15. Light Energy

- Light is the form of energy which makes the objects visible to us. When light reaches from object to our eyes, it becomes visible to us.
- Reflection, refraction and dispersion are the important properties of light.
- In reflection the angle of incidence is equal to the angle of reflection and the frequency, speed and wavelength of light remain unchanged.
- In refraction, the ratio of the speed of light in one medium to another medium remains constant and called refractive index. Refractive index of medium 2 with respect to medium 1,

$$n_{12} = \frac{\text{speed of light in medium 1}}{\text{speed of light in medium 2}}$$

- The refractive index is also measured as the ratio of sine of angle of incidence to sine of angle of refraction, i.e., $n = \frac{\sin i}{\sin r}$
- For spherical mirror, the focal length of the mirror is half of the radius of curvature. The focal length (f), object distance (u) and image distance (v) for the mirror are related as

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

This relation is called mirror formula.

- The distances referred to here are always measured from the pole. The distances measure in the direction of incident ray are taken as positive and in opposite direction of incident ray are taken as negative.
- In plane mirror virtual image of same size as object is formed behind the mirror at a distance equal to the distance of the object from the mirror.
- The number of images of an object placed between two plane mirrors inclined at an angle θ,

$$n = \left(\frac{360°}{\theta} - 1\right), \text{ if } \left(\frac{360°}{\theta}\right) \text{ is even integer}$$

and $$n = \left(\frac{360°}{\theta}\right), \text{ if } \left(\frac{360°}{\theta}\right) \text{ is odd integer}$$

- Due to reflection in plane mirror left handedness is changed into right handedness and vice-versa. This is known as lateral inversion. However, the mirror does not invert vertically up and down.
- In refraction the image formed appears little closer as compared to the distance of real object such that

$$\text{apparent depth} = \frac{\text{Real depth}}{\text{Refractive index}}.$$

- The focal length of lens (f), the distance of object (u) and distance of image (v) from the lens are related as:

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

This relation is called lens formula.

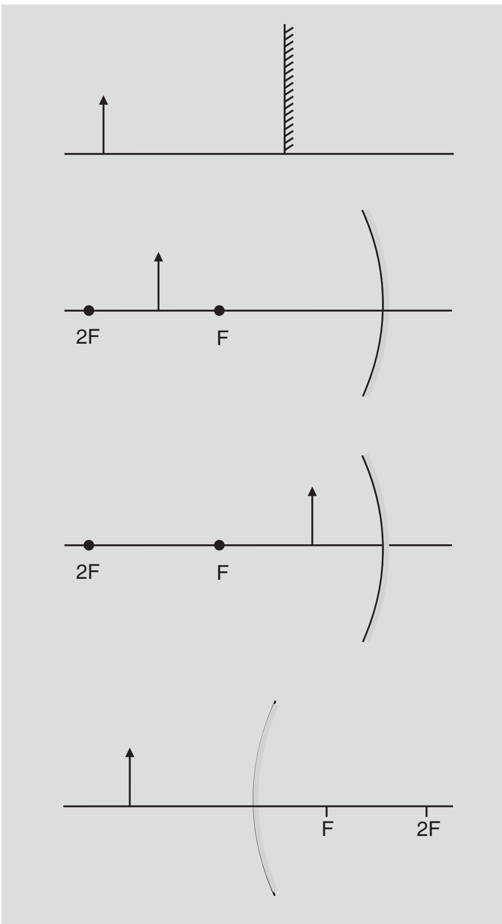
- When light passes through a prim it splits into its constituents colours. This phenomenon is called dispersion of light.
- The rainbow is the consequence of dispersion of light.
- A person who can see distant objects and not able to see the nearby objects is suffering from hyper metropia or long-sightedness. This defect of vision can be corrected by using convex lens.
- A person who can see the nearby objects and not able to see the distant objects is suffering from myopia or short-sightedness. This defect of vision can be removed by using concave lens.
- The least distance of distinct vision for normal human eye is 25 cm and far distance is infinity.

