

## Class 10 Science

### Light Reflection and Refraction

#### REFLECTION

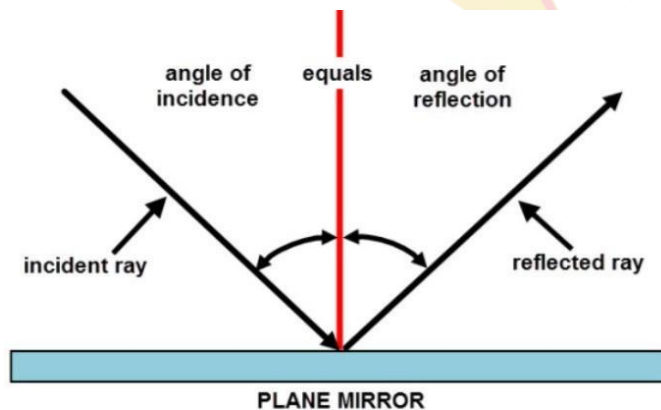
**Reflection of Light:** The phenomenon of bouncing back of light into the same medium by the smooth surface is called reflection.

**Incident light:** Light which falls on the surface is called incident light.

**Reflected light:** Light which goes back after reflection is called reflected light.

**The angle of incidence:** The angle between the incident ray and the normal.

**An angle of reflection:** The angle between the reflected ray and the normal.



**Laws of reflection:** There are two laws of reflection

- (i) The incident ray, the reflected ray and the normal at the point of incidence, all lie in the same plane.
- (ii) Angle of incidence is always equal to the angle of reflection i.e.  $\angle i = \angle r$

**Image:** If light rays coming from a point after reflection meet at another point or appear to meet at another point, then second point is called image of the first point. There are two types of image, i.e.

**Real image:** When the rays of light, after reflection from a mirror, actually meet at a point, then the image formed by these rays is said to be real. Real images can be obtained on a screen.

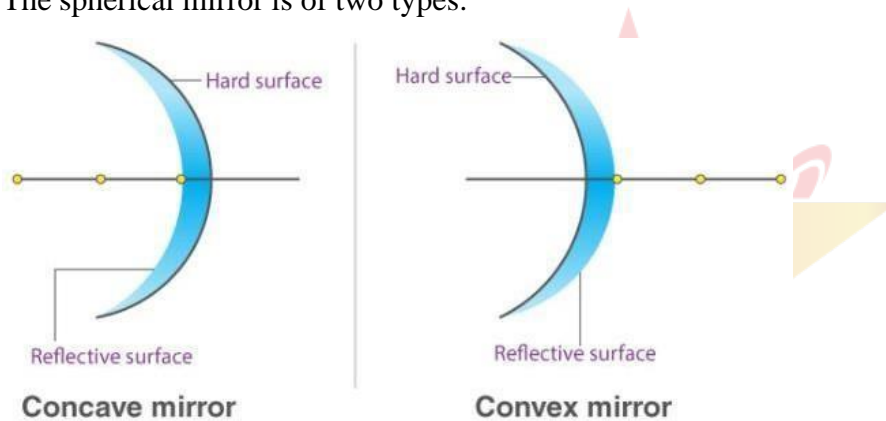
**Virtual image:** When the rays of light, after reflection from a mirror, appear to meet at a point, then the image formed by these rays is said to be virtual. Virtual images can't be obtained on a screen.

**Mirror:** The surface which can reflect the light is a mirror.

**Plane Mirror:** If the reflecting surface is a plane then the mirror is plane.

**Spherical Mirror:** If the reflecting surface is part of the hollow sphere then the mirror is a spherical mirror.

The spherical mirror is of two types:



**Convex mirror:** In this mirror reflecting surface is convex. It diverges the light so it is also called a diverging mirror.

**Concave mirror:** In this mirror reflecting surface is concave. It converges the light so it is also called converging mirror.

**Some definitions related to Spherical Mirror:**

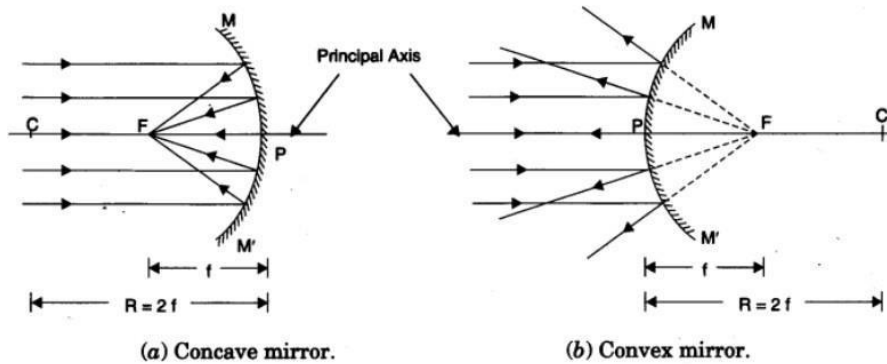
**Pole (Vertex):** The central point of a mirror is called its pole.

**Centre of curvature:** The centre of the sphere of which the mirror is a part is called the centre of curvature. It is denoted by C.

**Radius of curvature:** The radius of the sphere of which the mirror is a part is called the radius of curvature. It is denoted by R.

**Principal axis:** The straight line passing through the pole and the centre of curvature of the mirror is called the principal axis.

**Principal focus:** It is a point on the principal axis at which the rays parallel to the principal axis meet after reflection or seem to come from. For a concave mirror, the focus lies in front of the mirror and for a convex mirror, it lies behind the mirror. In short, a concave mirror has a real focus while a convex mirror has a virtual focus.



**Focal plane:** A plane, drawn perpendicular to the principal axis and passing through the principal focus.

**Focal length:** The distance between the pole and the focus is called the focal length. It is represented by  $f$ . The focal length is half the radius of curvature.

$$F = R/2$$

### Reflection by Spherical mirror:

A ray of light which is parallel to the principal axis of a spherical mirror, after reflection converges or diverges from focus.

A ray of light passing through or appearing from the center of curvature of spherical mirror is reflected back along the same path.

A ray of light passing through or appearing from the focus of spherical mirror becomes parallel to the principal axis.

A ray of light which is incident at the pole of a spherical mirror is reflected back making same angle with principal axis.

## Image formation by Concave mirror

S.No.	Position of object	Position of image	Nature of image	Uses
1.	Between the pole and the principal focus	Behind the mirror	Virtual, erect and magnified	Shaving mirror, dentist mirror
2.	At the principal focus	At infinity	Extremely magnified	In torches, head lights
3.	Between focus and the centre of curvature	Beyond centre of curvature	Real, inverted and bigger than object.	In flood lights
4.	At the centre of curvature	At the centre of curvature	Real, inverted and equal to the size of the object	Reflecting mirror for projector lamps
5.	Beyond the centre of curvature	Between the principal focus and centre of curvature	Real, inverted and diminished	
6.	At infinity	At the principal focus or in the focal plane	Real, inverted and extremely diminished in size	To collect heat radiations in solar devices

## Image formation by Convex mirror

S.No.	Position of object	Position of image	Nature of image	Uses
1.	At infinity	Appears at the principal focus	Virtual, erect and extremely diminished	Used as a rear view mirror
2.	Between infinity and the pole	Appears between the principal focus and the pole	Virtual, erect and diminished	Used as a rear view mirror

## Sign Conventions of Spherical Mirror

- All the distances are measured from the pole of the mirror as the origin.
- Distances measured in the direction of incident rays are taken as positive.
- Distances measured opposite to the direction of incident rays are taken as negative.
- Distances measured upward and perpendicular to the principal axis are taken as positive.
- Distances measured downward and perpendicular to the principal axis are taken as negative.

### **Mirror formula: $1/f=1/v+1/u$**

Where f, v and u are focal length, image distance, and object distance

### **Magnification by Spherical Mirror:**

This is the ratio of the height of the image to the height of the object. Magnification,

$$m=h_i/h_o$$

Where m = magnification,  $h_i$  = height of image,  $h_o$  = height of object

## **REFRACTION**

**Refraction of Light:** The bending of light at the interface of two different mediums is called Refraction of light.

If the velocity of light in medium is more, then medium is called optical rarer.

Example, air or vacuum is more optical rarer.

If the velocity of light in medium is less, then medium is called optical denser.

Example, glass is denser than air.

### **Laws of refraction:**

The incident ray, the refracted ray and the normal at the point of incidence all lie in the same plane.

The ratio of the sine of the angle of incidence to the sine of the angle of refraction is a constant.

$$\sin i/\sin r = n \text{ (constant)}$$

This constant is called the index of refraction or refractive index.

**Refractive Index:** If c is the speed of light in air and v is the speed of light in medium, then the refractive index of the medium is

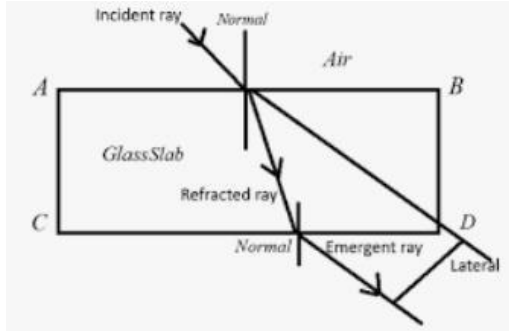
$$n = \frac{\text{speed of light in vacuum}}{\text{speed of light in the medium}} = \frac{c}{v}$$

Refractive index of medium with respect to air or vacuum is called Absolute Refractive Index.



## Refraction through a Rectangular Glass Slab:

When light ray enters into a glass slab, then the emergent ray is parallel to the incident ray. This perpendicular distance between the emergent ray and incident ray when the light passes out of a glass slab is called **lateral displacement**.



$i$  = angle of incidence,  $r$  = angle of refraction and  $e$  = angle of emergence

Angle of incidence = Angle of emergence, i.e.  $\angle i = \angle e$

**Lens:** The transparent refracting medium bounded by two surfaces in which at least one surface is curved is called lens. Lenses are mainly two types: Convex lens and Concave lens.



## Difference between Convex and Concave Lenses

Convex Lens	Concave Lens
On passing the light through the lens, it bends the light rays towards each other (i.e., it converges the rays). So due to this, it is called a converging lens.	On passing the light through the lens, it bends the light rays away from each other (i.e., it diverges the rays). So due to this, it is called a diverging lens.
A convex lens is thicker at the centre and thinner at the edges.	A concave lens is thicker at the edges and thinner at the centre.

Due to the converging rays, it is called a converging lens.	Due to the diverging rays, it is called a diverging lens.
Use for correction of long-sightedness.	Use for correction of short-sightedness.
It is also called a positive lens due to positive focal length nature.	It is also called a negative lens due to negative focal length nature.
e.g. Human Eye, Camera, etc.	e.g. Lights, Flashlights, etc.

**Center of Curvature:** The centers of two spheres, of which lens is part is called the centre of curvature.

**Radii of Curvature:** The radii of spheres, of which lens is part is called radius of curvature.

**Principal Axis:** The line joining the centers of curvature of two surfaces of lens is called principal axis.

**Optical Center:** It is a special point on the principal axis. Light incident on the optical centre passes through the lens without deviation.

**Principal Focus:** The point on the principal axis at which all incident rays parallel to the principal axis converge or appear to diverge after refraction through the lens.

**Refraction through a Lens:**

- An incident ray, parallel to the principal axis, after refraction passes through (or appears to come from), second focus of the lens.
- An incident ray, passing through the optical center of the lens, goes undeviated from the lens.
- An incident ray, passing through the (first) principal focus of the lens, or directed toward it, becomes parallel to the principal axis after refraction through lens.

**Image formation by a convex lens**

S.No.	Position of object	Position of image	Nature of image	Uses
1.	At infinity	At the principal focus or in the focal plane	Real, inverted and extremely diminished in size	Telescopes
2.	Beyond 2F	Between F and 2F	Real, inverted and diminished	In a camera, In eye while reading
3.	At 2F	At 2F	Real, inverted and equal to the size of the object	Photocopier
4.	Between F and 2F	Beyond 2F	Real, inverted and bigger than object	Projector, microscope objective
5.	At the principal focus	At infinity	Real, inverted and extremely magnified	Spotlights
6.	Between the optical centre and the principal focus	On the same side as that of object	Virtual, erect and magnified	Magnifying glass, eye lenses spectacles for short sightedness

## Image formation by a concave lens

S.No.	Position of object	Position of image	Nature of image	Uses
1.	At infinity	Appears at the principal focus on the same side as that of the object	Virtual, erect and extremely diminished	Spectacles for short sightedness
2.	Between infinity and the lens	Appears between the principal focus and the lens	Virtual, erect and diminished	Spectacles for short sightedness

### Sign conventions:

- All distances, object distance (u), image distance (v) and focal length (f) are measured from the optical centre.
- The distances measured in the direction of incident ray are taken as positive and distances measured against the direction of incident ray are taken as negative.
- All distances (heights) of objects and images above principal axis are taken as positive and those below the principal axis are taken as negative.

### Lens formula:

$$1/v - 1/u = 1/f$$

**Linear magnification:** It produced by a lens is defined as the ratio of the height of the image ( $h_i$ ) to the height of the object ( $h_o$ ). It is represented by  $m$

$$m = i/o \quad \text{or} \quad m = v/u$$

- (i) If the magnification of a lens is negative, then the image formed is inverted and real.  
(ii) If the magnification of a lens is positive, then the image formed is erect and virtual.

