PRAYAS

JEE 2025

Lecture-09

Physics

Ray optics

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Topics *to be covered*

1. Power
2. Thin Lens in Contact
3. Displacement Method
4.

Power (P)

$f = R/2$

* $P > 0 \longrightarrow$ Converging
* $P < 0 \longrightarrow$ Diverging

① For mirror $P = -\frac{1}{f_m}$ → focal length (with sign)

② For Lens $P = \frac{1}{f_L}$ → focal length (with sign)

If f = (in meter)

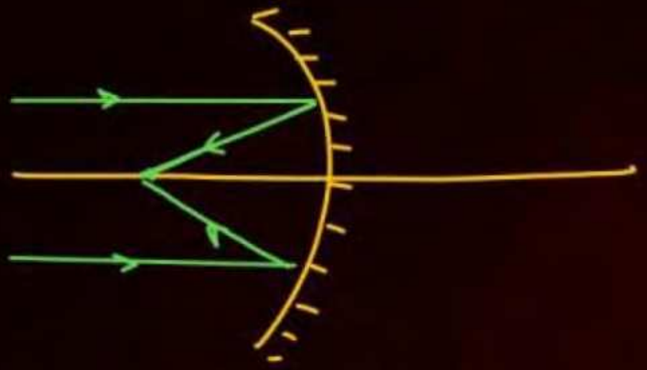
P ⟶ Unit Diopter, 'D'.

$$P = \frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

Lens in air

① $R = 40\,m$

$f = 20$



Concave mirror $f < 0$

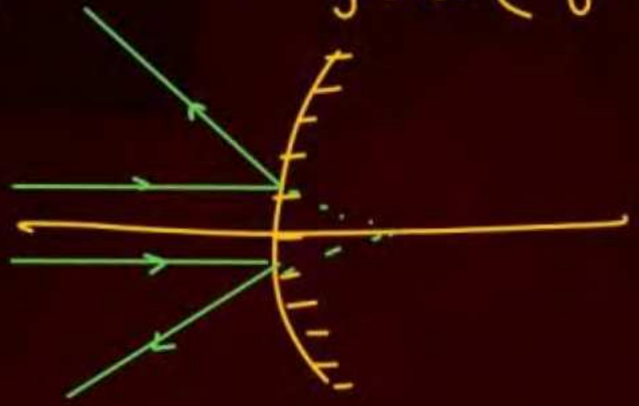
$f = -20$

$$P = -\frac{1}{f} = -\frac{1}{-20} = \frac{1}{20}$$

$P = \frac{1}{20}$, $P > 0$ (Converging)

② $R = 40$

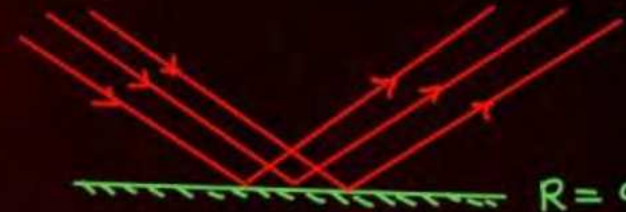
$f = 20$ (magnitude)



$$P = -\frac{1}{f} = -\frac{1}{(+20)}$$

$P = -\frac{1}{20}$ (diverging)

③ Plane mirror

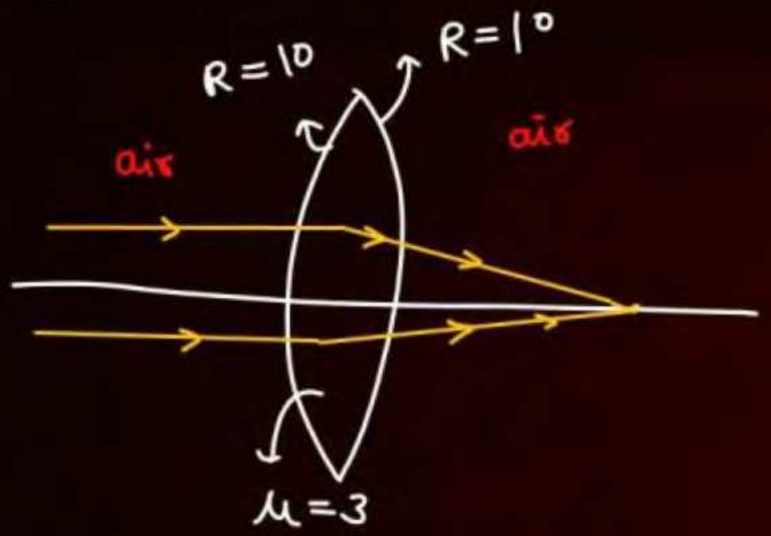


$R = \infty$

$f = \infty$

$$\text{Power} = -\frac{1}{f} = \frac{1}{-\infty} = 0$$

Q find Power of following

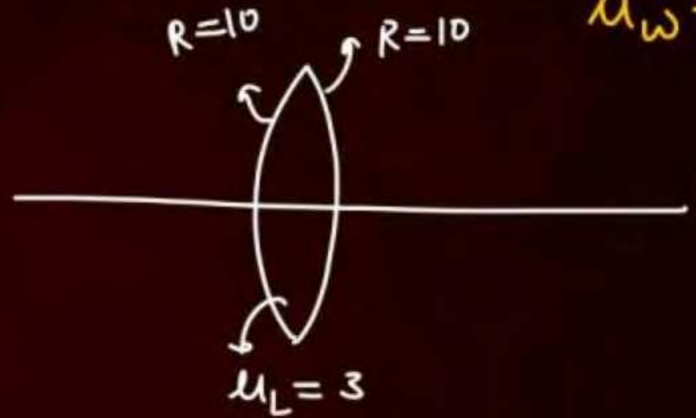


$$P = \frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$P = \frac{1}{f} = (3-1)\left(\frac{1}{10} - \frac{1}{-10}\right) = \frac{4}{10}$$

$$\boxed{P = \frac{4}{10}} \equiv P > 0 \equiv \text{Converging}$$

(b) If this lens is dipped in water $\mu_w = 4$



ATDB.uno

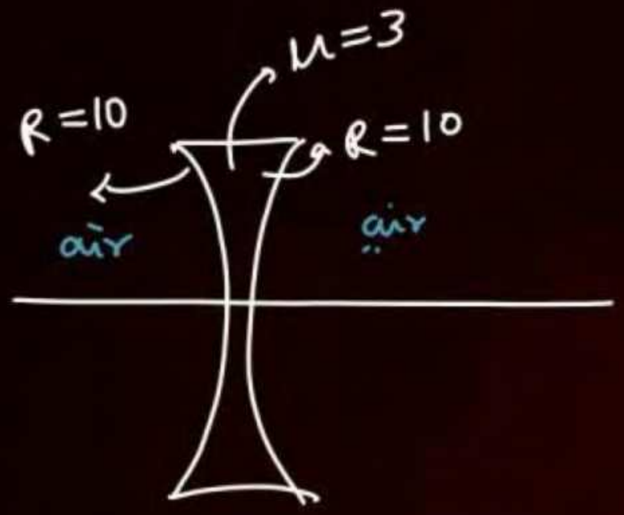
$$P = \frac{1}{f} = \left(\frac{3}{4} - 1\right)\left(\frac{1}{10} - \frac{1}{-10}\right) = -\frac{1}{4} \times \frac{2}{10}$$

P<0, Diverging.

