

PRAYAS

JEE 2025



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Lecture-09

Physics

Ray optics



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Topics *to be covered*

1

Power

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2

Thin Lens in Contact

3

Displacement Method

4



Power (P)

* $P > 0$ \longrightarrow Converging

* $P < 0$ \longrightarrow Diverging

① For mirror

$$P = - \frac{1}{f_m} \longrightarrow \text{focal length (with sign)}$$

$$f = R/2$$

② For Lens

$$P = \frac{1}{f_L} \longrightarrow \text{focal length (with sign)}$$

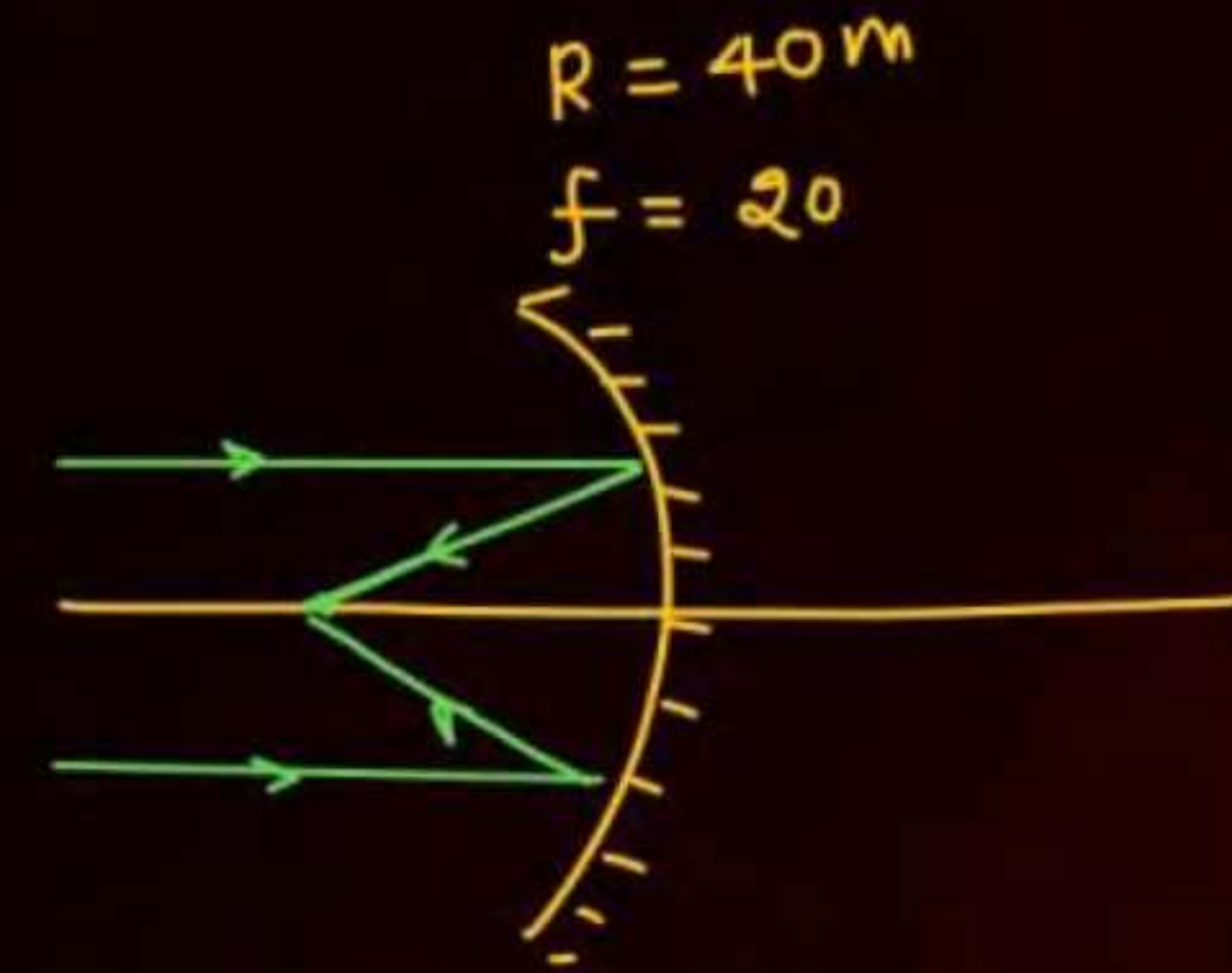
If $f \rightarrow$ (in meter)

$P \rightarrow$ Unit Diopter, 'D'.

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

Lens in air

①

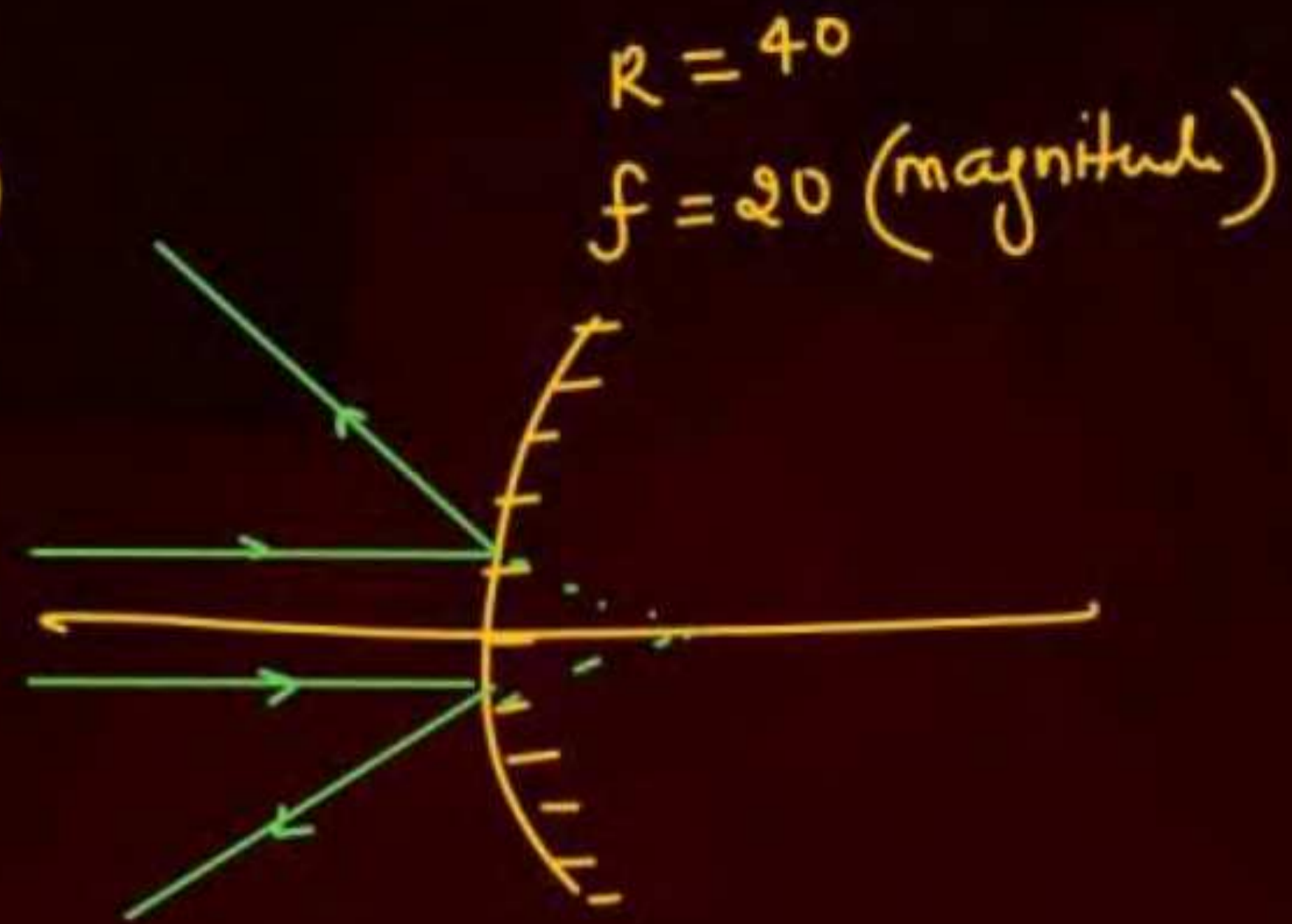


Concave mirror $f < 0$
 $f = -20$

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

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

②



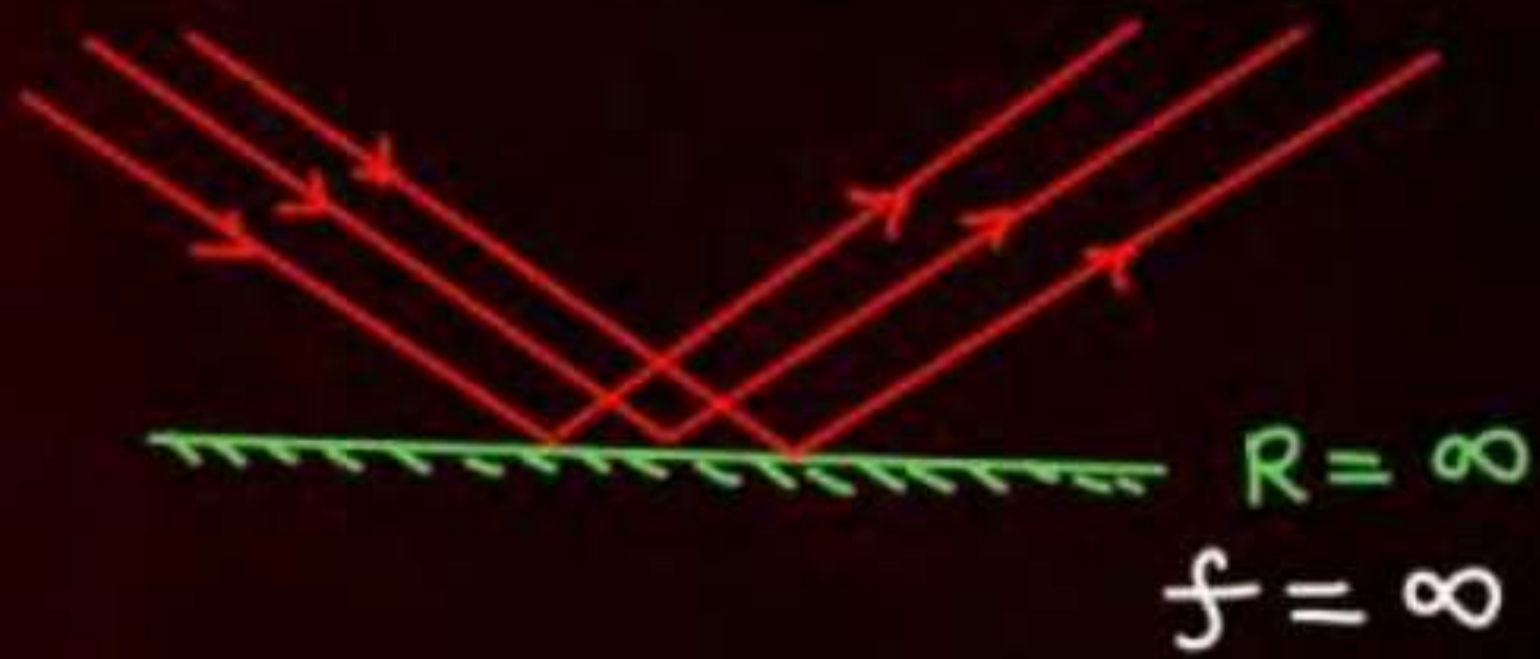
$$P = -\frac{1}{f} = -\frac{1}{(+20)}$$

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



③ plane mirror



$$R = \infty$$

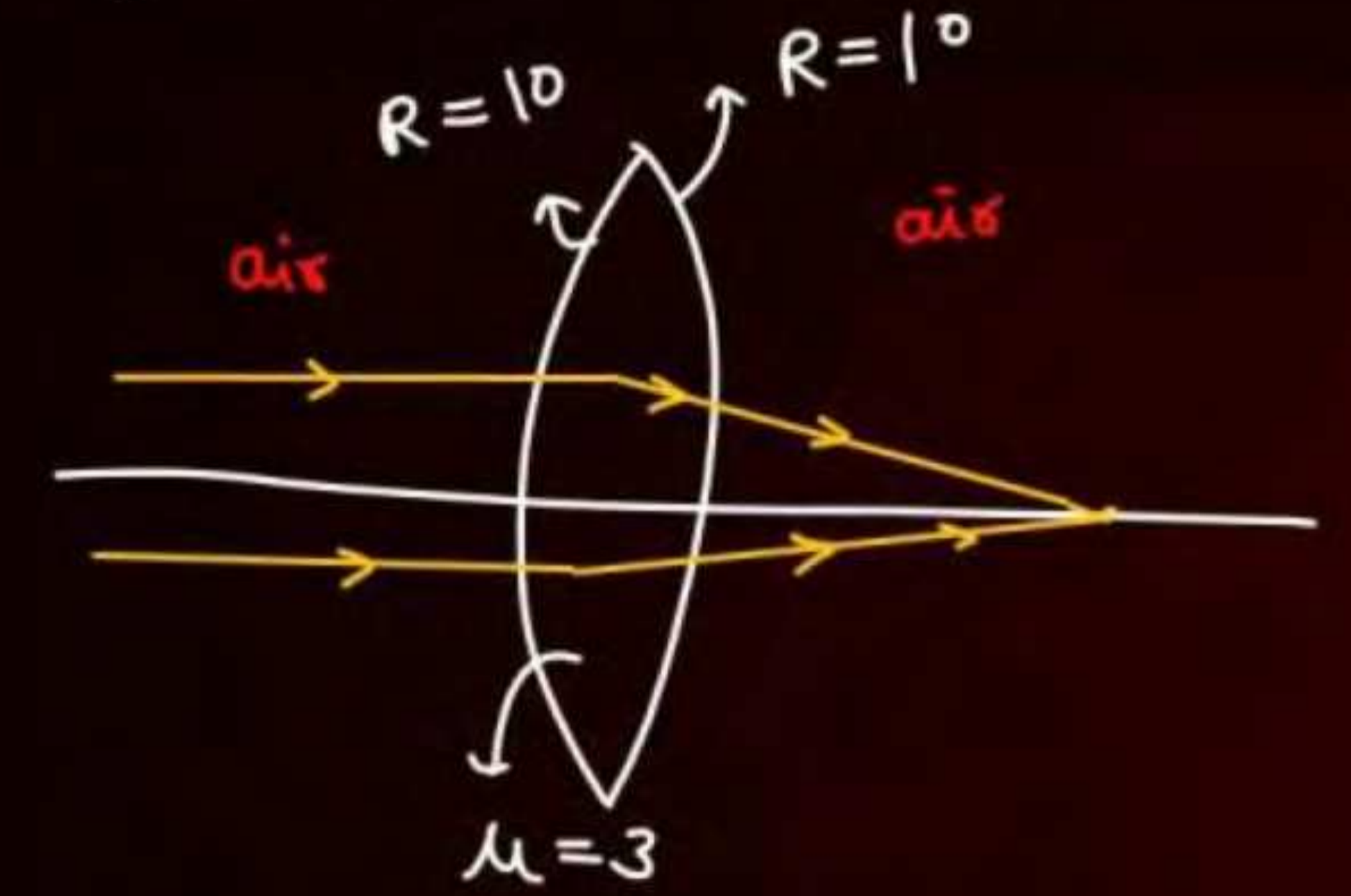
$$f = \infty$$

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



Q

find power of following



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

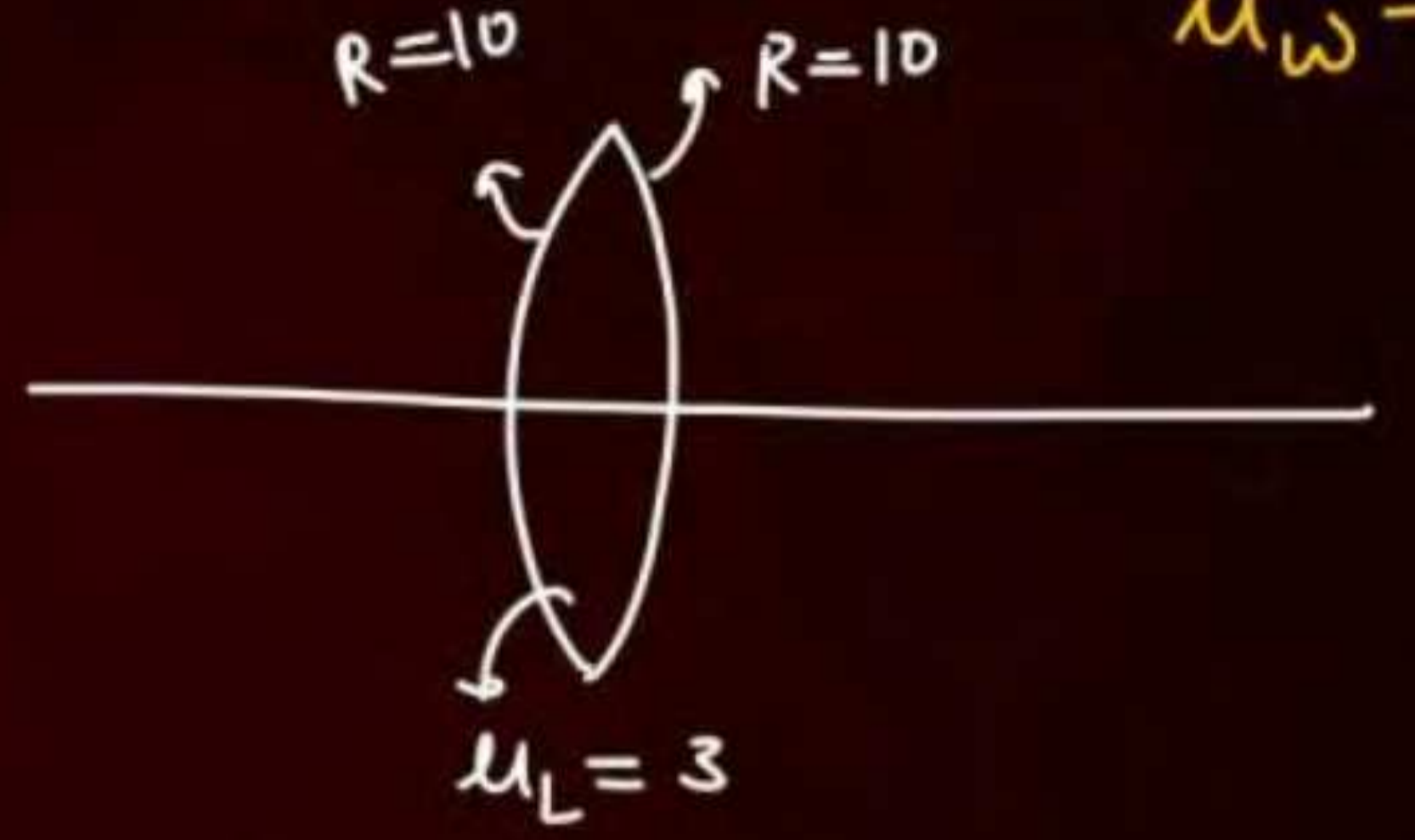
$$P = \frac{1}{f} = (3 - 1) \left(\frac{1}{10} - \frac{1}{-10} \right) = \frac{4}{10}$$

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

(b)