**Power of a Lens:** The ability of a lens to converge or diverge light rays is called power of the lens. It is defined as the reciprocal of the focal length. Power is measured in dioptre.

$$\text{Power [in dioptre (D)]} = 1/f \text{ (in m)}$$

For combination of lenses,

$$P = P_1 + P_2 + P_3 + \dots$$

**Remember the following points to solve any numerical for mirrors**

**MIRROR FORMULA**

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

Where  $u$  = position of object ,  $v$ = position of image and  $f$  = focal length of the mirror

Take  $u$  = always negative

Focal length  $f$  = +ve for convex mirror , -ve for concave mirror

Position of image  $v$ = +ve for virtual image, -ve for real image

$$\text{MAGNIFICATION (m)} = \frac{\text{size of image}}{\text{size of object}} = -\frac{v}{u} = \frac{f-v}{f} = \frac{f}{f-u}$$

$m$  = -ve for real image

= +ve for virtual image

### FOR LENS

$$\text{LENS FORMULA} \quad \frac{1}{v} - \frac{1}{u} = \frac{1}{f}$$

Where  $u$  = position of object ,  $v$ = position of image and  $f$  = focal length of the mirror

Take  $u$  = always negative

Focal length  $f$  = +ve for convex lens , -ve for concave lens

Position of image  $v$ = +ve for virtual image, -ve for real image

$$\text{MAGNIFICATION (m)} = \frac{\text{size of image}}{\text{size of object}} = \frac{v}{u} = \frac{f-v}{f} = \frac{f}{f+u}$$

$m$  = -ve for real image

= +ve for virtual image

## QUESTIONS FROM PREVIOUS BOARD EXAMS

Question 1.



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The laws of reflection hold true for



- (a) plane mirror only
- (b) concave mirror only
- (c) convex mirror only
- (d) all reflecting surface

Answer:

(d) The laws of reflection hold true for all reflecting surface.

Question 2.

List four characteristics of the images formed by plane mirror. (Delhi 2015, AI2011)

Answer:

Characteristics of the image formed by a plane mirror are

- (i) image distance is same as that of object distance
- (ii) image formed is virtual and erect
- (iii) image formed is of the same size as that of the object
- (iv) image formed is laterally inverted (left appears right and right appears left).

Question 3.

State the two laws of reflection of light. (Delhi 2011)

Answer:

Laws of reflection of light states that

- (i) The angle of incidence is equal to the angle of reflection.
- (ii) The incident ray, the reflected ray and the normal to the mirror at the point of incidence all lie in the same plane.

Question 4.

When an object is kept within the focus of a concave mirror, an enlarged image is formed behind the mirror. This image is

- (a) real
- (b) inverted
- (c) virtual and inverted
- (d) virtual and erect (2020)

Answer:

(d) When an object is placed between the principal focus and pole of a concave mirror, an enlarged virtual and erect image is formed behind the mirror.

Question 5.

What is the magnification of the images formed by plane mirror and why? (Delhi 2015)

Answer:

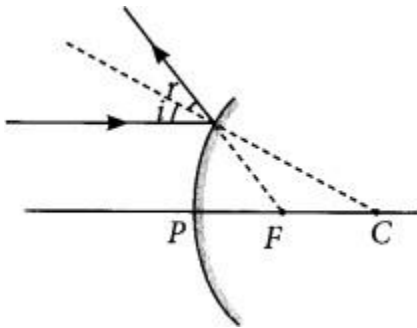
Magnification of images formed by plane mirror is unity because for plane mirror, the size of the image formed is equal to that of the object.

Question 6.

Draw a labelled ray diagram to show the path of the reflected ray corresponding to an incident ray of light parallel to the principal axis of a convex mirror. Mark the angle of incidence and angle of

reflection on it. (AI 2019)

Answer:

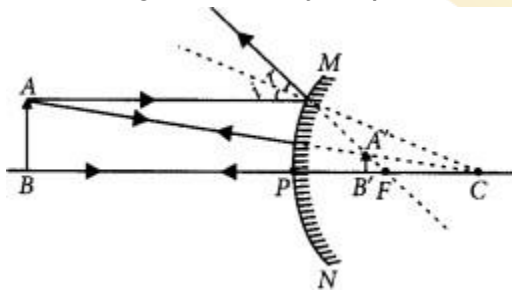


Question 7.

If the image formed by a spherical mirror for all positions of the object placed in front of it is always erect and diminished, what type of mirror is it? Draw a labelled ray diagram to support your answer. (2018)

Answer:

If the image formed by a spherical mirror is always erect and diminished then it is convex mirror.



Question 8.

An object is placed at a distance of 30 cm in front of a convex mirror of focal length 15 cm. Write four characteristics of the image formed by the mirror. (Delhi 2017)

Answer:

Four characteristics of the image formed by the given convex mirror are :

- (i) Virtual
- (ii) Erect
- (iii) Diminished
- (iv) Image is always formed behind the mirror between pole and focus.

Question 9.

An object is placed at a distance of 12 cm in front of a concave mirror of radius of curvature 30 cm. List four characteristics of the image formed by the mirror. (Delhi 2017)

Answer:

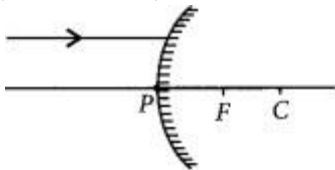
Radius of curvature (R) = 30 cm, object distance is 12 cm in front of the mirror. Thus, we can say that object is placed between focus and pole. Four characteristics of the image formed by the given concave mirror when object is placed between pole and focus are:

- (i) Virtual

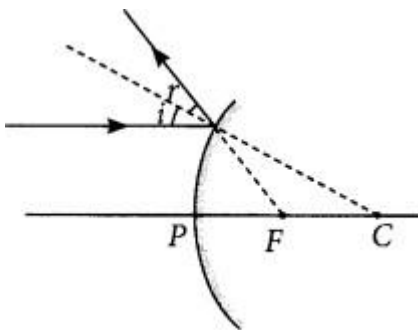
- (ii) Erect
- (iii) Enlarged
- (iv) Image is formed behind the mirror

Question 10.

A ray of light is incident on a convex mirror as shown. Redraw the diagram and complete the path of this ray after reflection from the mirror. Mark angle of incidence and angle of reflection on it. (Delhi 2016)



Answer:



Question 11.

Name the type of mirror used in the design of solar furnaces. Explain how high temperature is achieved by this device. (AI 2016)

Answer:

Concave mirror is used in the designing of solar furnaces.

When a solar furnace is placed at the focus of a large concave mirror, it focuses a parallel beam of light on the furnace. Therefore, a high temperature is attained at the point after some time.

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Question 12.

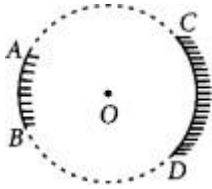
"The magnification produced by a spherical mirror is -3". List four information you obtain from this statement about the mirror/ image. (AI 2016)

Answer:

Negative sign of magnification indicates that the image is real and inverted. Since the image is real and inverted, the mirror is concave and magnification of -3 indicates that the image is magnified.

Question 13.

AB and CD, two spherical mirrors, from parts of a hollow spherical ball with its centre at O as shown in the diagram. If  $AB = 12$  and  $CD$ , what is the ratio of their focal lengths? State which of the two mirrors will always form virtual image of an object placed in front of it and why? (Foreign 2016)



Answer:

Focal length of a mirror is given by

Focal length = Radius of curvature/2

Since both the mirrors have same radius of curvature, therefore focal length of the two mirrors will be same, i.e.,

$$f_1/f_2 = 1/1$$

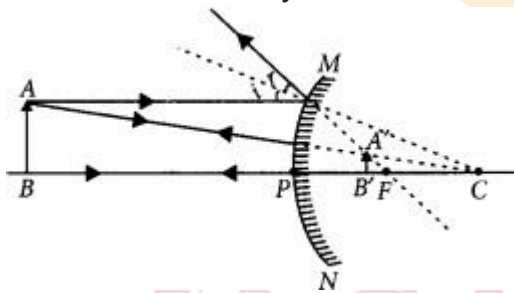
Since virtual image is always formed by convex mirror. The mirror AB will always form virtual image.

Question 14.

List two properties of the images formed by convex mirrors. Draw ray diagram in support of your answer. (Foiegn 2016)

Answer:

Convex mirrors always form diminished, virtual and erect images.



Question 15.

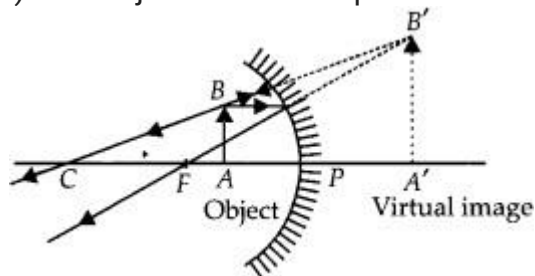
The linear magnification produced by a spherical mirror is +3. Analyse this value and state the (i) type of mirror and (ii) position of the object with respect to the pole of the mirror. Draw a ray diagram to show the formation of image in this case. (Foiegn 2016)

Answer:

Positive value of the magnification indicates that image is virtual and erect.

(i) Since the image is magnified, the mirror is concave.

(ii) The object is between pole and focus of the mirror as shown

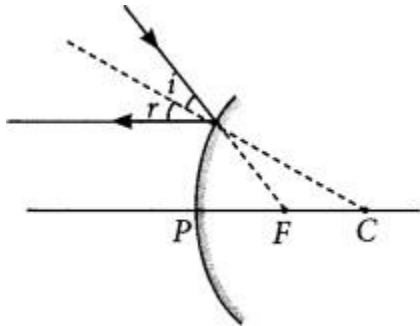


The image produced in second case will be real and inverted.

Question 16..

Díaw a íay diagíam to show the path of the íeflected íay coíesponding to an incident íay which is dírected towards the píncípial focus of a convex mííóí. Maík on it the angle of incidence and the angle of íeflection. (Delhi 2014)

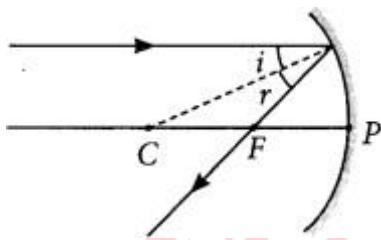
Answeí:



Question 17.

Díaw a íay diagíam to show the path of the íeflected íay coíesponding to an incident íay of light párallel to the píncípial axis of a concave mííóí. Maík the angle of incidence and angle of íeflection on it. (Delhi 2014)

Answeí:



Question 18.

List two possible ways in which a concave mííóí can píoduce a magnified image of an object placed in front of it. State the díffeíce if any between these two images. (AI2014)

Answeí:

A concave mííóí can píoduce a magnified image of an object when object is placed:

- (1) In between its pole and its focus
- (2) In between its focus and its centíe of cuívatuíe.

Díffeíce, between these two images:

Íhe image píoduced in fííst case will be vírtual and eéct.

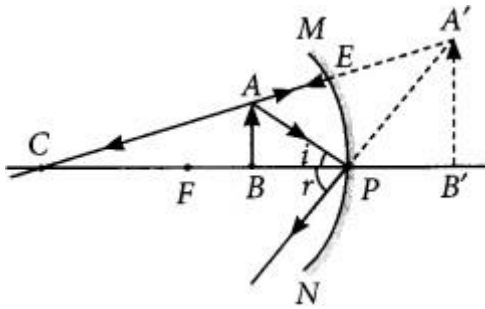
Íhe image píoduced in second case will be íeal and inveíteđ.

Question 19.

Íhe image foímed by a concave mííóí is obseíved to be vírtual, eéct and laígeí than the object. Wheíe should the position of the object be íelative to the mííóí? Díaw íay diagíam to justify youí answeí. (AI 2014)

Answeí:

Íhe position of the object should be between P and F

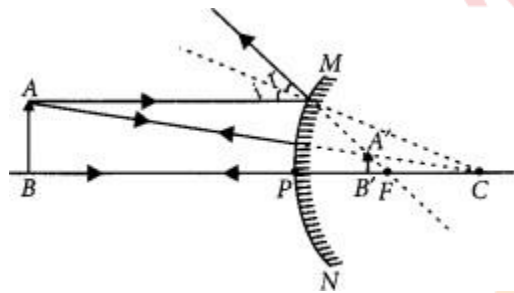


Question 20.

The linear magnification produced by a spherical mirror is  $+1/3$ . Analysing this value state the (i) type of mirror and (ii) position of the object with respect to the pole of the mirror. Draw any diagram to justify your answer. (AI 2014, Foieign 2014)

Answer:

- (i) Convex mirror
- (ii) Between infinity and the pole of the mirror.

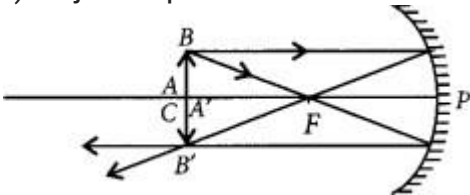


Question 21.