Correction

$$P = -\frac{1}{20}$$

Q

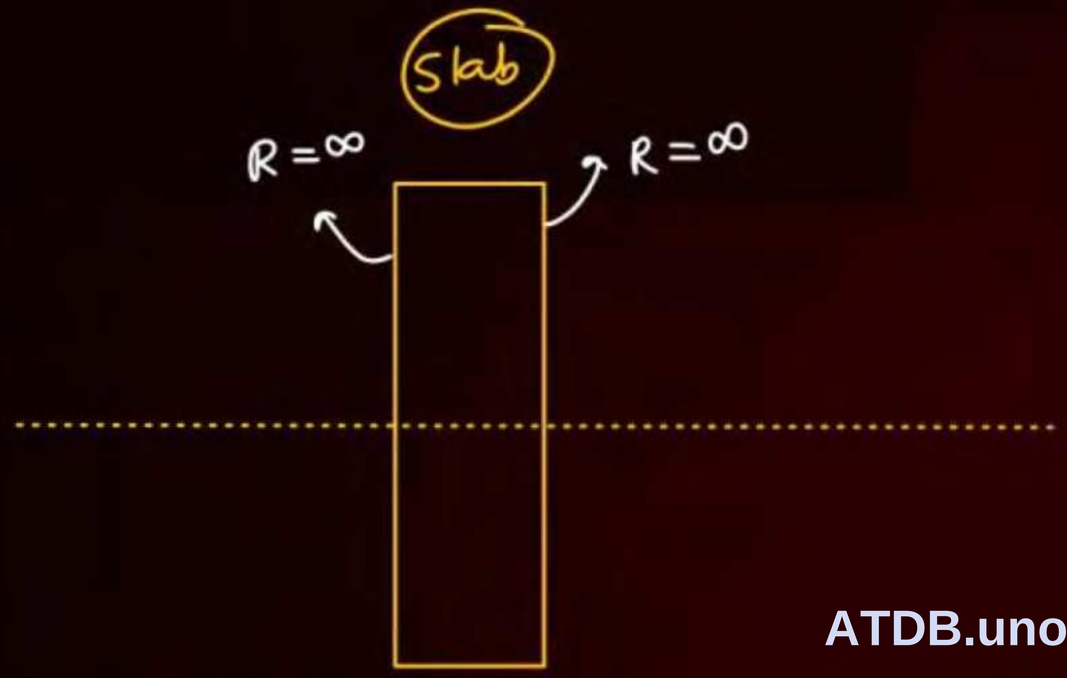


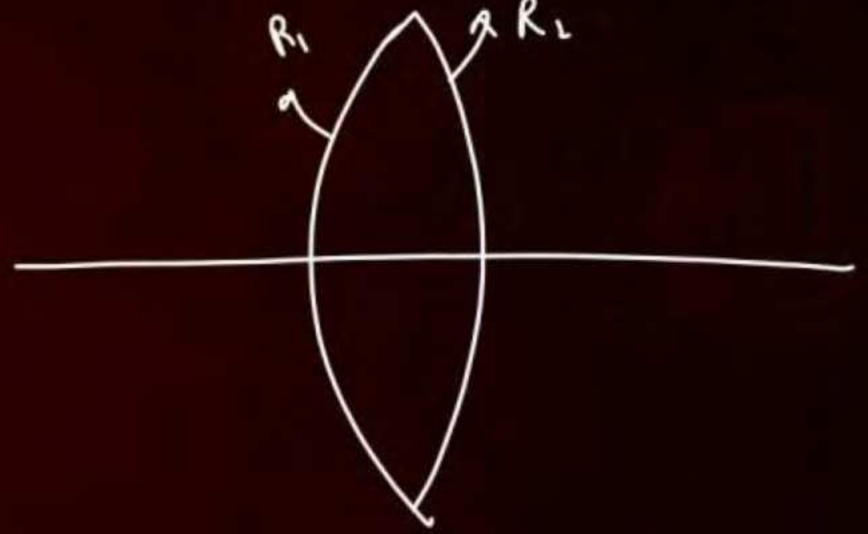
$$P = \frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$P = (3-1)\left(\frac{1}{-10} - \frac{1}{+10}\right)$$

$$P = \frac{-4}{10} \qquad P < 0 \equiv \text{Diverging}$$

ATDB.uno



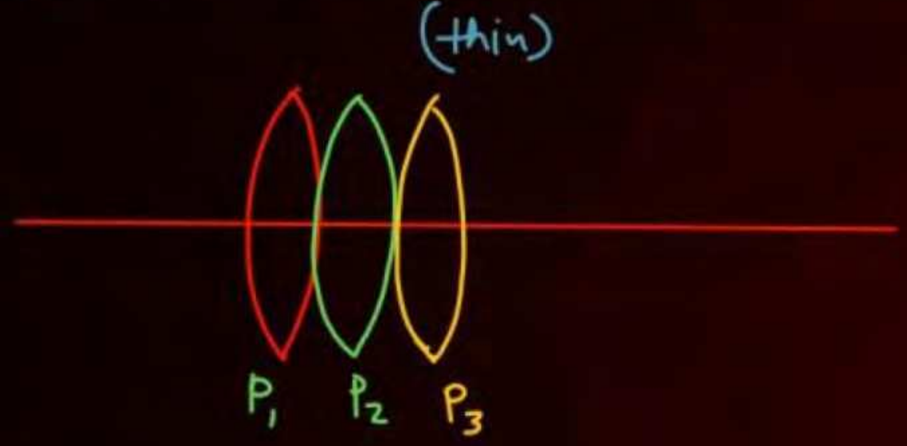


$$P = \frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$P = \frac{1}{f} = (\mu - 1)\left(\frac{1}{\infty} - \frac{1}{\infty}\right)$$

$$P = 0$$

Thin lens in Contact

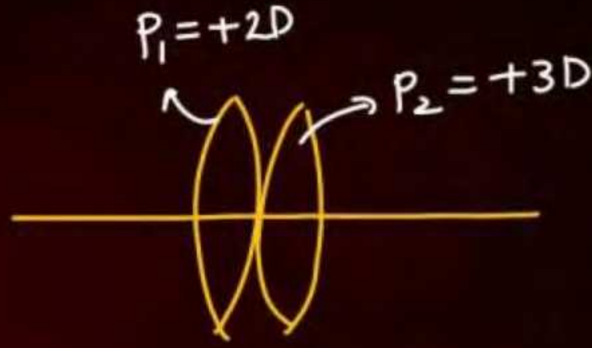


$$P_{net} = P_1 + P_2 + P_2 + \dots$$

$$P_{net} = \frac{1}{f_{net}} = \frac{1}{f_1} + \frac{1}{f_2} + \frac{1}{f_3}$$

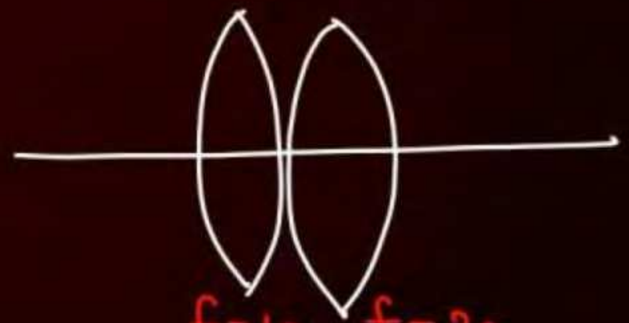
(with sign)

Q



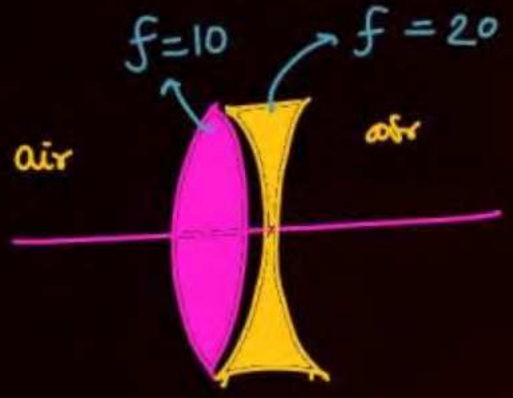
$$P_{net} = P_1 + P_2 = 2 + 3 = 5$$

Q



$$P_{net} = \frac{1}{f_{eq}} = \frac{1}{f_1} + \frac{1}{f_2} = \frac{1}{+10} + \frac{1}{20} = \frac{3}{20}$$

$$f_{eq} = \frac{20}{3} \qquad P_{net} = \frac{3}{20}$$



Q

① P_{net} ② f_{eq}.

