5. Refraction of Light

Let us assess

1. Question

Refractive indices of different materials are given. Find out through which medium light passes with maximum speed.

Medium	Refractive index
Glass	1.52
Glycerine	1.47
Sunflower oil	1.74
Water	1.33
Flint glass	1.62

Answer

Speed of light is maximum in Water.

The refractive indices of any medium are inversely proportional to the speed of light in it. We can see from the formula of refractive indices:

$$\text{Refractive index (n)} = \frac{\text{Speed of light in vacuum}}{\text{Speed of light in medium}}$$

$$\text{Speed}_{\text{glass}} = \frac{\text{Speed of light in vacuum}}{n_{\text{glass}}} = \frac{\text{Speed of light in vacuum}}{1.52}$$

Similarly, for,

$$\text{Speed}_{\text{glycerine}} = \frac{\text{Speed of light in vacuum}}{1.47}$$

$$\text{Speed}_{\text{sunflower oil}} = \frac{\text{Speed of light in vacuum}}{1.74}$$

$$\text{Speed}_{\text{water}} = \frac{\text{Speed of light in vacuum}}{1.33}$$

$$\text{Speed}_{\text{Flint glass}} = \frac{\text{Speed of light in vacuum}}{1.62}$$

Here we see that,

$$\text{Speed}_{\text{water}} > \text{Speed}_{\text{glycerine}} > \text{Speed}_{\text{glass}} > \text{Speed}_{\text{Flint glass}} > \text{Speed}_{\text{sunflower oil}}$$

We can also say that greater the refractive indices lesser will be speed.

2 A. Question

The nature of images formed by two lenses are given.

(i) An erect and magnified virtual image

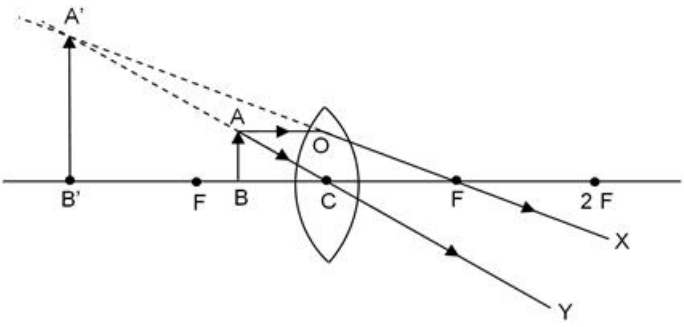
(ii) An erect and diminished virtual image

(a) What type of lens is used in each case?

Answer

i. Convex lens will form erect and magnified virtual image.

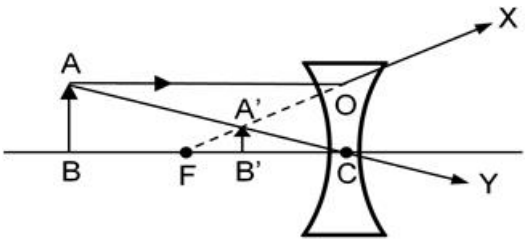
Diagram of convex lens when object is place between the focus F and optical centre C.



Here object is AB and its virtual image is A′B′. Image height is greater than object size (magnified) and image is upright (erect).

ii) Concave lens will form erect and diminished virtual image.

Diagram of concave lens when object is place between the infinity and optical centre C.



Here object is AB and its virtual image is A′B′. Image height is less than object size (diminished) and image is upright (erect).

2 B. Question

The nature of images formed by two lenses are given.

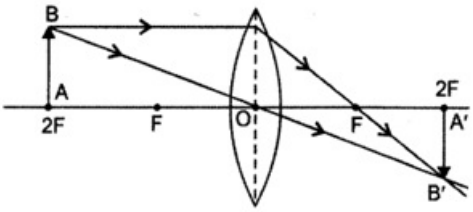
(i) An erect and magnified virtual image

(ii) An erect and diminished virtual image

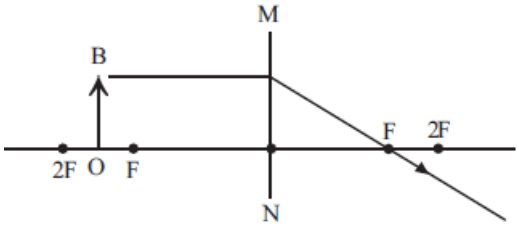
On using which of these lenses will we get an image having the same size as the object? What is the position of the object?

