1. Details of Module and its structure

Subject Name	Physics
Course Name	Physics 04 (Physics Part-2, Class XII)
Module Name/Title	Unit- 06, Module- 02: Reflection of Light from spherical surfaces Chapter- 09: Ray Optics and Optical Instruments
Module Id	leph_20902_eContent
Pre-requisites	Light, sources of light, transparent and opaque objects, ray of light, parallel beam, converging beam , diverging beam, real image , virtual image
Objectives	After going through this lesson, the learners will be able to: • Define the terms related to spherical mirrors. • Distinguish between Images formed by different type of mirrors • Describe methods to determine the focal length of a concave mirror • Find the position and size of the image formed by the mirrors for various positions of the objects placed in front of the mirror. • Calculate the position of the object in order to get the required magnification .
Keywords	Reflection, concave mirror, convex mirror, focal plane, aperture of a mirror, mirror formula, magnification

2. Development Team

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1. UNIT SYLLABUS

UNIT 6: Optics

Chapter–9: Ray Optics and Optical Instruments

Ray optics Reflection of light; spherical mirrors; mirror formula; refraction of light; total internal reflection and its applications; optical; fibers; refraction at spherical surfaces; lenses; thin lens formula; lens maker's formula; magnification, power of a lens; combination of thin lenses in contact; refraction and dispersion of light through a prism.

Scattering of light – blue color of sky and reddish appearance of the sun at sunrise and sunset

Optical instruments – microscopes and astronomical telescopes (refracting and reflecting) and their magnifying powers

Chapter 10 Wave Optics

Wave optics: wave front and Huygens's principle, reflection and refraction of plane wave at a plane surface using wave fronts. Proof of laws of reflection and refraction using Huygens's principle, Interference, Young's double slit experiment and expression for fringe width, coherent sources and sustained interference of light; diffraction due to a single slit width of central maximum; resolving power of microscope and astronomical telescope. Polarisation, plane polarised light, Malus's law, Brewster's law, uses of plane polarised light and polaroid.

2. MODULEWISE DISTRIBUTION OF UNIT SYLLABUS 15 MODULES

Module 1	• **Introduction** • **How we will study optics-plan** • **Light facts** • **Ray optics, beams** • **Light falling on surfaces of any shape texture** • **Peculiar observations**

Module 2	• **Reflection of light** • **Laws of reflection** • **Reflection of light by plane and spherical surfaces** • **Spherical Mirrors aperture, radius of curvature, pole principal axis** • **Focus, Focal length, focal plane** • **Image – real and virtual- magnification** • **Sign convention** • **The mirror equation, magnification formula** • **To find the value of image distance v for different values of object distance u and find the focal length of a concave mirror** • **Application of mirrors**
Module 3	• **Refraction of light** • **Optical density and mass density** • **Incident ray, refracted ray emergent ray** • **Angle of incidence, angle of refraction angle of emergence To study the effect on intensity of light emerging through different colored transparent sheets using an LDR** • **Refractive index** • **Oblique incidence of light, Snell's law** • **Refraction through a parallel sided slab Lateral displacement, factors affecting lateral displacement** • **To observe refraction and lateral displacement of a beam of light incident obliquely on a glass slab** • **Formation of image in a glass slab**
Module 4	• **Special effects due to refraction** • **Real and apparent depth** • **To determine the refractive index of a liquid using travelling microscope** • **Total internal reflection** • **Optical fibers and other applications**
Module 5	• **Refraction through a prism** • **Deviation of light -angle of deviation** • **Angle of minimum deviation** • **Expression relating refractive index for material of the prism and angle of minimum deviation** • **To determine the angle of minimum deviation for given prism by plotting a graph between angle of incidence and angle of deviation** • **Dispersion, spectrum**
Module 6	• **Refraction at spherical surfaces**

	• Radius of curvature • Refraction by a lens • Foci, focal plane, focal length, optical center, principal axis • Formation of images real and virtual • Lens maker's formula • Lens formula and magnification • Sign convention • Application of lens formula • Power of lens • Combination of thin lenses in contact
Module 7	• To study the nature and size of image formed by a ii) convex lens ii) concave mirror using a candle and a screen • To determine the focal length of convex lens by plotting graphs between u and v, between 1/u and 1/v • To determine the focal length of a convex mirror using a convex lens • To find the focal length of a concave lens using a convex lens • To find the refractive index of a liquid by using a convex lens and a plane mirror
Module 8	• Scattering of light – • blue color of sky • reddish appearance of the sun at sunrise and sunset • dust haze
Module 9	• optical instruments • human eye • microscope • astronomical telescopes reflecting and refracting • magnification • making your own telescope
Module 10	• wave optics • wave front • Huygens's principle shapes of wave front • plane wave front • Refraction and reflection of plane wave front using Huygens's principle • Verification of Laws of refraction and reflection of light using Huygens's principle
Module 11	• Superposition of waves • Coherent and incoherent addition of waves
Module 12	• Interference of light

	• **Young's double slit experiment** • **Expression for fringe width** • **Graphical representation of intensity of fringes** • **Effect on interference fringes in double slit experiment** • **Black and white or colored fringes**
Module 13	• **Diffraction** • **Diffraction at a single slit** • **Width of the central maxima** • **Comparison of fringes in young's experiment and those in diffraction from a single slit**
Module 14	• **Diffraction in real life** • **Seeing the single slit diffraction pattern** • **Resolving power of optical instruments** • **Validity of ray optics** • **Fresnel distance**
Module 15	• **Polarisation** • **to observe polarization of light using two polaroid** • **Plane polarised light** • **Polariser analyser Malus law** • **Brewster/s law** • **Polarisation due to scattering** • **Uses of plane polarised light and polaroids**

3. WORDS YOU MUST KNOW:

Let us remember the words and the concepts we have been using in the science course up to now:

- **Light:** Light is a form of energy which gives the sensation of vision when it falls on the retina of the eye.
- **Ray of light:** The straight line path along which light travels is called a ray of light. Light rays start from each point of a source and travel along straight line until they strike an object or a surface separating two media.
- **Beam of light:** A group of rays of light is called a beam of light.
- **Parallel beam of light**: If all the rays of light in the group are parallel to each other then the beam is said to be a parallel beam of light.
- **Converging beam of light**: If the rays of light in the group come closer to each other i.e. converge to a point, then the beam is said to be a converging beam of light.
- **Diverging beam of light**: If the rays of light in the group move away from each other i.e. diverge, then the beam is said to be a diverging beam of light.

- **Transparent medium:** A medium through which light can pass freely over large distance is called a transparent medium. Glass and still water are some examples of transparent objects.
- **Opaque medium:** A medium through which light cannot pass is called an opaque medium. Wood and metals are some examples of opaque objects.
- **Real image:** If the rays of light after reflection from a mirror actually meet at a point i. e. the reflected beam is a converging beam, then the image is said to be real image.
- **Virtual image:** If the rays of light after reflection from a mirror do not actually meet at a point but meet on producing backwards i.e. the reflected beam is a diverging beam, then the image is said to be a virtual image.