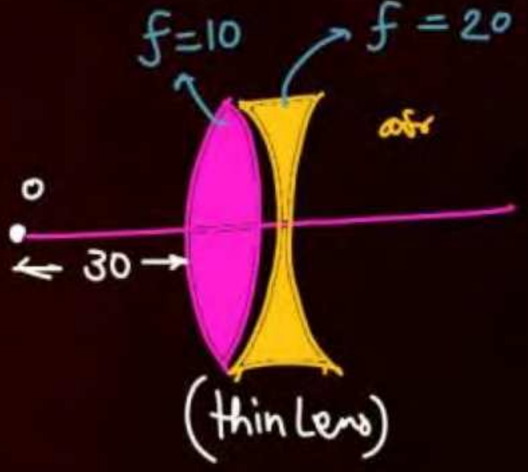
Sol $P_{net} = \frac{1}{f_{eq}} = \frac{1}{f_1} + \frac{1}{f_2} = \frac{1}{+10} + \frac{1}{-20} = +\frac{1}{20}$

$P = +\frac{1}{20}$ $f_{eq} = +20 \equiv$ (Convex lens की तरह)

SSSO

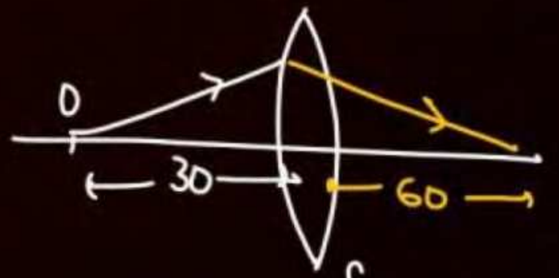
③ If an obj is placed at a distance 30 m from the both lens. find location of image

$u = -30$
$f = +20$
$v = \frac{uf}{u+f}$



(thin Lens)

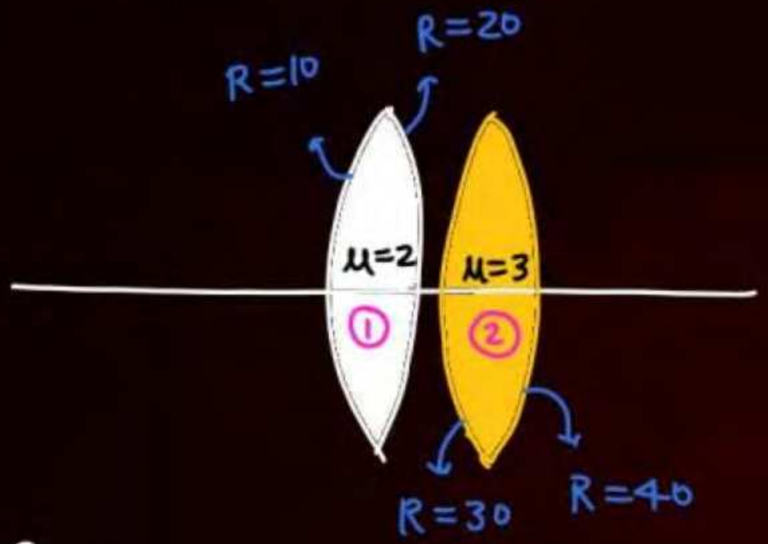
III



f=20

air

Q



① f_{eq}

② P_{net}

③ If an obj is placed at a distance 30 cm from lens ②

Sol

$$P_{net} = \frac{1}{f_{eq}} = \frac{1}{f_1} + \frac{1}{f_2}$$

$$\frac{1}{f_1} = (2-1)\left(\frac{1}{10} - \frac{1}{-20}\right)$$

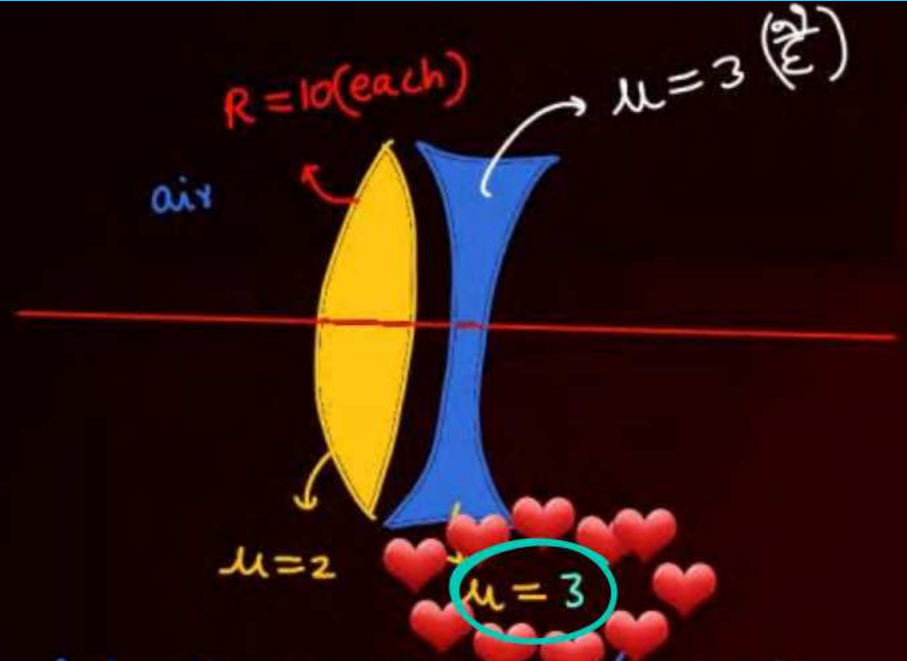
$$\frac{1}{f_2} = (3-1)\left(\frac{1}{+30} - \frac{1}{-40}\right)$$

f_{eq} = ✓

P_{net} = ✓

$$v = \frac{u f_{eq}}{u + f_{eq}}$$

Q



① Focal length of each lens (in air)

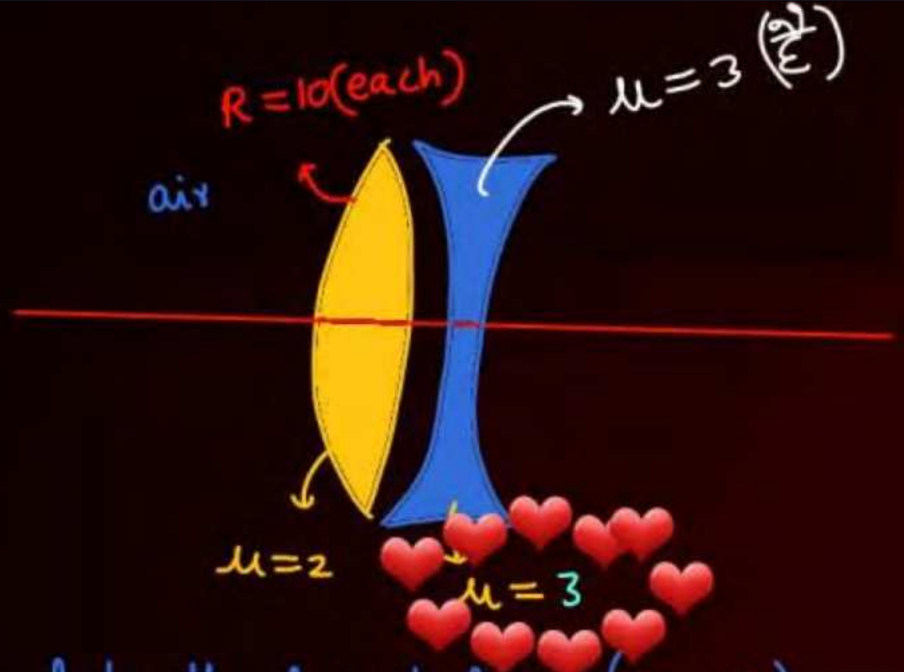
$$\frac{1}{f_1} = (2-1)\left(\frac{1}{10} - \frac{1}{-10}\right) = \frac{2}{10}$$

$$\frac{1}{f_2} = (3-1)\left(-\frac{1}{10} - \frac{1}{+10}\right) = \frac{-4}{10}$$

$f_1 = 5$

$f = -5/2$

Q



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$f_1 = 5$

$f = -5/2$

② f_{eq}, P_{net} =

$$P_{net} = \frac{1}{f_{eq}} = \frac{1}{f_1} + \frac{1}{f_2} = \frac{2}{10} - \frac{4}{10} = \frac{-2}{10}$$

$f_{eq} = -5$ (Concave Lens)

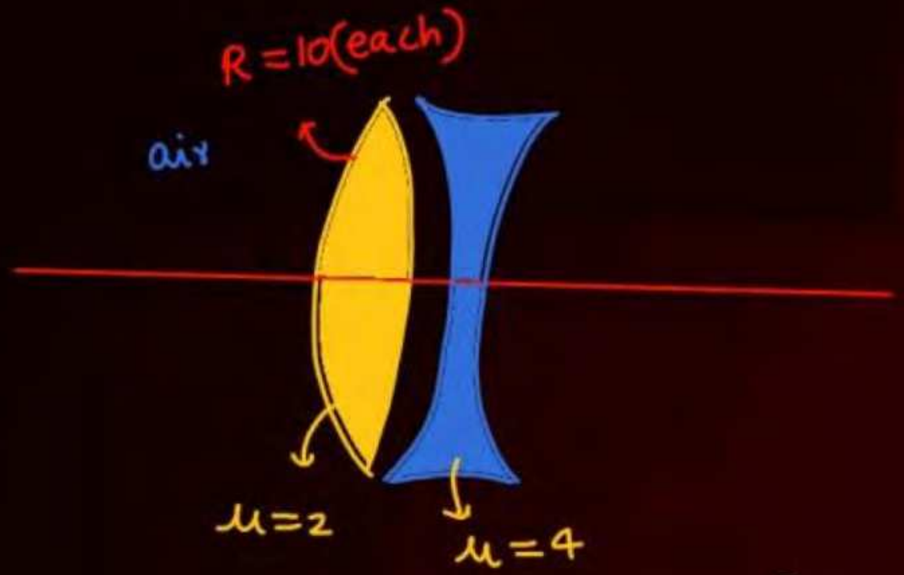
③ If an obj. is placed at a distance 30cm from lens find location of mirror.

