linear magnification

$$M = \frac{V}{u} = \frac{8.57cm}{30cm} = 0.29$$

∴ 0.29 times diminished virtual image formed 8.57cm behind the mirror.

2. An object is placed 20cm infront of a converging mirror of focal length 30cm. Determine the nature, position and magnification of the image.

Solution:

| REAL-IS POSITIVE (R·P) | NEW CARTESIAN (N·C) |
|---|---|
| $u = +20cm$ (real) | $u = -20cm$ (Left) |
| $f = +30cm$ (real focus) | $f = -30cm$ (left) |
| $V = ?$ | $V = ?$ |
| $\frac{1}{f} = \frac{1}{u} + \frac{1}{V}$ | $\frac{1}{f} = \frac{1}{u} + \frac{1}{V}$ |
| $\frac{1}{30} = \frac{1}{20} + \frac{1}{V}$ | $\frac{1}{-30} = \frac{1}{-20} + \frac{1}{V}$ |
| $\frac{1}{V} = \frac{1}{30} - \frac{1}{20} = \frac{2-3}{60}$ | $\frac{1}{V} = \frac{1}{20} - \frac{1}{30} = \frac{3-2}{60}$ |
| $\frac{1}{V} = \frac{-1}{60}$ | $\frac{1}{V} = \frac{1}{60}$ |
| $V = -60cm$ (Virtual) | $V = +60cm$ (Behind/right) |

Magnification; $M = \frac{V}{u} = \frac{60cm}{20cm} = 3.$

∴ 3 times magnified virtual image is formed 60cm behind the mirror.

3. A 2cm pin is erected 15cm infront of a concave Mirror of focal point 12cm from its pole. Calculate the size, nature and position of the image formed.

Solution:

| REAL-IS POSITIVE (R·P) | NEW CARTESIAN (N·C) |
|---|---|
| $u = +15\,cm$ (real) | $u = -15\,cm$ (left) |
| $f = +12cm$ (real) | $f = -12\,cm$ (left) |
| $\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$ | $\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$ |
| $\frac{1}{12} = \frac{1}{v} + \frac{1}{15}$ | $\frac{1}{-12} = \frac{1}{v} + \frac{1}{-15}$ |
| $\frac{1}{v} = \frac{1}{12} - \frac{1}{15} = \frac{5-4}{60}$ | $\frac{1}{v} = \frac{1}{15} - \frac{1}{12} = \frac{4-5}{60}$ |
| $\frac{1}{v} = \frac{1}{60}$ | $\frac{1}{v} = \frac{-1}{60}$ |
| $v = +60cm$ (real) | $v = -60\,cm$ (to the left) or infront |

Linear Magnification: $M = \frac{v}{u} = \frac{60cm}{15cm} = 4.$

To get the size of image $h_i = ?$

$$M = \frac{v}{u} = \frac{h_i}{h_o}$$

$$4 = \frac{h_i}{2cm}$$

$$h_i = 4 \times 2cm = 8cm.$$

An 8cm high real image is formed 60cm infront/left of the mirror.

4. A 0·25 times diminished virtual image is formed 10cm behind the convex mirror. What is the focal length of the mirror?

Solution:

| REAL-IS POSITIVE (R·P) | NEW CARTESIAN (N·C) |
|---|---|
| $V = -10cm$ (Virtual) | $V = +10cm$ (Behind/right) |
| Magnification: $M = 0·25$ | $M = 0·25$ |
| $M = \frac{V}{u}$ | $M = \frac{v}{u}$, $0·25 = \frac{10cm}{u}$ |
| $0·25 = \frac{10}{u}$ | $u = -40cm$ (left) or infront |
| $u = \frac{10}{0·25} = 40cm$ | $\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$ |
| $u = +40cm$ (real) | $\frac{1}{f} = \frac{1}{10} - \frac{1}{40} = \frac{4-1}{40}$ |
| NB: All objects are real | $\frac{1}{f} = \frac{3}{40}$, $f = +13·3cm$ |
| $\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$ | $f = 13·3cm$ (right) |
| $\frac{1}{f} = \frac{1}{40} + \frac{1}{-10} = \frac{1-4}{40}$ | or Behind the mirror |
| $\frac{1}{f} = \frac{-3}{40}$; $f = -13·3cm$ | |
| $f = -13·3cm$ (Virtual) | |

∴ The focal length of the mirror is 13·3cm

# Questions:

1. A four times magnified virtual image is formed 60cm behind the concave mirror. Find the focal length of the mirror. ($f = 20cm$)

2. Mirror used is convex; $u = 30cm$, $f = 18cm$; Required: nature, position and magnification of the image formed.

3. A four times magnified virtual image is formed by concave mirror of focal length 18cm. Find:
   (i) position of the object.
   (ii) position of the image.

4. An object 10cm high is placed 15cm infront of a concave mirror of focal length 18cm. Determine the size, position, nature and magnification of the image formed.

5. Show that $M = \frac{V}{f} - 1$ given that, $M = \frac{V}{u}$ and $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$

~~SCALE DRAWING~~

## USE OF SCALE DRAWING TO DETERMINE POSITION, SIZE AND NATURE OF THE IMAGE FORMED:

Examples:

1. An object 2cm long is erected 8cm infront of a concave mirror of radius of curvature 10cm. By using a scale drawing, determine the position, size and nature of the image formed.

2. An object 5cm long is placed on and perpendicular to the principal axis of a convex mirror of radius of curvature 20cm. Make a scale drawing to find the position, size and nature of the image when the object is 10cm from the pole of the mirror.

## COMMON USES FOR CURVED/SPHERICAL MIRRORS ARE IN:

(i) Salons as shaving mirrors
(ii) Torch as reflectors
(iii) Cars as a sight mirrors
(iv) Kitchen as mirror cookers/solar cooker reflector
(V) TV reflectors in projection lantern (projectors)

## USES OF CONCAVE MIRRORS

1. Shaving mirrors: The object (person's face) is placed between F and P. It gives a magnified upright image so that the tiny hairs on the face can be easily seen and shaved.

2. Dentist's Mirror: Used by the dentist while examining teeth. The teeth appear magnified and therefore easier for the dentist to examine.

3. Reflectors in a projector lamp: The lamp is placed at the centre of curvature of a concave mirror to magnify the picture onto a big screen.

4. Mirror telescopes: Rays from far away objects such as ~~stars~~ planets in space approach the mirror as parallel rays from infinity. An image is then formed on the focal plane of the mirror.

5. Solar Concentrators: Light from any source can be focused on to the focal point of a concave mirror. This concept is used to focus heat rays from the sun in the solar cookers and solar ovens.

# USES OF CONVEX MIRRORS

1. Driving mirrors: The driving mirrors of motor vehicles are convex mirrors because although they form a smaller image, the give an upright image with very wide field of view. Overtaking vehicles can be easily seen. However, drivers have to be careful and always remember that the image they see in their driving mirrors is always smaller and appears to be further away than it actually is.

2. Parking Bays and Supermarkets: Convex mirrors are useful in parking bays for drivers to be able to see around corners while driving inside narrow parking spaces.

   They are also used in large supermarkets for the workers to monitor large floor areas at a time.