Answer

When the object is placed at 2F in convex lens its image will be same size as the object. Here is the ray diagram:



3. Question



(a) MN represents a lens. What type of lens is this?

(b) What are the characteristics of the image?

(c) Copy the ray diagrams in the science diary and complete it.

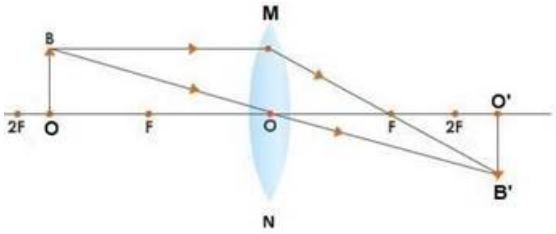
Answer

a) MN is convex lens

As after refraction by the lens (MN) ray converge to focus (F), this only happen with convex lens (converging lens).

b) Image will be larger than object (enlarged), can be taken on the screen (Real) and upside down (inverted).

c) Ray diagram :



Object – OB

Image – O'B'

Image is Enlarged, Real and inverted.

4. Question

What do you mean by power of a lens? What is the SI unit of the power of a lens? Calculate the power of a concave lens of focal length 25 cm.

Answer

Power term related to focal length of a lens. The reciprocal of the focal length of a lens in metres is called the power of the lens.

Its is a capacity of a lens to bend the rays of light. The smaller the focal length, the greater is the bending of a ray of light and vice- versa.

SI unit of power is diopter represented by D

Given:

concave lens of focal length =25 cm

From the formula of power,

$$\text{Power} = \frac{1}{\text{focal length in metre}}$$

Here focal length of concave length is taken as negative.

Therefore concave lens of focal length $= \frac{-25}{100}\text{m}$

$$\text{Power} = \frac{1}{-25/100}\text{D}$$

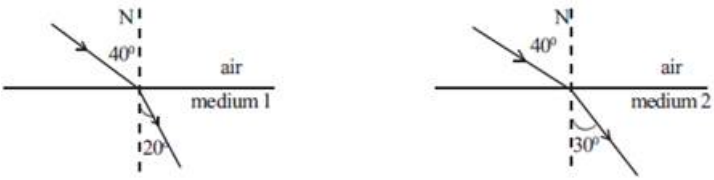
$$= \frac{100}{-25}\text{D}$$

$$= -4\,\text{D}$$

Power of concave lens is: - 4 D

5. Question

Observer the figure. Light falling on two different media are shown.



(a) Which medium has greater optical density?

(b) Why?

(c) Which medium has a greater refractive index?

Answer

(a) Medium 1 has greater optical density .

(b) In both the diagram ray is coming from the same medium i.e. air also angle of incident is same. In first case angle of refraction is 20^0 and in diagram 2^{nd} angle of refraction is 30^0 so derivation of light is more in medium 1 than in medium 2.So more the derivation of light greater the optical density.

(c) Medium 1 has greater index than medium 2.

Optical density of a medium 1 is greater than medium 2 so the speed of light in medium 1 will be slower than the speed of light in medium 2. Slower the speed indicates more the value of refractive index.

Many students get confused in optical density and physical density here optical density mean how fast or how slow light propagates through a medium where as physical density means how much lighter or heavier the object is when measuring with respect to water.

6 A. Question

An object of height 3 cm is placed in front of a convex lens of focal length 10 cm at a distance of 15 cm.

What is the distance of the image formed?

Answer

Given-

Lens using: convex

The height of object: 3cm

The focal length of lens: 10cm

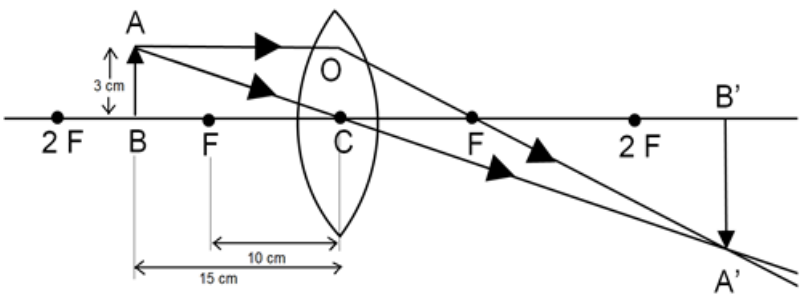
The object is placed at 15 cm from the optical center