$u = -30$

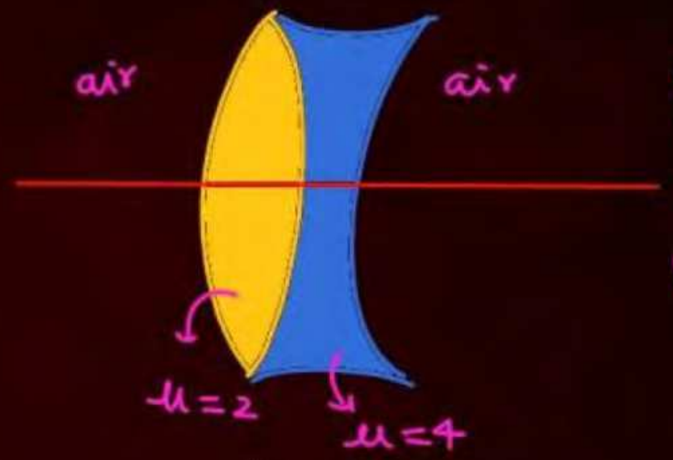
$f = -5$

$$v = \frac{150}{-30+(-5)} = \checkmark$$

Q



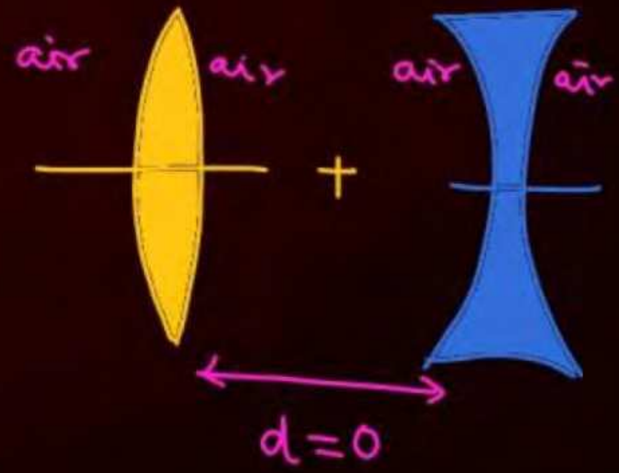
⇉



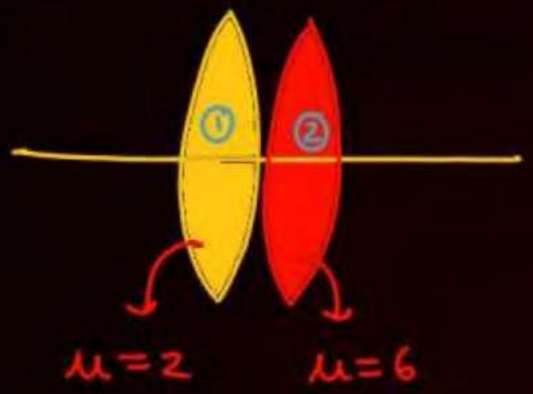
वे दो चिपके Lens हैं
दोनो हवा में
Very close to each other

(एक दी गई है)

=



Q $R = 10$ each

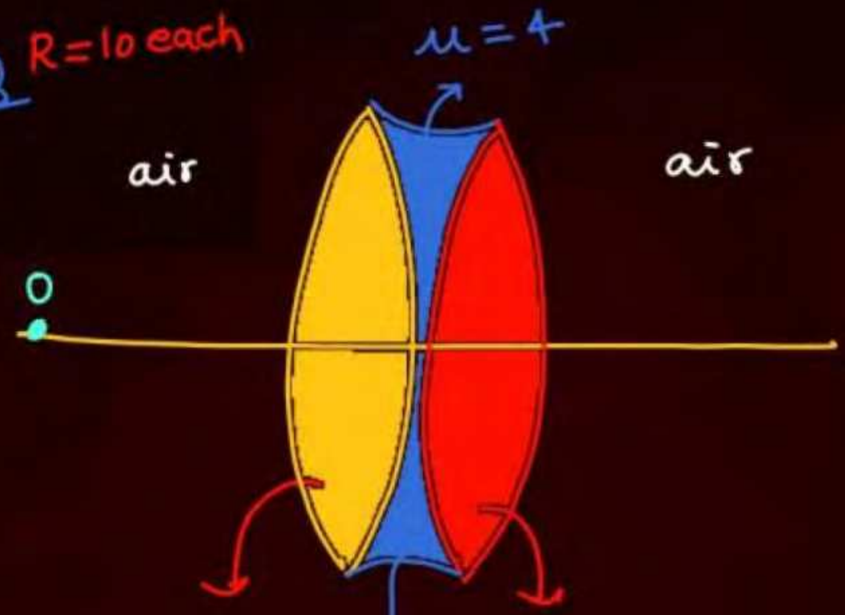


$$\frac{1}{f_1} = (2-1)\left(\frac{1}{10} - \frac{1}{-10}\right) = \frac{2}{10}$$

$$\frac{1}{f_2} = (6-1)\left(\frac{1}{10} - \frac{1}{-10}\right) = \frac{10}{10}$$

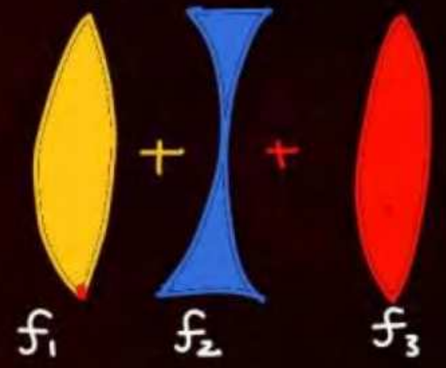
$$\frac{1}{f_{eq}} = \frac{1}{f_1} + \frac{1}{f_2} = \frac{12}{10}$$

Q $R = 10$ each



① $f_{eq} = ?$

$$\frac{1}{f_{eq}} = \frac{1}{f_1} + \frac{1}{f_2} + \frac{1}{f_3}$$



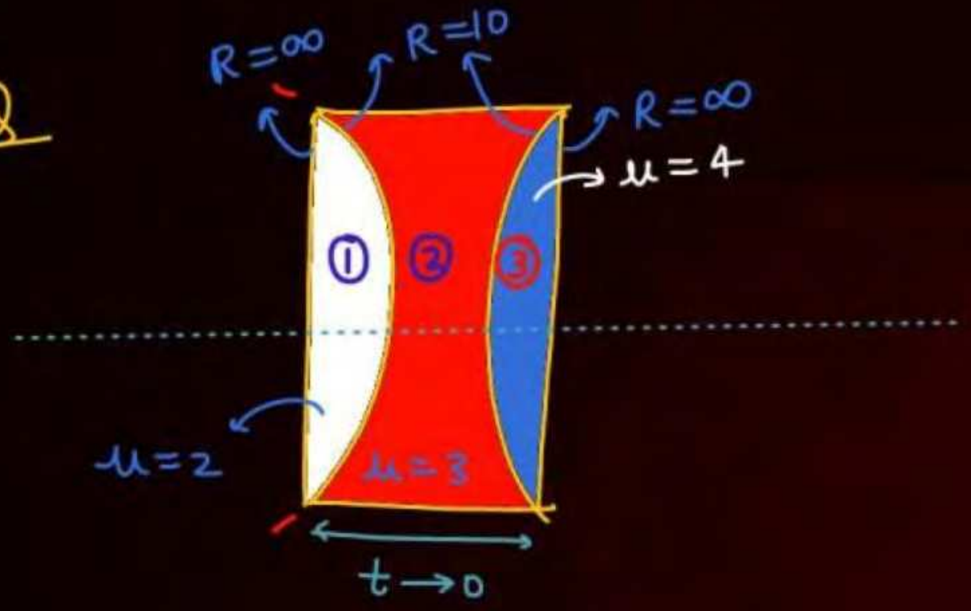
$$\frac{1}{f_1} = (2-1)\left(\frac{1}{10} - \frac{1}{-10}\right)$$