If this lens is dipped in water

$\mu_w = 4$

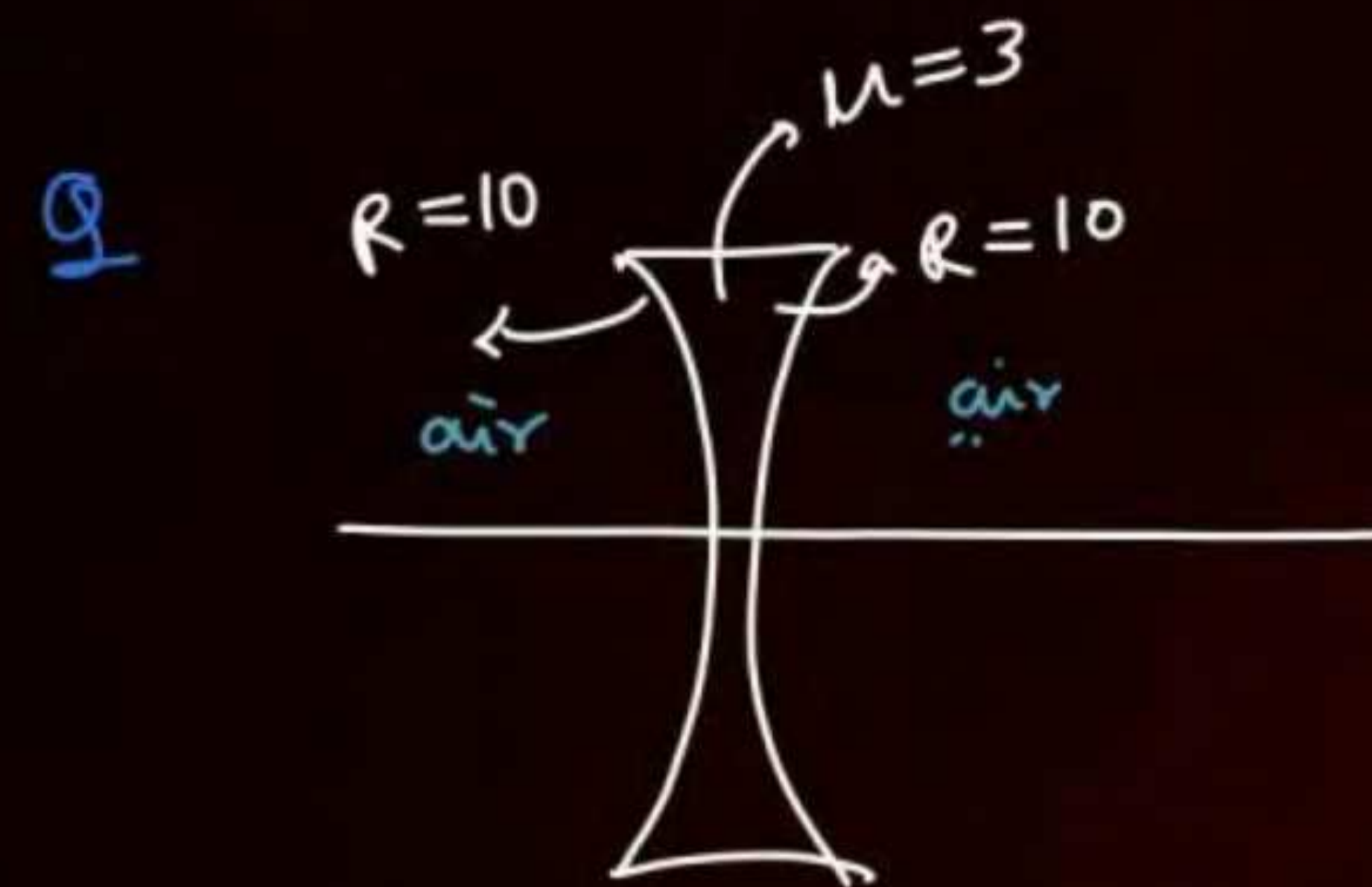


$$P = \frac{1}{f} = \left(\frac{3}{4} - 1 \right) \left(\frac{1}{10} - \frac{1}{-10} \right) = -\frac{1}{4} \times \frac{2}{10}$$

$P < 0$, Diverging

conclusion

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

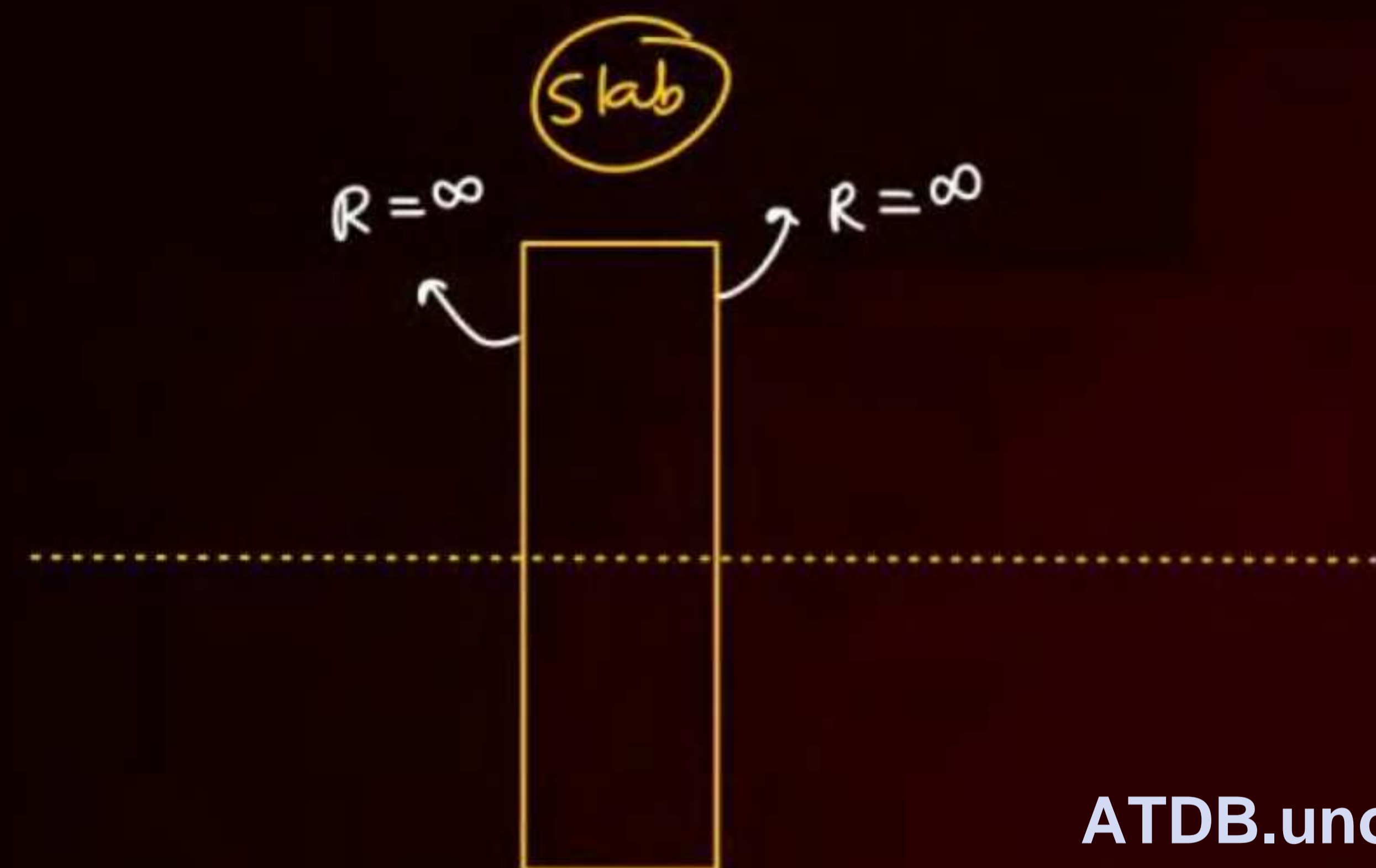


$$P = \frac{1}{f} = (\mu - 1) \left(\frac{1}{R_1} - \frac{1}{R_2} \right)$$

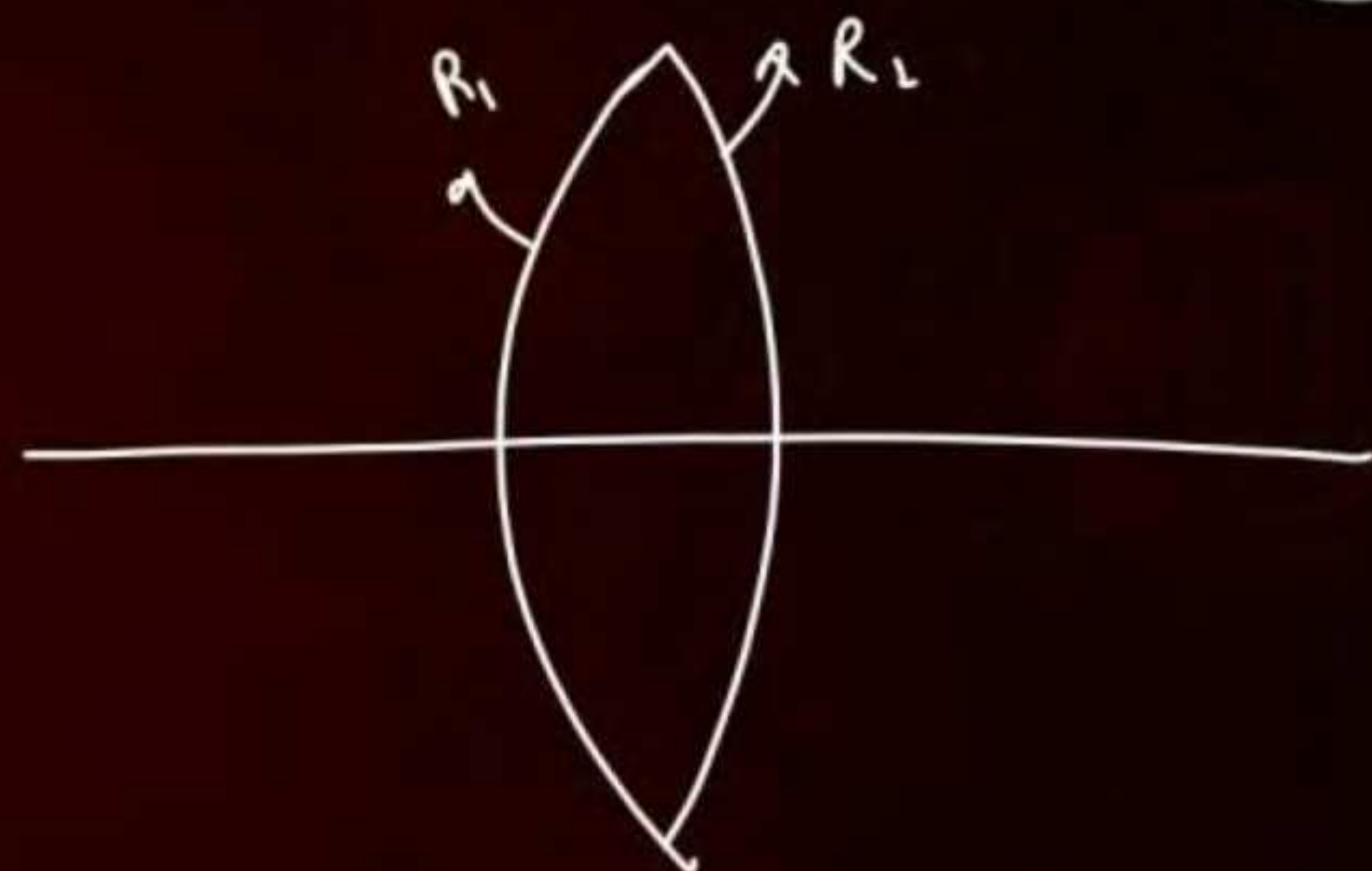
$$P = (3 - 1) \left(\frac{1}{-10} - \frac{1}{+10} \right)$$

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

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

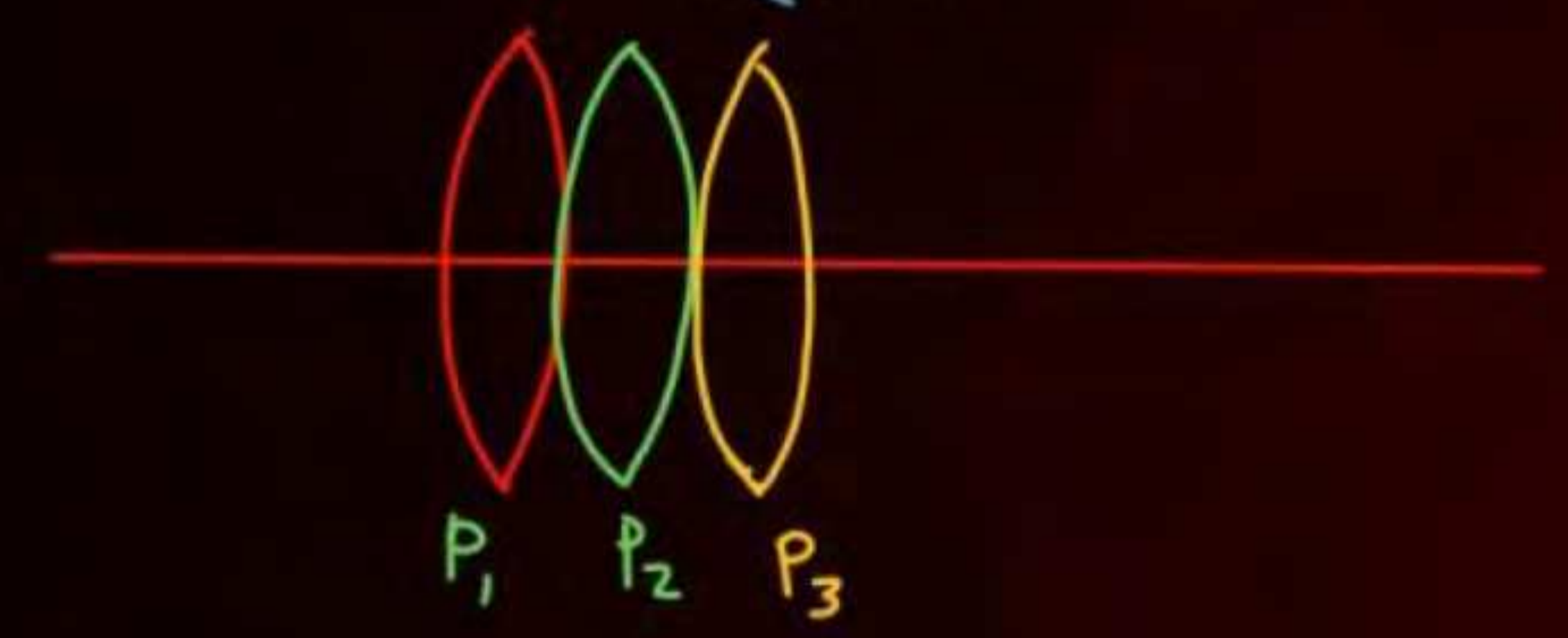
$$p = \frac{1}{f} = (\mu - 1) \left(\frac{1}{\infty} - \frac{1}{\infty} \right)$$

$$p = 0$$



Thin lens in contact

(thin)

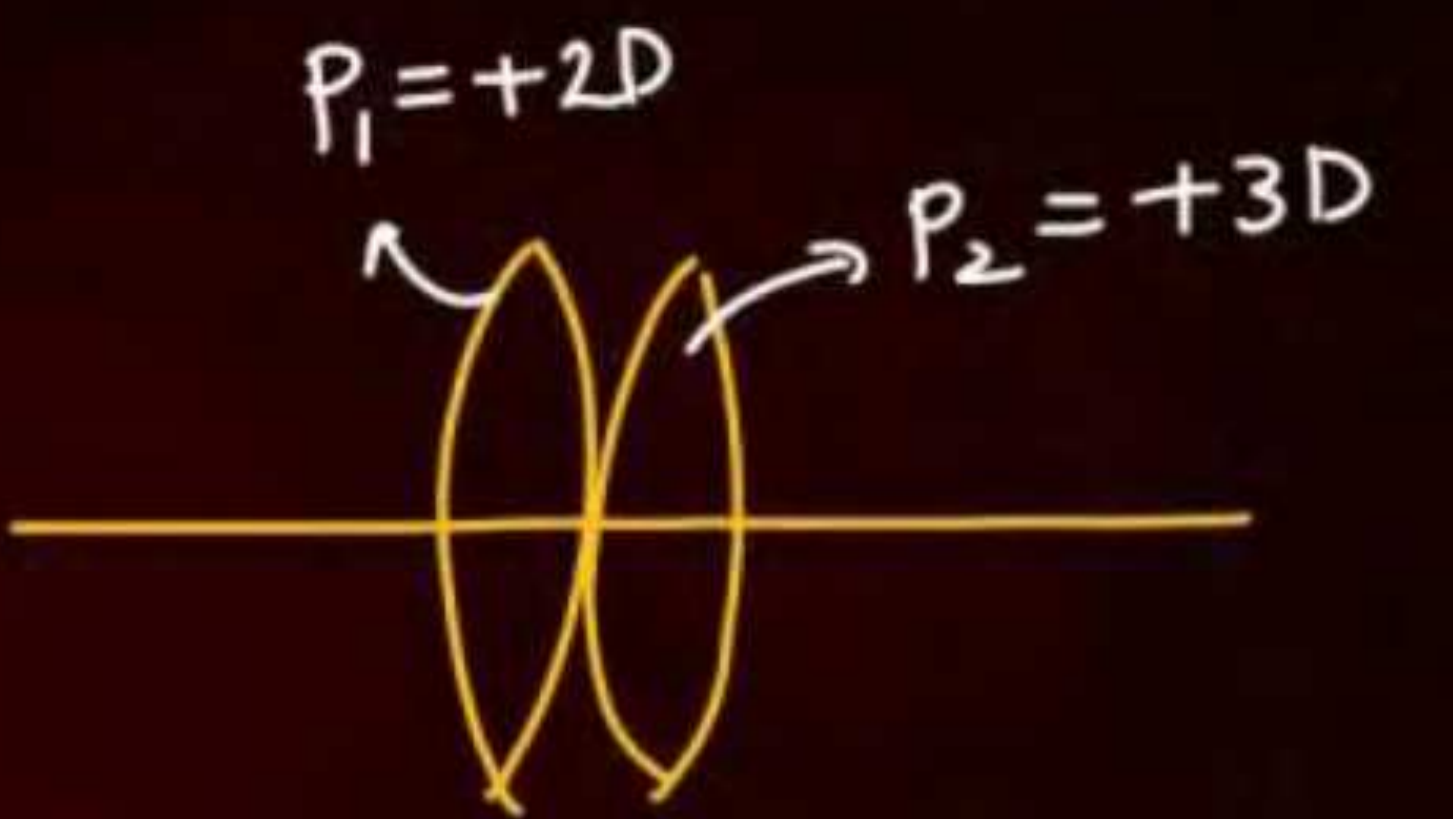


$$P_{net} = P_1 + P_2 + P_3 + \dots$$

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

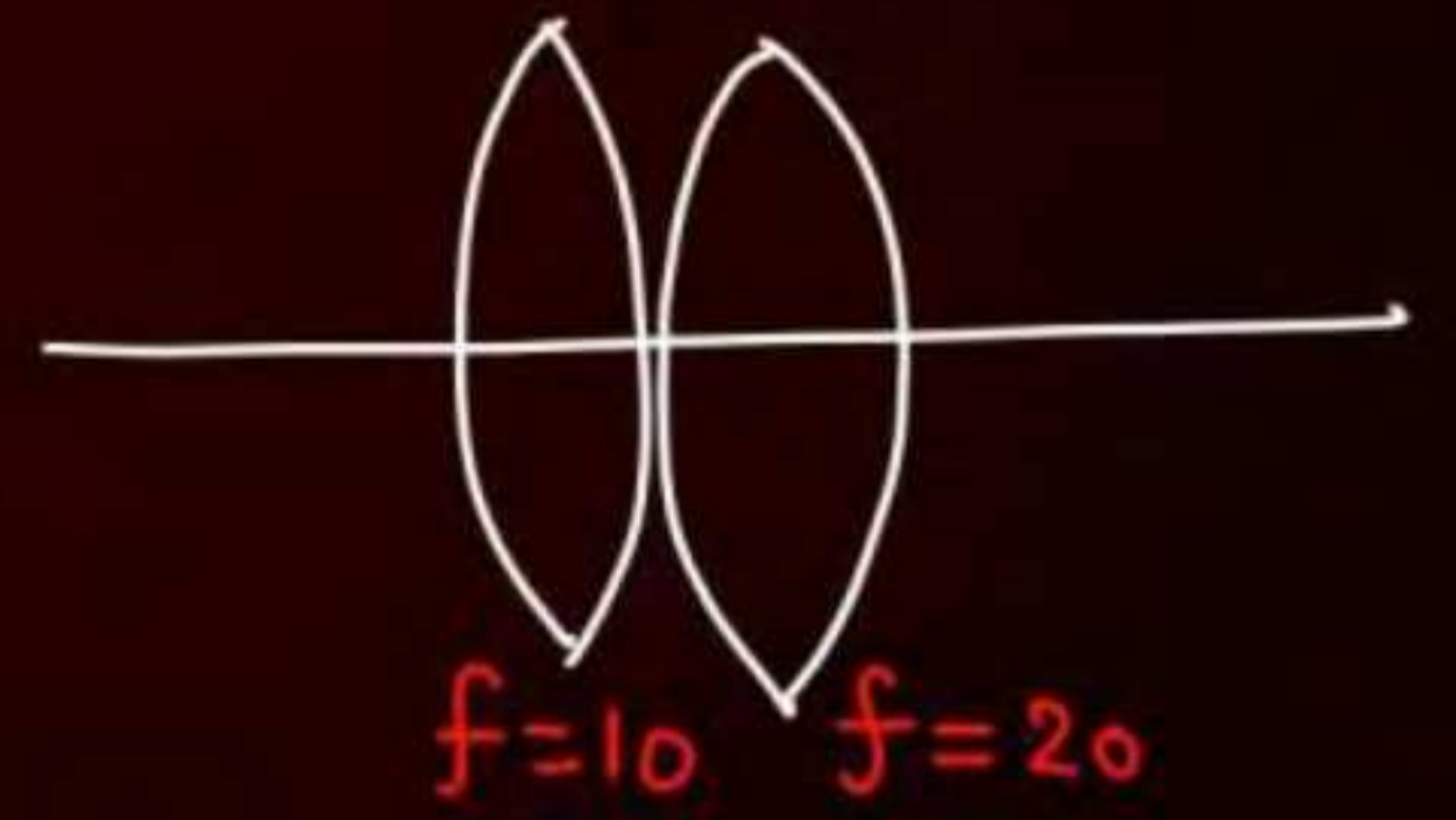
(with sign)