The linear magnification produced by a spherical mirror is  $-1$ . Analysing this value state the (i) type of mirror and (ii) position of the object with respect to the pole of the mirror. Draw any diagram to justify your answer. (Foieign 2014)

Answer:

- (i) Concave mirror because the image is real, inverted.
- (ii) Object is placed at C.



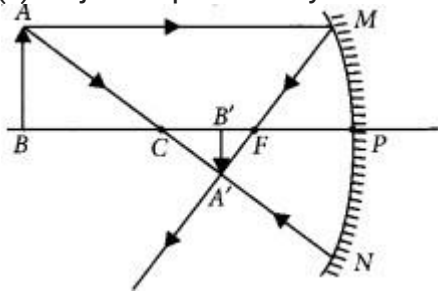
Question 22.

The linear magnification produced by a spherical mirror is  $-1/5$ . Analysing this value state the (i) type of spherical mirror and (ii) the position of the object with respect to the pole of the mirror. Draw any diagram to justify your answer. (Foieign 2014)

Answer:

- (i) Concave mirror

(ii) Object is placed beyond C.



Question 23.

Díaw íay diagrams foí the following cases when a íay of light:

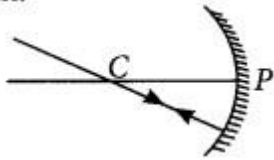
(i) passing thóugh centíe of cuívatuíe of a concave mííóí is incident on it.

(ii) páíallel to píncipal axis is incident on convex mííóí.

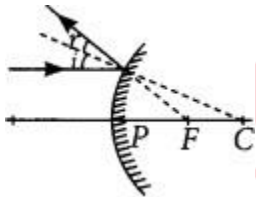
(iii) is passing thóugh focus of a concave mííóí incident on it. (2020)

Answeí:

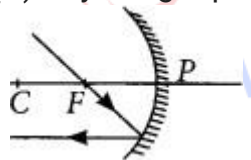
(i) Ray of light passing thóugh centíe of cuívatuíe of concave mííóí, afteí íeílection



(ii) Ray of light páíallel to the píncipal axis is incident on a convex mííóí afteí íeílection appeá to díveíge from the píncipal focus of a convex mííóí.



(iii) Ray of light passing thóugh focus of a concave mííóí afteí íeílection will emeíge páíallel



Question 24.

A concave mííóí is used foí image foímatíon foí díffeíent posítíon of an object. What ínfereínces can be díawn about the following when an object is placed at a dístance of 10 cm fírom the pole of a concave mííóí of focal length 15 cm?

(a) Posítíon of the image

(b) Síze of the image

(c) Natuíe of the image

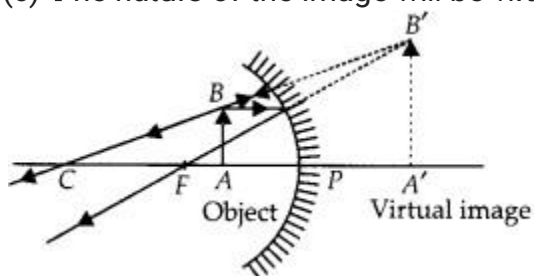
Díaw a labelled íay díagram to dístífy youí ínfereínces. (2020)

Answeí:

Given,  $f = -15$  cm,  $u = -10$  cm.

Thus the object is placed between the principal focus and pole of the mirror.

- (a) The position of the image will be behind the mirror.
- (b) The size of the image will be highly enlarged.
- (c) The nature of the image will be virtual and erect.



Question 25.

A concave mirror has a focal length of 20 cm. At what distance from the mirror should a 4 cm tall object be placed so that it forms an image at a distance of 30 cm from the mirror? Also calculate the size of the image formed. (AI 2019)

Answer:

Given  $f = -20$  cm  $v = -30$  cm  $u = ?$

Using  $1/v + 1/u = 1/f$

$$1/u = 1/f - 1/v = 1/-20 - 1/-30 = -3+260$$

$$\Rightarrow u = -60 \text{ cm}$$

$\therefore$  Object placed at 60 cm from the mirror.

Also magnification,  $m = h'/h = -v/u$

$$\Rightarrow h' = -(-30)/-60 \times 4 = -2 \text{ cm}$$

$\therefore$  The size of the image is 2 cm.

Question 26.

The image of a candle flame placed at a distance of 30 cm from a mirror is formed on a screen placed in front of the mirror at a distance of 60 cm from its pole. What is the nature of the mirror? Find its focal length. If the height of the flame is 2.4 cm, find the height of its image. State whether the image formed is real or inverted. (Delhi 2017)

Given:

Object distance,  $u = -30$  cm, image size,  $h' = ?$

Image distance,  $v = -60$  cm,

Object size,  $h = 2.4$  cm,

Focal length,  $f = ?$

Using mirror formula,

$$1/f = 1/v + 1/u \text{ OR } 1/f = -1/60 - 1/30 = -360 = -120$$

$$\text{or } f = -20 \text{ cm}$$

Hence, focal length is 20 cm

Also, magnification,  $m = h'/h = -v/u$

$$\text{or, } m = -(-60)/(-30) = -2 \text{ or } h'/h = -2$$

$$h' = -2 \times 2.4 = -4.8 \text{ cm}$$

As the image formed is real, therefore the mirror is concave.

The height of the image is 4.8 cm.

The image formed is enlarged and inverted.

Question 27.

An object 4 cm in height, is placed at 15 cm in front of a concave mirror of focal length 10 cm. At what distance from the mirror should a screen be placed to obtain a sharp image of the object. Calculate the height of the image. (Delhi 2017)

Answer:

Given : object distance,  $u = -15$  cm,  
object height,  $h = 4$  cm, focal length  $f = -10$  cm;

Image distance,  $v = ?$

Using mirror formula,

$$\frac{1}{v} + \frac{1}{u} = \frac{1}{f} \Rightarrow \frac{1}{v} + \frac{1}{(-15)} = \frac{1}{-10} \Rightarrow \frac{1}{v} = \frac{1}{15} - \frac{1}{10}$$

$$\text{or } \frac{1}{v} = \frac{10 - 15}{150} = \frac{-5}{150} = \frac{-1}{30} \text{ or } v = -30$$

In order to obtain a sharp image of the object on the screen, screen should be placed at a distance of 30 cm in front of the mirror.

Also, magnification,  $m = \frac{h'}{h} = -\frac{v}{u}$

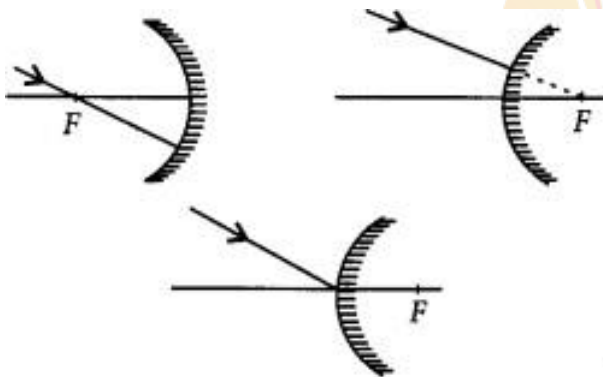
$$\text{or } h' = -\left(\frac{-30}{-15}\right) \times 4 \text{ or } h' = -\left(\frac{30}{15}\right) \times 4 = -2 \times 4$$

$$\text{or } h' = -8 \text{ cm}$$

Thus, the height of the image is 8 cm.

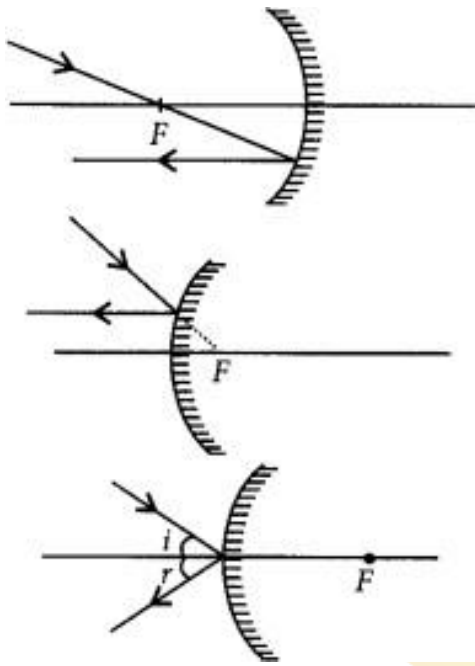
Question 28.

Draw the following diagram in which a ray of light is incident on a concave/convex mirror, on your answer sheet. Show the path of this ray, after reflection, in each case.



Answer:

The path of the rays are shown in figure.



Question 29.

The image of an object formed by a mirror is real, inverted and is of magnification -1. If the image is at a distance of 40 cm from the mirror, where is the object placed? Where would the image be if the object is moved 20 cm towards the mirror? State reason and also draw ray diagram for the new position of the object to justify your answer. (AI 2016)

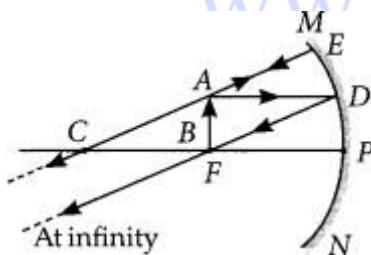
Answer:

Since the image formed by the mirror is real and inverted, therefore the mirror is concave and magnification of the mirror will be

$$m = -v/u \Rightarrow -1 = -v/u \Rightarrow v = u$$

i.e., object and image both are formed at the centre of curvature, i.e., 40 cm from the mirror.

Now, if the object is moved 20 cm towards the mirror, the object will be at the focus of the mirror and therefore the image will be formed at infinity.



Question 30.

The image formed by a spherical mirror is real, inverted and its magnification is -2. If the image is at a distance of 30 cm from the mirror, where is the object placed? Find the focal length of the mirror. List two characteristics of the image formed if the object is moved 10 cm towards the mirror. (AI 2016)

Answer:

Since the image formed is real and inverted, the mirror is concave.

Magnification,  $m = -v/u \Rightarrow -2 = -v/u \Rightarrow v = 2u$

Now, if  $v = -30$  cm then  $u = -15$  cm

As focal length of the mirror is

$$f = uv/u+v = -15 \times -30 / -15 - 30 = f = 450 / -45 = -10 \text{ cm}$$

If the object is shifted 10 cm towards the mirror, then the object is between principal focus and the optical centre and the image formed will be virtual and erect.

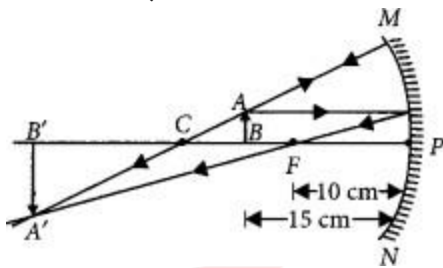
Question 31.

To construct a ray diagram we use two rays of light which are so chosen that it is easy to determine their directions after reflection from the mirror. Choose these two rays and state the path of these rays after reflection from a concave mirror. Use these two rays to find the nature and position of the image of an object placed at a distance of 15 cm from a concave mirror of focal length 10 cm. (Delhi 2015, AI 2012)

Answer:

We use two rays of light, one passing through the centre of curvature of a concave mirror, and another is parallel to the principal axis. After reflection, the ray passing through the centre of a concave mirror is reflected back along the same path and the ray parallel to the principal axis will pass through the principal focus.

$u = -15$  cm,  $f = -10$  cm



From ray diagram,  $v = -30$  cm, i.e., beyond C. Nature of image is real, inverted and magnified. Question

32.

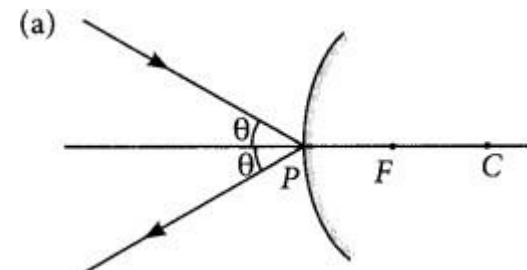
Draw a ray diagram to show the path of the reflected ray in each of the following cases. A ray of light incident on a convex mirror:

(a) strikes at its pole making an angle  $\theta$  from the principal axis.

(b) is directed towards its principal focus.

(c) is parallel to its principal axis. (Fóeign 2015)

Answer:



(b) Refer to answer 17.

(c) Refer to answer 6.

Question 33.

A spherical mirror produces an image of magnification -1 on a screen placed at a distance of 50 cm from the mirror.

- (a) Write the type of mirror.
- (b) Find the distance of the image from the object.
- (c) What is the focal length of the mirror?

(Delhi 2014, AI 2014)

Answer:

(a) Concave mirror

(b) Magnification,  $m = -v/u$  or  $v = u$

$\therefore$  Distance of the image from the object is,  $v - u = 0$

(c) As the image is formed at centre of curvature i.e.,  $v = R$ .

$\therefore$  focal length of the mirror,  $f = -50/2 = -25$  cm

Question 34.

A spherical mirror produces an image of magnification -1 on a screen placed at a distance of 40 cm from the mirror.

- (i) Write type of mirror.
- (ii) What is the nature of the image formed?
- (iii) How far is the object located from the mirror?

(Delhi 2014)

Answer:

(i) This is a concave mirror.