$$\frac{1}{f_2} = (4-1)\left(\frac{1}{-10} - \frac{1}{+10}\right)$$

$$\frac{1}{f_3} = (6-1)\left(\frac{1}{+10} - \frac{1}{-10}\right)$$

② obj is placed at a distance 30 cm from lens

Q



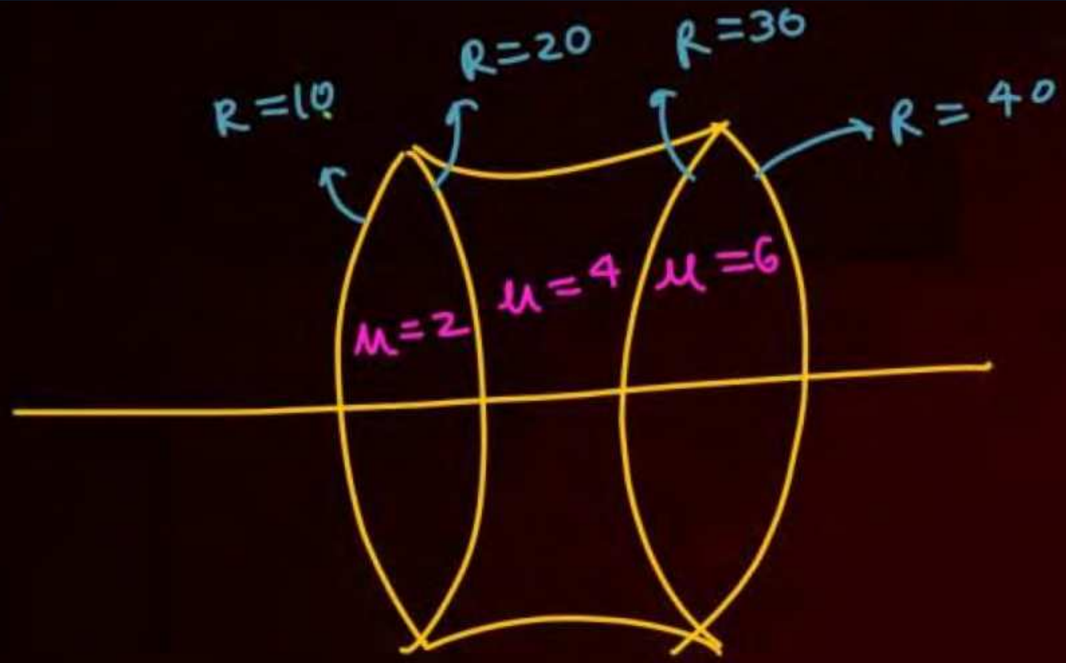
$$\frac{1}{f_1} = (2-1)\left(\frac{1}{\infty} - \frac{1}{-10}\right)$$

$$\frac{1}{f_2} = (3-1)\left(\frac{1}{-10} - \frac{1}{+10}\right)$$

$$\frac{1}{f_3} = (4-1)\left(\frac{1}{+10} - \frac{1}{\infty}\right)$$

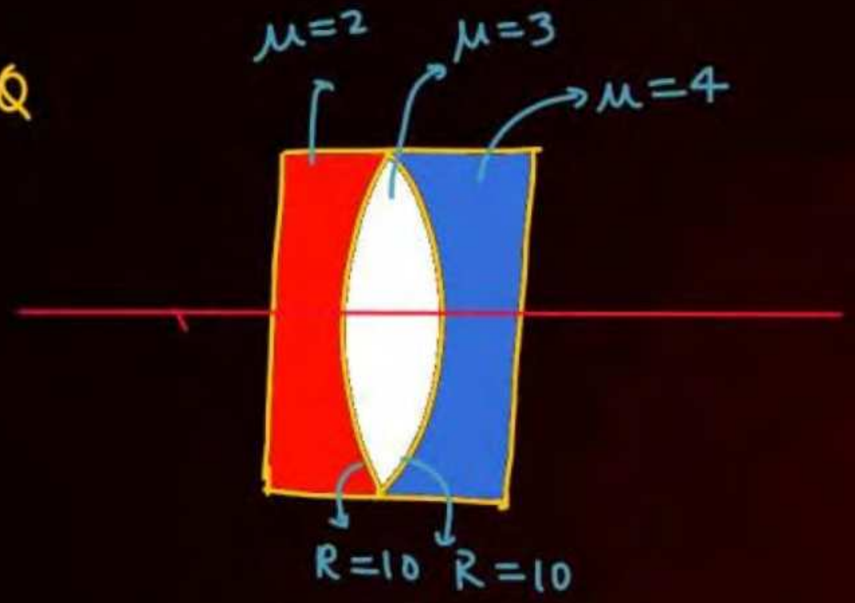
$$\frac{1}{f_{eq}} = \frac{1}{f_1} + \frac{1}{f_2} + \frac{1}{f_3}$$

Q



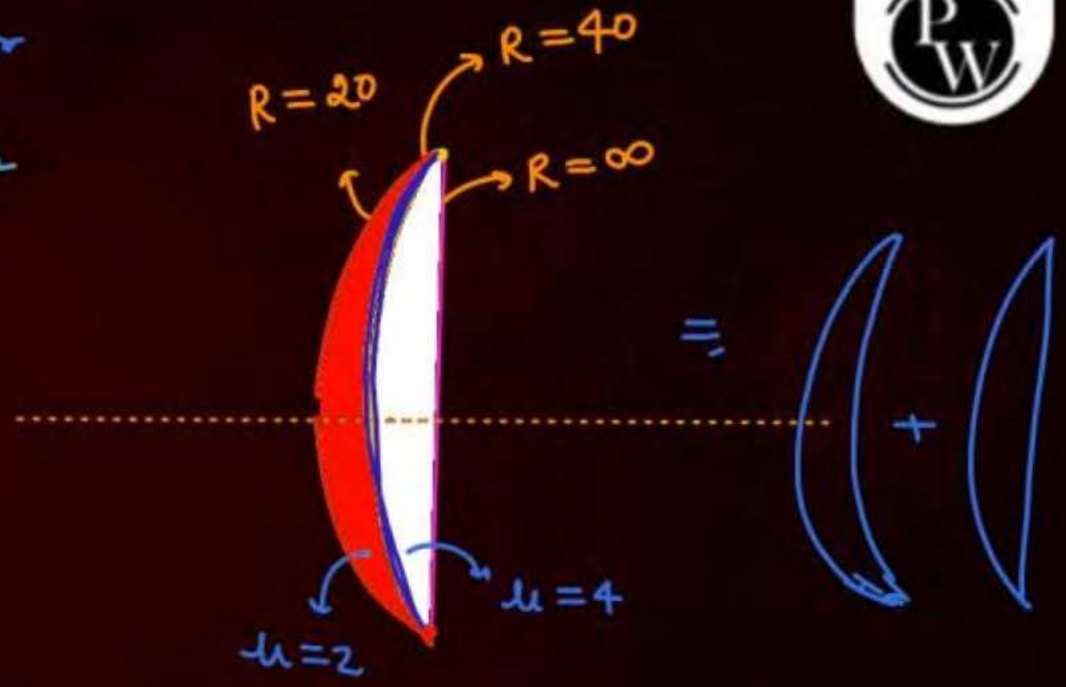
$$\frac{1}{f_{eq}} = (2-1)\left(\frac{1}{10} - \frac{1}{-20}\right) + (4-1)\left(\frac{1}{-20} - \frac{1}{+30}\right) + (6-1)\left(\frac{1}{+30} - \frac{1}{-40}\right)$$

Q



$$\frac{1}{f_{eq}} = (2-1)\left(\frac{1}{\infty} - \frac{1}{+10}\right) + (3-1)\left(\frac{1}{10} - \frac{1}{-10}\right) + (4-1)\left(\frac{1}{-10} - \frac{1}{\infty}\right)$$