4. INTRODUCTION:

Nature has endowed the human eye (retina) with the sensitivity to detect electromagnetic waves within a small range of the electromagnetic spectrum. Electromagnetic radiation belonging to this region of the spectrum (wavelength of about 400 nm to 750 nm) is called light. It is mainly through light and the sense of vision that we know and interpret the world around us.

In order to see, we need light and normal eye. When light from an object enters our eye we see an object. But every object does not emit light then how do we see those objects?

To find answer to this we need to study, what happens to light when it strikes a surface.

5. REFLECTION OF LIGHT:

When light falls on a surface**, it partly bounces back, partly absorbed by the surface and the remaining part is transmitted through the surface.**

The phenomenon of **bouncing back of light from the surface** of a material is called **reflection of light.**

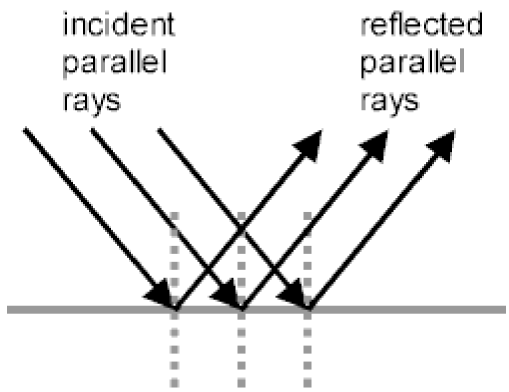
Light from a source cannot be seen by us, as it travels from a source to the surface which it illuminates. But its direction is given by rays.

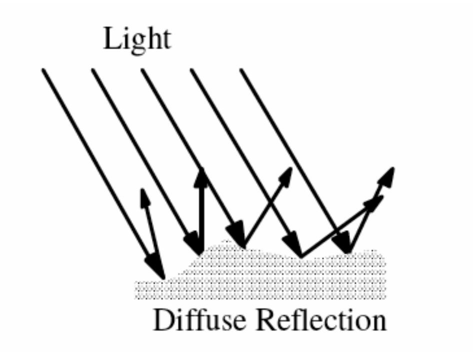
The ray of light which strikes the surface is called **incident ray**.

The ray of light which bounces back /reflected from the surface is called **reflected ray.**

Point of incidence is the point on the surface where the ray strikes the surface.

A normal at the point of incidence is the perpendicular to the tangent drawn on the surface at that point.





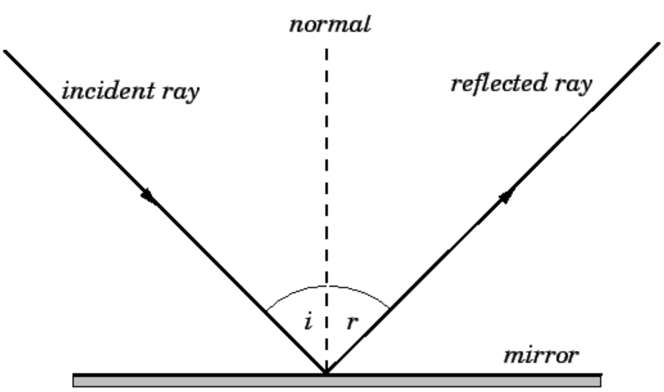
Regular and diffused reflection

http://dev.physicslab.org/img/0d2259ab-23c7-4ded-b1bd-6d30e77b95fc.gif

For a flat polished plane surface, all normal are parallel for all points on the surface while for an irregular surface these are not parallel

The angle which the incident ray makes with the normal drawn at the point of incidence is called the **angle of incidence (i).**

The angle which the reflected ray makes with the normal drawn at the point of incidence is called the **angle of reflection (r).**

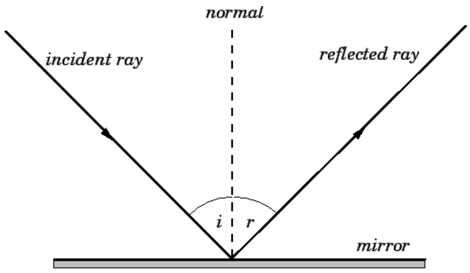


Reflection of light follows two laws.

6. LAWS OF REFLECTION OF LIGHT: -

These laws are followed in every situation of reflection. They predict the reflected ray

1) The angle of reflection *r* is equal to angle of incidence i
2) The incident ray, the reflected ray and the normal at the point of incidence, all lie in the same plane.



NOTE: - These laws of reflection of light hold true for any surface including curved surfaces.

EXAMPLE:-A ray of light strikes normally on a plane mirror, what will be the angle of reflection?

SOLUTION: - As angle of incidence is zero, so the angle of reflection will also be zero, i. e. the ray of light will retrace its path.

EXAMPLE: - A ray of light strikes on a plane mirror, if the angle of incidence is i, what will be the angle by which this ray of light will be deviated?

SOLUTION: - It will be deviated by (180-2i) degree.

7. REFLECTION FROM PLANE AND SPHERICAL SURFACES

We are familiar with the laws of reflection.

The angle of reflection (i.e., the angle between reflected ray and the normal to the reflecting surface or the mirror) equals the angle of incidence (angle between incident ray and the normal).

Also that the incident ray, reflected ray and the normal to the reflecting surface at the point of incidence lie in the same plane.

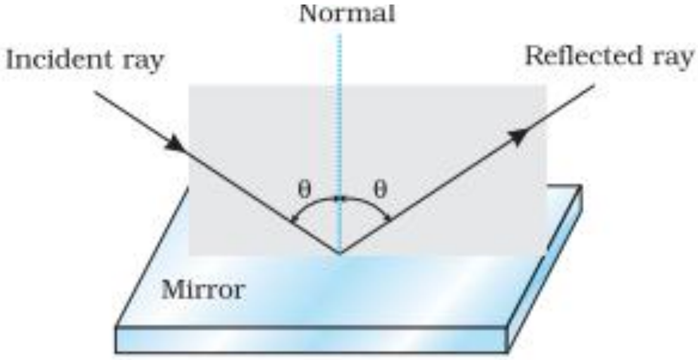
These laws are valid at each point on any reflecting surface whether plane or curved.

However, we shall restrict our discussion to the special case of curved surfaces, that is, spherical surfaces.

The normal in this case is to be taken as normal to the tangent to surface at the point of incidence. That is, the normal is along the radius, the line joining the center of curvature of the mirror to the point of incidence.

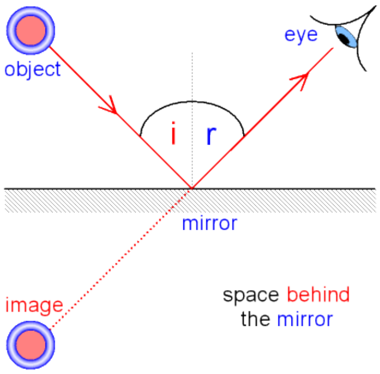
Reflection from a plane mirror: -

Commonly used looking mirrors are plane mirrors. These plane mirrors are pieces of glass with a silver coating on their back.

