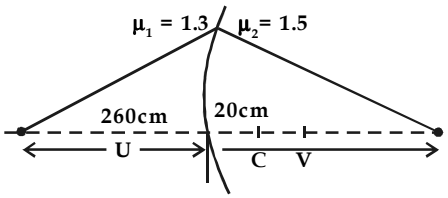
9. Ray Optics

HOMEWORK SOLUTION

1. R = 20 cm

u = – 260 cm

$$\frac{\mu_2}{v} - \frac{\mu}{u} = \frac{\mu_2 - \mu_1}{R_1}$$



$$\frac{1.5}{v} - \frac{1.3}{(-260)} = \frac{1.5-1.3}{20}$$

$$\frac{1.5}{v} = \frac{02}{20} - \frac{1.3}{260}$$

$$\frac{1.5}{v} = \frac{1}{100} - \frac{1.3}{260}$$

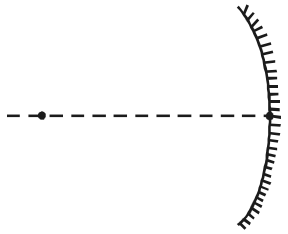
$$\frac{1.5}{v} = \frac{260-130}{260\times100}$$

$$v = \frac{260\times1.5}{130}\times100$$

$$v = 300 \text{ cm}$$

2. u = – 6 cm

k = – 30 cm



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

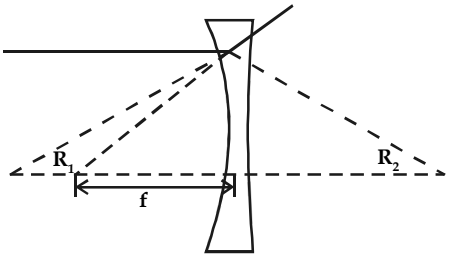
$$\Rightarrow \frac{1}{v} + \frac{1}{-6} = \frac{1}{-30}$$

$$\Rightarrow \frac{1}{v} = \frac{1}{6} - \frac{1}{30} \Rightarrow \frac{1}{v} = \frac{1}{6\times30}$$

$$v = \frac{30}{4} \Rightarrow v = +7.5 \text{ cm}$$

3. For first refraction

$u_1 = -\infty$, $R = -R_1 = -10$ cm



$$\frac{\mu_2}{v} - \frac{\mu_1}{u_1} = \frac{\mu_2 - \mu_1}{R_1}$$

$$\Rightarrow \frac{1.5}{v_1} - \frac{1}{-\infty} = \frac{1.5-1}{-10}$$

$$\Rightarrow v_1 = \frac{-1.5\_10}{5} \Rightarrow v_1 = -30 \text{ cm}$$

The above image will act as object for next refraction

$\therefore$ $u_2 = v_1 = -30$ cm, $R = R_2 = 15$ cm

$$\Rightarrow \frac{\mu_2}{v_2} - \frac{\mu_1}{u_2} = \frac{\mu_2 - \mu_1}{R_2}$$

$$\Rightarrow \frac{1}{v_2} - \frac{1.5}{(-30)} = \frac{1-1.5}{15}$$

$$\Rightarrow \frac{1}{v_2} = \frac{0.5}{15} - \frac{1.5}{30} \Rightarrow \frac{1}{v_2} = \frac{-1}{30} - \frac{1}{20}$$

$$v_2 = \frac{-30\times20}{50} \Rightarrow v_2 = \frac{-60}{5}$$

$$\Rightarrow v_2 = -12 \text{ cm}$$

$\Rightarrow$ focal length of concave lens = – 12 cm

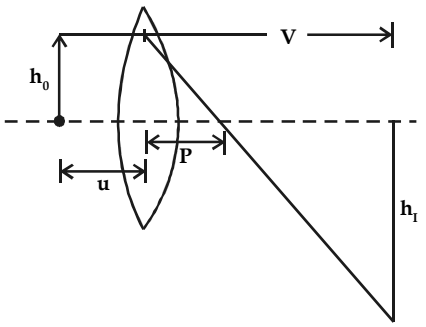
4. $f = 50$

$f = \frac{1}{p} \Rightarrow f = \frac{1}{5}\,m \Rightarrow f = \frac{100}{5}\,cm$

$\Rightarrow f = 20\,cm$

for real image

$m = \frac{h_I}{h_o} = \frac{-v}{u} = 4$



$v = -4u$

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

$\Rightarrow \frac{1}{(-4u)} - \frac{1}{u} = \frac{1}{20}$

$\Rightarrow \frac{-5}{4u} = \frac{1}{20} \Rightarrow u = \frac{20\times5}{4} \Rightarrow u = -25\,cm$

for virtual image :