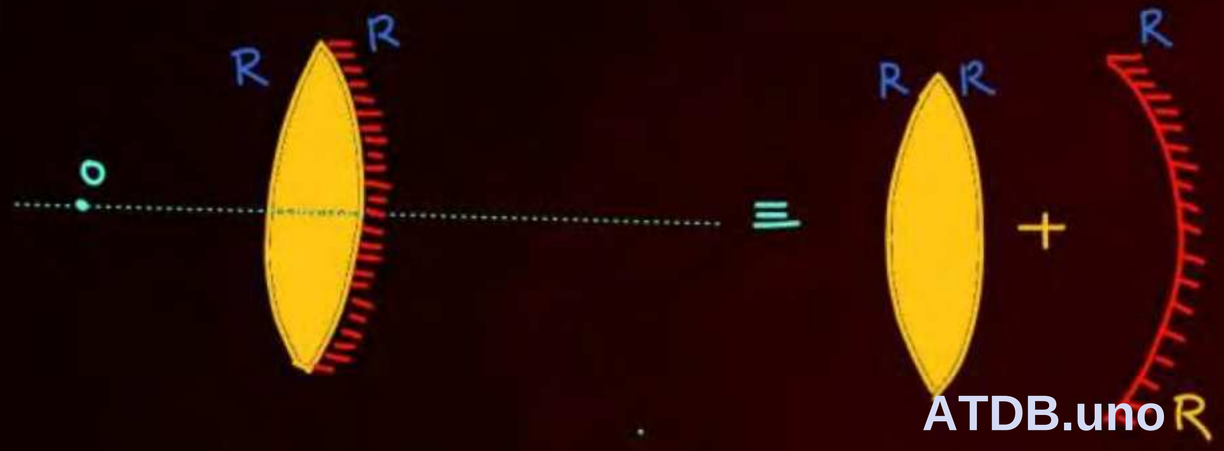
Q



$$\frac{1}{f_{eq}} = (2-1)\left(\frac{1}{+20} - \frac{1}{+40}\right) + (4-1)\left(\frac{1}{+40} - \frac{1}{\infty}\right)$$

Silvering of lens

Q find f_{eq}



$$P_{net} = P_L + P_m + P_L = 2P_L + P_m$$

$$P_L = \frac{1}{f_L} = (\mu-1)\left(\frac{1}{R} - \frac{1}{-R}\right) = (\mu-1)\frac{2}{R}$$

$$P_m = -\frac{1}{f_m} = -\frac{1}{(-R/2)} = \frac{2}{R}$$

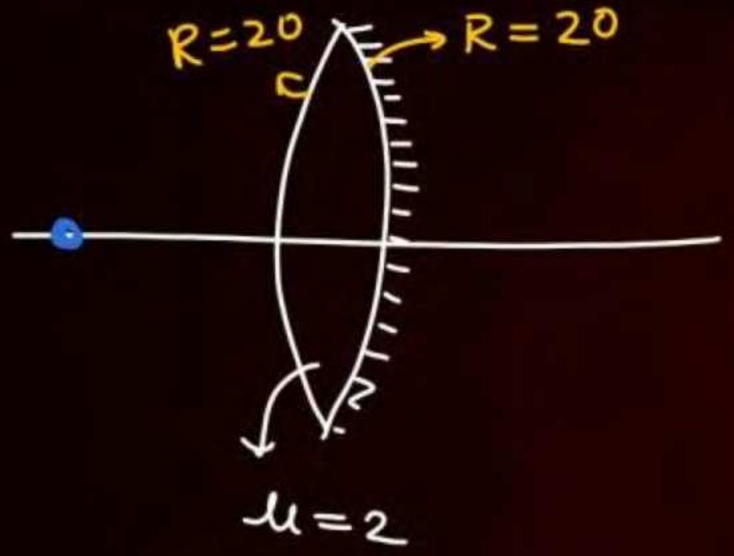
$$P_{net} = 2P_L + P_m$$

$$P_{net} = 2(\mu-1)\frac{2}{R} + \frac{2}{R} = -\frac{1}{f_{eq}}$$

$$P_{net} = \ominus \frac{1}{f_{eq}}$$

whole system is behave like mirror.

Q find focal length of following



Soln $P_{net} = 2P_L + P_m$

$f_m = R/2 = \frac{-20}{2} = -10$

$P_L = \frac{1}{f} = (\mu-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) = (2-1)\left(\frac{1}{20} - \frac{1}{-20}\right)$

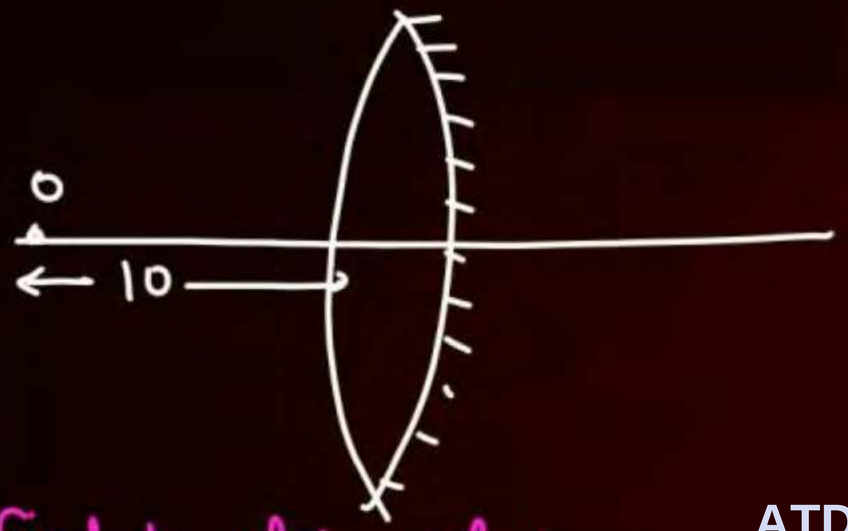
$= \frac{1}{10}$

$P_m = -\frac{1}{f_m} = -\frac{1}{\left(\frac{-20}{2}\right)} = \frac{1}{10}$

$P_{net} = 2 \times \frac{1}{10} + \frac{1}{10} = \frac{3}{10} = -\frac{1}{f_{eq}}$

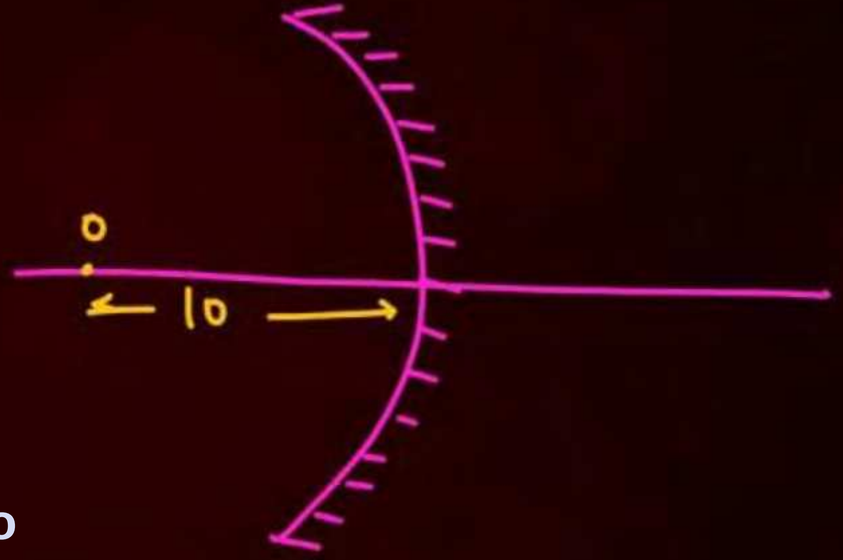
$f_{eq} = -\frac{10}{3} \equiv$ Concave Mirror

(b)



find location of image

$f = 10/3$

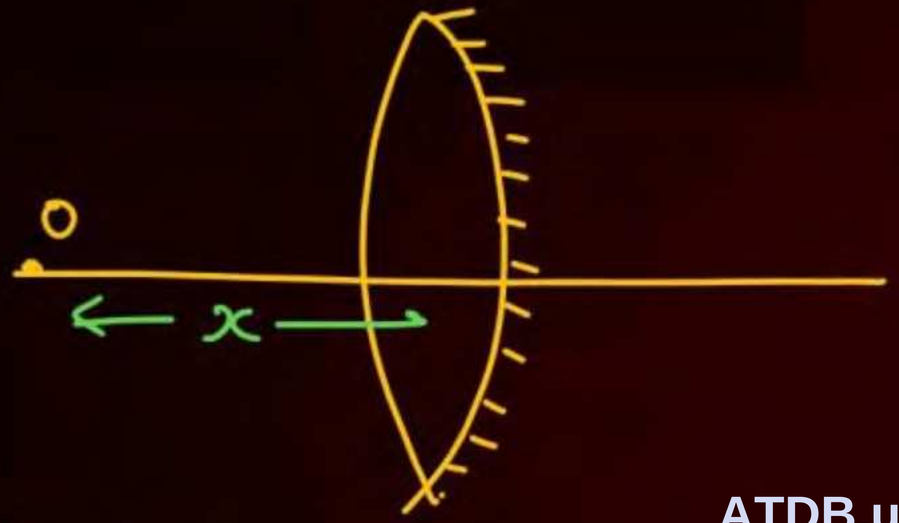


$u = -10$

$f = -10/3$

$$v = \frac{uf}{u-f}$$ (mirror formula)