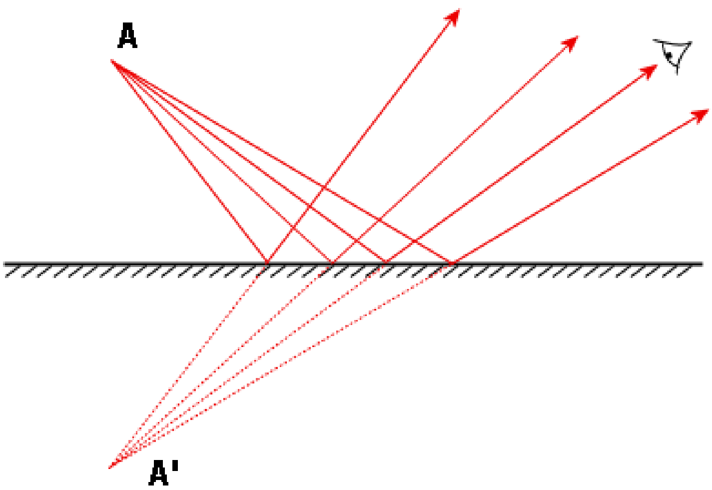


Check the plane containing the incident ray normal and the reflected ray

Properties of image formed by plane mirror: -



http://www.gcsescience.com/virtual-image-mirror.gif



1) A plane mirror forms a **virtual image** as it is not formed by the **actual intersection of reflected rays,** so it cannot be taken on a screen.
2) The image formed by a plane mirror is **erect.**
3) **The size of the image is the same as the object.**
4) The image is formed **as far behind the mirror as the object is placed in front of it. (the reason for lateral inversion)**
5) The image formed is **laterally inverted**,

Reflection from spherical mirror: -

If we take a large glass hollow sphere whose inner surface is very smooth and we silver its outer surface and cut a small portion of it. It will reflect light following laws of reflection of light. We will study the characteristics of the image formed by these mirrors.

Similarly if we take a large glass hollow sphere whose surface is very smooth and we silver its inner surface and cut a small portion of it. It will also reflect light following laws of reflection of light. We will see that the characteristics of the image formed by these mirrors will be different from those formed by the previous type of mirrors.

The mirrors so formed are called **spherical mirrors.**

Thus spherical mirror is a part of a hollow glass sphere whose one of the two surfaces is polished.

If we choose to make a mirror from a sphere, we can have Spherical mirrors of two types.

i) **Concave mirror**
ii) **Convex mirror**.

Concave mirror: - It is a part of a hollow glass sphere whose inner surface is polished.

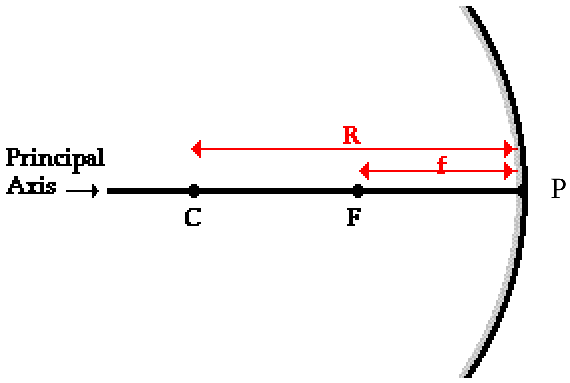
The reflecting surface of concave mirror is on the hollow side

Convex mirror: It is a part of a hollow glass sphere whose outer surface is polished.

The reflecting surface of convex mirror is on the outer side of the sphere.

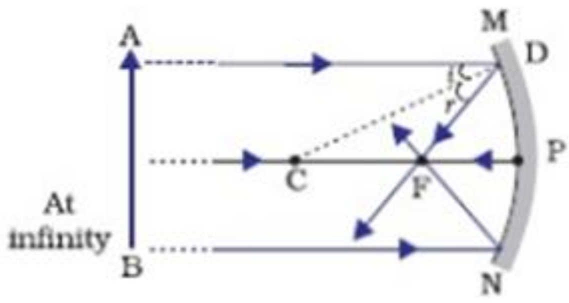
8. Terms related to spherical mirrors:

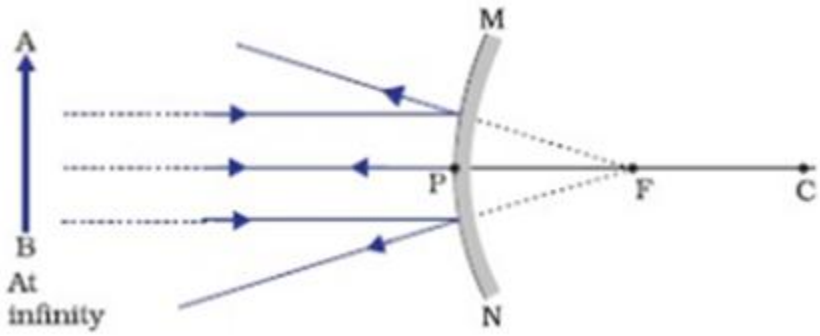
- **Pole: -** The geometrical center of the surface of the mirror is called its pole. It is marked as point (p) in the diagram.
- **Centre of curvature: -** It is the center of the hollow sphere of which the mirror is a part. It is marked as point (C) in the diagram.
- **Radius of curvature: -** It is the radius of the sphere of which the mirror is a part.
- **Principal axis: -** The line joining the pole and the center of curvature of the



mirror is called its principal axis.

- **Aperture of a mirror:-** The diameter of the circular cross section of the sphere, used to form the spherical mirror is called its aperture
- **Focus point and focal length: -** Consider a parallel beam of light parallel to the principal axis; to be is incident on a concave or a convex mirror. Let us consider only a paraxial beam i.e. a beam of incident light that is confined close to the pole of the mirror. The reflected rays are then observed to converge to a point on the principal axis in case of a concave mirror; they appear to diverge from a point on the principal axis in case of a convex mirror. This is shown in the figures below. This point of convergence or apparent convergence is called the focus point (F).



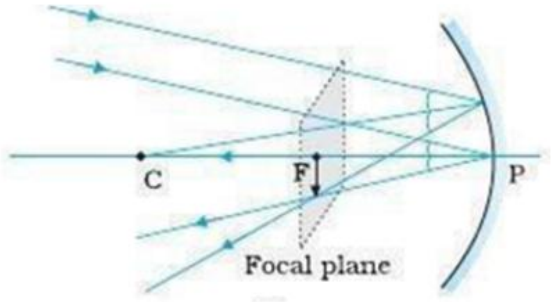


Thus t**he point, on the principal axis, where rays of light parallel to the principal axis and confined close to its pole, converge to, or appear to diverge from, after reflection is called the focus point of the mirror.**
The distance between the focus point and the pole of a spherical mirror, is known as the focal length of that mirror.

https://youtu.be/FaK3oS1QuaU?t=157

If the parallel paraxial beam was incident, at some angle with the principal axis, the reflected rays converge, or appear to diverge, from a point in a plane passing through focus point and normal to the principal axis.