$m = \frac{v}{4} = 4 \Rightarrow v = 4u$

$\Rightarrow \frac{1}{v} - \frac{1}{u} = \frac{1}{f} \Rightarrow \frac{1}{4u} - \frac{1}{u} = \frac{1}{20}$

$\Rightarrow \frac{-3}{4u} = \frac{1}{20} \Rightarrow u = -15\,cm$

5. $\frac{1}{f} = \left[\frac{\mu_2}{\mu_1} - 1\right]\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$

$\Rightarrow \frac{1}{f} = (1.5 - 1) \times \left[\frac{1}{25} - \frac{1}{-25}\right]$

$\Rightarrow \frac{1}{f} = 5\times\frac{2}{25} \Rightarrow f = 25\,cm$

$Power = \frac{1}{f} = \frac{1}{25\,cm}$

$Power = \frac{100}{25\,m}$

$= 4\,D$

6. $\frac{1}{f} = \left[\frac{\mu_2}{\mu_1} - 1\right]\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$

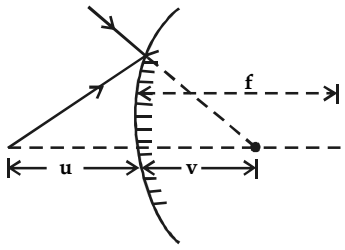
$\Rightarrow \frac{1}{f} = \left[\frac{1.5-1}{1}\right]\left[\frac{1}{-20} - \frac{1}{25}\right]$

$\Rightarrow \frac{1}{f} = \frac{-05\times45}{20\times25}$

$\Rightarrow f = -18.518\,cm$

7. $u = -6\,cm$

$f = +12\,cm$



$\frac{1}{v} + \frac{1}{u} = \frac{1}{f} \Rightarrow \frac{1}{v} + \frac{1}{6} = \frac{1}{12}$

$\Rightarrow \frac{1}{v} = \frac{1}{12} + \frac{1}{6}$

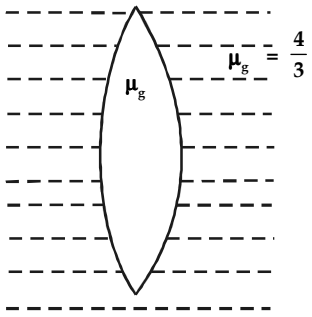
$\frac{1}{v} = \frac{3}{12}$

$v = 4\,cm$

8. $f = 20\,cm$

$\mu_g = 0.5$

$\mu_w = \frac{4}{3}$



$$\frac{1}{f} = \frac{\mu_2 - \mu_1}{\mu_1}\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$$

Considering $R_1 = R_2$ [Equi radial lens]

$$\frac{1}{20\,cm} = \frac{1.5-1}{1}\left[\frac{1}{R} - \frac{1}{-R}\right]$$

$$\Rightarrow \frac{1}{200\,m} = 0.5 \times \frac{2}{R}$$

$R = 20\,cm$

For water-lens

$\mu_2 = 1.5$ and $\mu_1 = \frac{4}{3}$

$$\therefore \frac{1}{f_{new}} = \frac{1.5 - \frac{4}{3}}{\frac{4}{3}}\left[\frac{1}{20} - \frac{1}{-20}\right]$$

$$\frac{1}{f} = \frac{\frac{0.5}{3}}{\frac{4}{3}} \times \frac{2}{20}$$

$$\Rightarrow \frac{1}{f} = \frac{0.5}{40}$$

$f = 80\,cm$

9. $R = 18\,cm$

$u = -12\,cm$

$$\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{(\mu_2 - \mu_1)}{R}$$

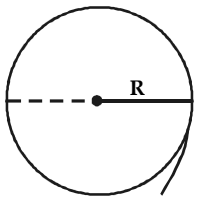
$$\Rightarrow \frac{1}{v} - \frac{1.5}{-12} = \frac{(1-1.5)}{-18}$$

$$\Rightarrow \frac{1}{v} = -\left[\frac{1.5}{12} - \frac{5}{18}\right]$$

$$\frac{1}{v} = -\left[\frac{4.5-1}{2\times3\times6}\right]$$

$$v = \frac{-36}{3.5}$$

$\Rightarrow v = -10.28\,cm$



10. $u = -2.5\,cm, \quad f = 10\,cm$

$$\Rightarrow \frac{1}{v} - \frac{1}{u} = \frac{1}{f} \Rightarrow \frac{1}{v} - \frac{1}{(-2.5)} = \frac{1}{10}$$