(c)



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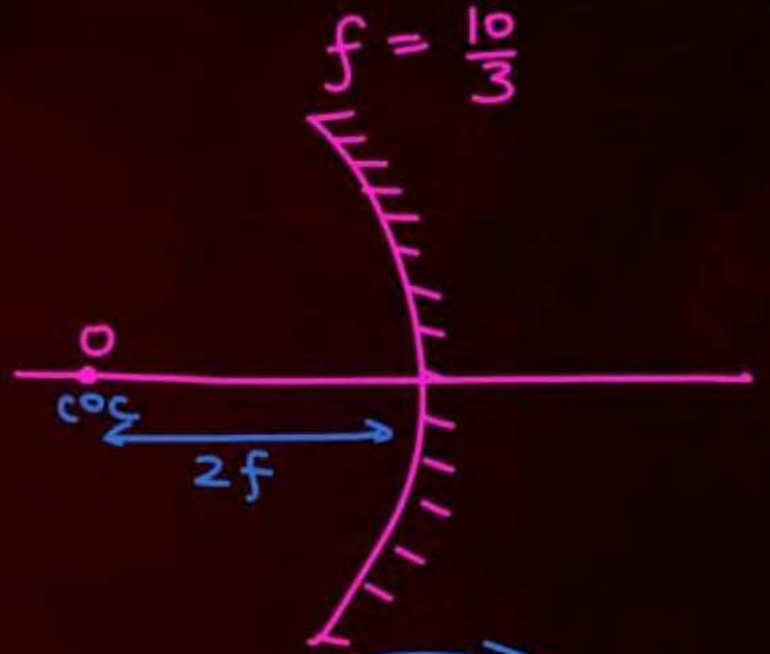
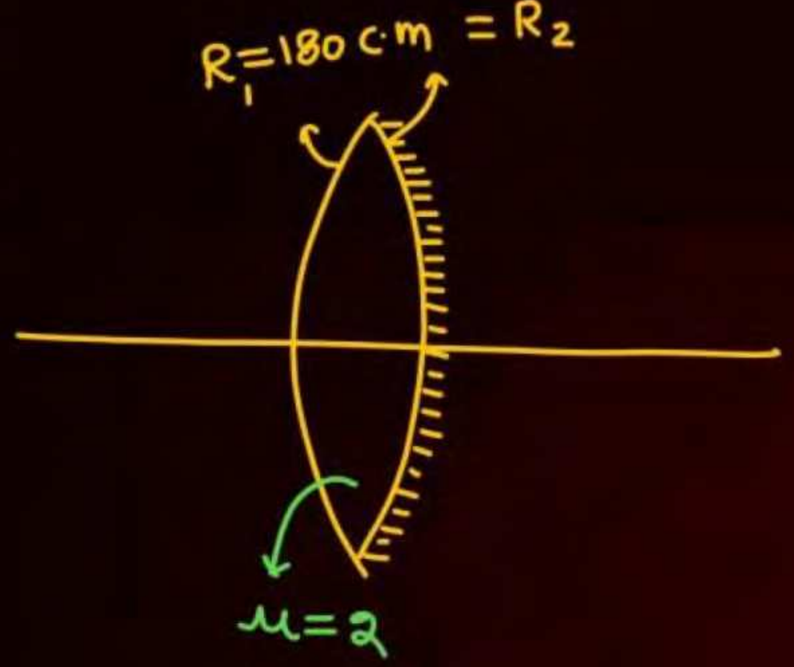


find value of x so that image formed on object.

Ans $x = 2f$

Q



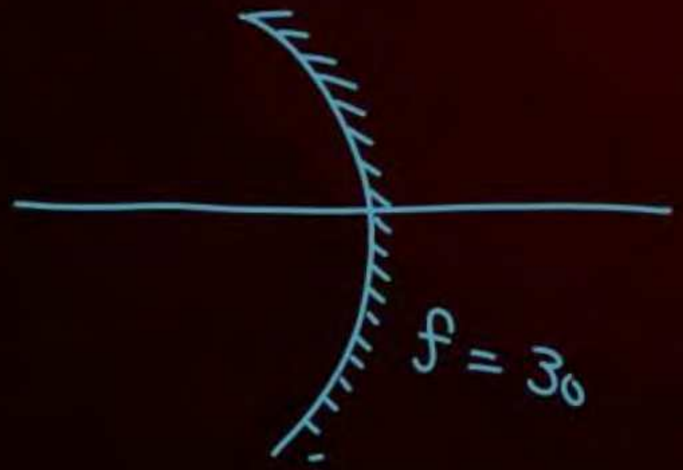
$$P_{net} = 2P_L + P_m$$

$$P_L = (2-1)\left(\frac{1}{180} - \frac{1}{-180}\right) = \frac{1}{90}$$

$$P_m = -\frac{1}{f_m} = -\frac{1}{\frac{-180}{2}} = \frac{1}{90}$$

$$P_{net} = 2 \times \frac{1}{90} + \frac{1}{90} = \frac{3}{90} = \frac{1}{30}$$

III

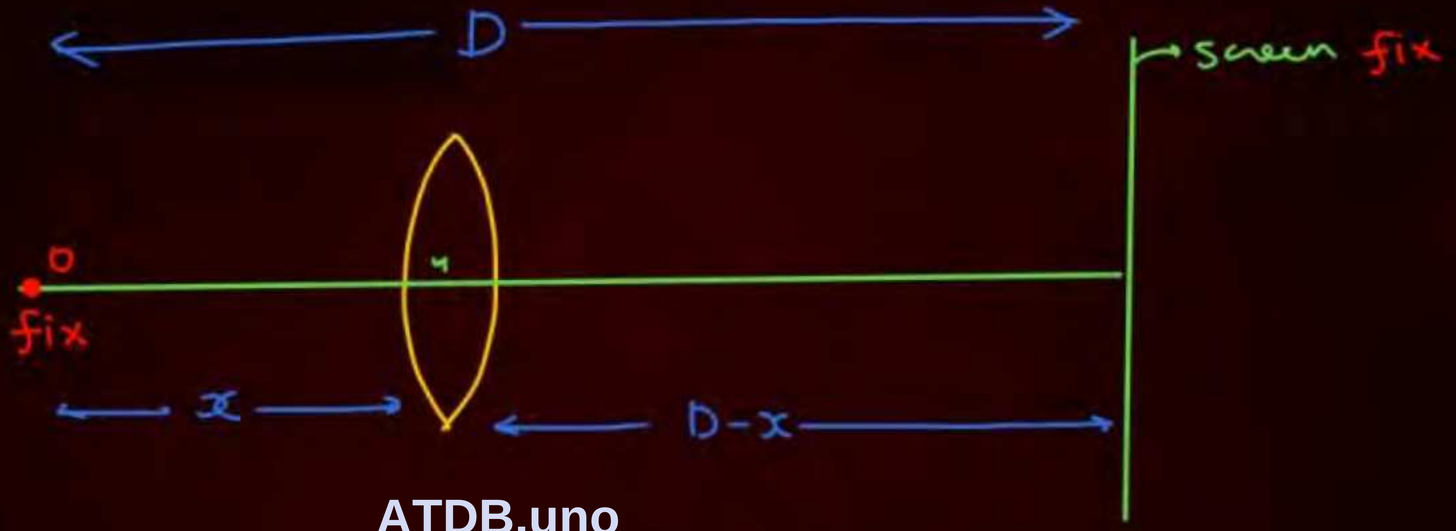


$$P_{net} = \frac{1}{30} = -\frac{1}{f_{eq}}$$

$$\boxed{f_{eq} = -30}$$ (concave)

Displacement Methode

final image formed at Screen.