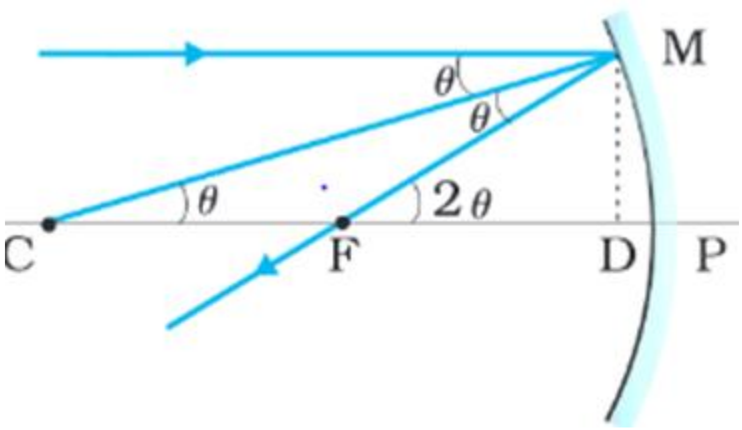
The vertical plane passing through the focus point and perpendicular to the principal axis is called the focal plane of the given spherical mirror.



RELATION BETWEEN RADIUS OF CURVATURE AND FOCAL LENGTH:-

Let C be the centre of curvature of the mirror. Consider a ray of light parallel to the principal axis striking the mirror at M. CM is normal to the mirror at the point M. Let ϴ be the angle of incidence. Let MD be drawn perpendicular from M on to the principal axis.

In the diagram, we have



$$\angle MCP = \theta \ \ and \ \angle MFP = 2\theta$$

$$tan\theta = \frac{MD}{CD} \quad and \quad tan2\theta = \frac{MD}{FD}$$

For small angles, tan θ is nearly equal to the ∠ θ itself,

(Provided angle is measured in radians)

$$\theta = \frac{MD}{CD} \quad and \quad 2\theta = \frac{MD}{FD}$$

$$\frac{MD}{FD} \ = 2\frac{MD}{CD}$$

Or DF = DC/2

For small angle θ, the point D is very close to the point P and we can take

DF = PF and DC = PC

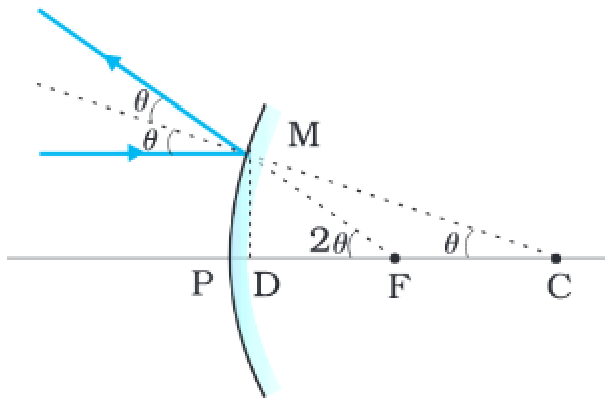
Thus, PF= PC/2

Or f = R/2

Or focal length is equal to half the radius of curvature

This relation is true for convex mirrors also; this can be proved in the same way using the ray diagram given below.

For convex mirror



PF= F and PC = R

Let C be the centre of curvature of the given convex mirror. Consider a ray of light parallel to principal axis striking the mirror at M. CM is normal to the mirror at the point M. Let ϴ be the angle of incidence. Let MD be the perpendicular dropped from M onto the principal axis.

We have:

$$\angle MCP = \theta \ \ and\ \angle MFP = 2\theta$$

$$tan\theta = \frac{MD}{CD} \quad and \quad tan2\theta = \frac{MD}{FD}$$

For small angles, tan ϴ is nearly equal to angle θ

$$\theta = \frac{MD}{CD} \quad and \quad 2\theta = \frac{MD}{FD}$$

$$\frac{MD}{FD} \ = 2\frac{MD}{CD}$$

Or DF = DC/2

For small values of angle ϴ, the point D is very close to the point P

Thus PF= PC/2

Or f = R/2

EXAMPLE:

The surface of a concave mirror is *pointed* towards the sun. Light from the sun hits the mirror and converges to a point. How far is this *converging point* from the mirror's pole if the radius of curvature (R) of the mirror is 150 cm?

SOLUTION:-

The distance, of the point of convergence (of the incident parallel beam), from the pole of the mirror equals to the focal length of the mirror.

Now f = R / 2

f = 150/2 cm = 75 cm

EXAMPLE -

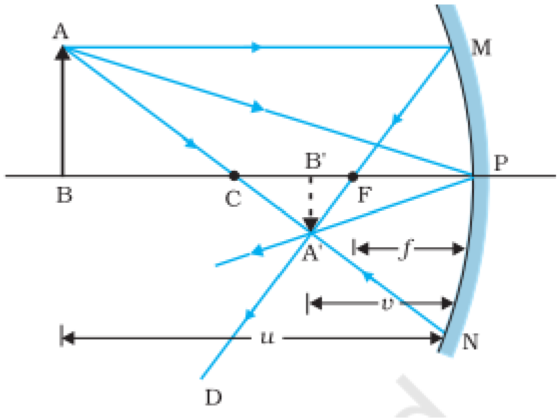
How would you find the rough focal point of a concave mirror?

SOLUTION:

1. Hold the concave mirror in a stand and let it face the sun. (**Very important precaution:- make sure that you don't look towards the sun directly or through mirror, also do not let the light, reflected from the mirror, come towards your eyes.).**
2. Direct the light reflected by the mirror to fall on a screen or white paper.
3. Adjust the distance between the screen/paper and the mirror so that a well-defined and clear bright spot is formed on the paper.
4. As the beam of light coming from the sun, is a parallel beam, it will focus at the focus point of the mirror.
5. Measure the distance between the mirror and the paper. This distance is an approximate measure of the focal length of the mirror.

REAL IMAGE AND VIRTUAL IMAGE: -

Real image: - If the **rays of light, after reflection actually intersect i.e. meet, then the image formed is called a real image**. It can be obtained on the screen and a real image when formed is always inverted with respect to the object.
For example, the image formed by a concave mirror when the object is placed at infinity, is a real image.



Virtual image: - If the rays of light, **after reflection, don't actually intersect but appear to diverge from a point,** then the image formed is called a virtual image. Virtual image cannot be obtained on the screen; virtual image when formed is always erect with respect to the object,
For example, the image formed by a convex mirror when the object is very far away i.e. at infinity, is a virtual image.

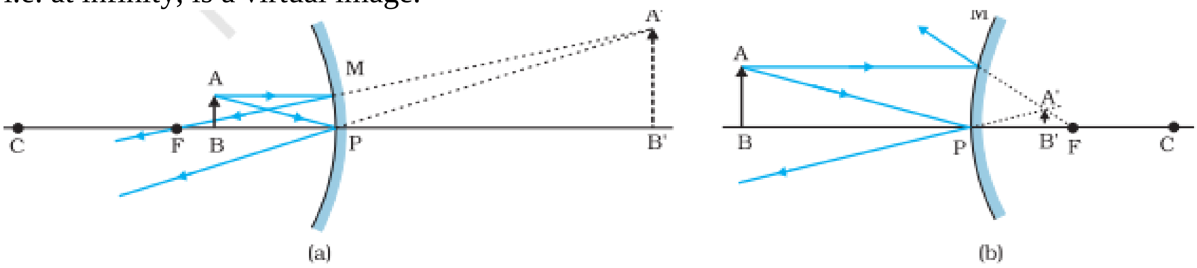


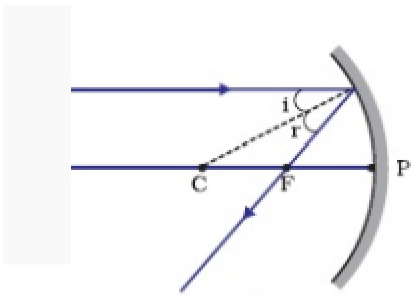
Image formation by (a) a concave mirror with object between P and F, and (b) a convex mirror.