$$\Rightarrow \frac{1}{v} = \frac{1}{10} - \frac{1}{2.5}$$

$$v = \frac{25\times10}{15} \Rightarrow \frac{50}{3} \Rightarrow v = 16.66\,cm$$

11. $$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$$

$$\Rightarrow \frac{1}{f} = \frac{1}{15} + \frac{1}{10}$$

$$\Rightarrow \frac{1}{f} = \frac{2.5}{15\times10}$$

$$f = \frac{150}{25} \Rightarrow f = 6\,cm$$

12. $f = -15\,cm \quad f = u = -10\,cm$

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

$$\Rightarrow \frac{1}{v} - \frac{1}{-10} = \frac{1}{-15} \Rightarrow \frac{1}{v} = \frac{-1}{10} - \frac{1}{15}$$

$$\Rightarrow v = \frac{-10\times15}{25}$$

$v = -6\,cm \quad \therefore$ Image is virtual

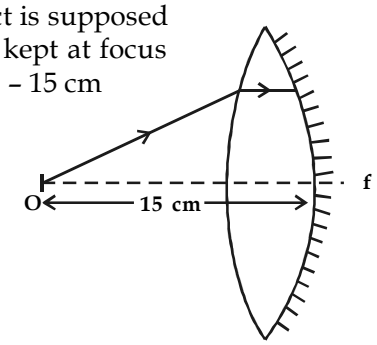
$$m = \left|\frac{v}{u}\right| \Rightarrow m = \frac{6}{10}$$

$\Rightarrow$ m = 0.6 cm

13. f = 15 cm

Object is supposed to be kept at focus

$\therefore$ u = – 15 cm



14. **Given :**

f_0 = 15 cm
f_r = 4.5 cm
L = 24 cm
v_r = – 36 cm

To Find :

M = ?

Solution :

i) $\frac{1}{f_e} = \frac{1}{v_e} - \frac{1}{u_e}$

$\frac{1}{4.5} = \frac{1}{-36} - \frac{1}{u_e}$

$\Rightarrow \frac{1}{u_e} = \frac{1}{-36} - \frac{1}{4.5}$

$= -0.0277 - 0.2222$
$= -0.2499$
$u_e = -4$ cm

ii) $v_0 = L - u_e$
$= 24 - 0.4$
$= 20$ cm

iii) $\frac{1}{f_0} = \frac{1}{v_0} - \frac{1}{u_o}$

$\frac{1}{1.5} = \frac{1}{20} - \frac{1}{u_0}$

$\Rightarrow \frac{1}{u_0} = \frac{1}{20.00} - \frac{1}{1.5}$

$= 0.05 - 0.6666$
$u_0 = -1.621$ cm

$M = \left(\frac{20}{1.621}\right)\frac{36}{4}$

$= (12.33)\ (9)$
M = 110.97

15. **Given :**

f_0 = 2 cm
f_e = 5 cm
v_e = – 25 cm
L = 20 cm

To Find :

u_e, v_0, u_0, M = ?

Solution :

i) $\frac{1}{f_e} = \frac{1}{v_e} - \frac{1}{u_e}$

$\frac{1}{5} = \frac{1}{-25} - \frac{1}{u_e}$

$\Rightarrow \frac{1}{u_e} = -\frac{1}{25} - \frac{1}{5}$

$\frac{1}{u_e} = \frac{-5-25}{125} = \frac{-30}{125}$

$u_e = -\frac{125}{30} = -4.1666$ cm

ii) $u_e = L - u_e$
$= 20 - 4.1666$
$v_0 = 15.834$ cm

iii) $\frac{1}{f_0} = \frac{1}{v_0} - \frac{1}{u_e}$

$\frac{1}{2} = \frac{1}{-1.5-834} - \frac{1}{u_e}$

$\Rightarrow \quad \frac{1}{u_0} = \frac{1}{\mu_0} - \frac{1}{f_0}$

$= \frac{1}{15.83} - \frac{1}{2}$

$\Rightarrow \quad u_0 = -2.2893 \text{ cm}$

iv) $M = -\left(\frac{V_0}{u_0}\right)\left(1+\frac{D}{f_e}\right)$

$= \left(\frac{15.834}{2.2893}\right)\left(1+\frac{25}{5}\right)$

$= (6.9)\ (6)$

$= 41.5$

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16. $f_0 = 2 \text{ cm}$

$f_r = 8 \times 10^{-2} \text{ cm}$

i) $M = \frac{-f_0}{f_e} = \frac{200}{8}$

$M = -25$

ii) $L = f_0 + f_e$

$= (2.00 + 8) \text{ cm}$

$L = 2.08 \text{ m}$