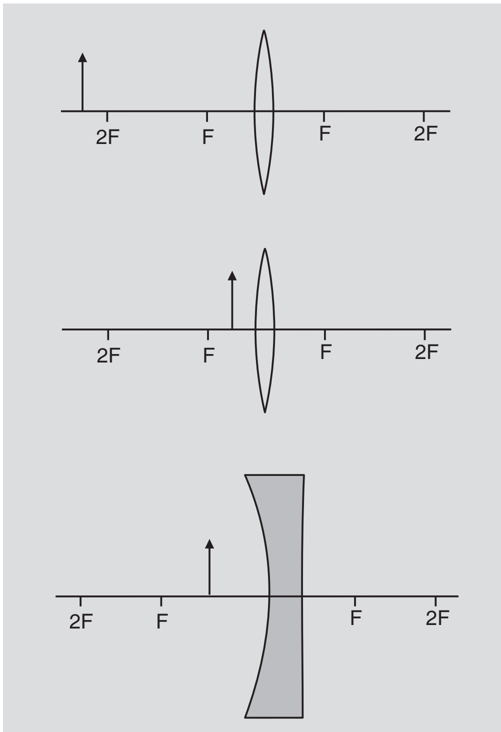
- The nature and position of image formed is given in the table.

	u	v	*nature*
For concave mirror/ Convex lens	$= f$ $> f < 2f$ $= 2f$ $> 2f$ ∞	∞ $> 2f$ $2f$ $< 2f > f$ f	Highly enlarged, real, inverted enlarged, real, inverted same size, real, inverted smaller, real, inverted highly diminished, real, inverted.
Convex mirror	Any value $< f$	Behind the mirror	Smaller, virtual and erect
Concave lens	Any value $< f$	On same side	Virtual, smaller and erect
Convex lens/ Concave miroor	$< f$	On same side/ Behind the mirror	Virtual, larger and erect

Build your Understanding

- Complete the ray diagrams for the formation of image.





- An object is placed at a distance of 30 cm from a convex lens of focal length 20 cm. Find the position and nature of the image.

Sol. For convex lens,

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

$$\frac{1}{20} = \frac{1}{v} - \frac{1}{-30}$$

or $$\frac{1}{v} = \frac{1}{20} - \frac{1}{30} = \frac{3-2}{60} = \frac{1}{60}$$

or $v = 60$ cm.

Image will be enlarged, real and erect.

- The size of the image formed by a concave mirror of focal length 12 cm is double of the size of the object. Find the position of the object.

For concave mirror,

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

$$\frac{I}{O} = -\frac{v}{u}$$

$$\Rightarrow \quad -\frac{v}{u} = 2$$

$$v = -2u$$

For real image v is negative

$\therefore \quad v = -(-2u) = 2u$

applying mirror formula

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

$$\frac{1}{-12} = \frac{1}{2u} + \frac{1}{u} = \frac{3}{2u}$$

$$\Rightarrow \quad u = -\frac{12 \times 3}{2} = -18 \text{ cm}$$

(in front of the mirror)

For virtual image

v is positive

$\therefore \quad v = +(-2u)$

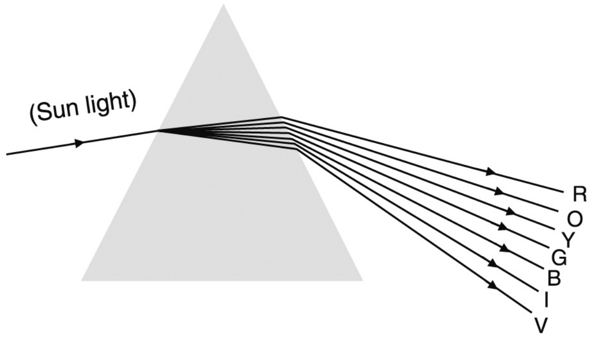
$$\therefore \quad \frac{1}{-12} = \frac{1}{-2u} + \frac{1}{u}$$

or, $$\frac{1}{-12} = \frac{+1-2}{-2u} = +\frac{1}{2u}$$

$\Rightarrow \quad u = -6$ cm (in front of the mirror)

- A fine beam of Sun light is incidents on one face of the prism. Draw the emergent rays and name the colours in the emergent beam in sequence.