A Plane mirror by itself always forms virtual image of any object placed in front of it.

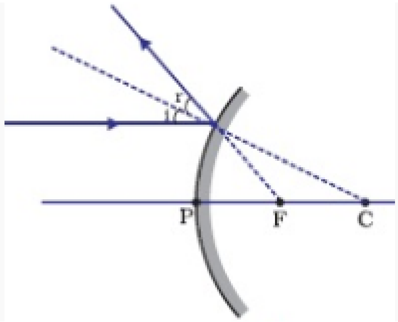
Formation of Image by Concave Mirror: -

Guidelines for tracing the path of rays falling on a Concave and Convex Mirror

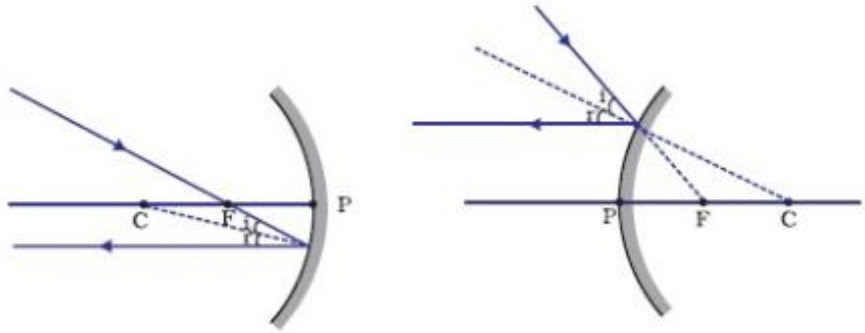
1. When a ray, parallel to principle axis strikes a concave mirror, the reflected ray passes through its focus on the principle axis.



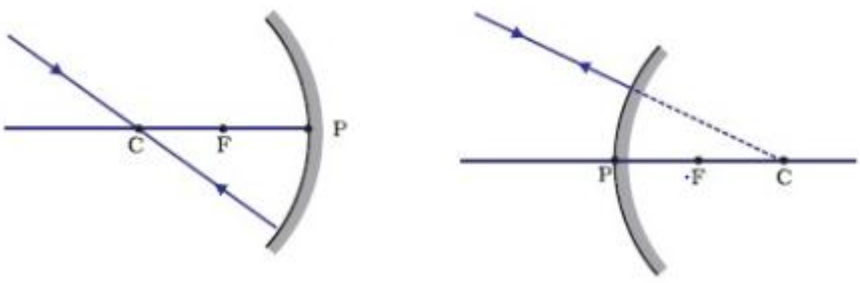
2. When a ray, parallel to principle axis strikes a convex mirror, the reflected ray appears to come from its focus point on the principle axis.



3. When a ray, passing through or appearing to pass through focus, strikes a concave or a convex mirror, the reflected ray will become parallel to the principle axis.



4. A ray, passing through or appearing to pass through the center of curvature of the spherical mirror, retraces its path after reflection.



5. A ray of light, incident obliquely towards the pole of the mirror is reflected obliquely following the laws of reflection of light.

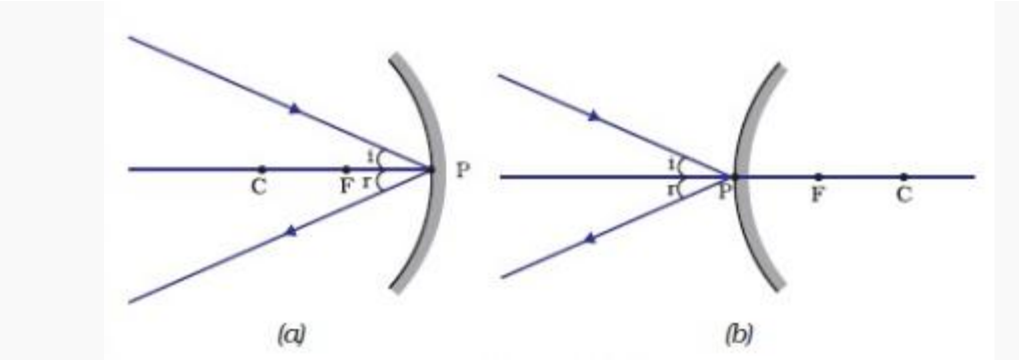
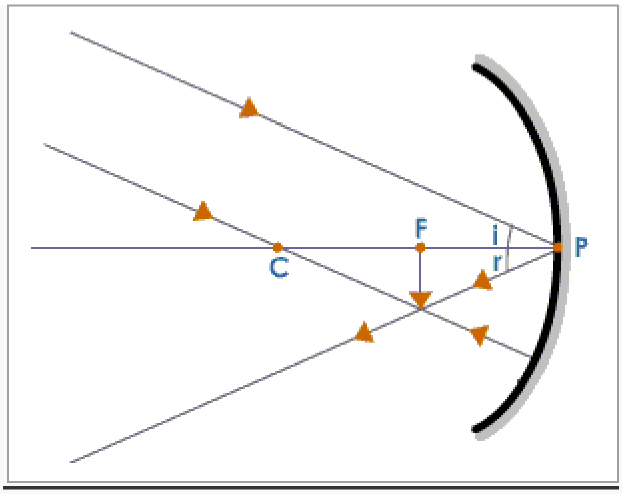
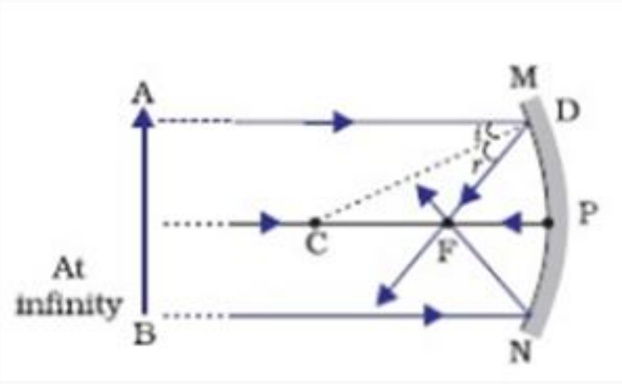