Q



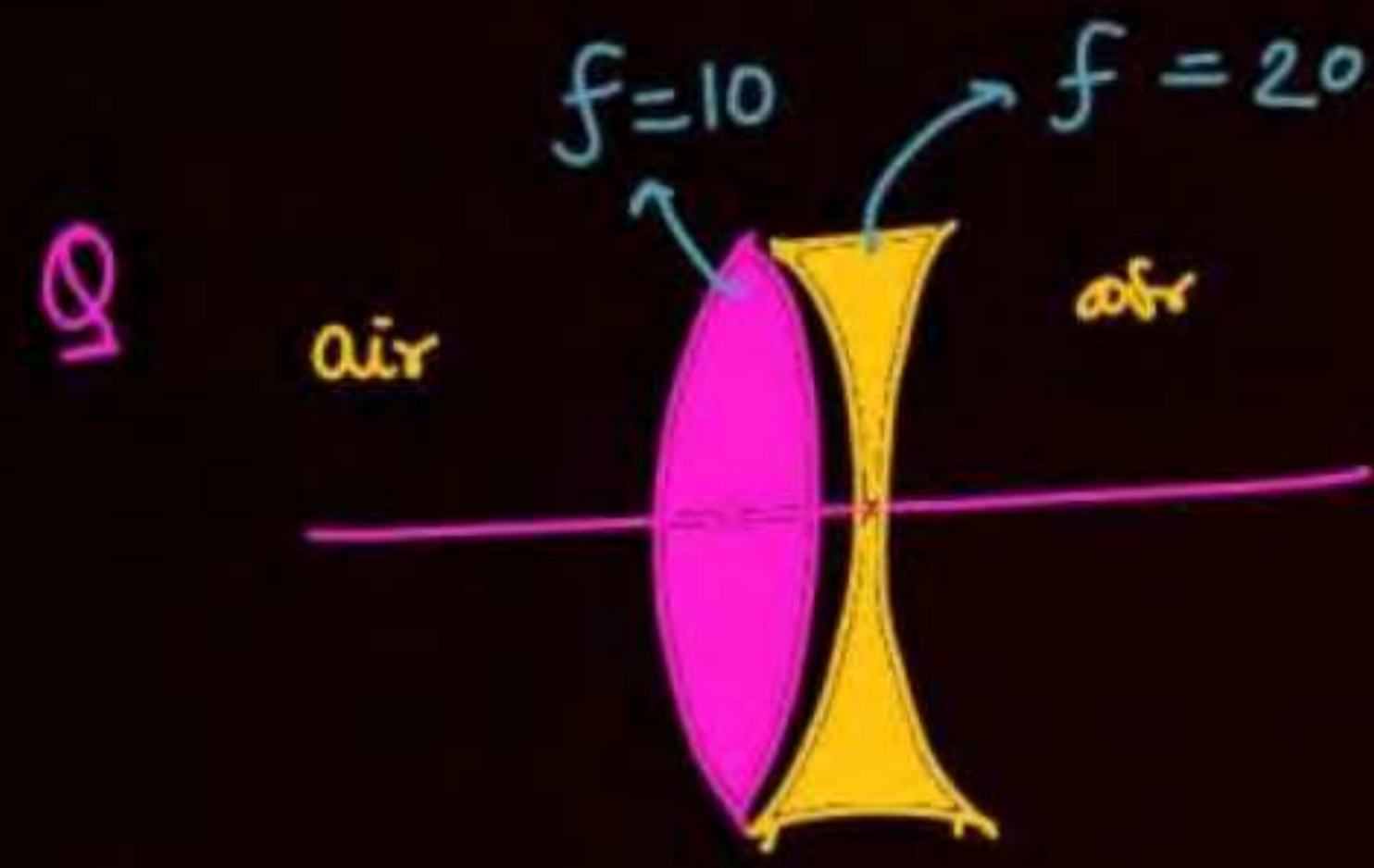
$$P_{net} = P_1 + P_2 = 2 + 3 = 5$$

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

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



SSSS

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

① P_{net} ② f_{eq}

$$u = -30$$

$$f = +20$$

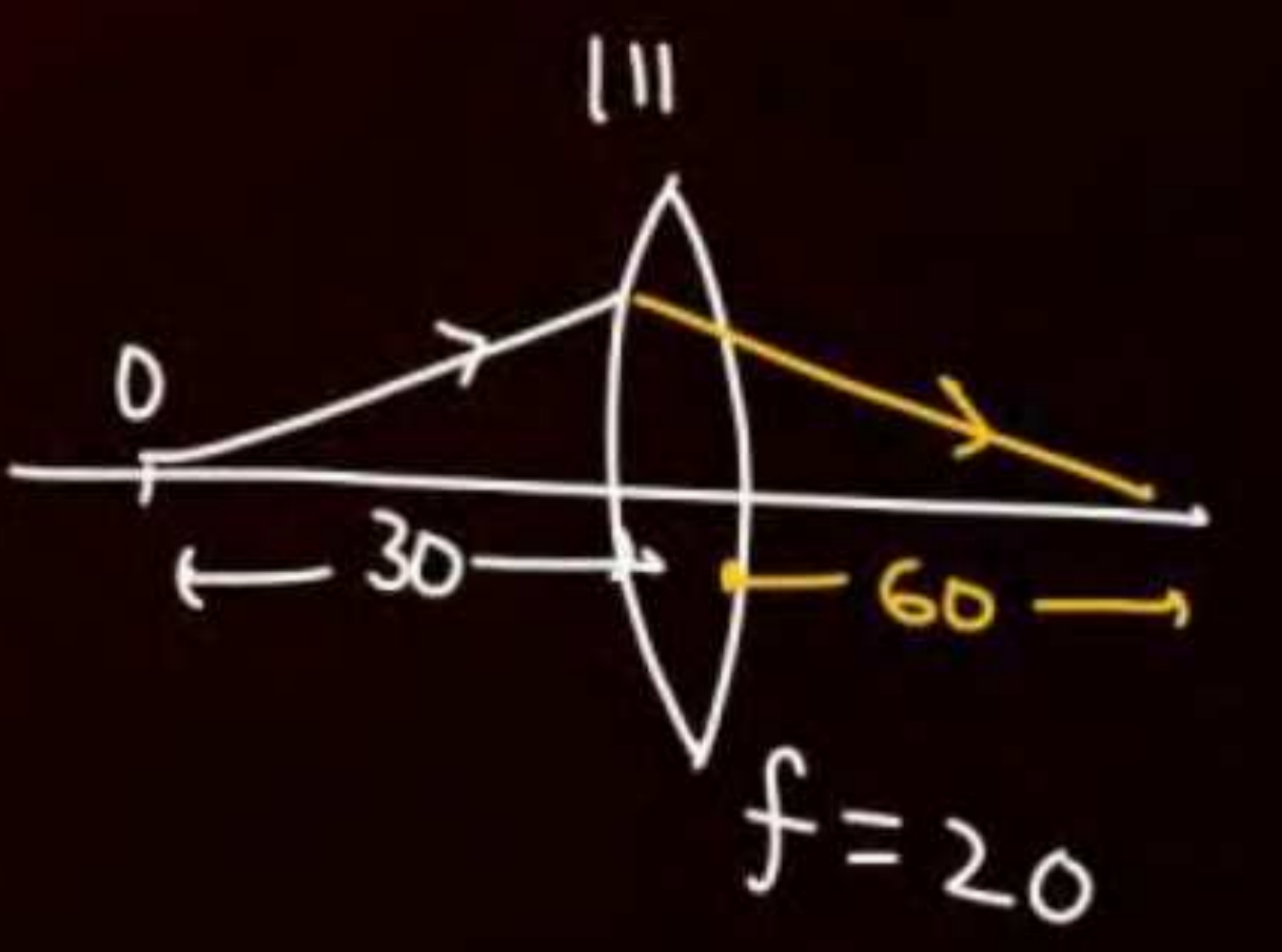
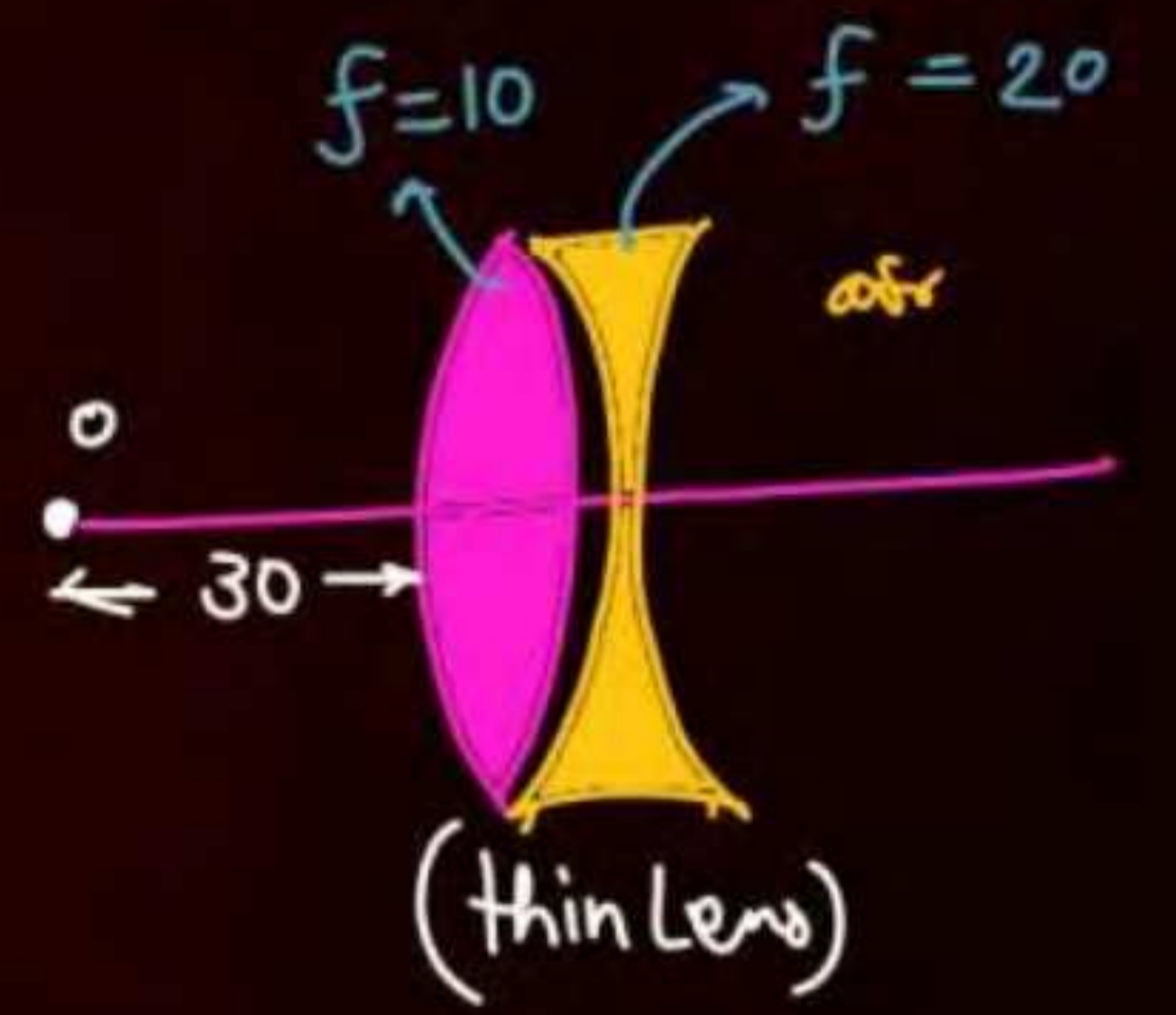
$$v = \frac{uf}{u+f}$$

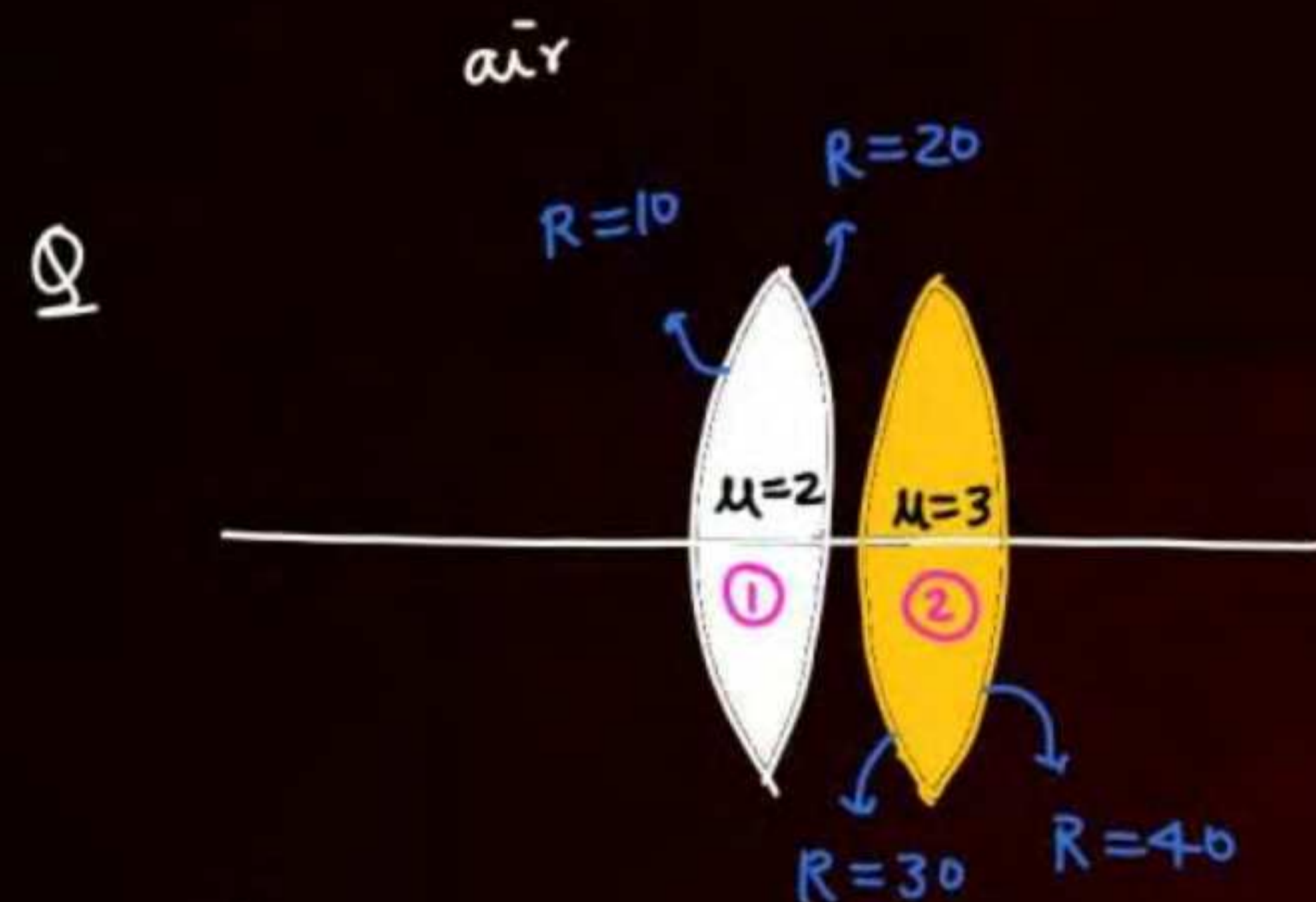
Sol

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

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





Solⁿ

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

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

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

- ① f_{eq}
- ② P_{net}
- ③ If an obj is placed at a distance 30 cm from lenses

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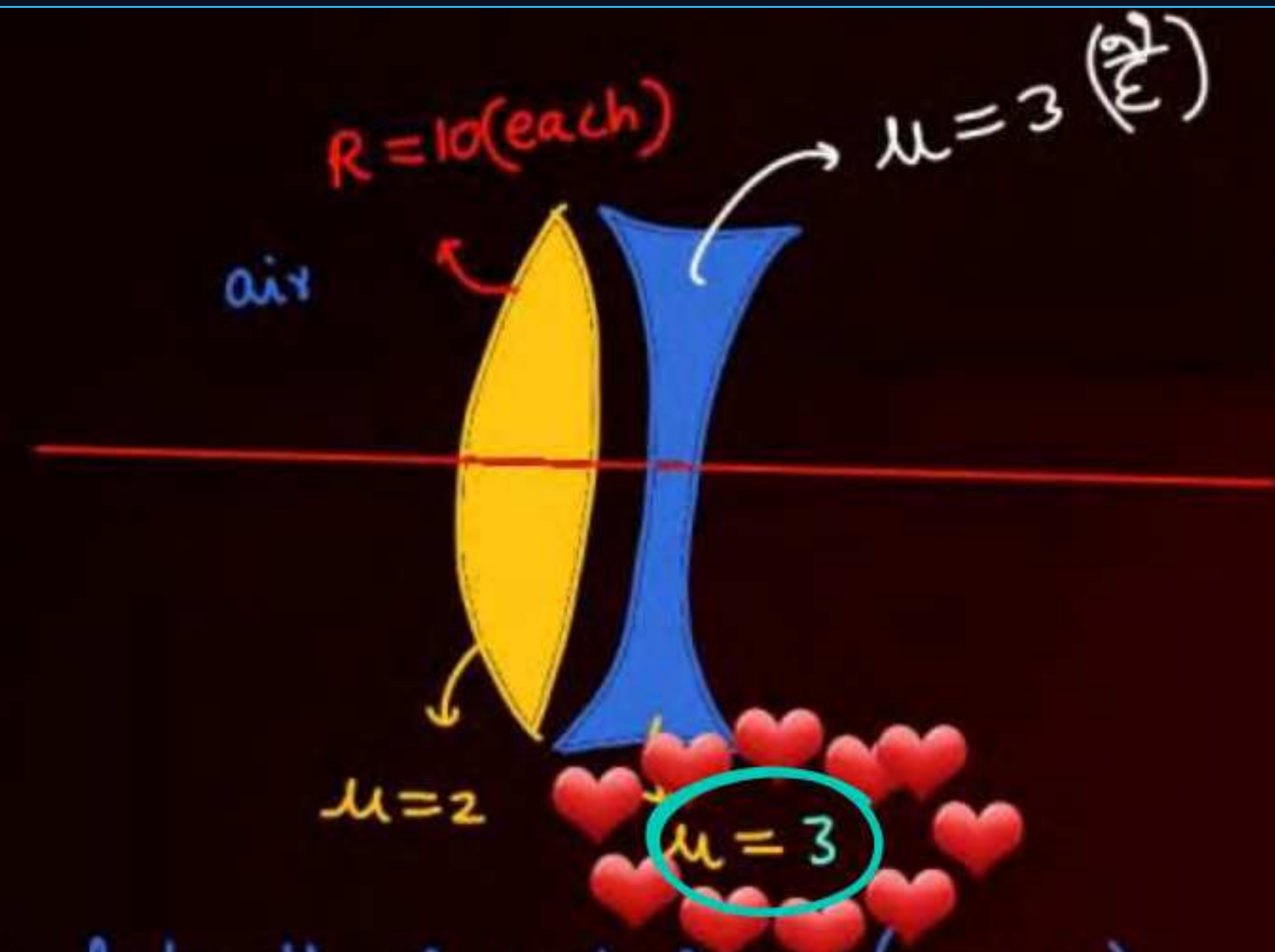
$$f_{eq} = \checkmark$$