(ii) The image is real and inverted and of same size.

(iii) As  $m = -1$

$\therefore m = -v/u \Rightarrow -1 = -v/u \Rightarrow u = v$

Hence, object is located at centre of curvature i.e., at distance of 40 cm from the pole of the mirror,

Question 35.

A spherical mirror produces an image of magnification -1.0 on a screen placed at a distance of 30 cm from the pole of the mirror.

- (i) Write the type of mirror in this case.
- (ii) What is the focal length of the mirror?
- (iii) What is the nature of the images formed?(Delhi 2014)

Answer:

(i) The mirror is concave mirror.

(ii) Distance the image from the mirror = - 30 cm

Magnification,  $m = -v/u$

Here  $m = -1$  and  $v = -30$  cm

$-1 = -(-30)/u$

$\therefore u = -30$  cm

As  $v = u$ , object is placed at centre of curvature. Therefore, focal length of the mirror,

$f = -30/2 = -15$  cm

(iii) Image formed is real and inverted and of the same size of the object.

Question 36.

A student wants to project the image of a candle flame on a screen 48 cm in front of a mirror by

keeping the flame at a distance of 12 cm from its pole.

(a) Suggest the type of mirror he should use.

(b) Find the linear magnification of the image produced.

(c) How far is the image from its object?

(d) Draw a ray diagram to show the image formation in this case. (AI 2014)

Answer:

(a) Concave mirror

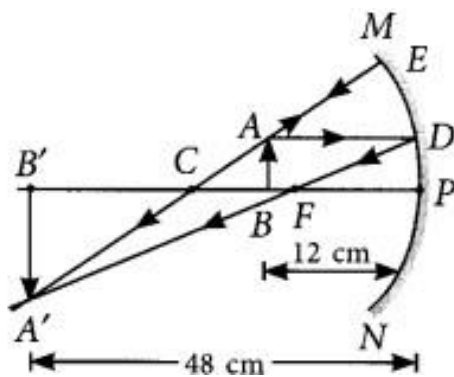
(b) Linear magnification,

$$m = -v/u = -(-48)/12 = -4$$

(c) The distance between the image and the object

$$= 48 - 12 = 36 \text{ cm}$$

(d)



Question 37.

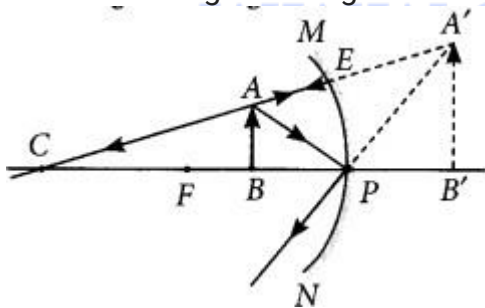
A student wants to obtain an erect image of an object using a concave mirror of 12 cm focal length. What should be the range of distance of the candle flame from the mirror? State the nature and size of the image he is likely to observe. Draw a ray diagram to show the image formation in this case. (Foreign 2014)

Answer:

To obtain an erect image, the object is placed in between pole and the focus of the concave mirror. So range of distance of the candle flame from the mirror is in between 12 cm.

Nature of the image = Virtual and erect.

Size of the image = Enlarged



Question 38.

Mention the types of mirrors used as (i) rear view mirrors, (ii) shaving mirrors. List two reasons to justify your answer in each case. (Delhi 2013, Delhi 2012)

Answer:

(i) Convex mirror is used as rear view mirror because



- (a) it gives erect image.
- (b) it gives diminished image thus provides wide view of traffic behind the vehicle.
- (ii) Concave mirror is used as shaving mirror because
  - (a) it gives erect image when mirror is close to the face.
  - (b) it gives enlarged image of the face so that a person can shave safely.

Question 39.

Calculate the magnification of the image of an object placed perpendicular to the principal axis of a concave mirror of focal length 15 cm. The object is at a distance of 20 cm from the mirror. (Delhi 2013)

Answer:

Given, focal length of concave mirror,

$$f = -15 \text{ cm}$$

Object distance,  $u = -20 \text{ cm}$

Image distance,  $v = ?$

Using mirror formula,

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

$$\text{or } \frac{1}{v} = \frac{1}{f} - \frac{1}{u} = \frac{1}{-15} - \frac{1}{-20} = \frac{-4+3}{60}$$

$$\frac{1}{v} = \frac{-1}{60} \quad \text{or } v = -60 \text{ cm}$$

Using magnification formula,

$$m = -v/u = -(-60/-20) \text{ or } m = -3$$

So, the magnification,  $m = -3$ .

Question 40.

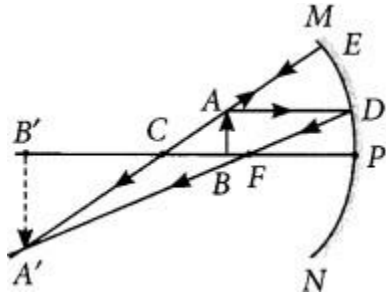
To construct ray diagram we use two light rays which are so chosen that it is easy to know their directions after reflection from the mirror. List these two rays and state the path of these rays after reflection. Use these rays to locate the image of an object placed between centre of curvature and focus of a concave mirror. (AI2012)

Answer:

A ray parallel to the principal axis, after reflection, will pass through the principal focus in case of a concave mirror or appear to diverge from the principal focus in case of a convex mirror.

A ray passing through the centre of curvature of a concave mirror or directed in the direction of the centre of curvature of a convex mirror, after reflection, is reflected back along the same path.

The light rays come back along the same path because the incident rays fall on the mirror along the normal to the reflecting surface.



Question 41.

State the types of mirrors used for (i) headlights and (ii) rear view mirrors, in motorcycles. Give reason to justify your answer in each case. (AI 2012)

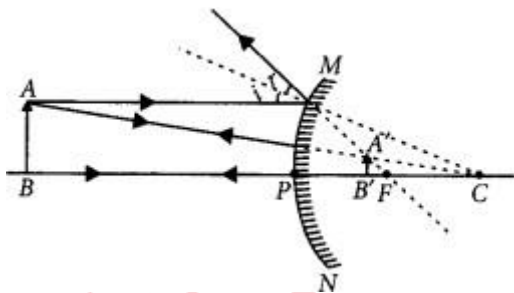
Answer:

- (i) Concave mirrors are used in headlights of cars to get powerful beams of light.
- (ii) Convex mirrors are used as rear-view mirrors of vehicle to get a wide field of view and erect image of traffic behind.

Question 42.

An object is placed between infinity and the pole of a convex mirror. Draw a ray diagram and also state the position, the relative size and the nature of the image formed. (AI 2011)

Answer:



Position: Image is formed between pole and principal focus of the mirror.

Relative size : Image formed is diminished.

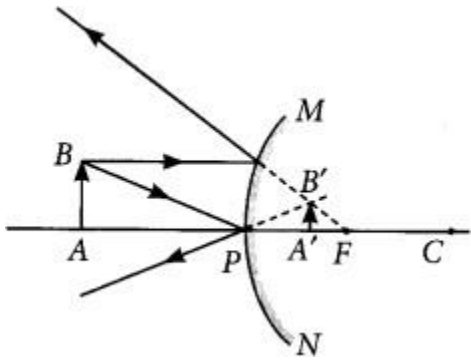
Nature : Image formed is virtual and erect.

Question 43.

With the help of a ray diagram explain why a convex mirror is preferred for rear view mirrors in the motor cars. (Foiegn 2011)

Answer:

Convex mirror is preferred for rear view mirrors in motor cars because no matter where the object is located in front of convex mirror, it always gives erect and diminished image of the object, so that driver is able to see the large traffic view in small area and the image is erect. This can be interpreted from the following diagram.



Question 44.

An object 4.0 cm in size, is placed 25.0 cm in front of a concave mirror of focal length 15.0 cm.

(i) At what distance from the mirror should a screen be placed in order to obtain a sharp image?

(ii) Find the size of the image.

(iii) Draw a ray diagram to show the formation of image in this case. (2020)

Answer:

(i) Given,  $h = 4 \text{ cm}$ ,

$u = -25 \text{ cm}$  (concave mirror),  $f = -15 \text{ cm}$

Using mirror formula,

$$\frac{1}{f} = \frac{1}{v} + \frac{1}{u} \text{ or } \frac{1}{v} = \frac{1}{f} - \frac{1}{u}$$

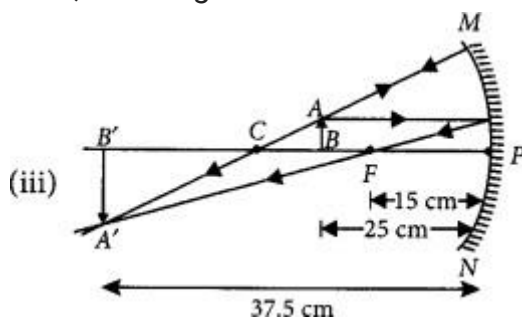
$$= \frac{1}{-15} - \frac{1}{-25} = \frac{-25 + 15}{15 \times 25}$$

$$\therefore v = \frac{15 \times 25}{-10} = -37.5 \text{ cm}$$

(ii) Magnification,  $m = \frac{h'}{h} = \frac{-v}{u}$

$$\therefore h' = \frac{-v}{u} \times h = \frac{37.5}{-25} \times 4 = -6 \text{ cm}$$

Thus, the image is real and inverted.



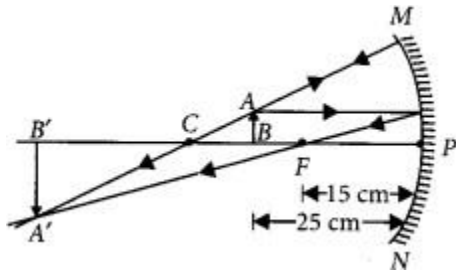
Question 45.

(a) A concave mirror of focal length 10 cm can produce a magnified real as well as virtual image

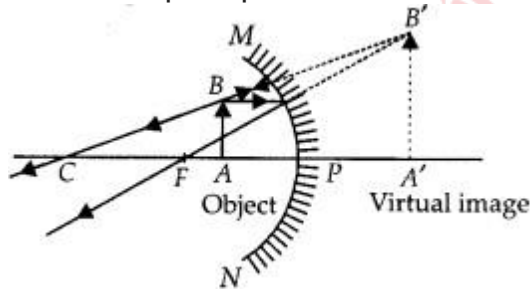
of an object placed in front of it. Draw ray diagrams to justify this statement,  
 (b) An object is placed perpendicular to the principal axis of a convex mirror of focal length 10 cm. The distance of the object from the pole of the mirror is 10 cm. Find the position of the image formed. (2020)

Answer:

(a) A magnified real image is produced in a concave mirror when the object is placed between principal focus and centre of curvature.



A magnified virtual image is produced in a concave mirror when the object is placed between the pole and the principal focus of the mirror.



(b) Given,  $f = +10$  cm (convex mirror) and  $u = -10$  cm  
 From mirror formula,

$$\frac{1}{f} = \frac{1}{v} + \frac{1}{u} \quad \text{or} \quad \frac{1}{v} = \frac{1}{f} - \frac{1}{u}$$

$$\text{or} \quad \frac{1}{v} = \frac{1}{10} - \frac{1}{-10} = \frac{-10-10}{-100}$$

$$\therefore v = \frac{-100}{-20} = 5 \text{ cm behind the mirror.}$$

Question 46.

(a) A security mirror used in a big showroom has radius of curvature 5 m. If a customer is standing at a distance of 20 m from the cash counter, find the position, nature and size of the image formed in the security mirror.

(b) Neha visited a dentist in his clinic. She observed that the dentist was holding an instrument fitted with a mirror. State the nature of this mirror and reason for its use in the instrument used by dentist. (2020)

Answer:

(a) Given radius of curvature of the mirror,  
 $R = 5$  m

∴ Focal length,  $f = R/2 = 2.5 \text{ m}$  (convex mirror) and  $u = -20 \text{ m}$

From mirror formula,

$$\begin{aligned} 1/f &= 1/v + 1/u \text{ OR } 1/v = 1/f - 1/u \\ &= 1/2.5 - 1/-20 = -20 - 2.5 / -20 \times 2.5 \\ \therefore v &= 2.22 \text{ m} \end{aligned}$$

Thus, the image is formed 2.22 m behind the mirror. The image is diminished, virtual and erect.

(b) Concave mirrors are used by dentist. Dentist use it as it is a converging mirror and when used at close range forms a highly enlarged, virtual and erect image of the object.

Question 47.

(a) To construct a ray diagram we use two rays which are so chosen that it is easy to know their directions after reflection from the mirror. Use these two rays and draw ray diagram to locate the image of an object placed between pole and focus of a concave mirror.

(b) A concave mirror produces three times magnified image on a screen. If the object is placed 20 cm in front of the mirror, how far is the screen from the object? (Delhi 2017)

Answer:

(a) Two light rays whose path of reflection are properly known are :

(i) When the incident ray passes through the centre of curvature of a concave mirror, it gets reflected in the same path.

(ii) When the ray is incident obliquely to the principal axis, towards the pole of mirror, it gets reflected back by making equal angles with the principal axis (laws of reflections).

