CH # 14 REFRACTION OF LIGHT AND OPTICAL INSTRUMENTS

Some important formulae:

$$\mu = \frac{Speed\ of\ light\ in\ air}{Speed\ of\ light\ in\ medium}$$

$$\mu = \frac{Sin\angle i}{Sin\angle r}$$

$$i)\ \frac{1}{f} = \frac{1}{P} + \frac{1}{q} \qquad ii)\ M = \frac{q}{P} = \frac{hi}{ho} \qquad iii) f = \frac{R}{2}$$

Nature of image:
If 'q' is +ve image will be REAL.
If 'q' is –ve image will be VIRTUAL.

Nature of lens:
If 'f' is +ve given lens is CONVEX.
If 'f' is –ve given lens is CONCAVE.

14.1: Calculate the speed of light in glycerin if its index of refraction is 1.47.

GIVEN:
Refractive index of glycerin = μ = 1.47
Speed of light in vacuum = c = 3 x 10^8m/s

REQUIRED:
Speed of light in glycerin = V = ?

SOLUTION:

$$\text{Refractive index} = \frac{Speed\ of\ light\ in\ vacuum}{speed\ of\ light\ in\ glycerin}$$

$$1.47 = \frac{3 \times 10^8}{\text{V}}$$

V = 3 x 10^8 x 1.47

V = 2.04 x 10^8 m/s

14.2: The speed of light in water is 2.25 x 10^5Km/s. What is the index of refraction of water.

GIVEN:
Speed of light in water = v = 2.25 x 10^5 Km/s = 2.25 x 10^5 x 10^3 = 2.25 x 10^8 m/s
Speed of light in vacuum = c = 3 x 10^8m/s

REQUIRED:
Refractive index of water = μ = ?

SOLUTION:

$$\text{Refractive index} = \frac{Speed\ of\ light\ in\ vacuum}{speed\ of\ light\ in\ water}$$

$$\mu = \frac{3 \times 10^8}{2.25 \times 10^8}$$

μ = 1.33

14.3: Light travels from air into water whose index of refraction is 1.33 if the angle of incidence is 40 ^{0} what is the angle of refraction?

GIVEN:

Refractive index of water = μ = 1.33

Angle of incidence = $\angle$i = 40^0

REQUIRED:
Angle of refraction = $\angle$r = ?

SOLUTION:

$$\text{Refractive index} = \frac{Sin\ \angle \text{i}}{Sin\ \angle \text{r}}$$

$$1.33 = \frac{Sin\ 40^0}{Sin\ \angle \text{r}}$$

$$Sin\ \angle \text{r} = \frac{Sin\ 40^0}{1.33}$$

$$Sin\ \angle \text{r} = \frac{0.642}{1.33}$$

$$Sin\ \angle \text{r} = 0.4832$$

$$\angle \text{r} = Sin^{-1}(0.4832)$$

$$\angle \text{r} = 28.9^0$$

14.4: The focal length of convex lens is 10cm. Where an object should be placed to get (a) real image (b) Virtual image twice the size of the object?

GIVEN:

Focal length = f = 10cm
Magnification = M = 2

REQUIRED:
a) Object distance for real image = P = ?
b) Object distance for virtual image = P = ?

SOLUTION:

$$\text{Magnification} = \text{M} = \frac{\text{q}}{\text{P}}$$

$$\text{M} = \frac{\text{q}}{\text{P}}$$

$$2 = \frac{\text{q}}{\text{P}}$$

2P = q

a) For real image q = 2P,
By using lens formula,

$$\frac{1}{\text{f}} = \frac{1}{\text{P}} + \frac{1}{\text{q}}$$

$$\frac{1}{10} = \frac{1}{\text{P}} + \frac{1}{2\text{P}}$$

$$\frac{1}{10} = \frac{2+1}{2\text{P}}$$

$$\frac{1}{10} = \frac{3}{2\text{P}}$$

2P = 3 x 10

2P = 30

$$P = \frac{30}{2}$$

P = 15cm

a) For virtual image q = –2P,
By using lens formula,

$$\frac{1}{\text{f}} = \frac{1}{\text{P}} + \frac{1}{\text{q}}$$

$$\frac{1}{10} = \frac{1}{\text{P}} + \frac{1}{(-2\text{P})}$$

$$\frac{1}{10} = \frac{1}{\text{P}} - \frac{1}{2\text{P}}$$

$$\frac{1}{10} = \frac{2-1}{2\text{P}}$$

$$\frac{1}{10} = \frac{1}{2\text{P}}$$

2P = 1 x 10

2P = 10

$$P = \frac{10}{2}$$

P = 5cm

14.5: Find the focal length of convex lens if :

a) P = 5cm, q = 10cm and image is virtual.

b) P = 30cm, q = 10cm and image is real.