$$P_{net} = \checkmark$$

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



Q



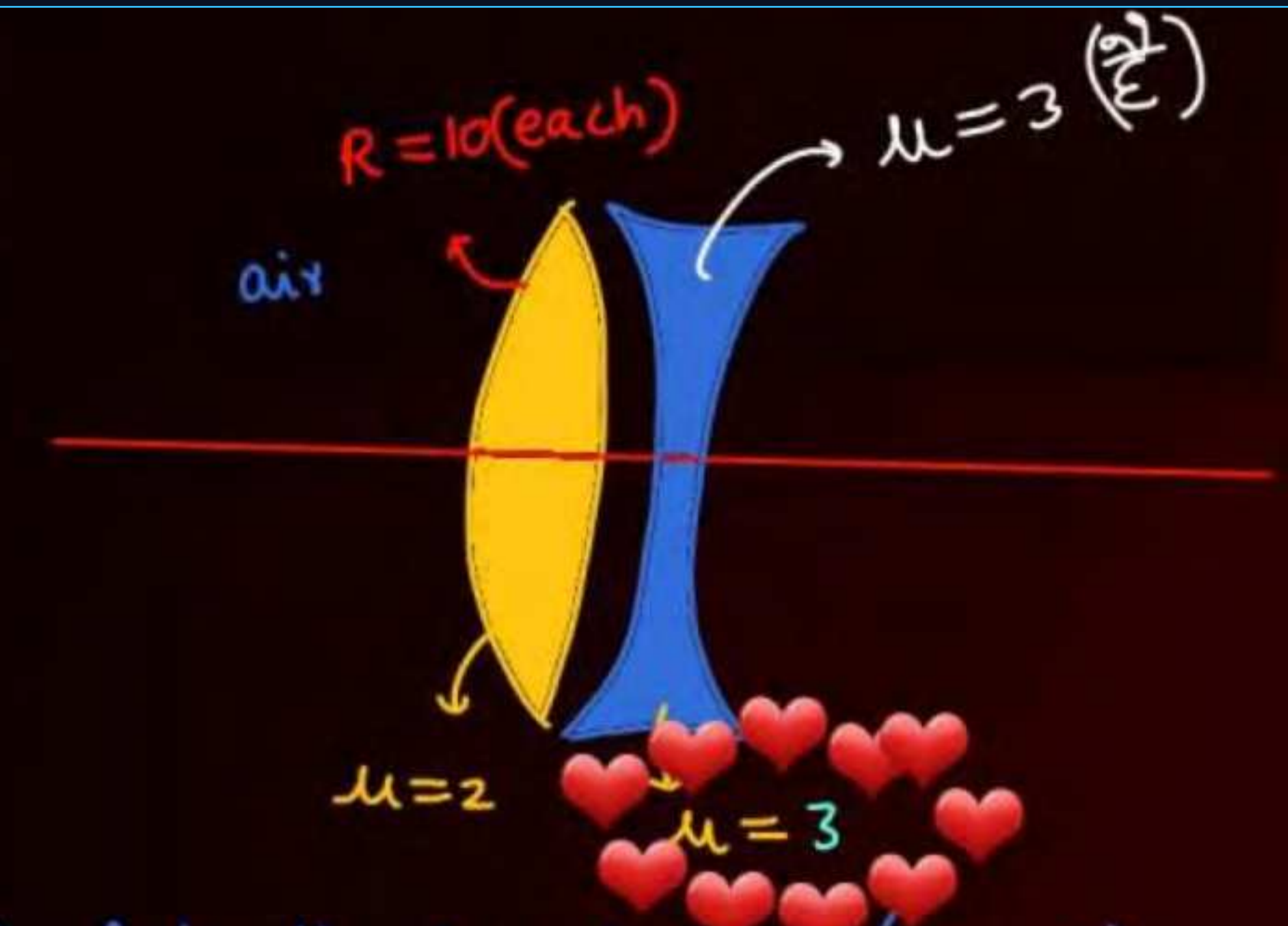
① focal length of each lens (in air) **ATDB.uno**

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

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

$$\begin{aligned} f_1 &= 5 \\ f &= -5/2 \end{aligned}$$

Q



② $f_{eq}, P_{net} =$

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

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

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

$$u = -30$$

$$f = -5$$

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

① focal length of each lens (in air) ATDB.uno

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

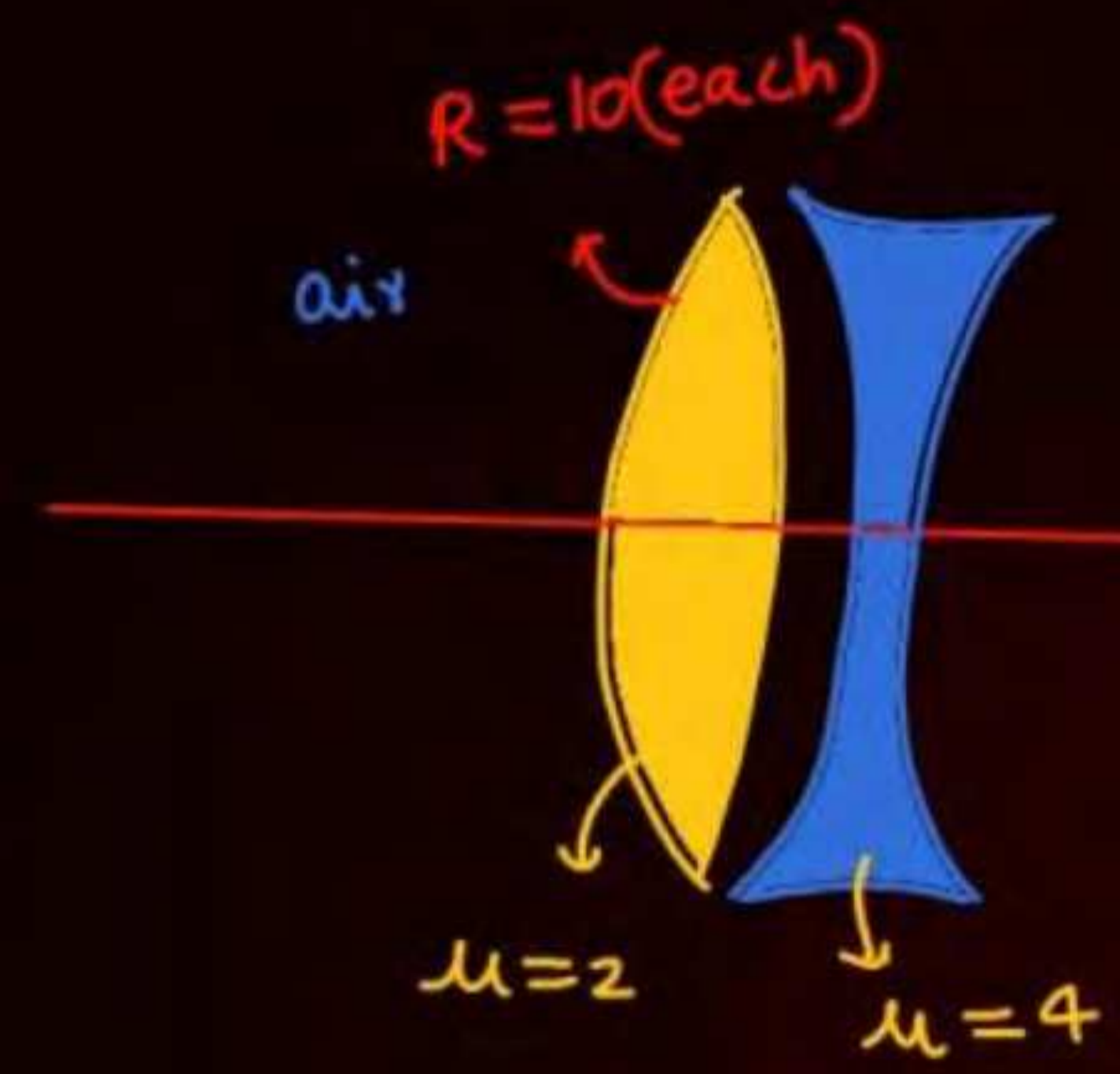
$$\frac{1}{f_2} = (3-1) \left(-\frac{1}{10} - \frac{1}{+10} \right) = -\frac{4}{10}$$

