Supplementary Textual Material

in

Physics

for

Class XII

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UNIT - VI

COMBINATION OF A LENS AND A MIRROR

Consider a coaxial arrangement of a lens and a mirror. Let an object be placed in front of the lens. The incident rays, from the object, first undergo refraction at lens and are then incident on the mirror. To obtain the position of the image due to the combination, we can proceed as follows :

Using refraction formula, we can calculate where the image would have been formed, had there been only the lens. We next take this image formed, as a real, (or virtual), object for the mirror. Using the mirror formula, we can then locate the position of its final image formed by the mirror. This final position, would be the position of the image due to the combined effect of refraction by the lens and reflection by the mirror. This procedure is illustrated through the following examples.

Example 1 : A convex lens, of focal length 20cm, has a point object placed on its principle axis at distance of 40cm from it. A plane mirror is placed 30cm behind the convex lens. Locate the position of image formed by this combination.

Solution :

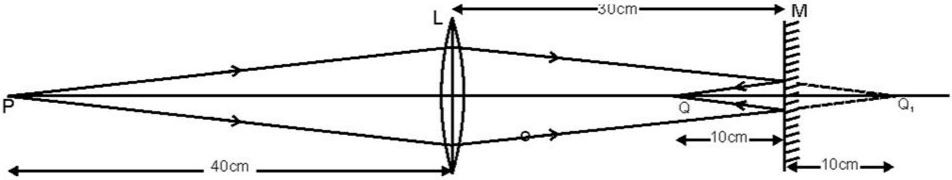


Figure (i)

We first consider the effect of the lens. For the lens, we have

u = -40cm and f = +20cm

Using the lens formula, we get

$$\frac{1}{\vartheta}-\frac{1}{(-40)}=\frac{1}{20} \therefore \vartheta=+40\text{cm}$$

Had there been the lens only the image would have been formed at Q_1. The plane mirror M is at a distance of 30cm from the lens L. We can, therefore, think of a Q_1 as a **virtual object,** located at a distance of 10cm, behind the plane mirror M. The plane mirror therefore forms a **real image** (of this virtual object Q_1) at Q, 10cm in front of it. This is show in the Figure (i)

Example 2 : A convex lens is placed in contact with a plane mirror. An axial point object, at a distance of 20cm from this combination, has its image coinciding with itself. What is the focal length of the convex lens?

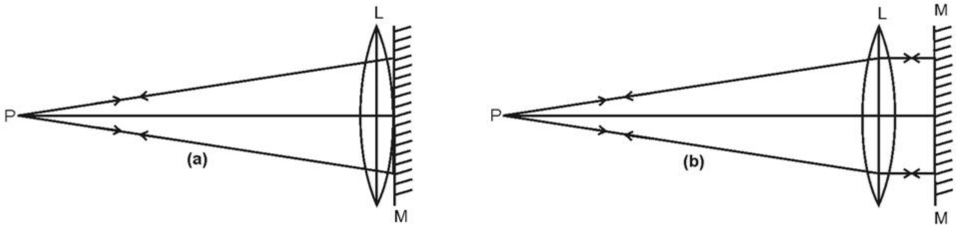


Figure (ii)

Solution :

Figure (ii) (a) shows a convex lens L in contact with a plane mirror M. P is the point object, kept in front of this combination at a distance of 20cm, from it. Since the image of the object is coinciding with the object itself, the rays from the object, after refraction from the lens, should fall **normally** on the mirror M, so that they retrace their path and form an image coinciding with the object itself. This will be so, if the incident rays from P form a **parallel** beam perpendicular to M, after refraction from the lens. For clarity, M has been shown at a finite distance from L, in figure (ii) (b). For lens L, since the rays from P, form a parallel beam after refraction, P must be at the focus of the lens. Hence focal length of the lens is 20cm.

Example 3 : A convex lens, and a convex mirror, (of radius of curvature 20cm) are placed co-axially with the convex mirror placed at a distance of 30cm from the lens. For a point object, at a distance of 25cm from the lens, the final image; due to this combination, coincides with the object itself. What is the focal length of the convex lens?