Suppose an object is placed between focus and pole of the concave mirror. Then by using the above two rays, the image of the object can be located as

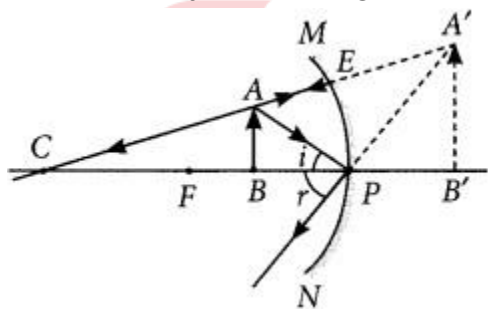


Image formed is virtual, erect, magnified and it is formed behind the mirror.

(b) Given : Magnification,  $m = -3$

Object distance,  $u = -20 \text{ cm}$

Magnification,  $m = -v/u$  or  $-3 = -v/-20$

or  $v = -60 \text{ cm}$

The screen is placed in front of the mirror at a distance of 60 cm from the pole.

Thus, the screen is placed 40 cm ( $= 60 \text{ cm} - 20 \text{ cm}$ ) away from the object.

Question 48.

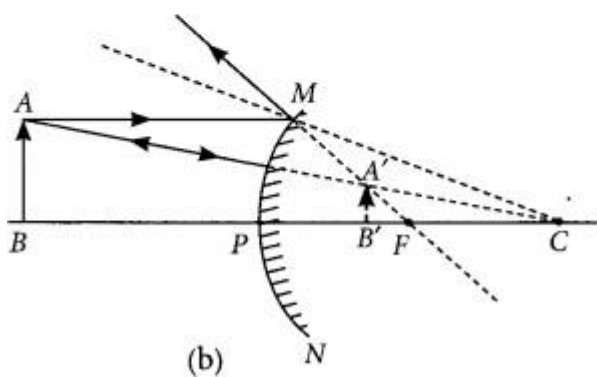
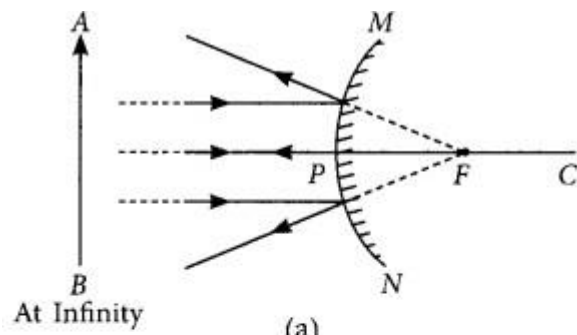
(a) If the image formed by a mirror for all positions of the object placed in front of it is always diminished, erect and virtual, state the type of the mirror and also draw a ray diagram to justify your answer. Write one use such mirrors are put to and why?

(b) Define the radius of curvature of spherical mirrors. Find the nature and focal length of a spherical mirror whose radius of curvature is +24 cm. (AI2017)

Answer:

(a) If the image formed by a mirror for all positions of the object placed in front of it is always diminished, erect and virtual then the mirror is convex mirror.

The ray diagrams for the formation of image by a convex mirror for the first position when the object is at infinity and the second position when the object is at a finite distance from the mirror are shown.



### Use of Convex Mirrors

Convex mirrors are commonly used as rear-view (wing) mirrors in vehicles because they always give an erect, though diminished image. Also, they have a wide field of view as they are curved outwards. Thus, convex mirrors enable the driver to view a large area.

(b) Radius of Curvature: The radius of the sphere of which the reflecting surface of a spherical mirror forms a part, is called the radius of curvature of the mirror. It is represented by the letter R.

∴ The radius of curvature is equal to twice the focal length.

$$\therefore R = 2f$$

$$\text{If } R = +24 \text{ cm } \therefore f = \frac{R}{2} = \frac{24}{2} = 12 \text{ cm}$$

Since the radius of curvature is positive, the mirror is convex mirror. Hence the nature of the image is virtual and erect.

Question 49.

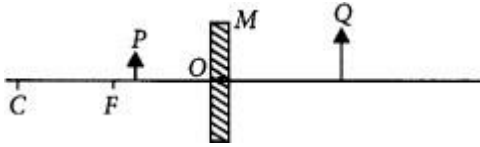
(a) Define the following terms in the context of spherical mirrors:

- (i) Pole
- (ii) Centre of curvature

- (iii) Píncipal axis
- (iv) Píncipal focus
- (b) Díaw íay diagráms to show the píncipal focus of a

(i) Concave mííóí (ii) Convex mííóí

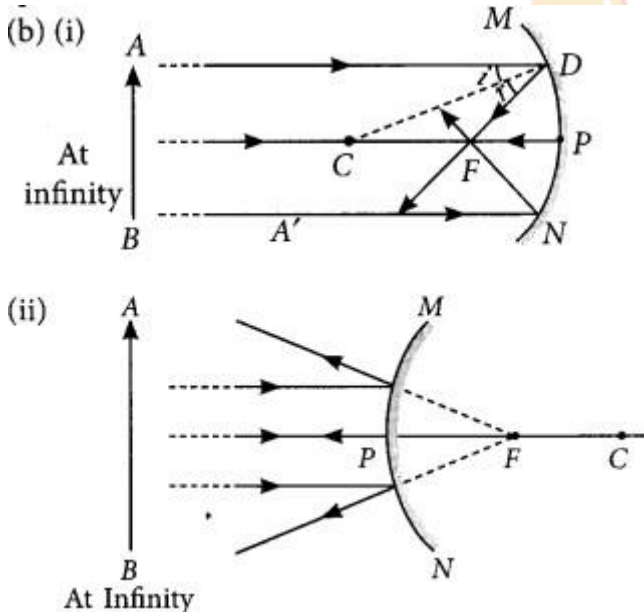
(c) Consider the following diagram in which M is a mííóí and P is an object and Q is its magnified image foímed by the mííóí.



State the type of the mííóí M and one chaáctereístic píopeíty of the image Q. (Delhi 2016)

Answer:

- (a) (i) Pole : The centíe of the íeflecting suíface of a spherícal mííóí is a point called the pole. It lies in the suíface of the mííóí and its íepíesented by the letteí P.
- (ii) Centíe of cúvatuíe: The íeflecting suíface of a spherícal mííóí is a paít of a spheré which has a centíe. This point is called the centíe of cúvatuíe of spherícal mííóí and is íepíesented by the letteí C.
- (iii) Píncipal axis : An imaginaíy line passing thúgh the pole and the centíe of cúvatuíe of a spherícal mííóí and nórmal to the mííóí at its pole is called píncipal axis.
- (iv) Píncipal focus : Incident íays páallel to píncipal axis, afteí íeflection eíteí conveíge to as appeaí to díveíge fírom a fixed point on the píncipal axis known as píncipal focus of the spherícal mííóí.



(c) The object is placed between focus and pole of the mííóí and a magnified image is foímed behind the mííóí.

∴ The mííóí is concave and image foímed is vírtual and eíect.

Question 50.

It is desired to obtain an eíect image of an object, using concave mííóí of focal length of 12 cm.

(i) What should be the íange of distance of a , object placed in fíront of the mííóí?

(ii) Will the image be smaller or larger than the object? Draw ray diagram to show the formation of image in this case.

(iii) Where will the image of this object be, if it is placed 24 cm in front of the mirror? Draw ray diagram for this situation also to justify your answer.

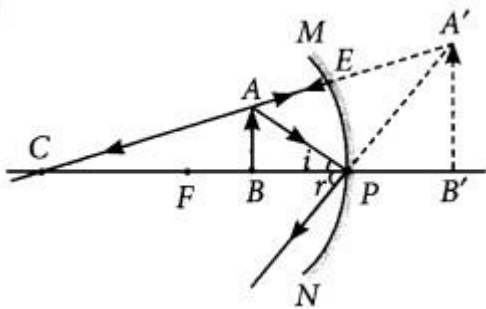
Show the positions of pole, principal focus and the centre of curvature in the above ray diagrams. (AI2016)

Answer:

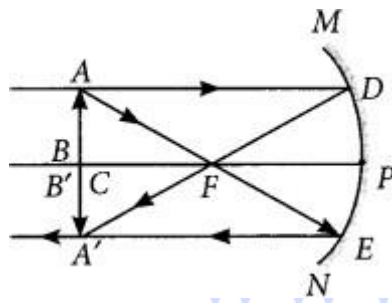
Given : focal length of the concave mirror  $f = 12$  cm

(i) If the object is placed between the pole and focus of the concave mirror, then the image formed is virtual and erect. Therefore, the range of distance of the object should be  $0 < u < 12$  cm.

(ii) The image formed will be enlarged as shown below.



(iii) If the object is placed 24 cm in front of the mirror i.e., at the centre of the curvature then the image will also be formed at the centre of the curvature.



Question 51.

Suppose you have three concave mirrors A, B and C of focal lengths 10 cm, 15 cm and 20 cm. For each concave mirror you perform the experiment of image formation for three values of object distances of 10 cm, 20 cm and 30 cm. By giving reason, answer the following:

(a) For the three object distances, identify the mirror/mirrors which will form an image of magnification -1.

(b) Out of the three mirrors, identify the mirror which would be preferred to be used for shaving purposes/make up.

(c) For the mirror B draw ray diagram for image formation for object distances 10 cm and 20 cm. (Fóigein 2016)

Answer:

Given  $f_a = 10$  cm,  $f_b = 15$  cm,  $f_c = 20$  cm

$u_a = 10 \text{ cm}$ ,  $u_b = 20 \text{ cm}$ ,  $u_c = 30 \text{ cm}$

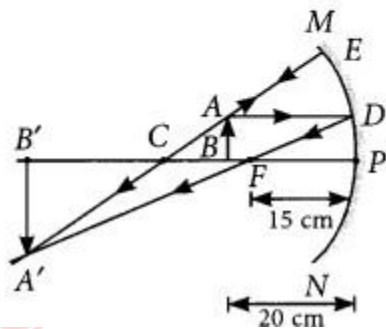
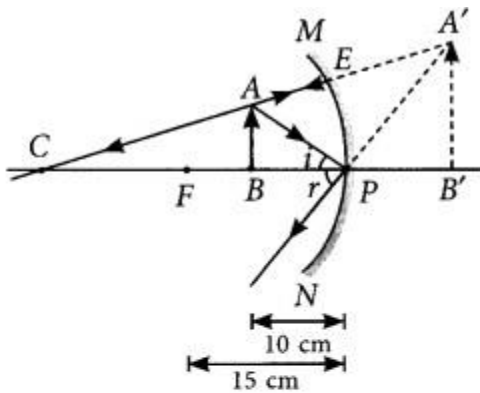
(a) Magnification of -1 implies that size of image is same as that of object or image is formed at the same distance as of the object. This is the case when the object distance,  $u = 2f$ , i.e., when the object is at the centre of the curvature.

For  $f_a$ ,  $u_b$  and for  $f_b$ ,  $u_c$ , we get magnification - 1.

(b) Concave mirror forms virtual, erect and magnified image when the object is between focus and pole of the mirror, i.e., object distance should be less than the focal length of the mirror.

For object distance 10 cm, mirrors of focal length  $f_b = 15 \text{ cm}$  and  $f_c = 20 \text{ cm}$  can be used.

(c)



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Question 52.

A student has focused the image of a candle flame on a white screen using a concave mirror. The situation is as given below:

Length of the flame = 1.5 cm

Focal length of the mirror = 12 cm

Distance of flame from the mirror = 18 cm

If the flame is perpendicular to the principal axis of the mirror, then calculate the following:

(a) Distance of the image from the mirror

(b) Length of the image

If the distance between the mirror and the flame is reduced to 10 cm, then what would be observed on the screen? Draw a ray diagram to justify your answer from this situation. (Fóigein 2015)

Answer:

Given: focal length of the concave mirror,  $f = -12 \text{ cm}$



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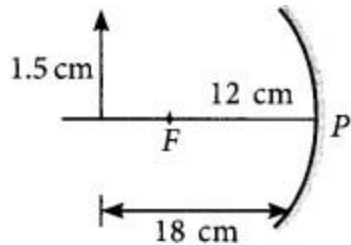


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Length of the flame,  $h = 1.5 \text{ cm}$   
 Distance of flame from the mirror,  $u = -18 \text{ cm}$



(a) As,  $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$

or  $\frac{1}{v} = \frac{1}{f} - \frac{1}{u} = \frac{1}{-12} - \frac{1}{-18} = \frac{-3+2}{36} = \frac{-1}{36}$

or  $v = -36 \text{ cm}$

(b) Let  $h'$  be the length of the image.

$\therefore$  Magnification,  $m = h'/h = -v/u$

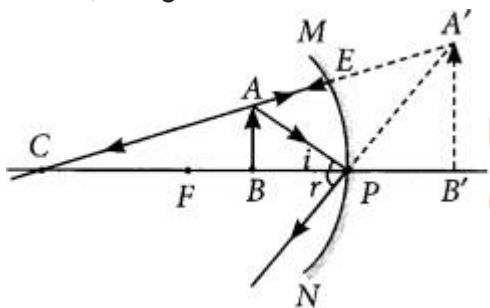
$\therefore h' = -v \times h/u = -(-36) \times 1.5 / -18 = -3 \text{ cm}$

If the distance between the mirror and the flame is reduced to 10 cm, then

$1/v = 1/f - 1/u = 1/-12 - 1/-10 = -1/120$

$\therefore v = -60 \text{ cm}$

Hence, image is formed behind the mirror.