$$f_1 = 5$$

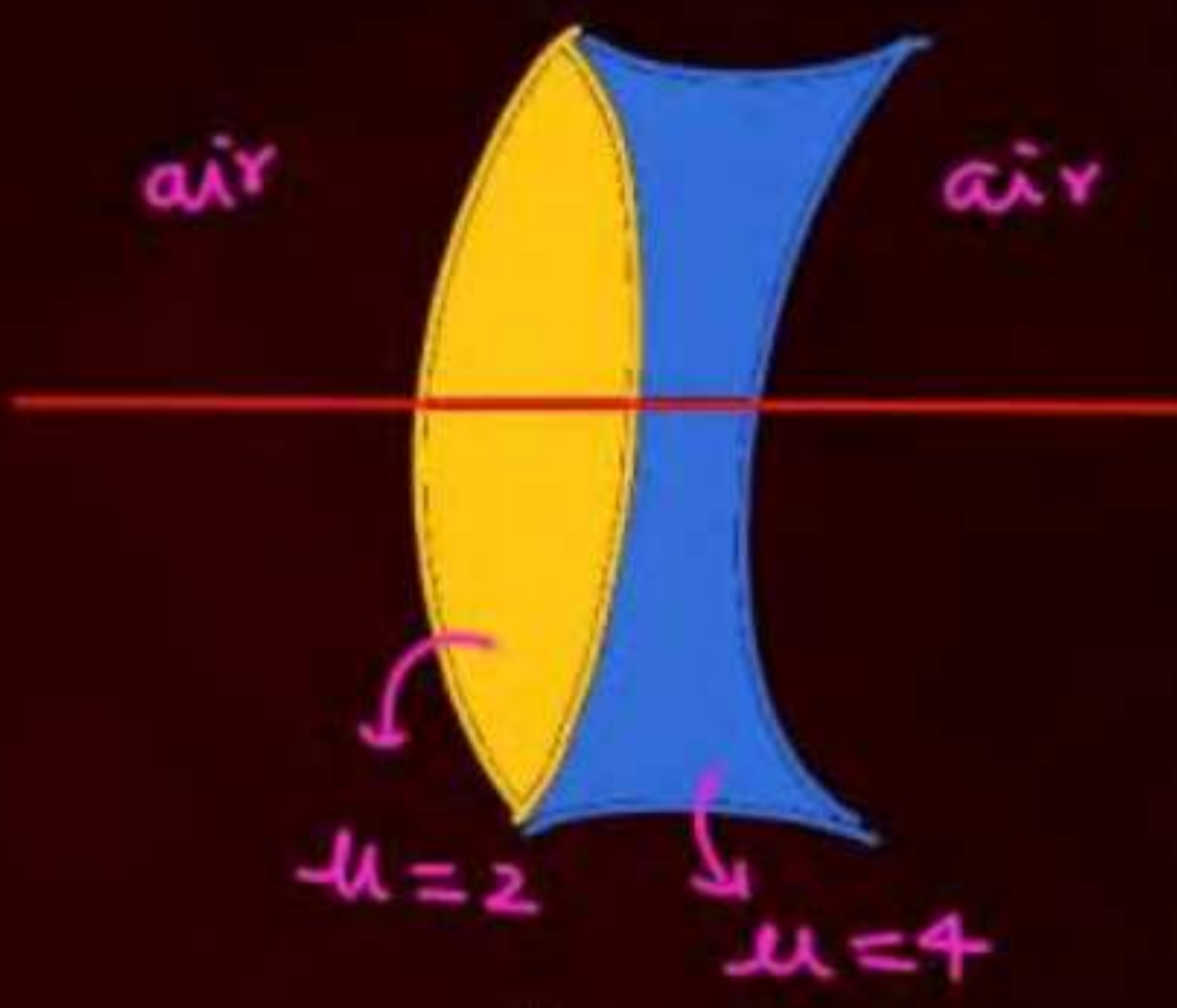
$$f = -5/2$$



Q

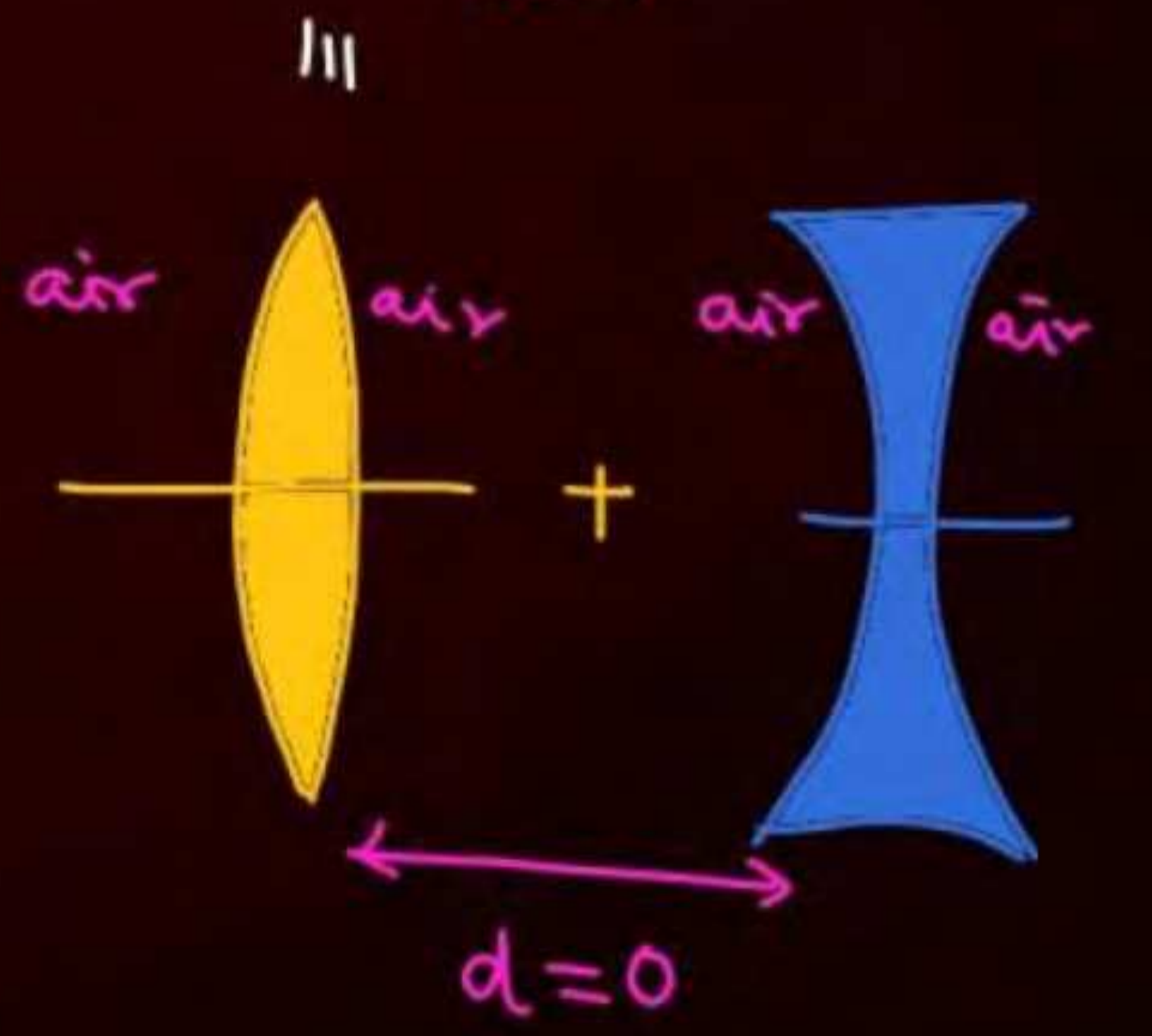


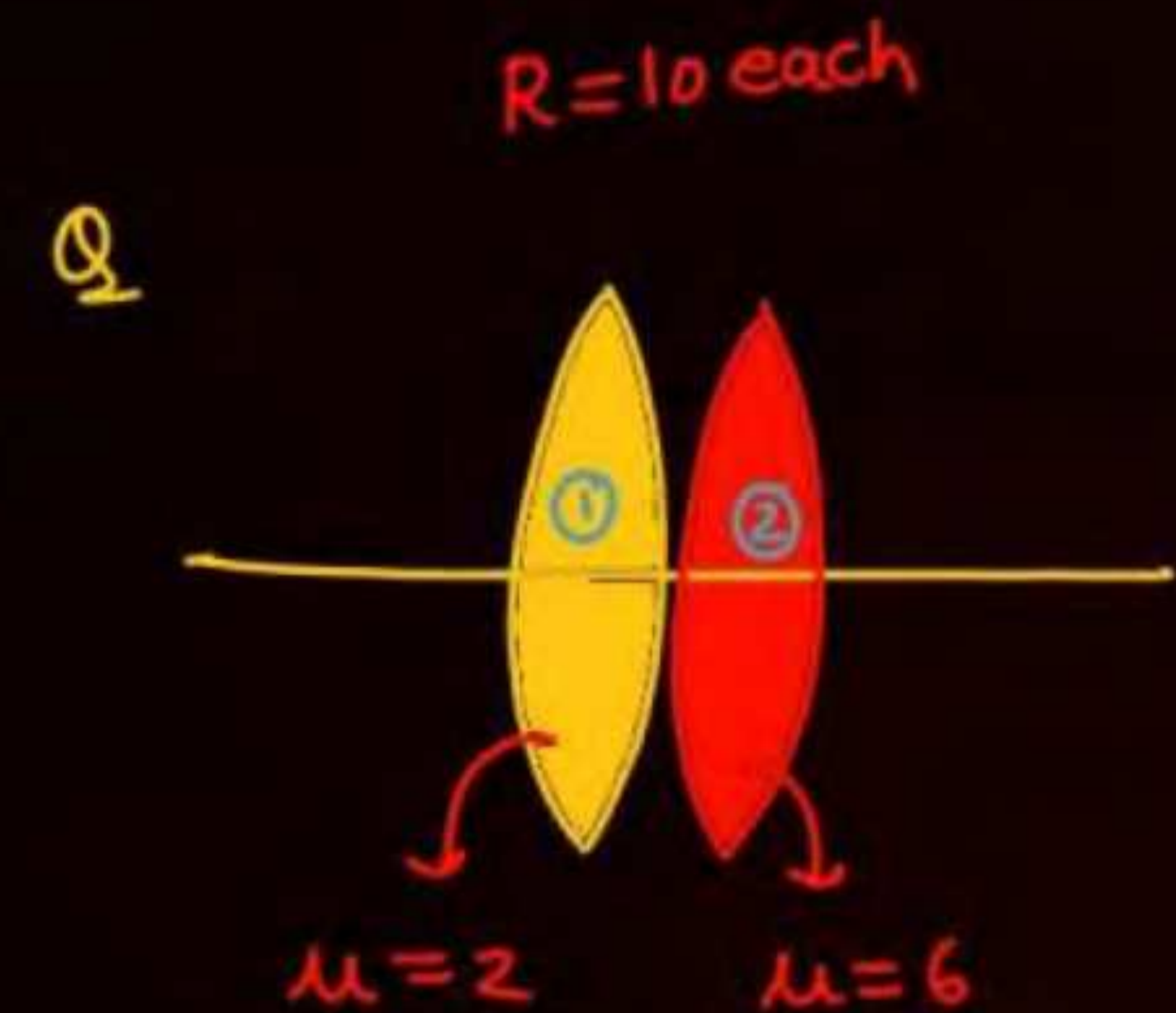
\Rightarrow



ये दो चिपके Lens हैं
 दोनो एवा में
 Very close to each other

(सकती है)
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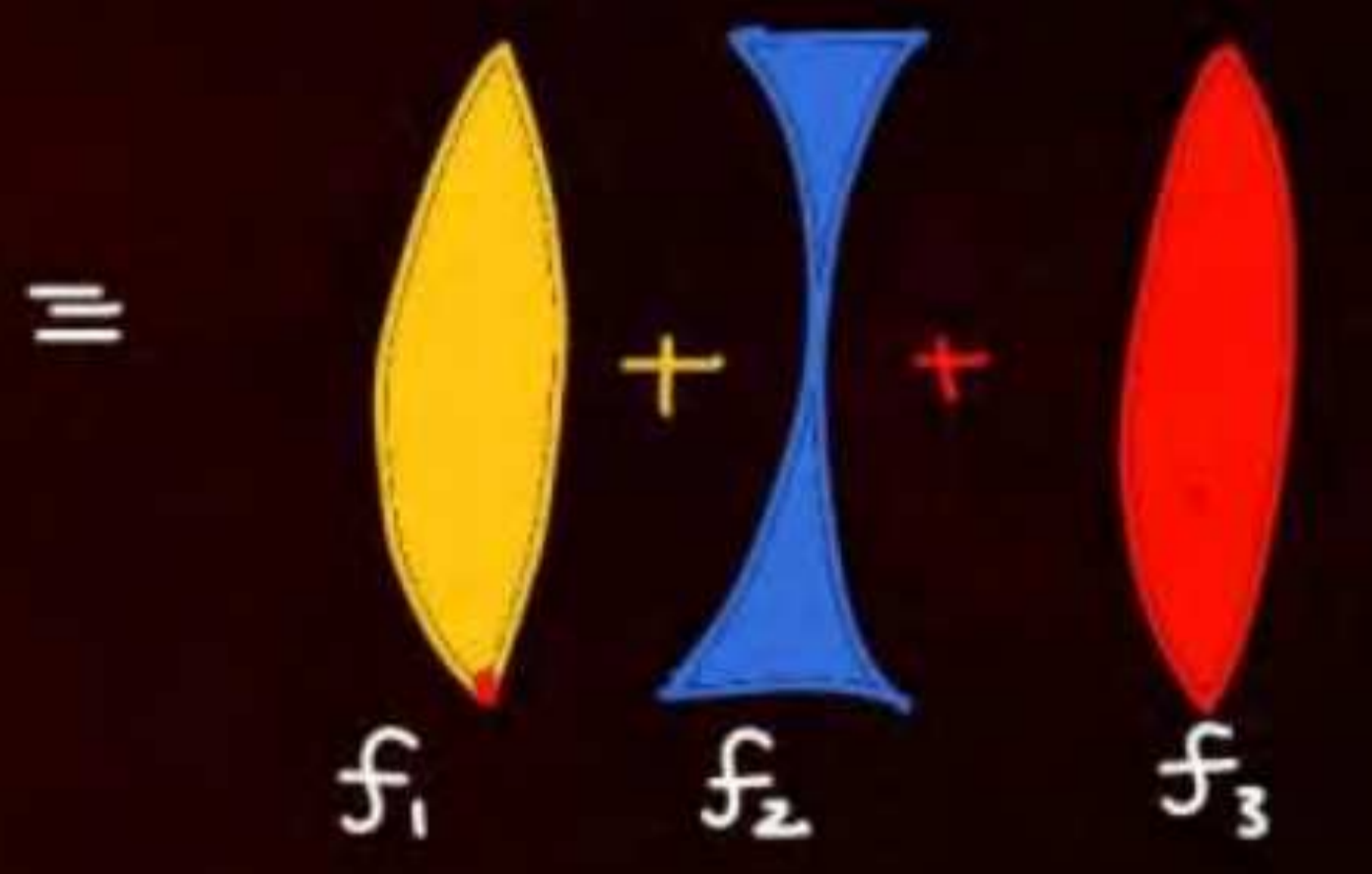
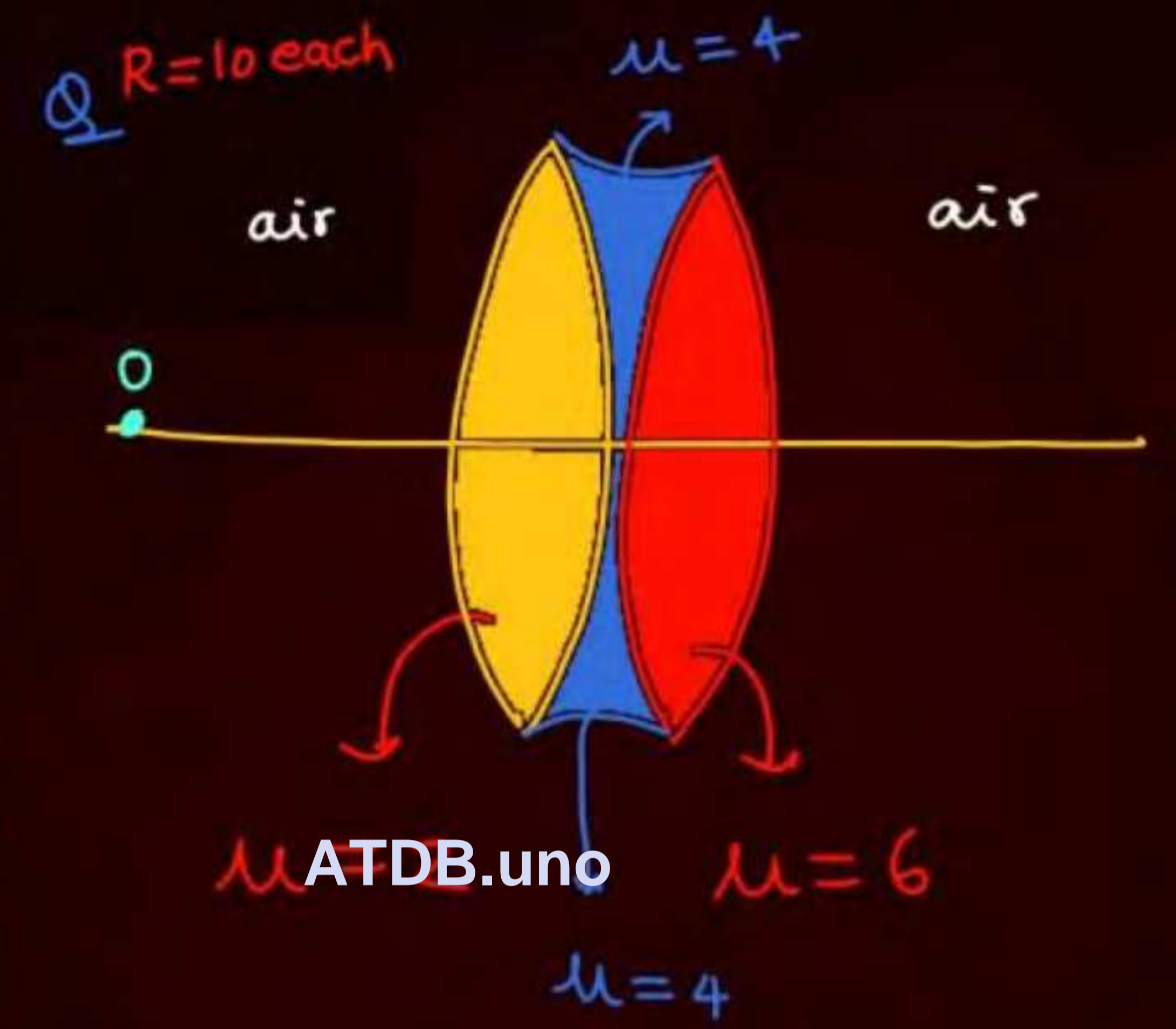




$$\frac{1}{f_1} = (2-1) \left(\frac{1}{10} - \frac{1}{-10} \right) = \frac{2}{10}$$

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

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



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

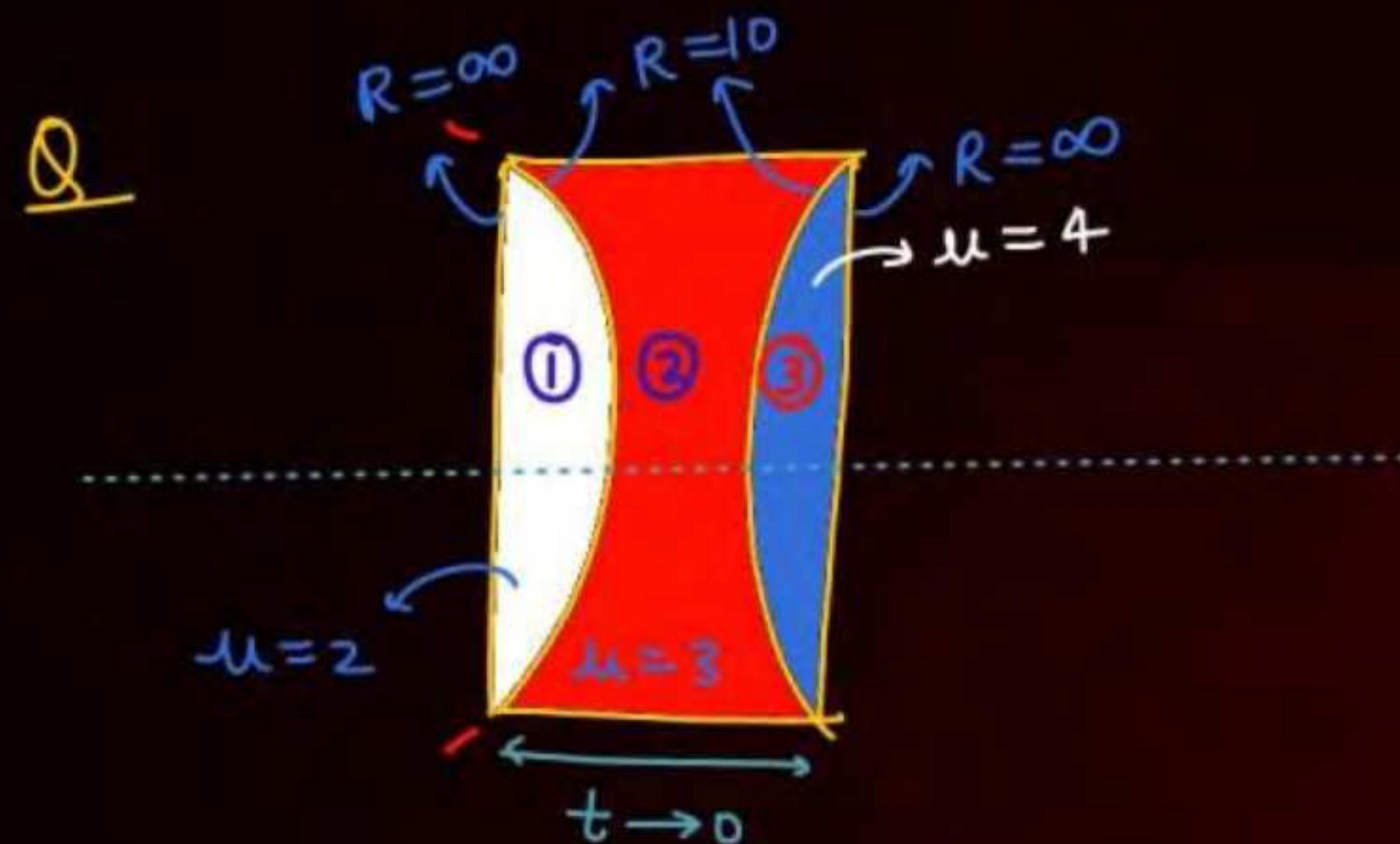
$$\frac{1}{f_2} = (4-1) \left(\frac{1}{-10} - \frac{1}{+10} \right)$$

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

① $f_{eq} = ?$

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

② obj is placed at a distance 30 cm from lens

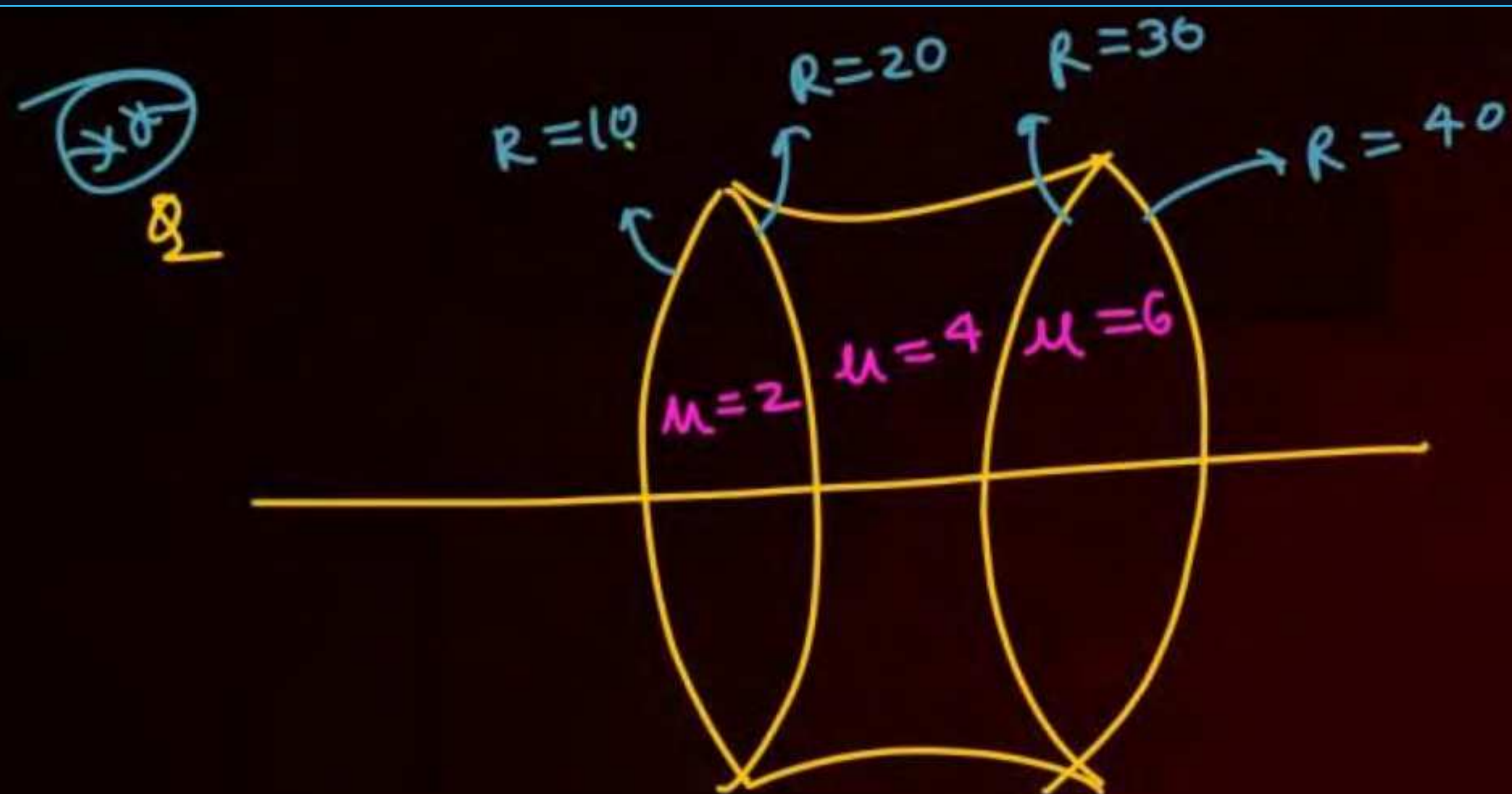


$$\frac{1}{f_1} = (2-1) \left(\frac{1}{\infty} - \frac{1}{-10} \right)$$

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

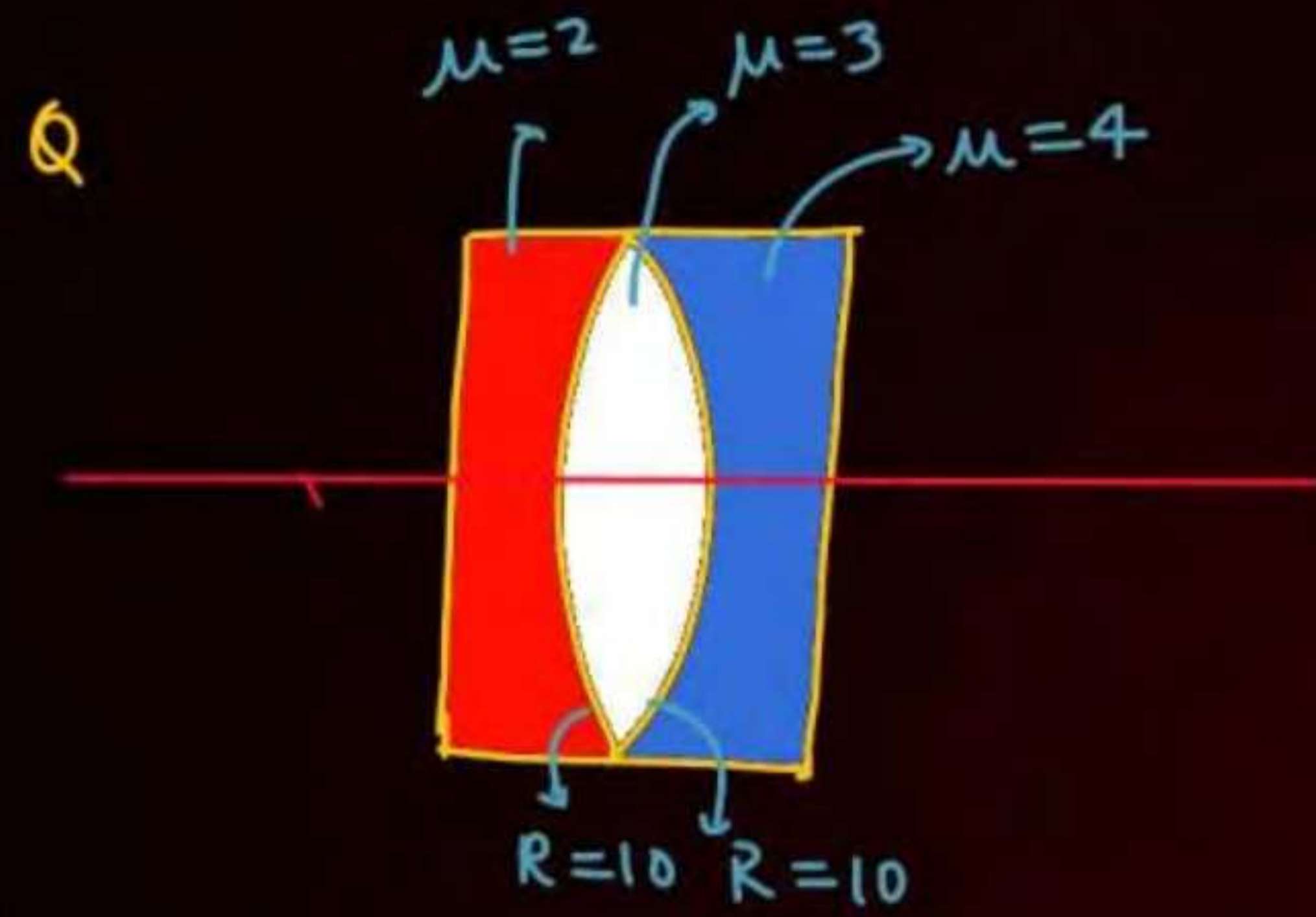
$$\frac{1}{f_3} = (4-1) \left(\frac{1}{+10} - \frac{1}{\infty} \right)$$