Sol:



Changes During Refraction

- When light goes from rarer medium to denser medium its speed decreases due to which its wavelength decreases but the frequency remains constant, hence there is no change in colour. Colour is the function of frequency not of wavelength.

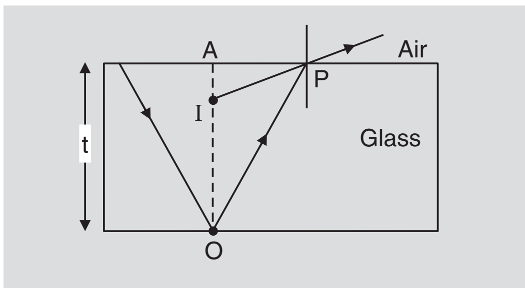
  For normal incidence, $i = r = 0$ but $n \neq 0$,

$$n = \frac{C_1}{C_2} = \frac{\lambda_1}{\lambda_2}$$

- Refractive index of glass

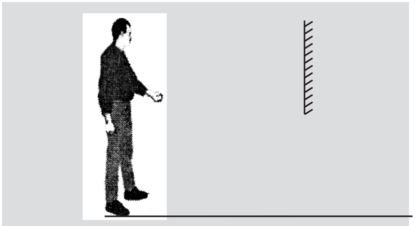
$$n = \frac{t}{AI}$$

or the apparent depth, $AI = \dfrac{t}{n} = \dfrac{\text{Real depth}}{\text{refractive index}}$

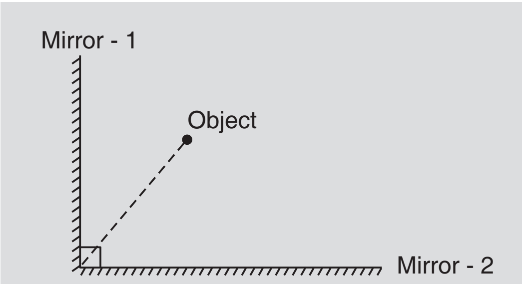


✔ Maximise Your Marks

- Draw the ray diagram for compete image formation and write the relation between the height of the object and mirror reqired.



- Draw ray diagram to show the formation of maximum number of images from the following arrangemtns of the mirrors.



★ Stretch Yourself

1. A plane mirror moves with velocity v toward a stationary object. What is the velocity of the image with respect to the object.
2. The distance between object and image is 40 cm. What is the position of the convex lens so that the size of the image and object are equal. Also write the value of focal length of the lens.
3. Does the colour of the image formed by convex lens depend upon the refractive index of the material of the lens?
4. Name the lens in which larger virtual image is formed.
5. Name the lens in which small and virtual image is formed.
6. Can a concave mirror form a virtual image? Mention the condition.

? Test Yourself

1. Find the value of v and write the nature of image in the given table

	u	*v*	*Nature of the image*
Convex lens of focal length 24 cm	16 cm 36 cm	....	....
Convex mirror of focal length 12 cm	18 cm 24 cm 8 cm	....	....
Concave lens of focal length 20 cm	40 cm 10 cm	....	....
Concave mirror of focal length 20 cm	15 cm 40 cm 60 cm	....	....

2. Mention the conditions of regular and diffused reflection.
3. Why does light split into its constituents colours when passed through a prism.
4. Explain:
   (i) In refraction of lenses if sides of the lens changes, there is no change in the focal length of the lens.
   (ii) When lens is placed in medium of refractive index greater than its material, it will behave as if it is of opposite nature, compared to what it behaves as when placed in a medium of lesser refractive index.
   (iii) In convex mirror and concave lens image formed is always virtual.
5. Can we take a photograph of virtual image?
6. In prism red colour light deviate least and violet colour light deviates most. Why?
7. Long-sightedness can be removed using convex lens and short-sightedness can be corrected removed by using concave lens. How?