The formula of the lens:

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

So, let suppose image is formed at a distance of v cm from the optical center

Ray diagram will look something like this:



Here (from sign convention direction of incident light is left to right)

AB = object = +3cm (upward direction from x-axis)

CF = focal length = 10 cm (direction is C to F (right side) i.e. left to right same as direction of incident light)

CB = u = - 15 cm (direction is C to B i.e. right to left opposite to incident light direction)

So, let the distance of image will be v cm,

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

So $v = \frac{(-15)\times(10)}{(-15)+(10)}$

$$v = \frac{-150}{-5}$$

$$v = 30\ \text{cm}$$

Here we see that v is positive so image will be formed in right side of lens (C'B')

6 B. Question

An object of height 3 cm is placed in front of a convex lens of focal length 10 cm at a distance of 15 cm.

What is the nature of the image?

Answer

Nature of the image is real (can be taken on a screen) , inverted (upside down)and Enlarged (large than object size) .

6 C. Question

An object of height 3 cm is placed in front of a convex lens of focal length 10 cm at a distance of 15 cm.

What is the height of the image?

Answer

From the formula of magnification

$$\text{Magnification} = \frac{\text{Height of image } (h_i)}{\text{Height of object } (h_o)} = \frac{v}{u}$$

So, Height of image (h_i) = $\frac{v}{u} \times$ Height of object (h_o)

Here height of object h_o is: + 3 cm

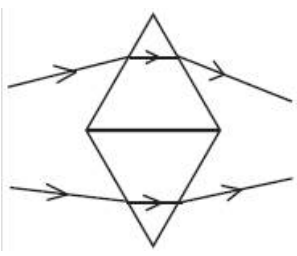
Height of image (h_i) = $\frac{30}{-15} \times 3$

Height of image (h_i) = $-6\ \text{cm}$

Extended activities

1. Question

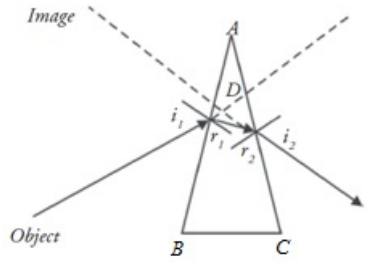
Observe the refraction taking place when two prisms are kept together. Analysing the figure, prove that lens is a combination of prisms.



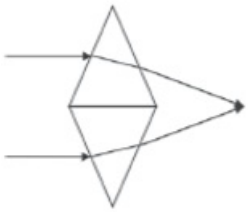
Answer

A prism is a transparent triangular piece of glass. It consists with plane (flat) refracting sides, an apex (top

point) and a base (bottom). A ray of light incident to a prism is always bent towards the base of the prism. Here is light from the object bend toward the base of prism (AB).

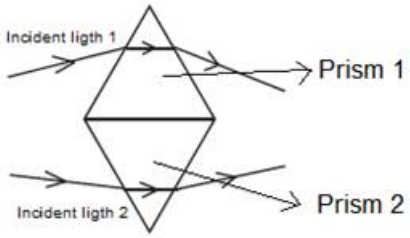


So let consider two prisms placed base to base. Light rays through them coverage (come together) at some point on the other side of the prism. Look here -



In most of the cases, curved surface lenses are spherical (part of a sphere) and such lenses are called spherical lenses. This type of lens is also called plus lens.

Here is a complete ray diagram of two prism

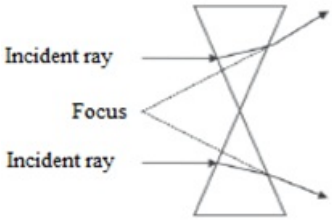


We assume incident light 1 and 2 are coming from infinity so in the diagram both the ray was seen to convergent at a particular point. This is same as in convex lens i.e. when a ray of light from infinity strike to the lens converge at a point called focus. The same thing is happening here also so when these two prisms joint together and made thinner then this will act as a convex lens.

Additional Information:

To make concave lens we have to join two prisms from its apex.

Look here:-



As when incident ray falls to one of the side of prism it bend toward the base of a prism, making light to diverge (spread apart) on the other side of the prism. This type of lens is also called minus lens.