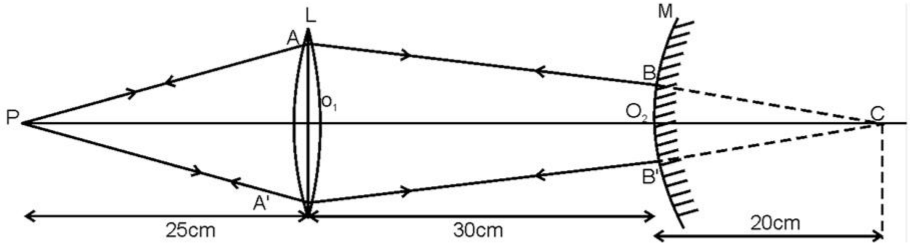


Figure (iii)

Solution:

The final image, formed by the combination, is coinciding with the object itself. This implies that the rays, from the object, are retracing their path, after refraction from the lens and reflection from the mirror. The (refracted) rays are, therefore, falling normally on the mirror.

It follows that the rays A B, and A' B', when produced, are meeting at the centre of curvature, C of the mirror. Hence O_2C = 20cm, the radius of curvature of the mirror.

From the figure (iii), we then see that for the convex lens u = -25cm and ϑ = +(30+20)cm = +50cm. If f is the focal length of the lens, we have

$$\frac{1}{50} - \frac{1}{(-25)} = \frac{1}{f}$$

$$\therefore \frac{1}{f} = \frac{1+2}{50}$$

$$\therefore f = \frac{50}{3} \text{cm} = 16.67\text{cm}$$

Example 4 : A convex lens, of focal length 20cm, is placed co-axially with a convex mirror of radius of curvature 20cm. The two are kept 15cm apart from each other. A point object is placed 60cm in front of the convex lens. Find the position of the image formed by this combination.

Solution: The ray diagram, for the image formed by the combination, is shown below in Figure.(iv)

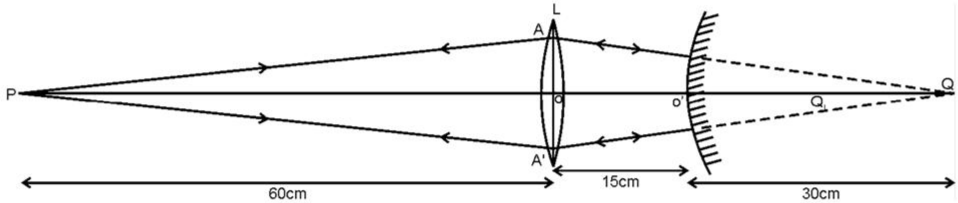


Figure (iv)

For the convex lens, we have

u_1 = -60cm and f = +20cm

Hence, using the lens formula, we get

$$\frac{1}{\vartheta_1} - \frac{1}{(-60)} = \frac{1}{20}$$

$$\therefore \frac{1}{\vartheta_1} = \frac{1}{20} - \frac{1}{60}$$

$$\therefore \vartheta_1 = 30\text{cm}$$

Had there been only the lens L, the image of P would have been formed at Q_1 which acts as a **virtual object** for the convex mirror.

$\therefore$ $O'Q_1$ = distance of this virtual object (Q_1) from convex mirror = OQ_1 – $O'Q_1$ = (30-15)cm = 15cm

Hence for the convex mirror,

u_2= +15cm and R =+20cm,

Using the mirror formula, we get

$$\frac{1}{\vartheta_2} + \frac{1}{u_2} = \frac{2}{R},$$

$$\text{i.e,} \frac{1}{\vartheta_2} + \frac{1}{15} = \frac{2}{20}$$

$$\therefore \frac{1}{\vartheta_2} = \frac{1}{10} - \frac{1}{15}$$

$$\therefore \vartheta_2 = +30\text{cm}$$

Hence the final image (Q) formed is a virtual image formed at a distance of 30cm behind the convex mirror.

Example 5 : A convex lens, of focal length 20cm, and a concave mirror, of focal length 10cm, are placed co-axially 50cm apart from each other. An incident beam parallel to its principal axis, is incident on the convex lens. Locate the position of the (final) image formed due to this combination.

Solution : The incident beam, on lens L, is parallel to its principal axis. Hence the lens forms an image Q_1 at its focal point, i. e, at a distance O Q_1 (=20cm) from the lens. This image, Q_1, now acts as a real object for the concave mirror. For the mirror, we then have: u = -30cm, and f = -10cm,

Hence using mirror formula, we get

$$\frac{1}{\vartheta} + \frac{1}{(-30)} = \frac{1}{(-10)}$$

$$\therefore \frac{1}{\vartheta} = \frac{1}{30} - \frac{1}{10}$$

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

The lens – mirror combination, therefore, forms a real image Q at a distance of 15cm from M. The ray diagram is as shown in figure (v) below.