GIVEN:
a) Image distance = P = 5cm
Object distance = q = –10cm (Virtual image)

REQUIRED:
f = ?

GIVEN:
b) Image distance = P = 30cm
Object distance = q = 10cm

REQUIRED:
f = ?

SOLUTION:

a) $$\frac{1}{\text{f}} = \frac{1}{\text{P}} + \frac{1}{\text{q}}$$

$$\frac{1}{\text{f}} = \frac{1}{5} + \frac{1}{(-10)}$$

$$\frac{1}{\text{f}} = \frac{1}{5} - \frac{1}{10}$$

$$\frac{1}{\text{f}} = \frac{2-1}{10}$$

$$\frac{1}{\text{f}} = \frac{1}{10}$$

f = 10cm

b) $$\frac{1}{\text{f}} = \frac{1}{\text{P}} + \frac{1}{\text{q}}$$

$$\frac{1}{\text{f}} = \frac{1}{30} + \frac{1}{10}$$

$$\frac{1}{\text{f}} = \frac{1+3}{30}$$

$$\frac{1}{\text{f}} = \frac{4}{30}$$

$$\text{f} = \frac{30}{4}$$

f = 7.5 cm

14.6: The focal length of convex lens is 1m and an object is placed at a distance of 2m before it. Determine the position, nature and magnification of the image.

GIVEN:
Focal length = f = 1m

Object distance = P = 2m

REQUIRED:
Position of image = q = ?
Nature of image = ?
Magnification = M = ?

SOLUTION:
By using lens formula,

$$\frac{1}{f} = \frac{1}{P} + \frac{1}{q}$$
$$\frac{1}{1} = \frac{1}{2} + \frac{1}{q}$$
$$1 - \frac{1}{2} = \frac{1}{q}$$
$$\frac{1}{q} = \frac{2-1}{2}$$
$$\frac{1}{q} = \frac{1}{2}$$

q = 2cm

We know that,

$$M = \frac{q}{P}$$
$$M = \frac{2}{2}$$

M = 1 (Same size)

14.7: The distance between the object and the screen is 49cm. A convex lens is placed between the object and the screen so as to get an image on the screen magnified six times. Calculate the focal length of the lens.

GIVEN:
Distance between the object and the screen = P + q = 49cm
Magnification = M = 6

REQUIRED:
Focal length = f = ?

SOLUTION:

$$M = \frac{q}{P}$$
$$6 = \frac{q}{P}$$

6P = q - - - - - - - - (1)
According to given condition,
P + q = 49
P + 6P = 49
7P = 49

$$P = \frac{49}{7}$$

P = 7cm

Put it in equation (1),
q = 6(7)
q = 42cm

$$\frac{1}{f} = \frac{1}{P} + \frac{1}{q}$$
$$\frac{1}{f} = \frac{1}{7} + \frac{1}{42}$$
$$\frac{1}{f} = \frac{6+1}{42}$$
$$\frac{1}{f} = \frac{7}{42}$$
$$\frac{1}{f} = \frac{1}{6}$$

f = 6cm

14.8: The distance between the object and a concave lens is 18cm. The focal length of the lens is 6cm. Determine the nature, position and magnification by using lens formula.

GIVEN:
Object distance = P = 18cm
Focal length = f = – 6cm (Concave lens)

REQUIRED:
Image distance = q = ?
Magnification = M = ?
Nature of image = ?

SOLUTION:
By using lens formula,

$$\frac{1}{f} = \frac{1}{P} + \frac{1}{q}$$
$$\frac{1}{-6} = \frac{1}{18} + \frac{1}{q}$$
$$-\frac{1}{6} - \frac{1}{18} = \frac{1}{q}$$
$$\frac{1}{q} = \frac{-3-1}{18}$$
$$\frac{1}{q} = \frac{-4}{18}$$

$$q = -\frac{18}{4}$$

q = – 4.5 cm

Since q is –ve therefore nature of image is virtual.

$$M = \frac{q}{P}$$

$$M = \frac{4.5}{18}$$

M = 0.25 times