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



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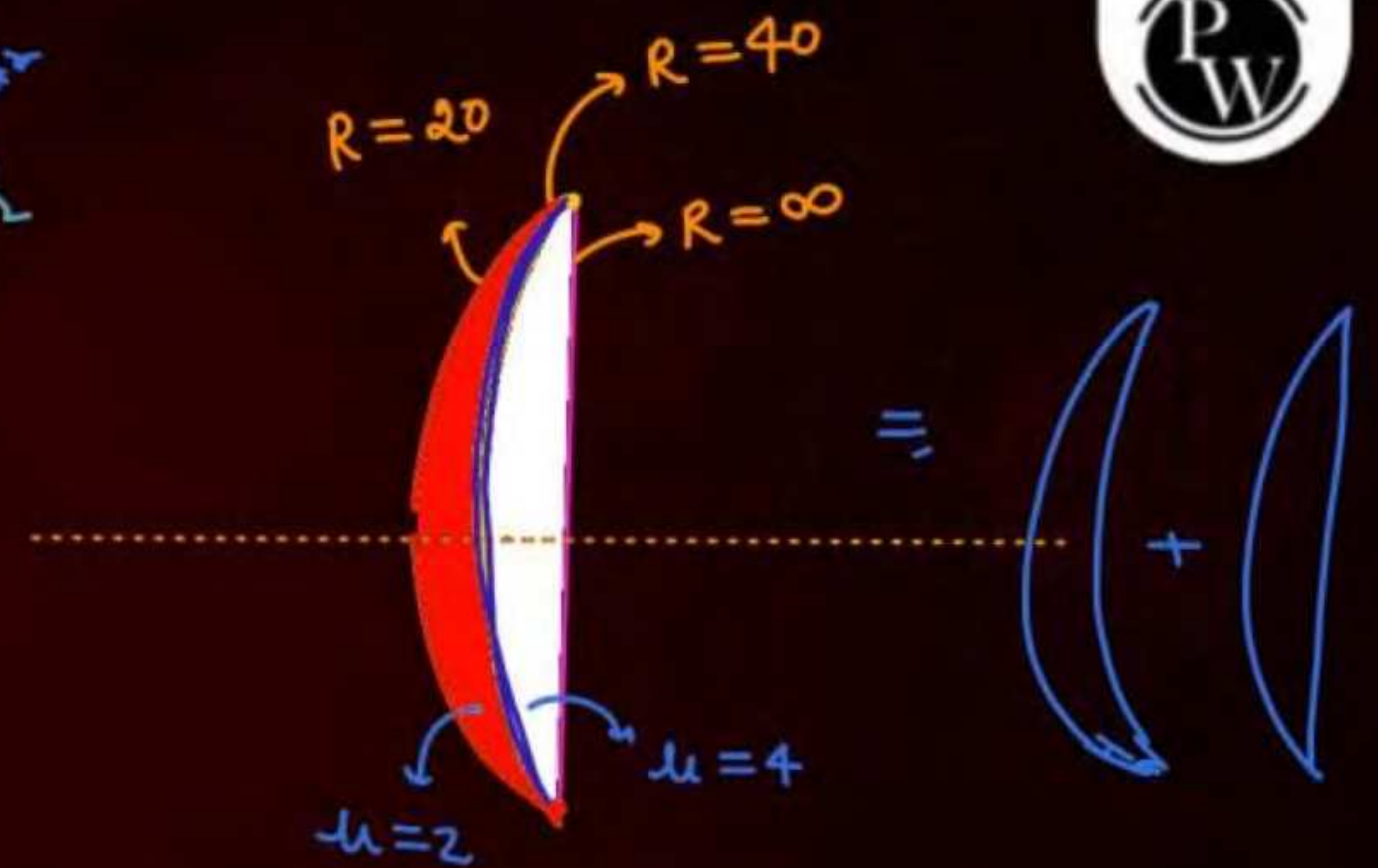
$$\frac{1}{f_{eq}} = (2-1) \left(\frac{1}{10} - \frac{1}{-20} \right) + (4-1) \left(\frac{1}{-20} - \frac{1}{+30} \right) + (6-1) \left(\frac{1}{+30} - \frac{1}{-40} \right)$$



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

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Q

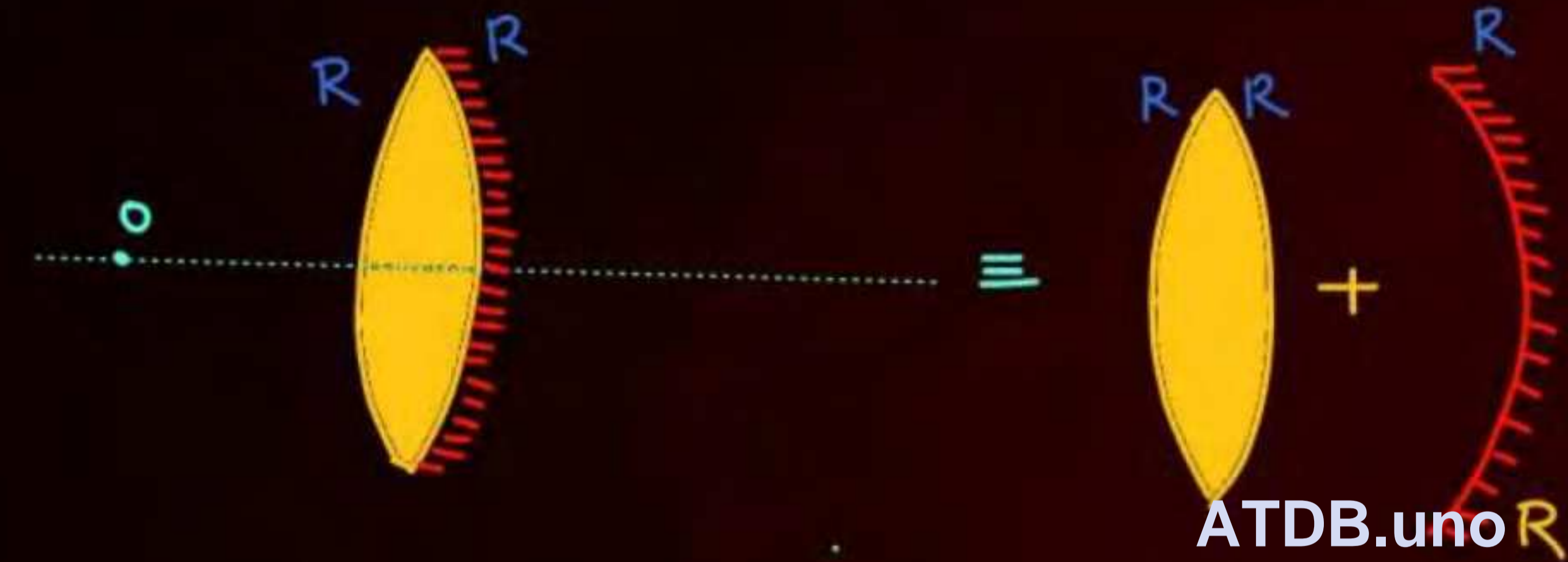


$$\frac{1}{f_{eq}} = (2-1) \left(\frac{1}{+20} - \frac{1}{+40} \right) + (4-1) \left(\frac{1}{+40} - \frac{1}{\infty} \right)$$



Silvering of lens

Q find feq



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

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

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

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

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

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

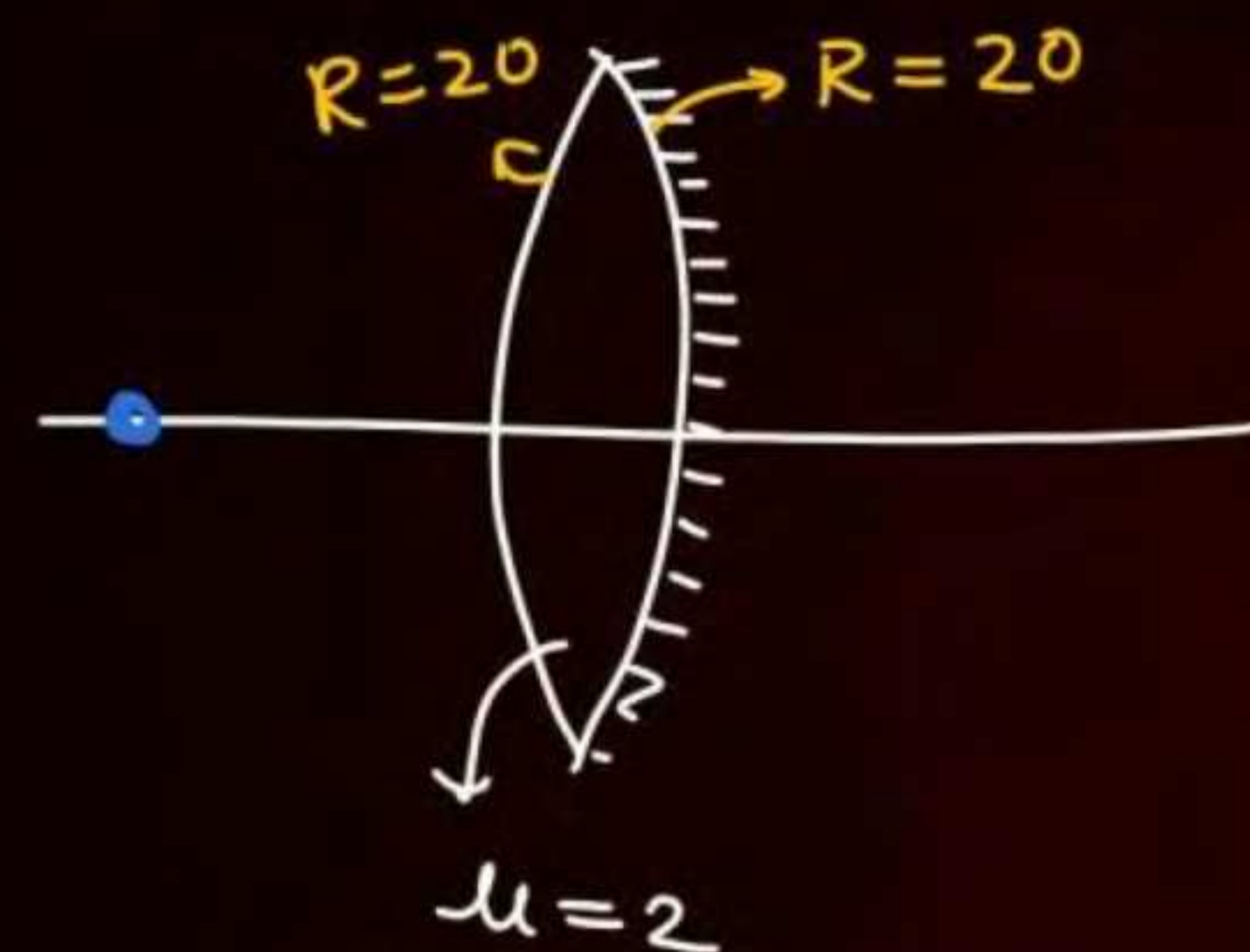
whole system is behave like mirror.





find focal length of following

Q



Solⁿ

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

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

$$P_L = \frac{1}{f} = (\mu - 1) \left(\frac{1}{R_1} - \frac{1}{R_2} \right) = (2 - 1) \left(\frac{1}{20} - \frac{1}{-20} \right) = \frac{1}{10}$$

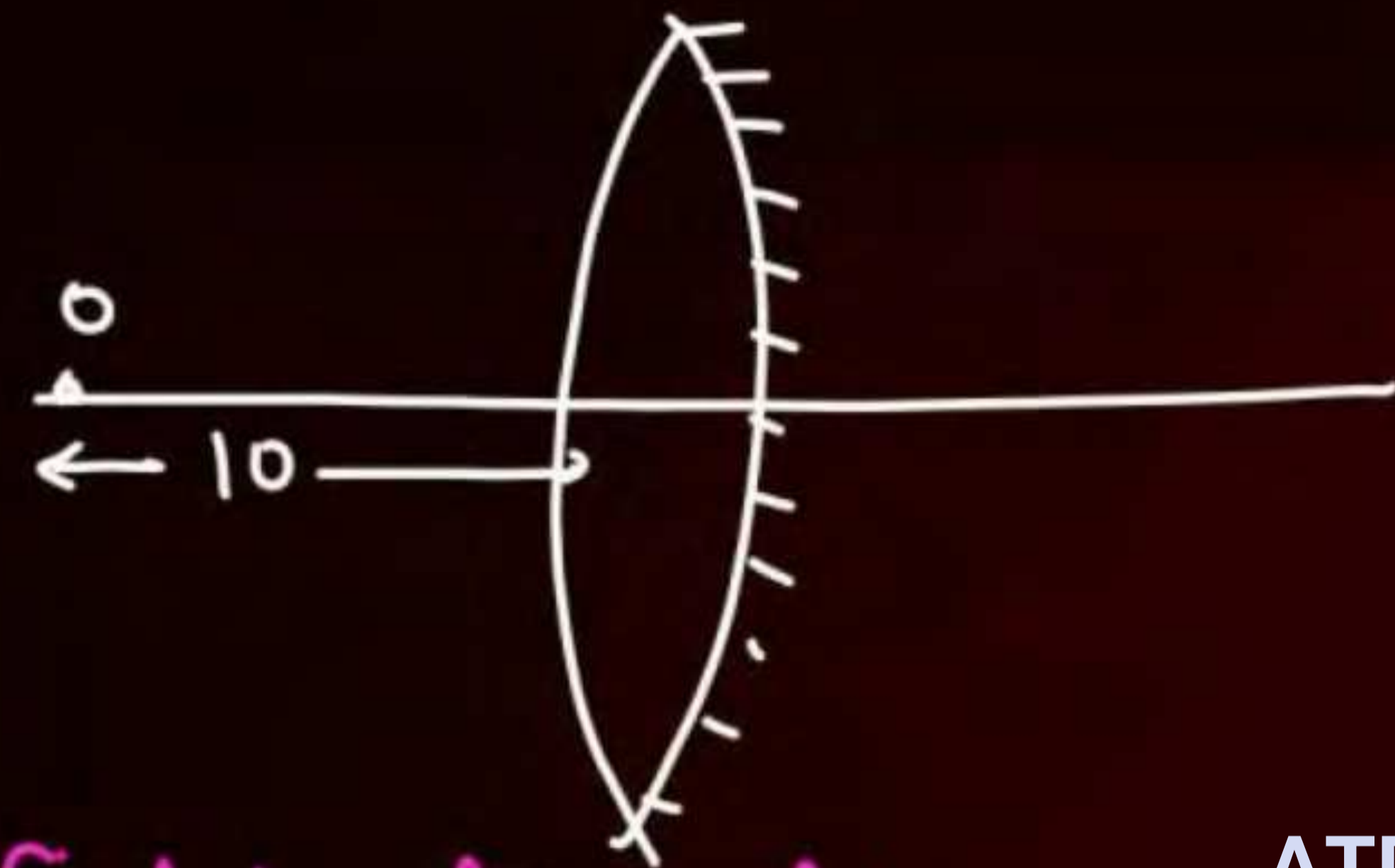
$$P_m = -\frac{1}{f_m} = -\frac{1}{\left(\frac{-20}{2} \right)} = \frac{1}{10}$$