Image Formation by A Concave Mirror:-

Case 1:- When the object is placed at infinity



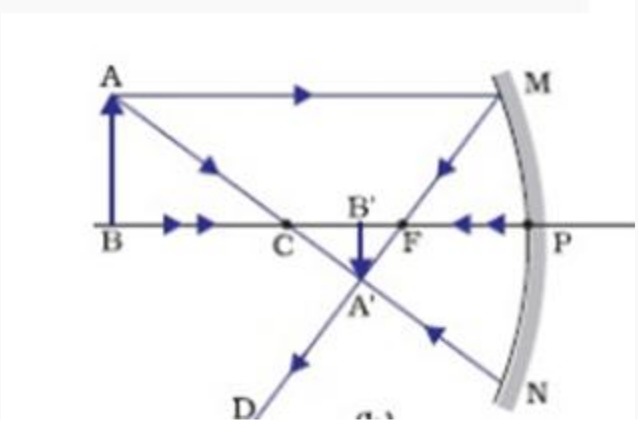


Position of the image: At focus

Nature of the image: real and inverted

Size of the image: highly diminished

Case 2: When the object is place beyond the centre of curvature

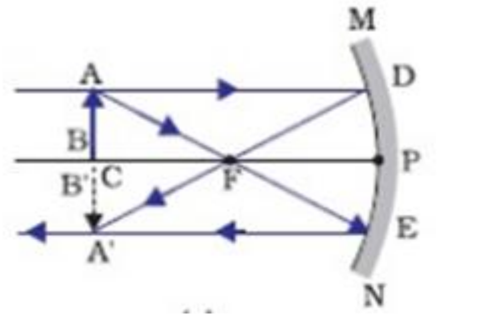


Position of the image: Between focus point and centre of curvature

Nature of the image: real and inverted

Size of the image: diminished

Case 3:- When the object is placed at the centre of curvature

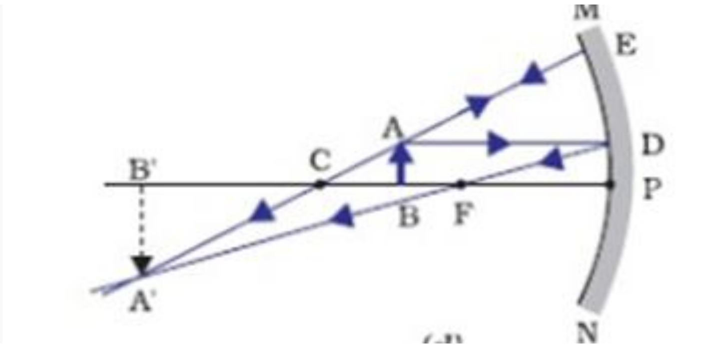


Position of the image: at centre of curvature

Nature of the image: real and inverted

Size of the image: same size as the object

Case 4:- When the object is placed between the focus point and the centre of curvature:

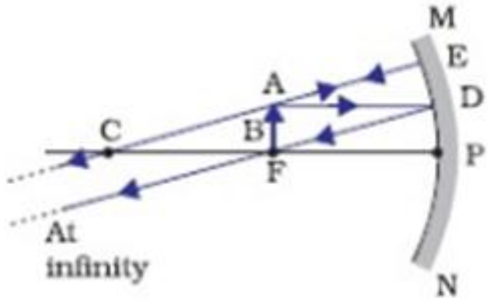


Position of the image: beyond centre of curvature

Nature of the image: real and inverted

Size of the image: enlarged

Case 5:- object is placed at focus point:

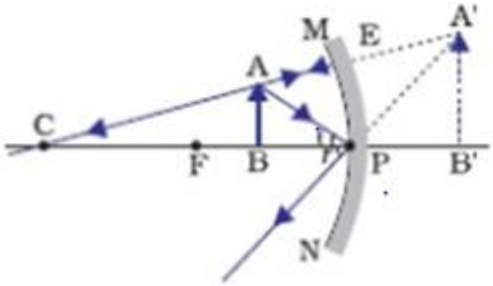


Position of the image: at infinity

Nature of the image: real and inverted

Size of the image: highly enlarged

Case 6:- When object is placed between the focus point and the pole of the mirror:



Position of the image: behind the mirror

Nature of the image: virtual and erect

Size of the image: enlarged

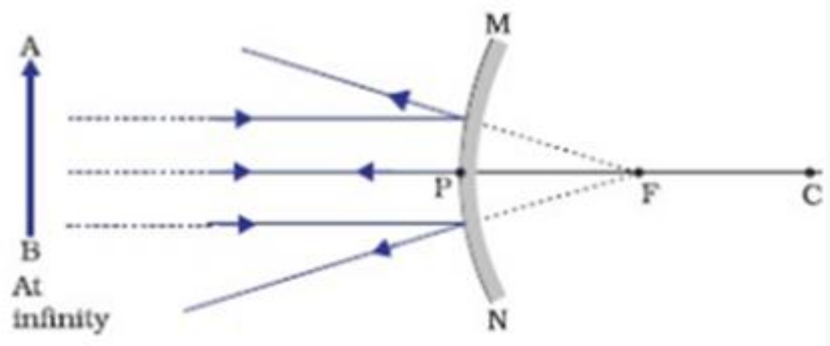
These results have been summarised in the table below:

Position of the object	Position of the image	Nature and size of the image
At infinity	At focus	Real, inverted and highly diminished
Beyond centre of curvature	Between focus and centre of curvature	Real, inverted and diminished
At centre of curvature	At centre of curvature	Real, inverted and of the same size as the object
Between focus and centre of curvature	Beyond centre of curvature	Real, inverted and enlarged
At focus	At infinity	Real, inverted and highly