$u = -x, \quad v = D - x$

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

$$\frac{1}{D-x} - \frac{1}{-x} = \frac{1}{f}$$

$$\frac{1}{D-x} + \frac{1}{x} = \frac{1}{f} = \frac{x + D - x}{(D-x)\,x} = \frac{D}{Dx - x^2}$$

$$Dx - x^2 = Df$$

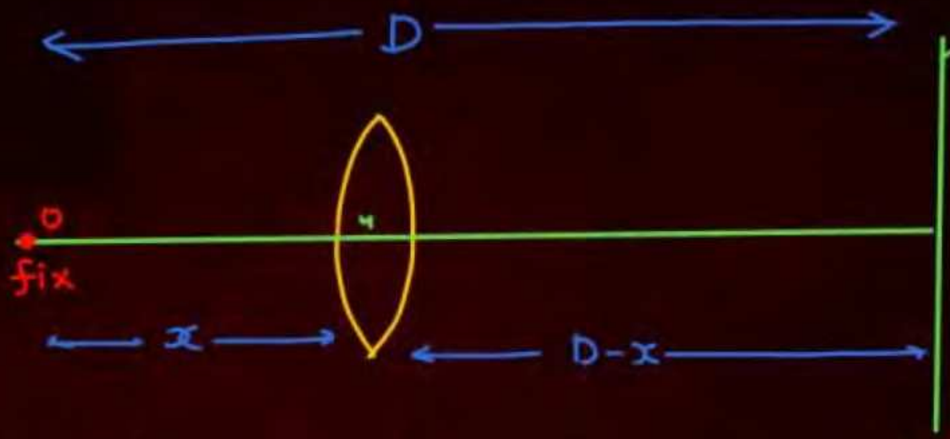
$$\boxed{x^2 - Dx + Df = 0}$$

$$x^2 - Dx + Df = 0$$

$D^2 - 4 \times 1 \times Df > 0$ ($\because$ 2 root, x_1 & x_2)

* $\boxed{D > 4f}$ → Two position of lens x_1 & x_2 detect
* $D = 4f$ → one one position
* $D < 4f$ → No position will observe

Displacement Methode



$$x^2 - Dx + Df = 0$$

$D > 4f \longrightarrow x_1 \& x_2$

$$x_1 = \frac{D + \sqrt{D^2 - 4Df}}{2}$$

$$x_2 = \frac{D - \sqrt{D^2 - 4Df}}{2}$$

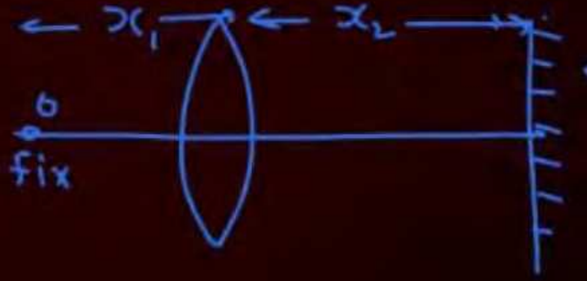
$x_1 - x_2 = d \equiv$ gap b/w two position of lens जिनसे screen पर image बनती

$$x_1 + x_2 = D$$

$$x_1 - x_2 = d$$

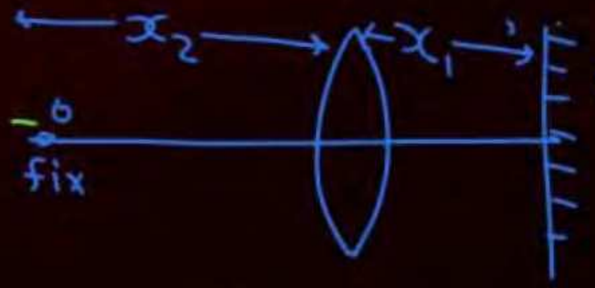
$$x_1 = \frac{D+d}{2}$$

$$x_2 = \frac{D-d}{2}$$



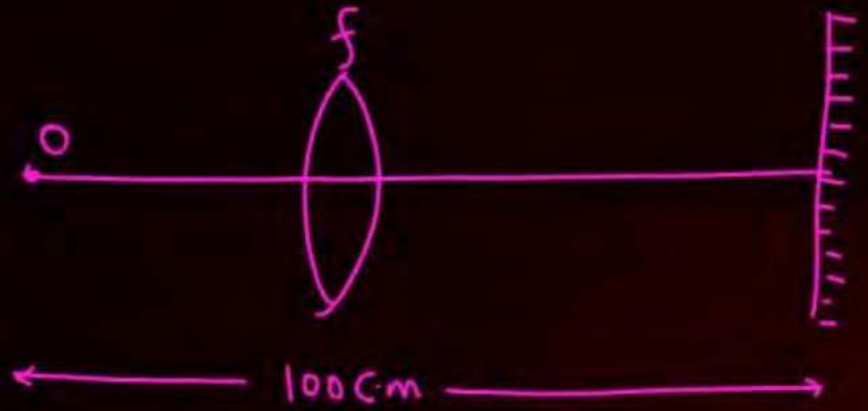
$$m_1 = \frac{x_2}{-x_1}$$

$$m_1 m_2 = 1$$



Screen $m_2 = \frac{x_1}{-x_2}$

Q



Gap b/w two position of lens so that image formed at screen is 20 cm. find f

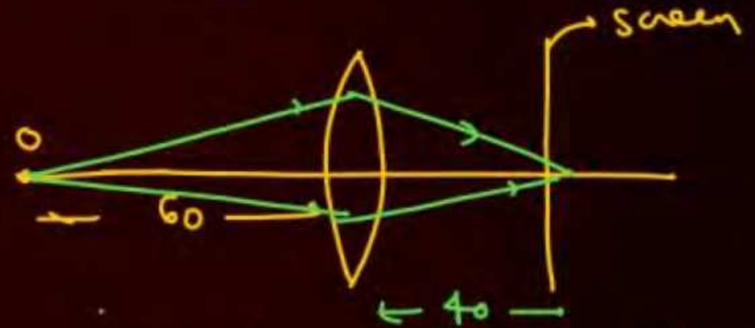
Soln

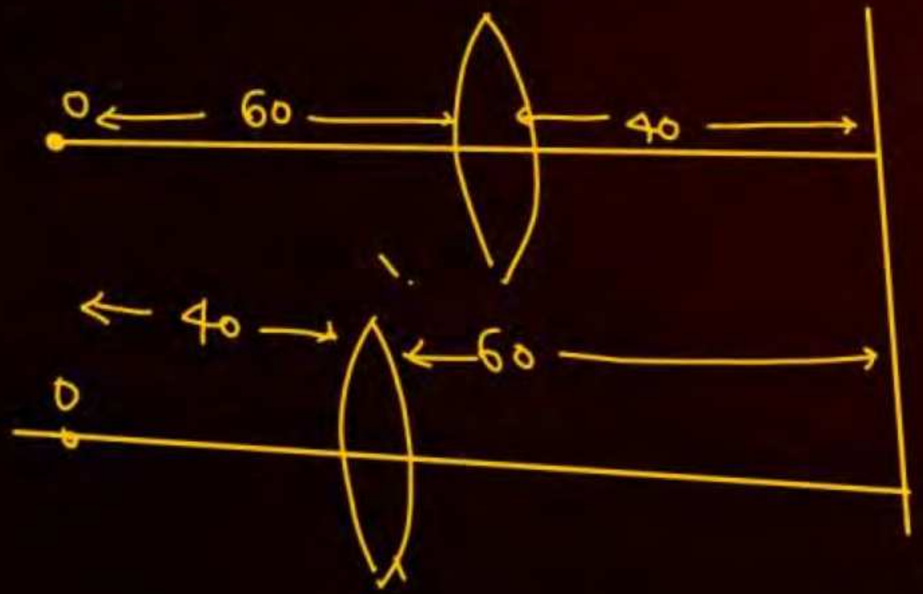
$D = 100$

$d = 20$

$x_1 = \frac{D+d}{2} = 60$

$x_2 = \frac{D-d}{2} = 40$





$\frac{1}{40} - \frac{1}{-60} = \frac{1}{f}$

$f = \checkmark$

* x की दो value पर x_1 & x_2 image Screen पर बनती

- lens की दो position पर x_1 & x_2 पर :

$$m_1 = \frac{h_{I_1}}{h_0} = \frac{v}{u} = \frac{x_2}{-x_1}$$

$$m_2 = \frac{h_{I_2}}{h_0} = \frac{x_1}{-x_2}$$

$$m_1 \times m_2 = 1 = \frac{h_{I_1}}{h_0} \times \frac{h_{I_2}}{h_0}$$

$$h_0 = \sqrt{h_{I_1} \times h_{I_2}}$$

$$x_1 = \frac{D+d}{2} \qquad x_2 = \frac{D-d}{2}$$

$$x^2 - Dx + Df = 0$$

Homework

- Revise optics class notes