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

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

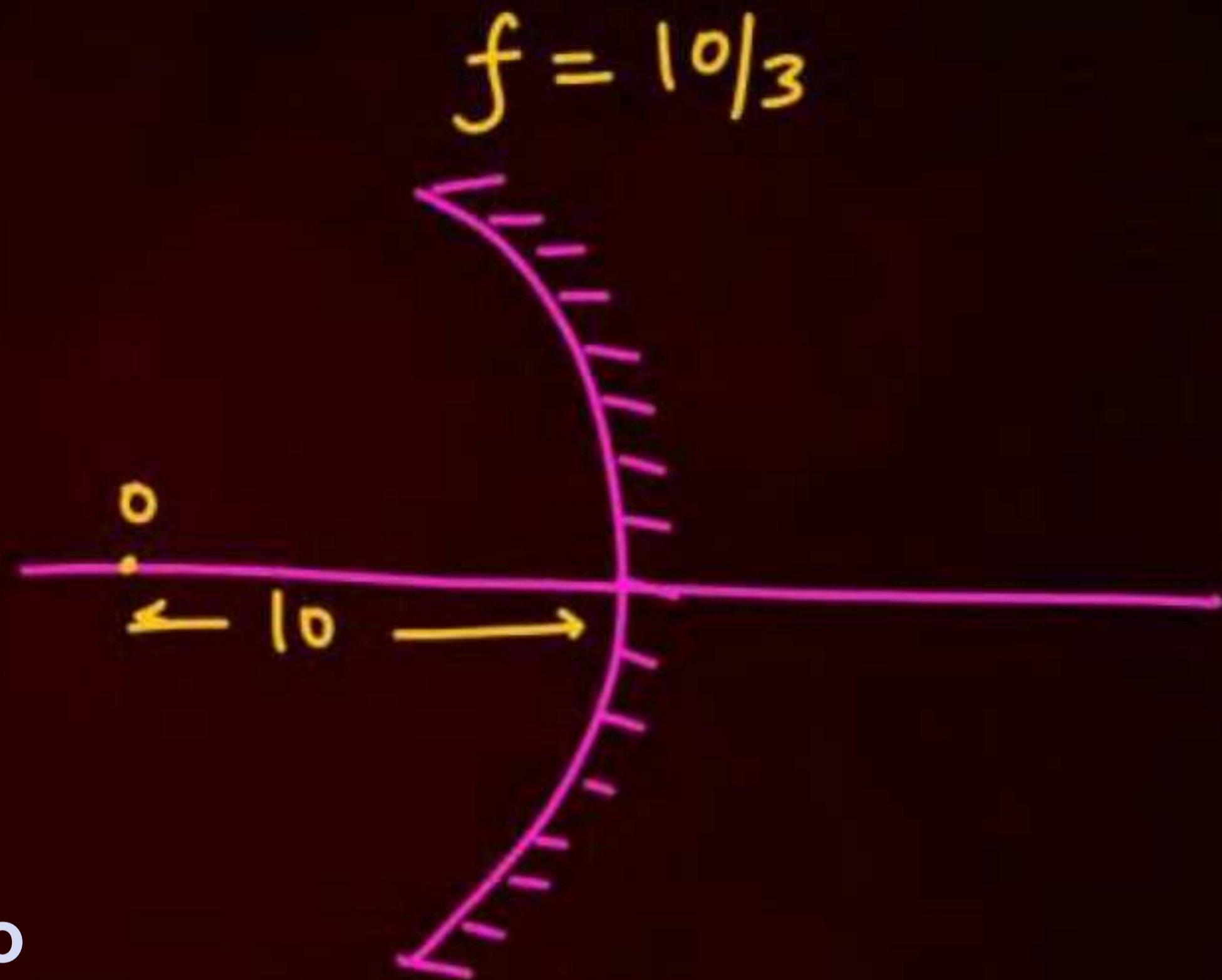


(b)



find location of image

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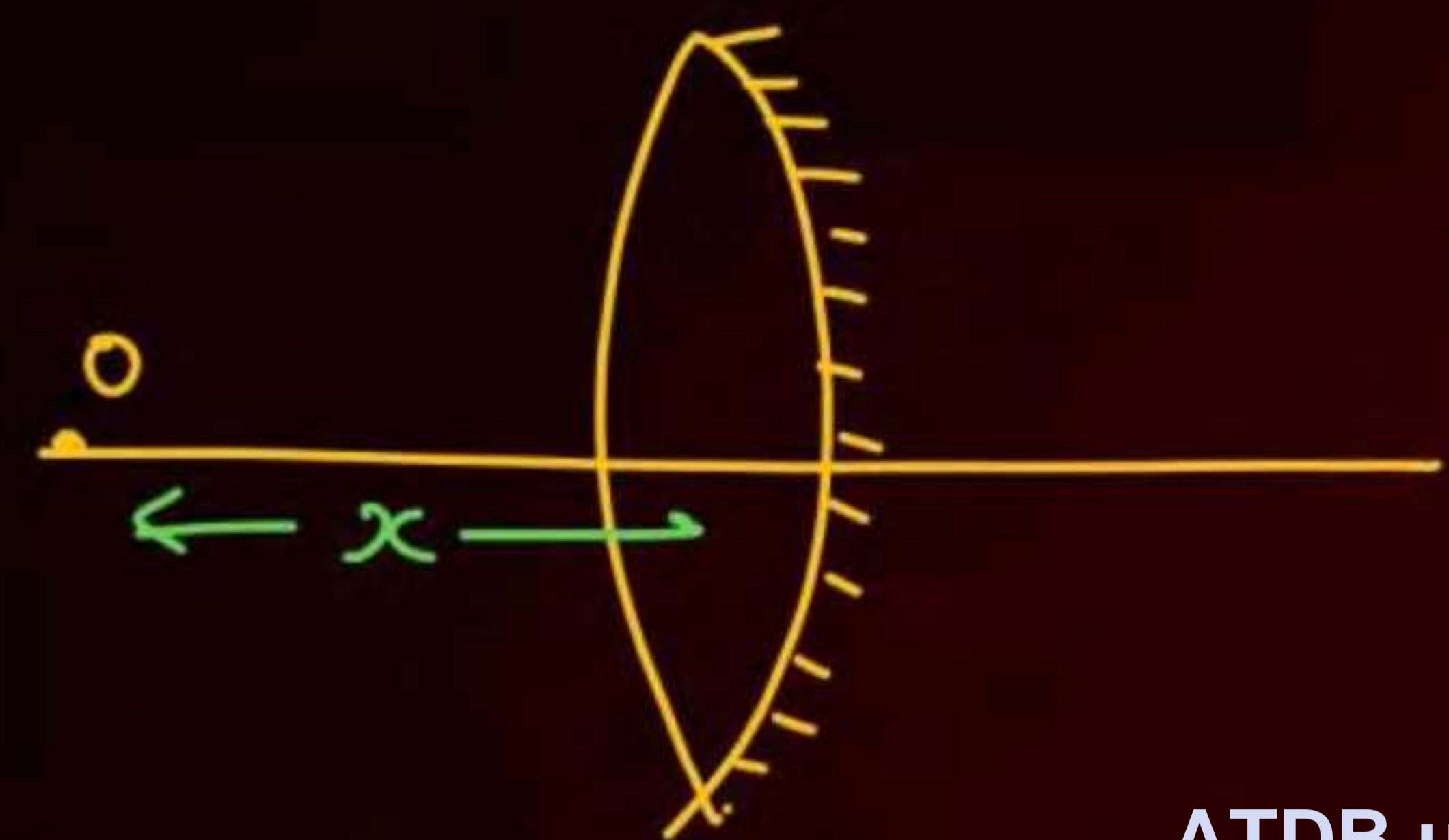
$$u = -10$$

$$f = -10/3$$

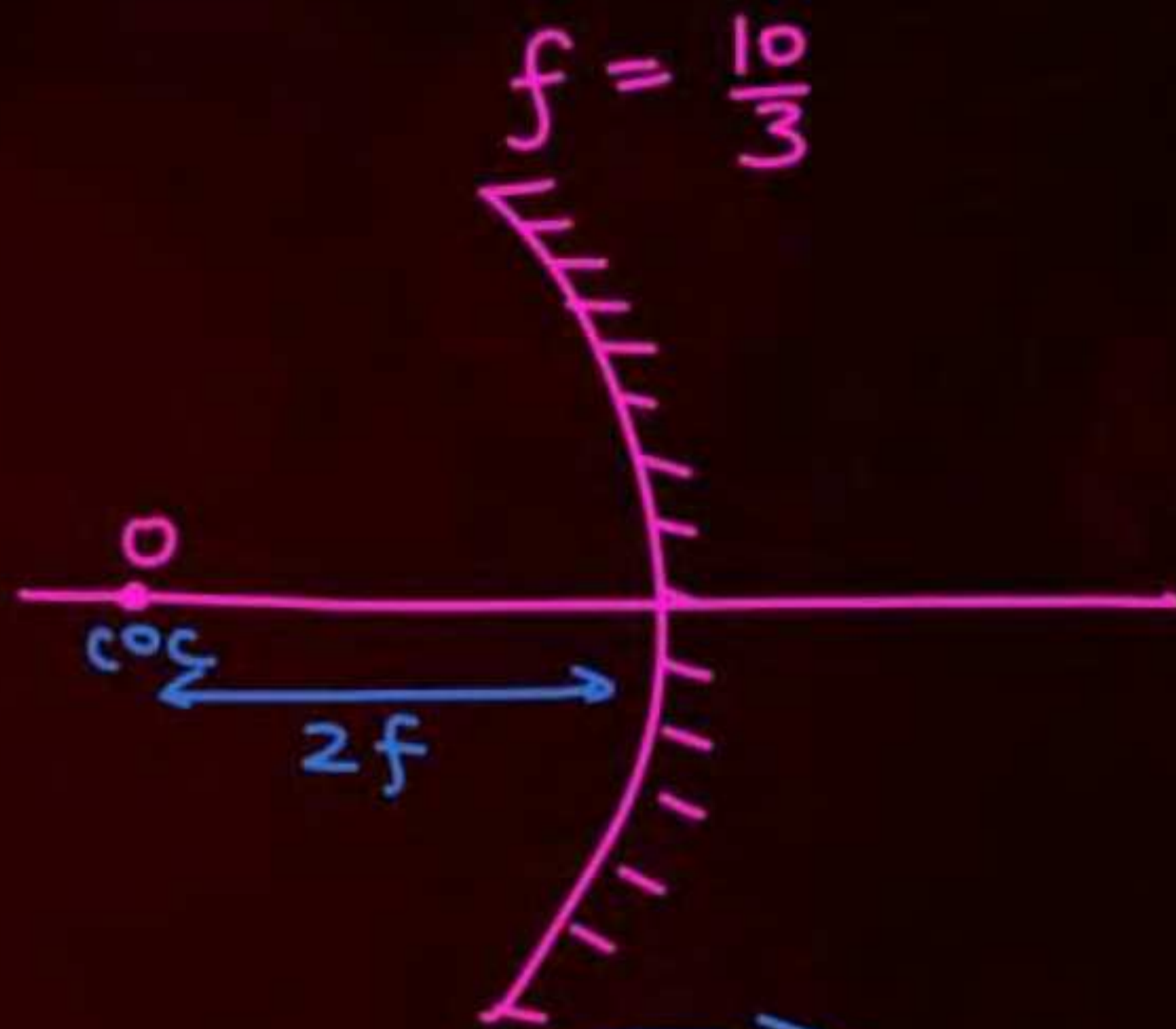
$$v = \frac{uf}{u-f} \text{ (mirror formula)}$$



©



||



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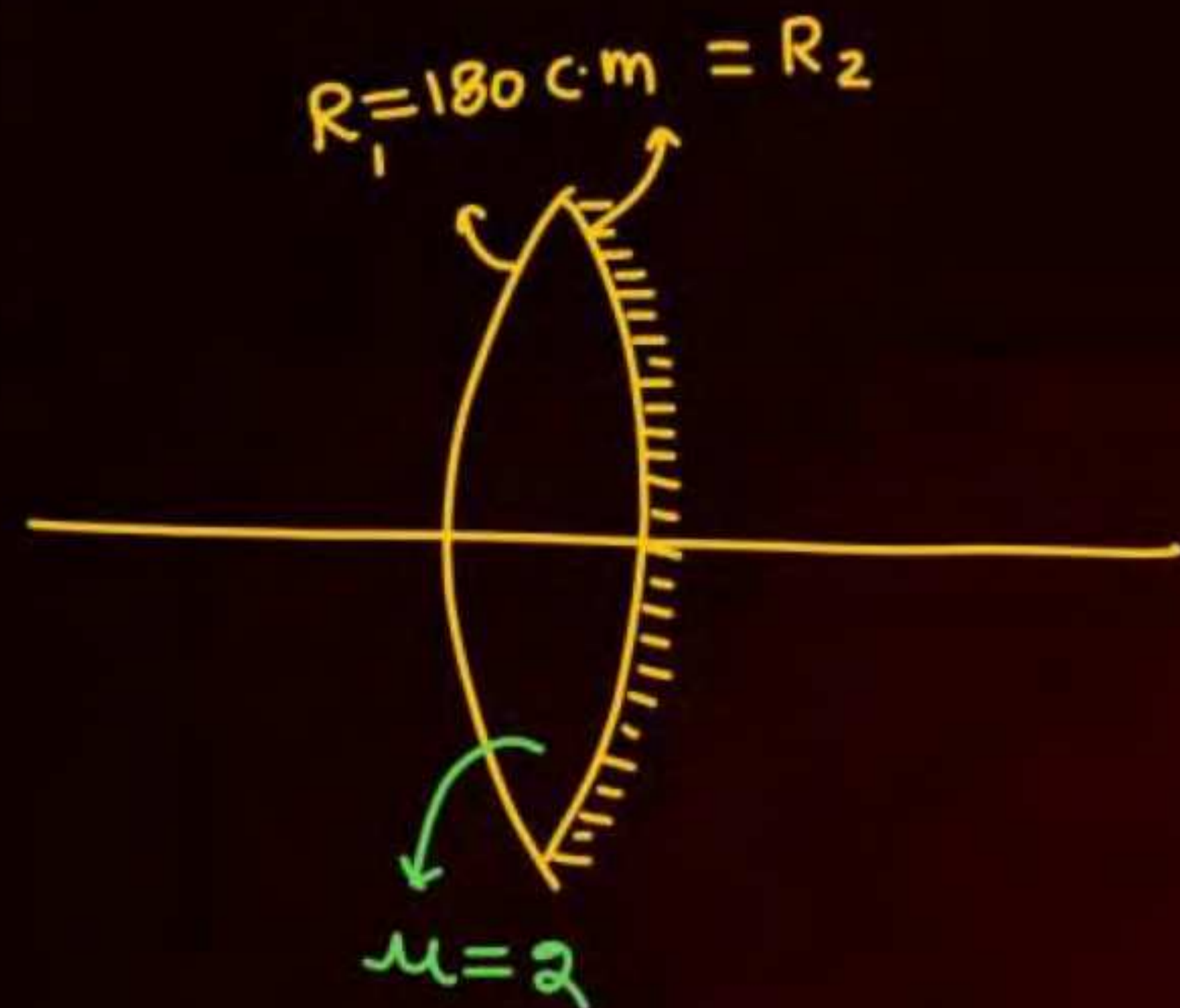
find value of 'x' so that
image formed on object.

Ans

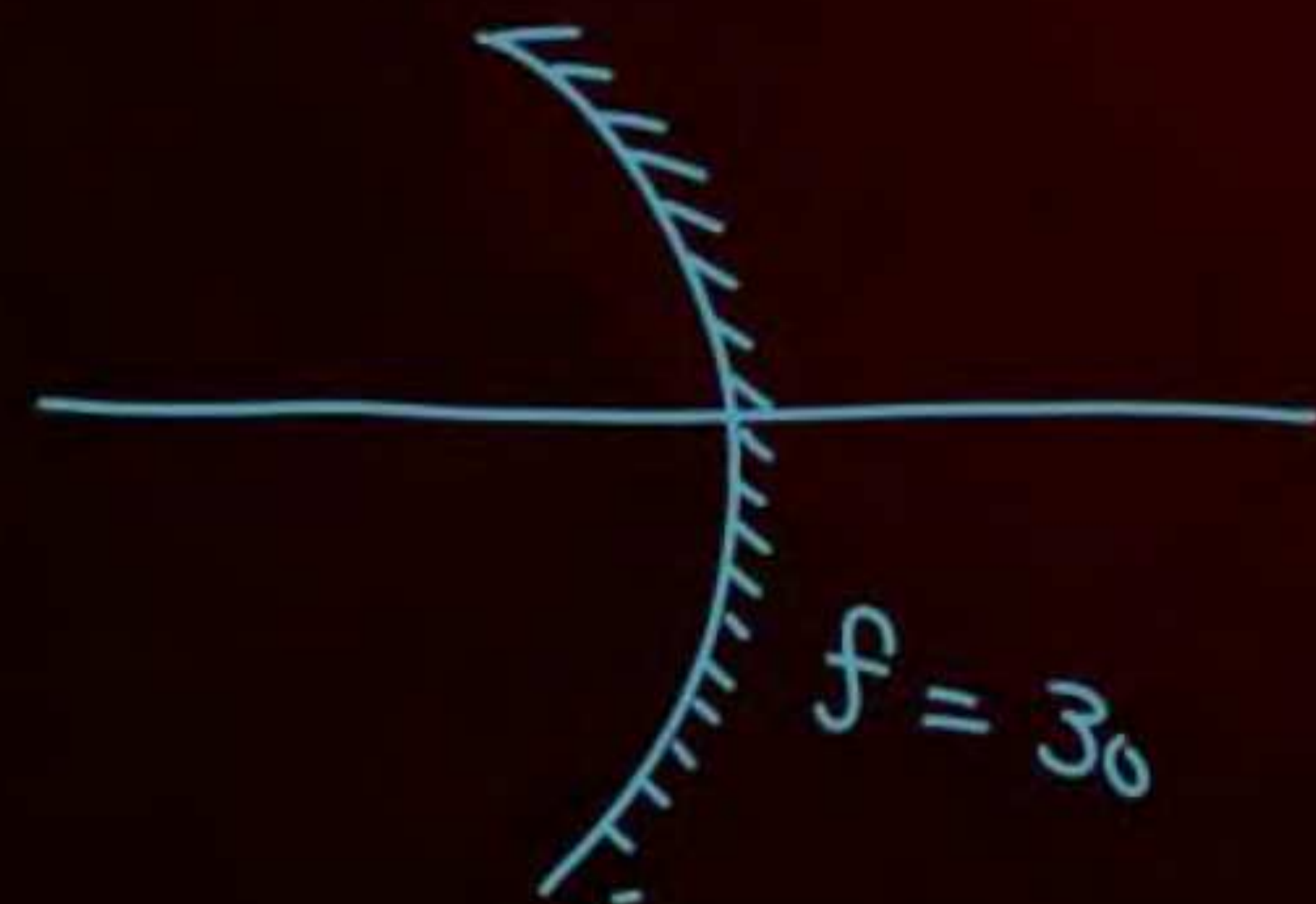
$x = 2f$



Q



|||



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

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

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

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

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$$P_{\text{net}} = \frac{1}{30} = -\frac{1}{f_{\text{eq}}} \quad \boxed{f_{\text{eq}} = -30} \text{ (Concave)}$$

Displacement method



final image formed at screen.

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

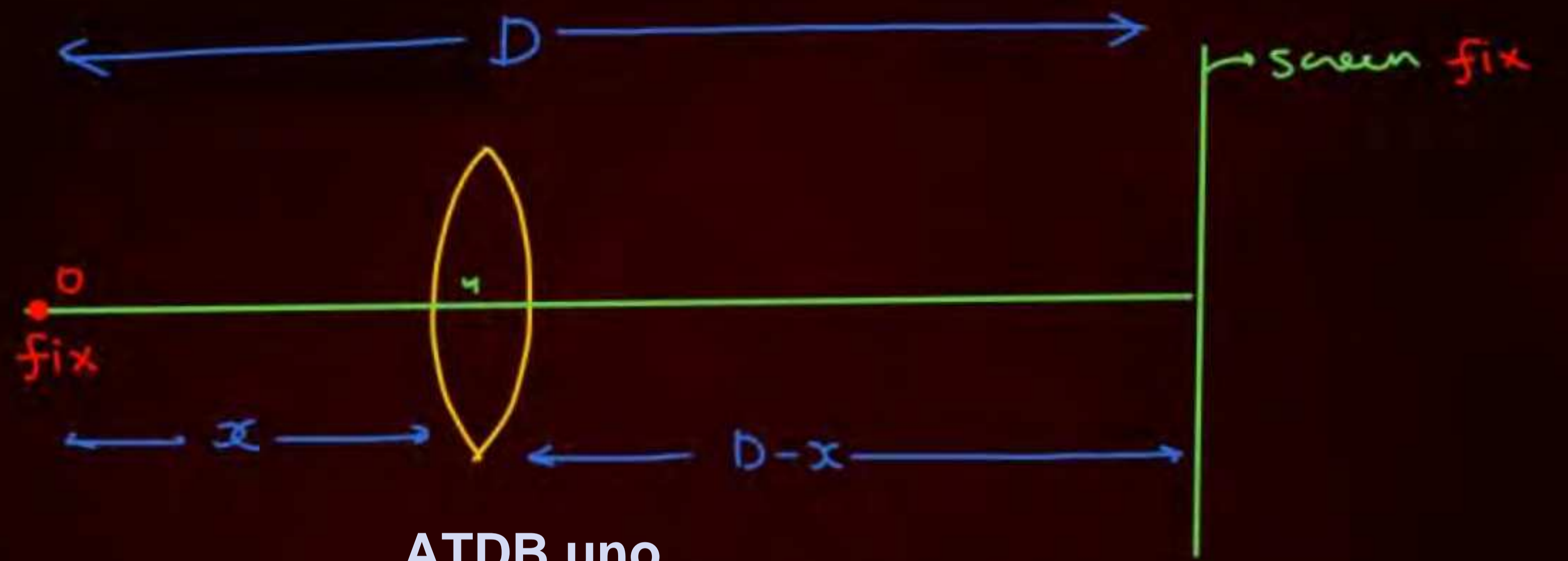
$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$$

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

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

$$Dx - x^2 = Df$$

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



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

$$D^2 - 4x \times Df > 0 \quad (\text{2 root, } x_1 \text{ \& } x_2)$$

- * $D > 4f$ → Two positions of lens x_1 & x_2 detect
- * $D = 4f$ → one one position
- * $D < 4f$ → No position will observe