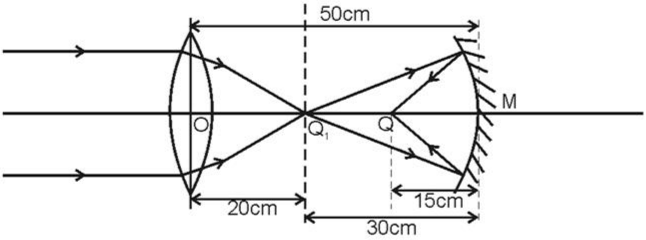


Figure (v)

EXERCISES

1. A point object is placed 60cm in front of a convex lens of focal length 30cm.

   A plane mirror is placed 10cm behind the convex lens. Where is the image formed by this system?

[Ans. At the optical center of the convex lens.]

2. A convex lens, of focal length 15cm, and a concave mirror, of radius of curvature 20cm, are placed co-axially 10cm apart. An object is placed in front of the convex lens so that there is no parallax between the object and its image formed by the combination. Find the position of the object.

[Ans. At a distance of 30cm from the lens]

3. Figure. (vi) show a plane mirror M placed at a distance of 10cm from a concave lens L. A point object is placed at a distance of 60cm from the lens. The image formed, due to refraction by the lens and reflection by the mirror, is 30cm behind the mirror. What is the focal length of this lens?

[Ans. - 30cm]

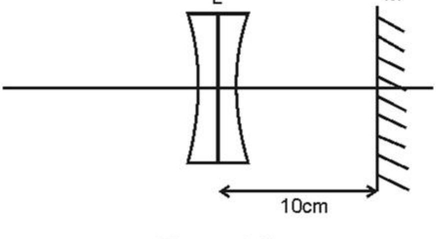


Figure (vi)

UNIT – IX

THE I-V CHARACTERISTICS OF A LIGHT EMITTING DIODE (LED)

The light emitting diode, represented by either of the two symbols shown here, is basically the same as a conventional p-n junction diode. Its actual shape is also shown here. The shorter, of its two leads, corresponds to its n **(or cathode side)** while the longer lead corresponds to its p **(or anode side).**

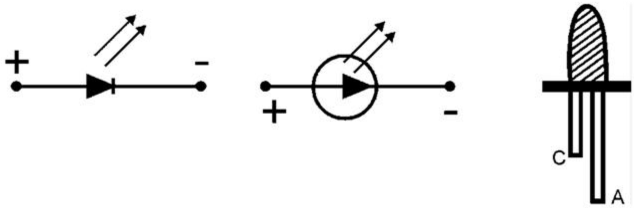
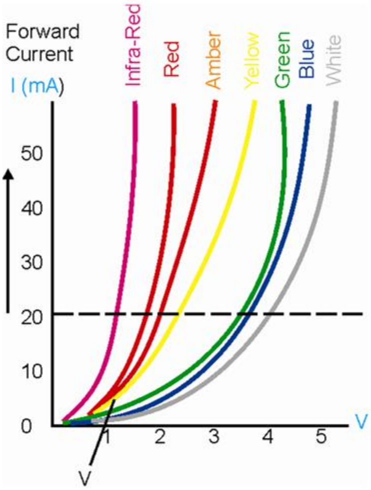


Figure : (i)

LED Symbol and Shape

The general shape, of the I-V characteristics of a LED, is similar to that of a conventional, p-n junction diode. However, the ‘barrier potential’ changes slightly with the colour.

The colour of the light emitted, by a given LED, depends on its band-gap energy. The energy of the photons emitted, is equal to (or slightly) less than this band gap energy. The other main characteristic, of the emitted light, its intensity, is determined by the forward current conducted by the junction.



LED's usually use a low voltage D C supply for their operation. A given LED has a 'safe value' of the forward current that it can carry. This value is around 5mA for the usual simple LED's and can go up to 30 mA, or more, for LED's needed for providing a high brightness output light. In practice, it is usual to have a (suitable) series resistor, connected to the LED, so that the forward current is limited to within its 'safe value'.