Question 53.

A student wants to project the image of a candle flame on the walls of school laboratory by using a mirror.

(a) Which type of mirror should he use and why?

(b) At what distance in terms of focal length 'f' of the mirror should he place the candle flame so as to get the magnified image on the wall?

(c) Draw a ray diagram to show the formation of image in this case.

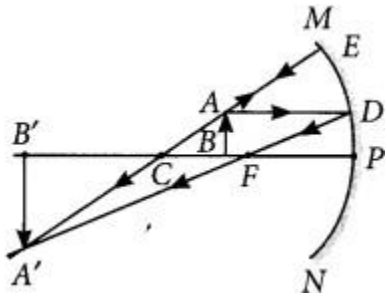
(d) Can he use this mirror to project a diminished image of the candle flame on the same wall? State 'how' if your answer is 'yes' and 'why not' if your answer is 'no' (Delhi 2014)

Answer:

(a) He should use concave mirror to get image of candle flame on the walls of school laboratory. Because concave mirror is a converging mirror and produce real image.

(b) He should place the candle flame in between centre of curvature C and principal focus F of the mirror to get the magnified image on the wall.

(c)



(d) Yes, he can use concave mirror to project a diminished image of the candle flame on the same wall. He has to place the candle flame beyond centre of curvature to get diminished image.

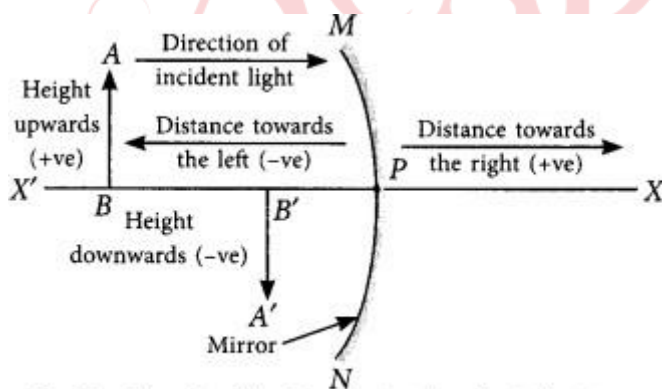
Question 54.

List the sign conventions for reflection of light by spherical mirrors. Draw a diagram and apply these conventions in the determination of focal length of a spherical mirror which forms a three times magnified real image of an object placed 16 cm in front of it. (Delhi 2012)

Answer:

Sign Convention for Reflection by Spherical Mirrors : While dealing with the reflection of light by spherical mirrors, we shall follow a set of sign conventions called the New Cartesian Sign Convention, the conventions are as follows:

- (i) The object is always placed to the left of the mirror. This implies that the light from the object falls on the mirror from the left-hand side.
- (ii) All distances parallel to the principal axis are measured from the pole of the mirror.
- (iii) All the distances measured to the right of the origin (along + x-axis) are taken as positive while those measured to the left of the origin (along - x-axis) are taken as negative.
- (iv) Distances measured perpendicular to and above the principal axis (along +y-axis) are taken as positive.
- (v) Distances measured perpendicular to and below the principal axis (along -y-axis) are taken as negative.



The New Cartesian Sign Convention for spherical mirrors

Given that  $m = -3$  (real image),  $u = -16$  cm

Magnification,  $m = -v/u$



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$$\therefore -3 = \frac{-v}{-16} \quad \text{or} \quad v = -48 \text{ cm}$$

**Mirror formula:**  $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$

$$\therefore \frac{1}{(-48)} + \frac{1}{(-16)} = \frac{1}{f}$$

$$\text{or} \quad \frac{-1-3}{48} = \frac{1}{f} \quad \text{or} \quad \frac{-4}{48} = \frac{1}{f} \quad \text{or} \quad f = -12 \text{ cm}$$

Question 55.

What is meant by power of a lens? (Delhi 2015)

Answer:

Power is the degree of convergence or divergence of light rays achieved by a lens.

It is defined as the reciprocal of its focal length.

i.e.,  $P = 1/f$

Question 56.

An object is placed at a distance of 15 cm from a convex lens of focal length 20 cm. List four characteristics (nature, position, etc.) of the image formed by the lens. (AI2017)

Answer:

Given : Object distance,  $u = -15 \text{ cm}$

Focal length,  $f = +20 \text{ cm}$

Using lens formula, As  $|u| < |f|$

The object is placed between F and optical centre of lens.

Thus, the four characteristics of the image formed by the convex lens are:

- (i) Erect
- (ii) Virtual
- (iii) Enlarged image,
- (iv) Image is formed on the same side of the lens as the object.

Question 65.

What is meant by power of a lens? What does its sign (+ve or -ve) indicate? State its S.I. unit related to focal length of a lens. (Delhi 2016)

Answer:

Refer to answer 57.

Positive sign (+) of power indicates that lens is convex and negative sign (-) of power indicates that lens is concave.

If focal length ( $f$ ) is expressed in metres, then, power is expressed in dioptres. The SI unit of power is dioptre. Thus, 1 dioptre is the power of lens whose focal length is 1 metre.  $1 \text{ D} = 1 \text{ m}^{-1}$

Question 58.

The refractive indices of glass and water with respect to air are  $3/2$  and  $4/3$  respectively. If speed of light in glass is  $2 \times 10^8 \text{ m/s}$ , find the speed of light in water. (AI 2016)

Answer:

$$\text{Given: } n_g = \frac{3}{2}, \quad n_w = \frac{4}{3}$$

Speed of light in glass,  $v = 2 \times 10^8$  m/s

$$\text{We know, } n_g = \frac{\text{speed of light in air}}{\text{speed of light in medium}}$$

$$\Rightarrow \frac{3}{2} = \frac{c}{2 \times 10^8} \Rightarrow c = 3 \times 10^8 \text{ m/s}$$

$$\text{Now, } n_w = \frac{\text{speed of light in air}}{\text{speed of light in water}}$$

$$\Rightarrow \frac{4}{3} = \frac{3 \times 10^8}{v}$$

$$\Rightarrow v = \frac{9}{4} \times 10^8 \text{ m/s} = 2.25 \times 10^8 \text{ m/s}$$

Question 59.

The absolute refractive indices of glass and water are  $\frac{4}{3}$  and  $\frac{3}{2}$  respectively. If the speed of light in glass is  $2 \times 10^8$  m/s, calculate the speed of light in (i) vacuum, (ii) water. (AI 2015)

Answer:

Given that:  $n_g = \frac{4}{3}$ ,  $n_w = \frac{3}{2}$ ,  $v_g = 2 \times 10^8$  m/s

Absolute refractive index of a medium,  $n_m = \frac{c}{v}$

where,  $c$  is the speed of light in vacuum and  $v$  is the speed of light in medium.

$$(i) \quad \therefore n_g = \frac{c}{v_g}$$

$$\text{or } c = n_g \times v_g = \frac{4}{3} \times 2 \times 10^8 = \frac{8}{3} \times 10^8 \text{ m/s}$$

$$(ii) \quad \text{As, } n_{gw} = \frac{n_g}{n_w} = \frac{v_w}{v_g}$$

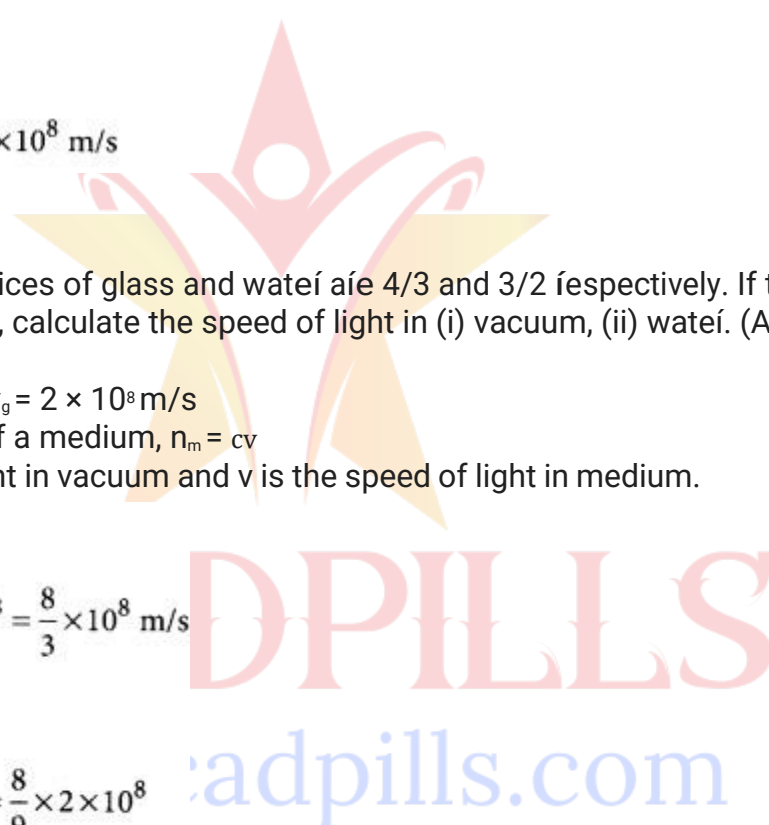
$$\therefore \frac{4/3}{3/2} = \frac{v_w}{2 \times 10^8} \text{ or } v_w = \frac{8}{9} \times 2 \times 10^8$$

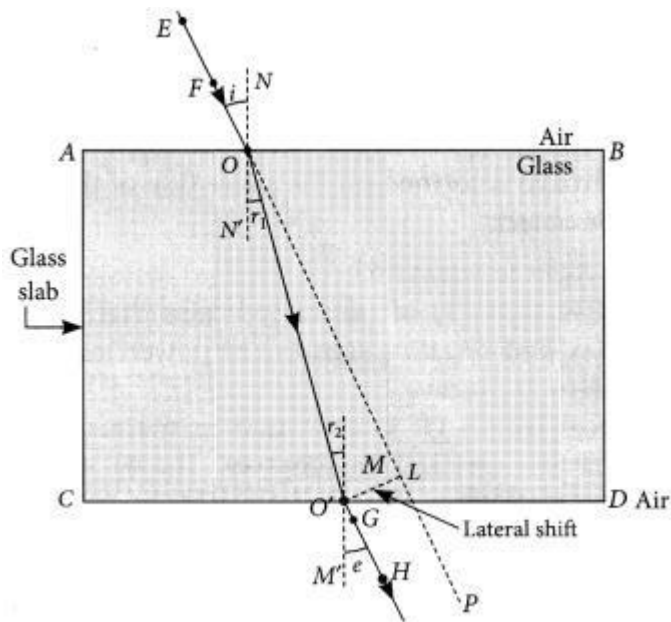
$$\Rightarrow v_w = \frac{16}{9} \times 10^8 \text{ m/s}$$

Note: The values given in question are not correct as the speed of light in vacuum is  $3 \times 10^8$  m/s

Question 60.  
"A ray of light incident on a rectangular glass slab immersed in any medium emerges parallel to itself." Draw labelled ray diagram to justify the statement". (Delhi 2013)

Answer:





Question 61.

The absolute refractive indices of glass and water are 1.5 and 1.33 respectively. In which medium does light travel faster? Calculate the ratio of speeds of light in the two media. (Delhi 2013 C)

Answer:

Given : refractive index of glass,  $n_g = 1.5$

Refractive index of water,  $n_w = 1.33$

Since, refractive index of medium,

$$n = \frac{\text{speed of light in air } (c)}{\text{speed of light in medium } (v)}$$

For glass  $n_g = \frac{c}{v_g}$  ..... (i)

For water  $n_w = \frac{c}{v_w}$  ..... (ii)

Since velocity of light in medium is inversely proportional to its refractive index, the light will travel faster in optically rarer medium i.e., water.

Dividing (i) by (ii),

$$\frac{n_g}{n_w} = \frac{v_w}{v_g} \quad \text{or} \quad \frac{v_g}{v_w} = \frac{n_w}{n_g}$$

$$\frac{v_g}{v_w} = \frac{1.33}{1.5}$$

So, the ratio of  $v_g$  and  $v_w$  is 1.33 : 1.5.

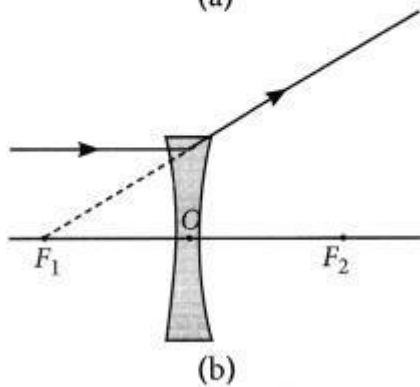
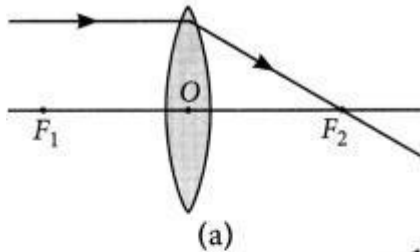
Question 62.