		enlarged
Between pole and focus	Behind the mirror	Virtual, erect and enlarged

Image formation by a convex mirror:-

Case 1:- When the object is placed at infinity

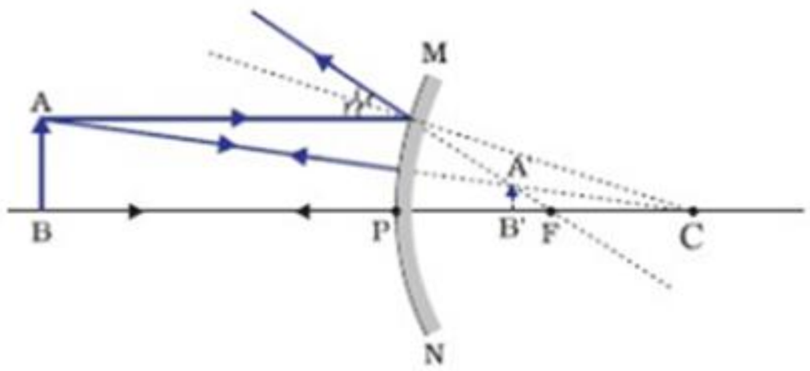


Position of image: at focus point

Nature of image: virtual and erect

Size of image: highly diminished

Case 2:- when object is placed between infinity and pole



Position of image: between focus and pole

Nature of image: virtual and erect

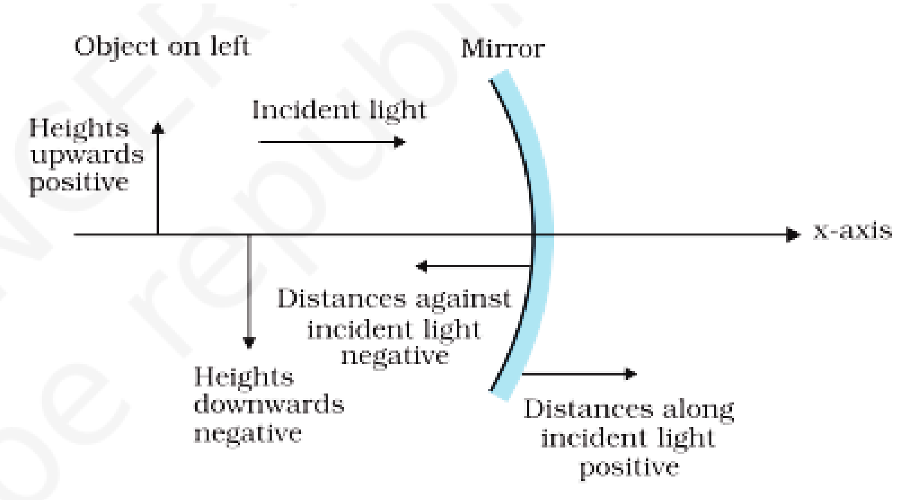
Size of image: diminished

These results have been summarised in the table below:

Position of the object	Position of the image	Size of the image	Nature of the image
At infinity	At the focus F, behind the mirror	Highly diminished, point-sized	Virtual and erect
Between infinity and the pole P of the mirror	Between P and F, behind the mirror	Diminished	Virtual and erect

9. SIGN CONVENTIONS: -

1. All distances are measured from the pole of the mirror.
2. Distances measured in the direction of incident rays are taken to be positive.
3. Distances measured in the direction opposite to the incident rays are taken to be negative.
4. All distances measured upwards with respect to the principle axis, are taken to be positive.
5. All distances measured downwards with respect to the axis are taken to be negative.



The Cartesian Sign Convention-

With a common accepted convention, it turns out that a single formula for spherical mirrors and a single formula for spherical lenses can handle all different cases.

EXAMPLE:

If one half of the reflecting surface of a concave mirror is covered with black paper, how would the image of an object, placed in front of the mirror be affected?

SOLUTION:

Now light will be reflected only from only half of the surface of the mirror, hence the brightness of the image formed will be reduced to half its earlier value. However complete image will still be formed and there would be no change in position or nature of the image formed.

(We have to remember that we would be now effectively having a mirror of half of the aperture of the earlier mirror.)

EXAMPLE

How is the focal length of a concave mirror affected if it is placed in water?

SOLUTION:

The focal length of the concave mirror will not change as the incident and the reflected light would still be propagating in the same medium

EXAMPLE

Why is a concave mirror preferable to a plane mirror for shaving?

SOLUTION:

A concave mirror forms an erect and enlarged image when the object is placed between the pole and the focus point of the mirror. A plane mirror, however, forms an image of the same size as the object; hence a concave mirror can provide a better view during shaving.

EXAMPLE

Why a convex mirror is used as a rear view mirror in vehicles?

SOLUTION:

The convex mirror is used as a rear view mirror because it gives a wider field of view of the traffic behind the vehicle. This is because it forms virtual, erect and diminished image of an object, irrespective of the distance of the object.

10. MIRROR FORMULA:-

The relation between object distance (u) the image distance (v), and the focal length (f) of the mirror is called mirror formula.

Let us try to obtain this formula.

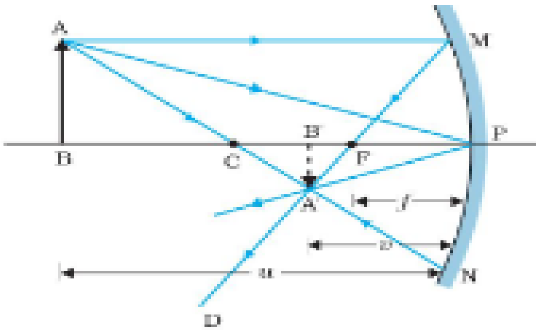
i) **Concave mirror**

When image is real

Let us consider an object AB placed beyond center of curvature of the mirror. (Using the same method we can derive the formula for any other position of the object)

As shown in the ray diagram, a real, inverted and diminished image A'B' is formed between F and C of the mirror.

For a small aperture mirror point M will be Close to point M, thus MP will be a straight line. Two right angled triangles A'B'F and MPF are similar triangles.



Therefore

$$\frac{A'B'}{PM} = \frac{B'F}{FP}$$

As PM =AB

So $$\frac{A'B'}{AB} = \frac{B'F}{FP}$$

Triangle A'B'P and triangle ABP are also similar triangles

$$\frac{A'B'}{AB} = \frac{B'P}{BP}$$

Comparing equations $\frac{A'B'}{AB} = \frac{B'F}{FP}$ and, $\frac{A'B'}{AB} = \frac{B'P}{BP}$

We get

$$\frac{B'F}{FP} = \frac{B'P}{BP}$$

As all distances are to be measured from pole, so

B'F = PB' – PF

Hence we write

$$\frac{(PB' - PF)}{PF} = \frac{PB'}{PB}$$

Using sign conventions, we can write

PF= - f,   PB = - u,   PB' = - v

Hence we get

$$\frac{(-\mathbf{v}+\mathbf{f})}{-\mathbf{f}} = \frac{-\mathbf{v}}{-\mathbf{u}}$$

Or

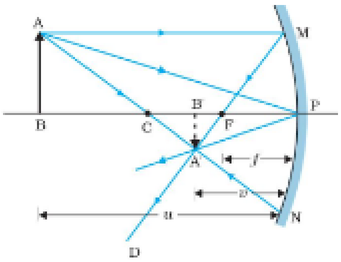
$$\frac{v}{f} - \frac{f}{f} = \frac{v}{u}$$

Solving this we get

$$\frac{\mathbf{1}}{\mathbf{v}} + \frac{\mathbf{1}}{\mathbf{u}} = \frac{\mathbf{1}}{\mathbf{f}}$$

Magnification (m):-

Magnification is the ratio of size of the image to the size of the object i.e.



M = $\frac{h'}{h}$ where h' is height of the image and h is height of the object.

From the ray diagram, we get from similar triangles A'B'P and triangle ABP

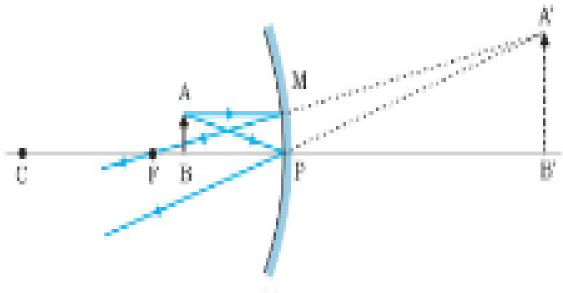
$$\frac{A'B'}{AB} = \frac{PB'}{PB}$$

Using sign convention

$$\frac{-h'}{h} = -\frac{-v}{-u}$$

NOTE: **Magnification 'm' is negative if the image is real but positive when the image is virtual.**

i. **When image is virtual:-**

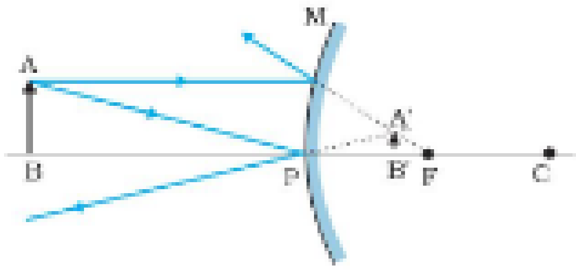


Mirror formula can also be derived using this diagram. The steps to be followed are exactly same as given above. In fact, the same derivation can be used for this also.

ii. For convex mirror:-

The following ray diagram can be used for it. The derivation will remain same.