Displacement Methode

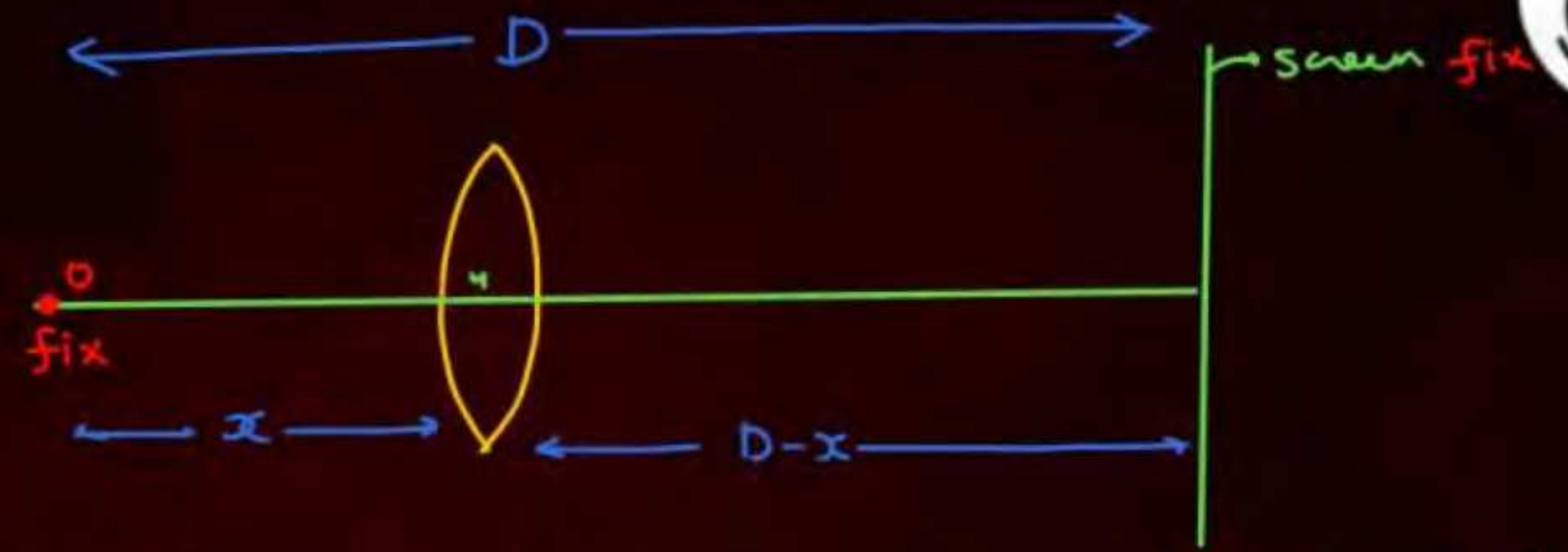


$$x^2 - Dx + Df = 0$$

$$D > 4f \longrightarrow x_1 \text{ \& \ } x_2$$

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

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



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

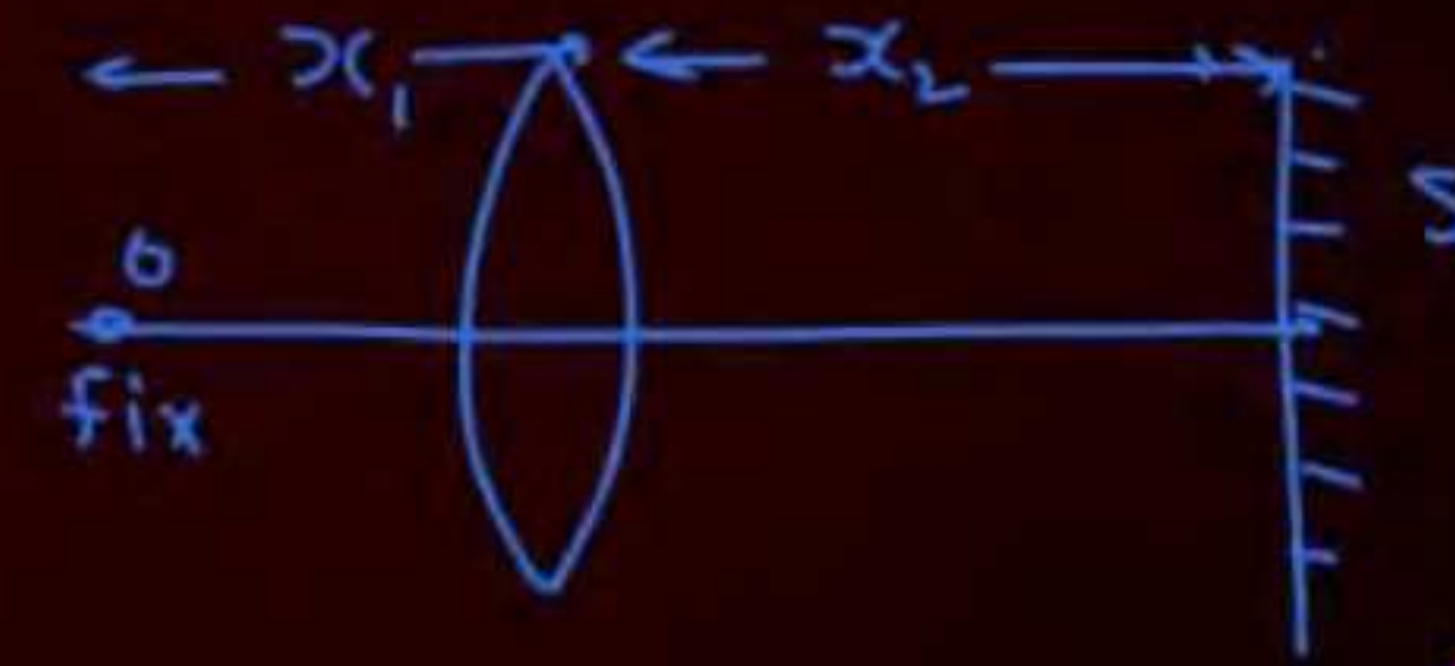
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$$x_1 + x_2 = D$$

$$x_1 - x_2 = d$$

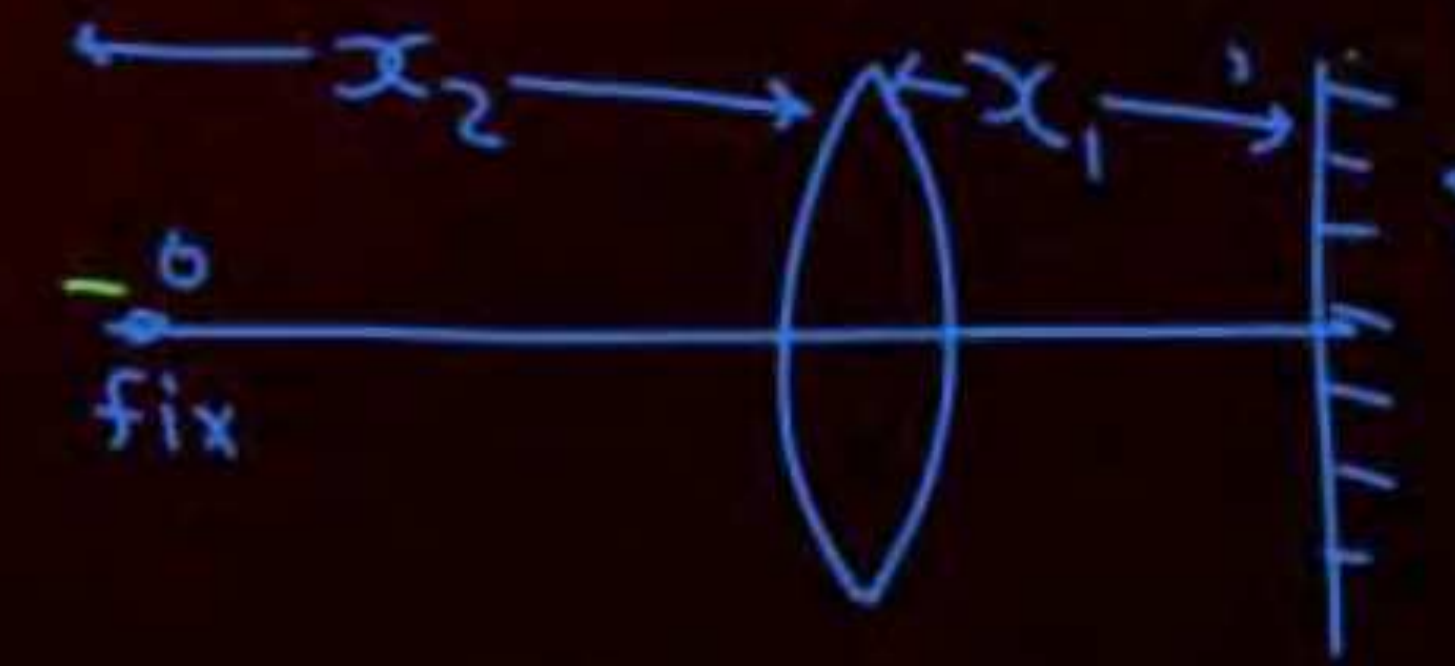
$$x_1 = \frac{D+d}{2}$$

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

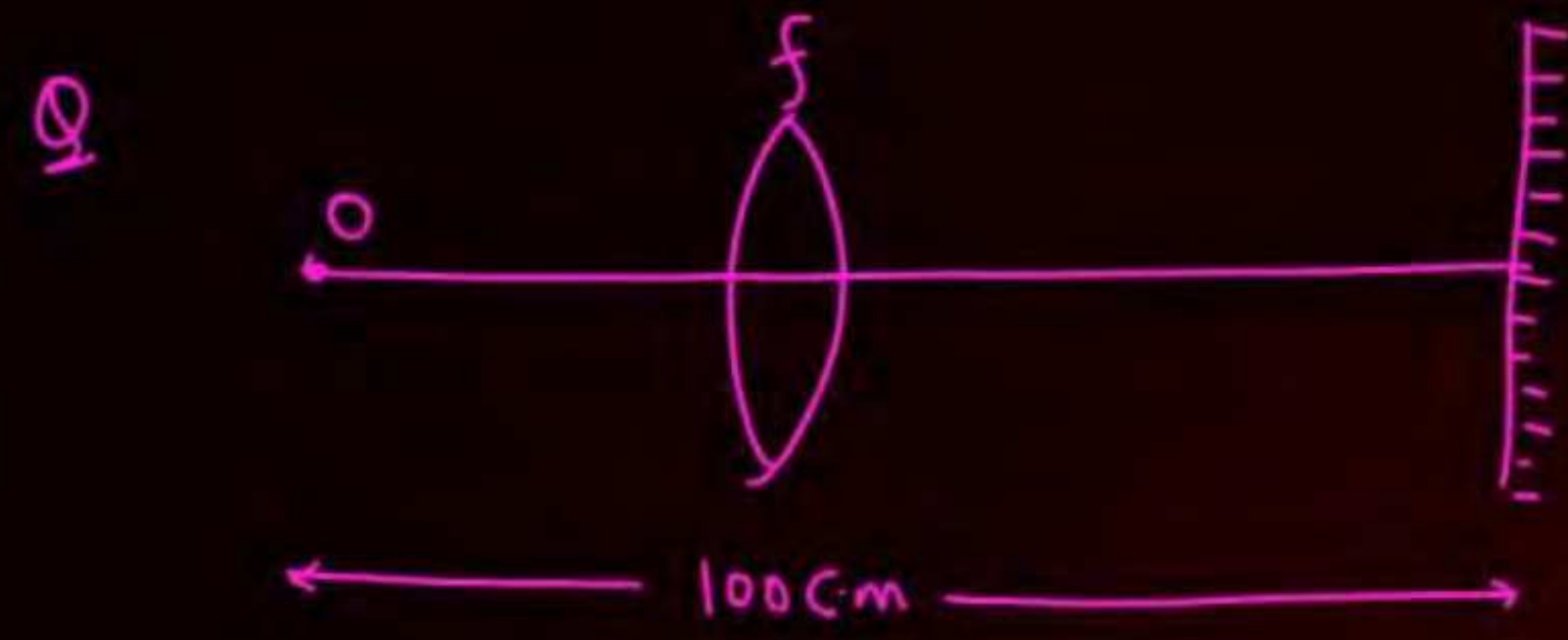


$$m_1 = \frac{x_2}{-x_1}$$

$$m_1 m_2 = 1$$



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



Solⁿ

$$D = 100$$

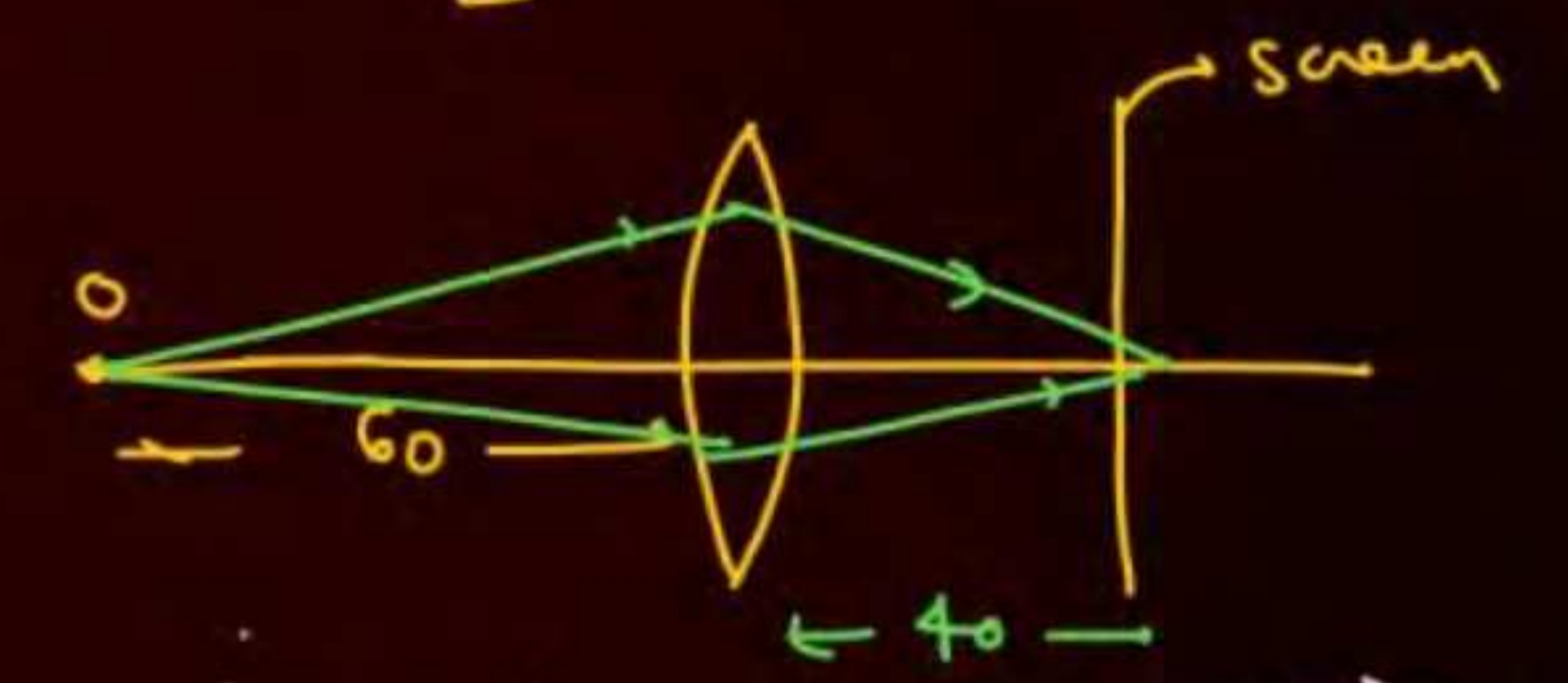
$$d = 20$$

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

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

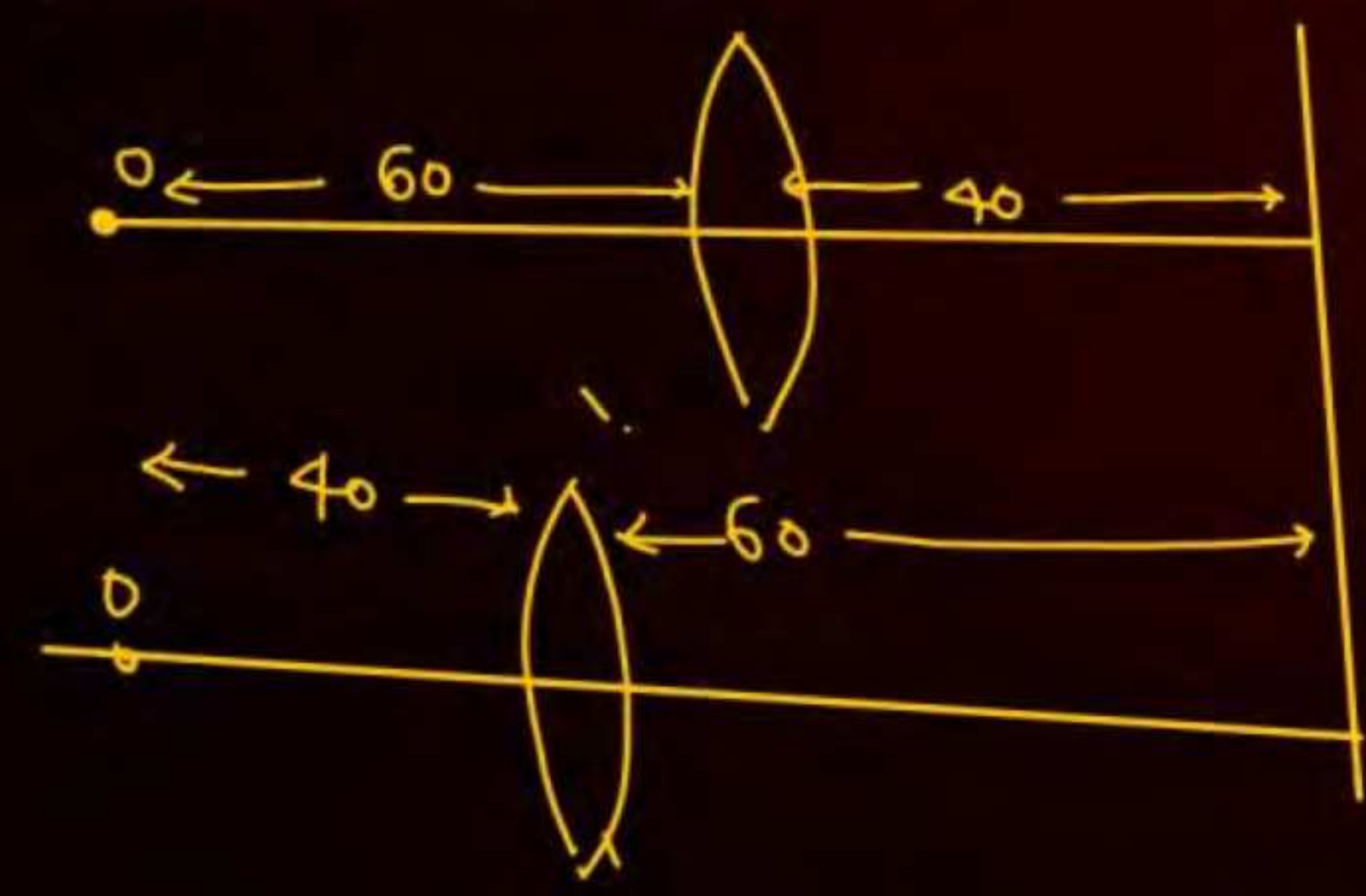
Gap b/w two positions of lens so that image formed at screen is 20 cm. find f .

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

$f = \checkmark$





x की दो value पर x_1 & x_2 image screen पर वही

- lens की दो position पर x_1 & x_2 पर

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

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

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

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

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

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



Homework

-Revise optics class notes

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THANK YOU

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