To construct a ray diagram we use two light rays which are so chosen that it is easy to know their directions after refraction from the lens. List these two rays and state the path of these rays after refraction. Use these two rays to locate the image of an object placed between 'f' and '2f' of a convex lens. (Fóieign 2012)

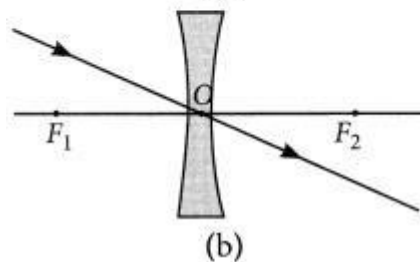
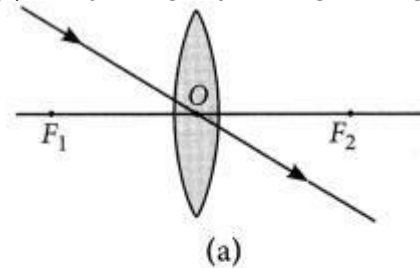
Answer:

The two rays are:

(i) A ray of light from the object, parallel to the principal axis, after refraction from a convex lens, passes through the principal focus on the other side of the lens and in case of concave lens, a ray appears to diverge from the principal focus located on the same side of the lens.

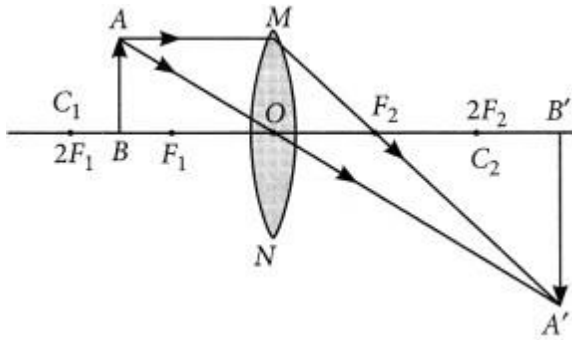


(ii) A ray of light passing through the optical center of a lens will emerge without any deviation.



When object is placed between F and 2F.





Question 63.

(a) Water has refractive index 1.33 and alcohol has refractive index 1.36. Which of the two medium is optically denser? Give reason for your answer.

(b) Draw a ray diagram to show the path of a ray of light passing obliquely from water to alcohol.

(c) State the relationship between angle of incidence and angle of refraction in the above case.

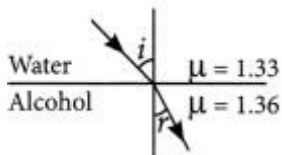
(2020)

Answer:

(a) Here, alcohol is optically denser medium as its refractive index is higher than that of water.

When we compare the two media, the one with higher refractive index is called the optically denser medium than the other as the speed of light is lower in this medium.

(b) Since light is travelling from water (rarer medium) to alcohol (denser medium), it slows down and bends towards the normal.



where  $i$  = angle of incidence and  $r$  = angle of refraction.

(c) According to Snell's law,

$$\sin i \sin r = \mu_{\text{alcohol}} \mu_{\text{water}} = 1.36 \times 1.33 = 1.0225$$

$$\therefore \sin i = 1.0225 \times \sin r$$

Question 64.

The refractive index of a medium 'x' with respect to a medium 'y' is  $\frac{2}{3}$  and the refractive index of medium 'y' with respect to medium 'z' is  $\frac{4}{3}$ . Find the refractive index of medium 'z' with respect to medium 'x'. If the speed of light in medium 'x' is  $3 \times 10^8 \text{ m s}^{-1}$ , calculate the speed of light in medium 'y'. (2020)

Answer:

Given, refractive index of medium x with respect to y,

$${}_y\mu_x = \frac{2}{3}$$

Refractive index of medium y with respect to z,

$${}_z\mu_y = \frac{4}{3}$$

$\therefore$  Refractive index of medium x with respect to z,

$${}_z\mu_x = {}_y\mu_x \cdot {}_z\mu_y = \frac{2}{3} \times \frac{4}{3} = \frac{8}{9}$$

$\therefore$  Refractive index of medium z with respect to x,

$${}_x\mu_z = \frac{1}{{}_z\mu_x} = \frac{9}{8}$$



Now speed of light in x =  $3 \times 10^8$  m/s

Speed of light in y,  $v_y = ?$

$$\therefore \mu_x = \frac{\text{Speed of light in y}}{\text{Speed of light in x}} = \frac{v_y}{3 \times 10^8 \text{ m/s}}$$

$$\Rightarrow v_y = \frac{2}{3} \times 3 \times 10^8 = 2 \times 10^8 \text{ m/s}$$

$$\Rightarrow v_y = 2 \times 3 \times 10^8 = 2 \times 10^8 \text{ m/s}$$

Question 65.

A real image  $\frac{2}{3}$ rd of the size of an object is formed by a convex lens when the object is at a distance of 12 cm from it. Find the focal length of the lens. (AI 2019)

Answer:

Given,  $h' = \frac{2}{3}h$ ,  $u = -12$  cm

$$\text{Magnification, } m = \frac{h'}{h} = \frac{v}{u}$$

$$\Rightarrow v = \frac{h'}{h} \times u = \frac{-\frac{2}{3}h}{h} \times (-12) = 8 \text{ cm}$$

$$\text{Using lens formula, } \frac{1}{v} - \frac{1}{u} = \frac{1}{f}$$

$$\Rightarrow \frac{1}{f} = \frac{1}{8} - \frac{1}{-12} = \frac{3+2}{24} \Rightarrow f = 4.8 \text{ cm}$$

$\therefore$  Focal length of the convex lens = 4.8 cm

Question 66.

State the laws of refraction of light. Explain the term 'absolute refractive index of a medium' and write an expression to relate it with the speed of light in vacuum. (2018)

Answer:

(a) Laws of refraction of light:

- (i) The incident ray, the refracted ray and the normal to the interface of two transparent media at the point of incidence, all lie in the same plane.
- (ii) The ratio of sine of angle of incidence to the sine of the angle of refraction is constant, for the light of a given colour and for the given pair of media.

This law is also known as Snell's law of refraction.

$$\frac{\sin i}{\sin r} = \text{constant},$$

where  $i$  is the angle of incidence and  $r$  is the angle of refraction.

This constant value is called refractive index of the second medium with respect to the first when the light travels from first medium to second medium.

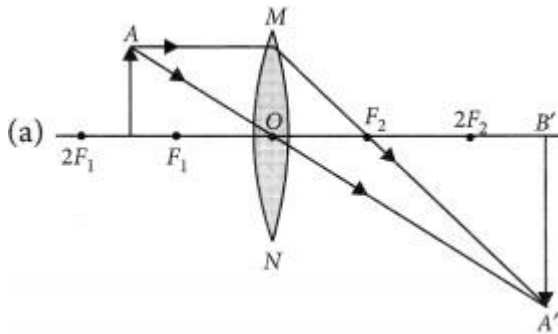
$$\Rightarrow \text{constant} = n_{21} = \frac{v_1}{v_2} \therefore \frac{\sin i}{\sin r} = \frac{v_1}{v_2}$$

If  $n$  is the absolute refractive index of the medium,  $c$  is the velocity of light in vacuum and  $v$  is the speed of light in a given medium, then  $n = \frac{c}{v}$ .

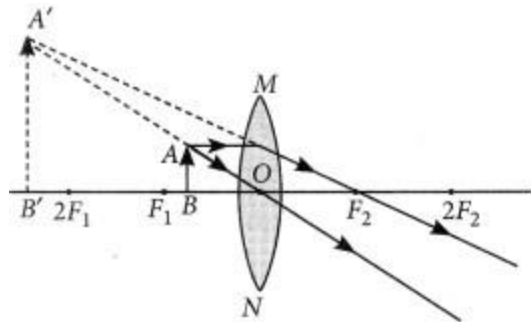
Question 67.

Draw ray diagrams to show the formation of three times magnified (a) real, and (b) virtual image of an object by a converging lens. Mark the positions of O, F and 2F in each diagram. (AI 2017)

Answer:



(b) Ray diagrams of an object placed between  $F_1$  and optical centre  $O$  of lens can be drawn as follows:



- (i) The image formed is virtual and erect.
- (ii) Image is formed in front of the lens.
- (iii) Image formed is enlarged.

Question 68.

(a) Draw a diagram to show the refraction of light through a glass slab and mark angle of refraction and the lateral shift suffered by a ray of light while passing through the slab.

(b) If the refractive index of glass for light going from air to glass is  $3/2$ , find the refractive index of air for light going from glass to air. (Delhi 2016)

Answer:

(a) Refer to answer 68.

(b) Refractive index of glass w.r.t air is 3

$${}_g n_a = 3/2$$

Now, refractive index of air w.r.t glass will be

$${}_a n_g = 1/{}_g n_a = 1/(3/2) = 2/3$$

Question 69.

The image of an object formed by a lens is of magnification  $-1$ . If the distance between the object and its image is 60 cm, what is the focal length of the lens? If the object is moved 20 cm towards the lens, where would the image be formed? State reason and also draw a ray diagram in support of your answer. (AI2016)

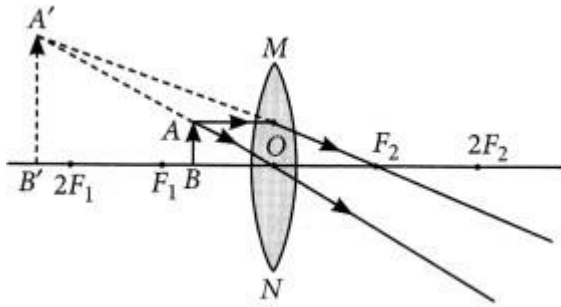
Answer:

Magnification of  $-1$  indicates that the image is real and inverted and is of the same size as of the object. The object must be at  $2f$  and image also at  $2f$  on the other side.

Total distance between image and object

$$\text{Also } 4f = 60 \text{ cm} \Rightarrow f = 15 \text{ cm}$$

If object is moved 20 cm towards the lens, then the object will be between focus and optical centre of the lens and image formed will be virtual and erect and on the same side of the lens.



Question 70.

(a) Define focal length of a spherical lens.

(b) A divergent lens has a focal length of 30 cm. At what distance should an object of height 5 cm from the optical centre of the lens be placed so that its image is formed 15 cm away from the lens? Find the size of the image also.

(c) Draw a ray diagram to show the formation of image in the above situation. (AI 2016)

Answer:

(a) Distance between the optical centre and the focus of the lens is known as the focal length of the lens.

(b) Given  $f = -30$  cm,  $v = -15$  cm,  $h = 5$  cm From the lens formula,

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f} \Rightarrow \frac{-1}{15} - \frac{1}{u} = \frac{-1}{30}$$

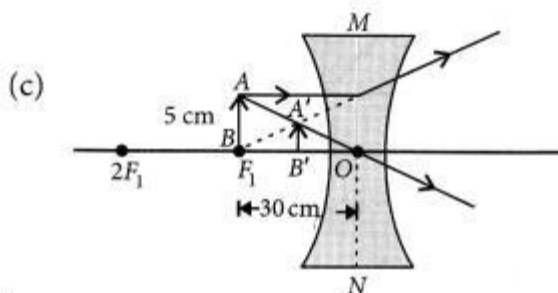
$$\Rightarrow \frac{-1}{u} = \frac{-1}{30} + \frac{1}{15} = \frac{-1+2}{30} = \frac{1}{30} \Rightarrow u = -30 \text{ cm}$$

Object should be placed 30 cm from the optical centre.

Also  $m = h'/h = v/u \Rightarrow h' = h(v/u)$

or  $h' = 5 \times -15/-30 = 2.5$  cm

Size of image formed is 2.5 cm

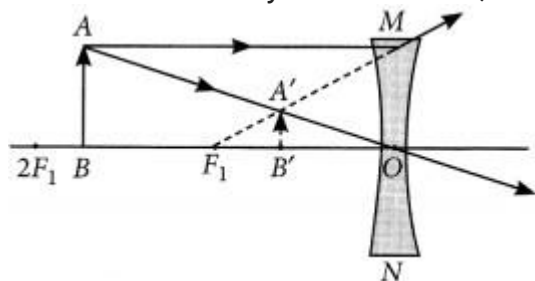


Question 71.

If the image formed by a lens for all positions of the object placed in front of it is always virtual, erect and diminished, state the type of the lens. Draw a ray diagram in support of your answer. If the numerical value of focal length of such a lens is 20 cm, find its power in new cartesian sign conventions. (Foieign 2016)

Answer:

Concave lens always forms virtual, erect and diminished image for all positions of the object.



Focal length of the concave lens

$$f = -20 \text{ cm} = -20100 \text{ m}$$

$$\text{Power of the lens, } P = 1/f(\text{in m}) = -100/20\text{m} = -5\text{D}$$

Question 72.

State the laws of refraction of light. If the speed of light in vacuum is  $3 \times 10^8 \text{ m/s}$ , find the absolute refractive index of a medium in which light travels with a speed of  $1.4 \times 10^8 \text{ m/s}$ . (Foieign 2015)

Answer:

Laws of refraction: Refer to answer 74.

$$\text{The speed of light in vacuum} = 3 \times 10^8 \text{ m/s}$$

$$\text{The speed of light in a medium} = 1.4 \times 10^8 \text{ m/s}$$

∴ Absolute refractive index

$$= \frac{\text{Speed of light in vacuum}}{\text{Speed of light in a medium}}$$

$$n = \frac{3 \times 10^8 \text{ m/s}}{1.4 \times 10^8 \text{ m/s}} = 2.14$$

Question 73.