Also using the sign convention, the formula, connecting u, v, and f, is again the same.



11. To find the values of image distance (v) for various values of (u) and to find the focal length (f) of a concave mirror-

EXAMPLE

An object, 4cm high is placed at a distance of 100 cm from a concave mirror of radius of curvature 40cm. Find the nature, position and the size of the image.

SOLUTION:-

Concave mirror

We have, here, as per sign convention

f = - 40/2 cm = -20cm

u = - 100 cm

v = ?

Object size, O = 4 cm

Image size, I = ?

Using $\frac{1}{f} = \left(\frac{1}{u}\right) + \left(\frac{1}{v}\right)$,

We get

$$\left(\frac{1}{-20}\right) = \left(\frac{1}{-100}\right) + \frac{1}{v}$$

$$\left(\frac{1}{v}\right) = \left(\frac{1}{100}\right) - \left(\frac{1}{20}\right)$$

$$= -\left(\frac{4}{100}\right) = -\left(\frac{1}{25}\right)$$

V = - 25 cm

As v is negative so the image formed is a real and inverted image.

Also $m = \frac{I}{O} = -\left(\frac{v}{u}\right)$

$$\left(\frac{I}{4}\right) = -\left(-\frac{25}{-100}\right)$$

$$I = -\frac{4}{4}cm = -1cm$$

As I is negative so the image is formed below the principal axis, thus the image is inverted

EXAMPLE

Find the positions of the object, placed in front of a concave mirror of focal length 10 cm, in order to get an image three times in height as compared to the height of the object.

SOLUTION:-

In case of concave mirror, magnified image could be real or virtual.

Case 1: Real image

Here m = -3 f = -10 cm

use $m = -\left(\frac{v}{u}\right)$

$$-3 = -\left(\frac{v}{u}\right)$$

$$v = 3u$$

$$\frac{1}{f} = \left(\frac{1}{u}\right) + \left(\frac{1}{v}\right)$$

$$\left(\frac{1}{-10}\right) = \frac{1}{u} + \frac{1}{3u}$$

$$= \frac{4}{3u}$$

$$u = -\frac{40}{3cm} = -13.3cm$$

Case 2: virtual image

m = + 3, f = -10 cm

$$3 = -\left(\frac{v}{u}\right)$$

$$v = -3u$$

$$\frac{1}{f} = \left(\frac{1}{u}\right) + \left(\frac{1}{v}\right)$$

$$\left(\frac{1}{-10}\right) = \frac{1}{u} + \left(-\frac{1}{3u}\right)$$

$$= \frac{2}{3u}$$

$$u = -\frac{20}{3}cm = -6.67cm$$

EXAMPLE

A 4.5 cm needle is placed 12 cm away from a convex mirror of focal length 15 cm. Find the location and magnification of the image. Describe what happens as the needle is moved farther from the mirror.

SOLUTION:

Given O = 4.5 cm u = - 12 cm f = 15 cm

Using $\frac{1}{f} = \left(\frac{1}{u}\right) + \left(\frac{1}{v}\right)$

$$\frac{1}{15} = \left(\frac{1}{-12}\right) + \frac{1}{v}$$

$$\frac{1}{v} = \frac{1}{15} + \frac{1}{12} = \frac{9}{60}$$

$$= \frac{3}{20}$$

$$V = \frac{20}{3} cm$$

Also $$m = -\left(\frac{v}{u}\right)$$

$$= -\frac{\frac{20}{3}}{-12} = \frac{5}{9}$$

As the needle is moved farther away from the mirror, object distance, u will increase, the image will move closer to the focus point; it will never be formed beyond the focus point.

12. Uses of concave and convex mirrors-

Uses of concave mirrors:-

a) They are commonly used in torches, search light and vehicles headlights to get powerful parallel beam of light. The source of light is placed at the focus point of the mirror.
b) They can be used as shaving mirrors to see a larger image of the face. This is because a concave mirror forms a virtual , enlarged and erect image when the object is placed close to it i.e. between its pole and its focus point and .
c) The dentist use concave mirrors to see large images of the teeth of the patients.
d) Large concave mirrors are also used to concentrate sunlight to produce heat is solar cookers

Uses of convex mirrors:-

a) Convex mirrors are used in vehicles as rear view mirror. This is because it produces an erect and diminished image of the object, always located between the pole and the focus point of the mirror. Therefore a wider view of the traffic behind can be seen in a small mirror.
b) They are also used in big departmental stores as anti-theft mirror because they give wide field of view.
c) At right angled road turns

13. SUMMARY:

- The phenomenon of bouncing back of light from a surface separating two media is called **reflection of light.**
- The angle of incidence *i* is equal to the angle of reflection *r*.
- The incident ray, the reflected ray and the normal at the point of incidence, all lie in the same plane.

- These laws of reflection hold true for all type of surfaces; whether plane or curved.
- Spherical mirrors are of two types. 1) concave and 2) convex
- Concave mirror: It is a part of a hollow glass sphere whose outer surface is polished. The reflecting surface of concave mirror is on the inner hollow side
- Convex mirror: - It is a part of a hollow glass sphere whose inner surface is polished. The reflecting surface of concave mirror is on the outer side of the sphere.
- Pole: - The geometrical center of the surface of the mirror is called its pole.
- Centre of curvature: - It is the center of the hollow sphere of which the mirror is a part.
- Radius of curvature: - It is the radius of the hollow sphere of which the mirror is a part.
- Principal axis: - The line joining the pole and the center of curvature of the mirror is called the principal axis.
- Aperture of a mirror: - The diameter of the circular cross section of the sphere, used to form the given spherical mirror is called its aperture.
- Focus point: - It's a point on the principal axis at which a paraxial parallel beam of light, parallel to the principal axis, either actually meet, or appear to come from after reflection from the mirror.
- Radius of curvature = 2 focal length
- A concave mirror forms a real and inverted image for all positions of the object beyond its focus point. The image formed is virtual, erect and enlarged when object is placed between its pole and its focus point.
- The image, formed by a convex mirror is always virtual, erect and diminished. It is always formed between the pole and the focus point of the mirror.
- Mirror formula : $\frac{1}{f} = \left(\frac{1}{u}\right) + \left(\frac{1}{v}\right)$
- Magnification m= size of the image/ size of the object = $\frac{I}{O}$
- $m = \frac{I}{O} = -\left(\frac{v}{u}\right)$
- For real image 'm' is negative and for virtual image 'm' is positive