State the laws of refraction of light. If the speed of light in vacuum is  $3 \times 10^8 \text{ m s}^{-1}$ , find the speed of light in a medium of absolute refractive index 1.5. (Delhi 2014, AI 2014)

Answer:

$$\text{The speed of light in vacuum} = 3 \times 10^8 \text{ m/s}$$

$$\text{Absolute refractive index} = 1.5$$

∴ The speed of light in a medium

$$= \frac{\text{Speed of light in vacuum}}{\text{Absolute refractive index}} = \frac{3 \times 10^8 \text{ m/s}}{1.5}$$

$$= 2 \times 10^8 \text{ m/s}$$

Question 74.

The image of a candle flame placed at a distance of 40 cm from a spherical lens is formed on a screen placed on the other side of the lens at a distance of 40 cm from the lens. Identify the type of lens and write its focal length. What will be the nature of the image formed if the candle flame is shifted 25 cm towards the lens? Draw a ray diagram to justify your answer. (Foieign 2014)

Answer:

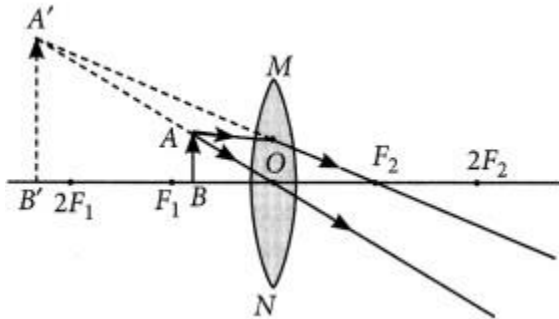
$$\text{Given : } u = -40 \text{ cm, } v = 40 \text{ cm}$$

$$1f = 140 + 140 = 280 \Rightarrow f = 20 \text{ cm}$$

Type of lens : Convex lens

Focal length = 20 cm

Nature of the image will be virtual and erect if the candle flame is shifted 25 cm towards the lens.



Question 75.

An object of height 6 cm is placed perpendicular to the principal axis of a concave lens of focal length 5 cm. Use lens formula to determine the position, size and nature of the image if the distance of the object from the lens is 10 cm. (Delhi 2013)

Answer:

Focal length of given concave lens,  $f = -5 \text{ cm}$

Distance,  $u = -10 \text{ cm}$ , object size,  $h = 6 \text{ cm}$

Image distance,  $v = ?$

Using lens formula,  $1f = 1v - 1u$

$$1/v = 1/f + 1/u = 1/-5 + 1/-10 = -3/10$$

$$v = -10/3 = -3.33 \text{ cm}$$

So, the image is located 3.33 cm from the lens. Magnification ( $m$ ) of lens is given by

$$m = v/u = -10/3 / -10 = 1/3 = 0.33$$

$m$  is positive implies that image is virtual and erect. Also, magnitude of  $m$  is less than one implies that image is diminished.

Since  $m = v/u = h'/h \Rightarrow 1/3 = h'/6$  of  $h' = 2 \text{ cm}$

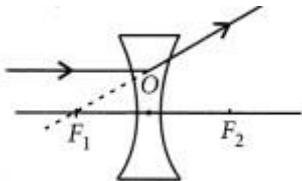
Question 76.

Draw ray diagram to show the path of the refracted ray in each of the following cases. A ray of light incident on a concave lens

(i) is parallel to its principal axis, (ii) is passing through its optical centre and (iii) is directed towards its principal focus. (Delhi 2013 C)

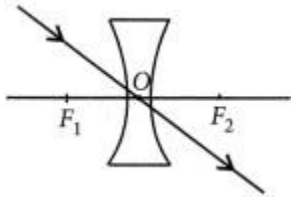
Answer:

(i) A ray of light incident on a concave lens is parallel to its principal axis, the diagram can be drawn as follows:

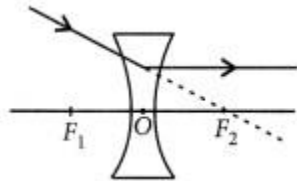


The refracted ray appears to pass through focus on the same side of the lens.

(ii) If a ray of light incident on a concave lens is passing through its optical centre then the refracted ray will go without deviation.



(iii) If a ray of light incident on a concave lens is directed towards its principal axis then it will go parallel to principal axis.



Question 77.

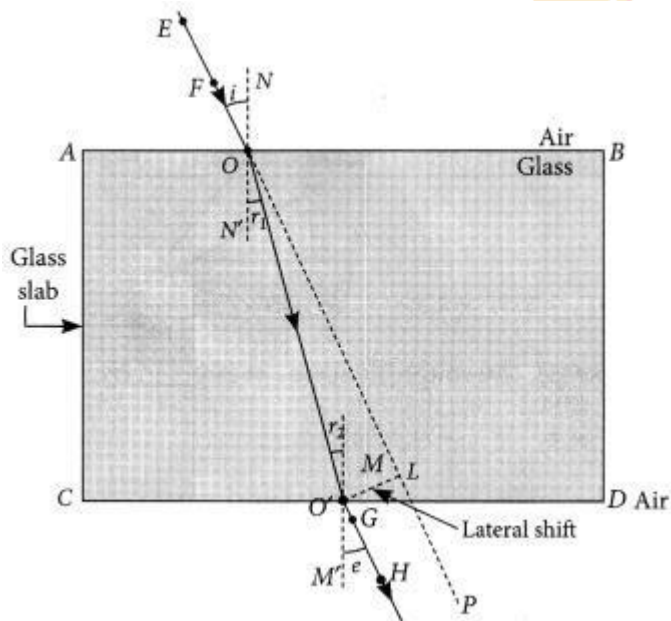
What is the principle of reversibility of light? Show that the incident ray of light is parallel to the emergent ray of light when light falls obliquely on a side of a rectangular glass slab. (AI 2011)

Answer:

Principle of reversibility of light states that the light will follow exactly the same path if the direction is reversed.

Using Snell's law of refraction,  $\frac{\sin i}{\sin r_1} = \frac{\sin e}{\sin r_2}$

Since  $i_1 = i_2$ , so  $i = e$



so PQ is parallel to RS.

So, we conclude that incident ray is parallel to the emergent ray.

Question 78.

Draw a ray diagram in each of the following cases to show the formation of image, when the object is placed:

- (i) between optical centre and principal focus of a convex lens.
- (ii) anywhere in front of a concave lens.

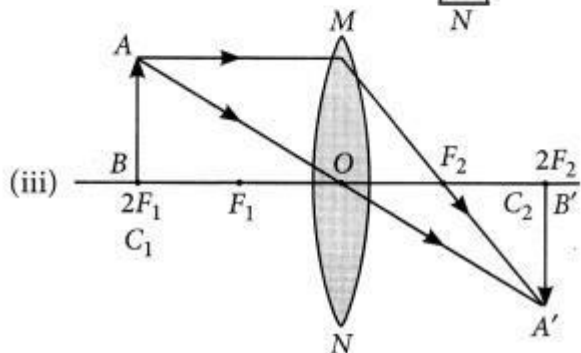
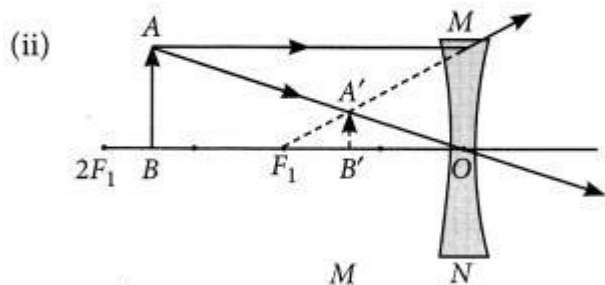
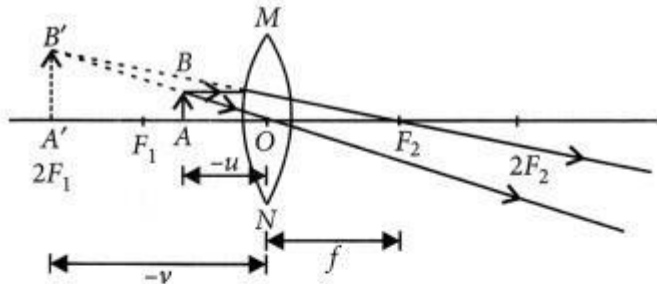
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(iii) at  $2F$  of a convex lens.

State the signs and values of magnifications in the above-mentioned cases (i) and (ii). (2020)

Answer:

(i) When an object is placed between  $F$  and optical centre,  $O$  of a convex lens, it forms a virtual and erect image. The ray diagram for this situation can be drawn as follows:



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In case (i), the magnification,  $m$  is given by,

$$m = v/u = -v/-u = \text{positive}$$

i.e., the image formed is virtual and erect.

In case (ii), the magnification,

$$m = v/u = -v/-u = \text{positive}$$

i.e., the image formed is virtual and erect.

Question 80.

Rishi went to a palmist to show his palm. The palmist used a special lens for this purpose.

(i) State the nature of the lens and reason for its use.

(ii) Where should the palmist place/hold the lens so as to have a real and magnified image of an object?

(iii) If the focal length of this lens is 10 cm, the lens is held at a distance of 5 cm from the palm, use lens formula to find the position and size of the image. (2020)



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Answer:

(i) The lens used here is a convex lens and it is used as a magnifying glass because at close range, i.e., when the object is placed between optical centre and principal focus it forms an enlarged, virtual and erect image of the object.

(ii) When this lens is placed such that the object is between the centre of curvature and the principal focus, the palmist obtains a real and magnified image.

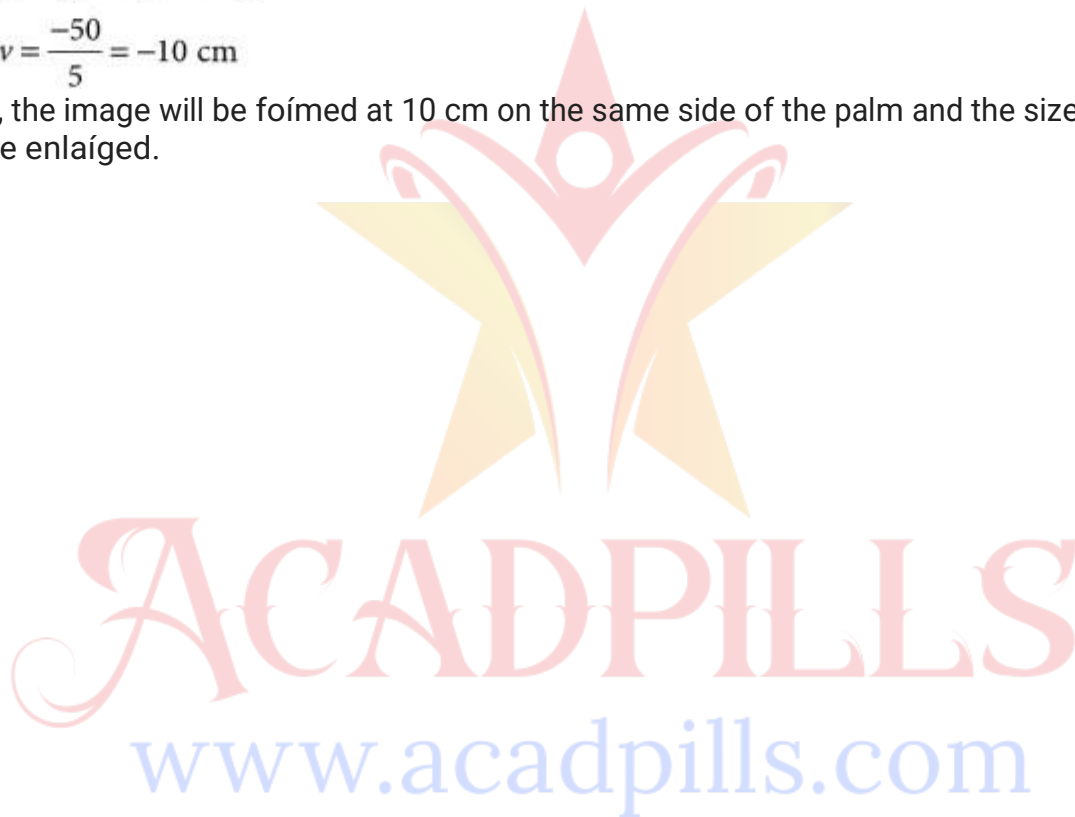
(iii) Given focal length,  $f = 10$  cm and  $u = -5$  cm According to lens formula,

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u} \quad \text{or} \quad \frac{1}{v} = \frac{1}{f} + \frac{1}{u}$$

$$\text{or} \quad \frac{1}{v} = \frac{1}{10} + \frac{1}{-5} = \frac{-5+10}{-50}$$

$$\therefore v = \frac{-50}{5} = -10 \text{ cm}$$

Thus, the image will be formed at 10 cm on the same side of the palm and the size of the image will be enlarged.



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