PRAYAS

JEE 2025

Lecture – 04 | **Physics**

Ray optics

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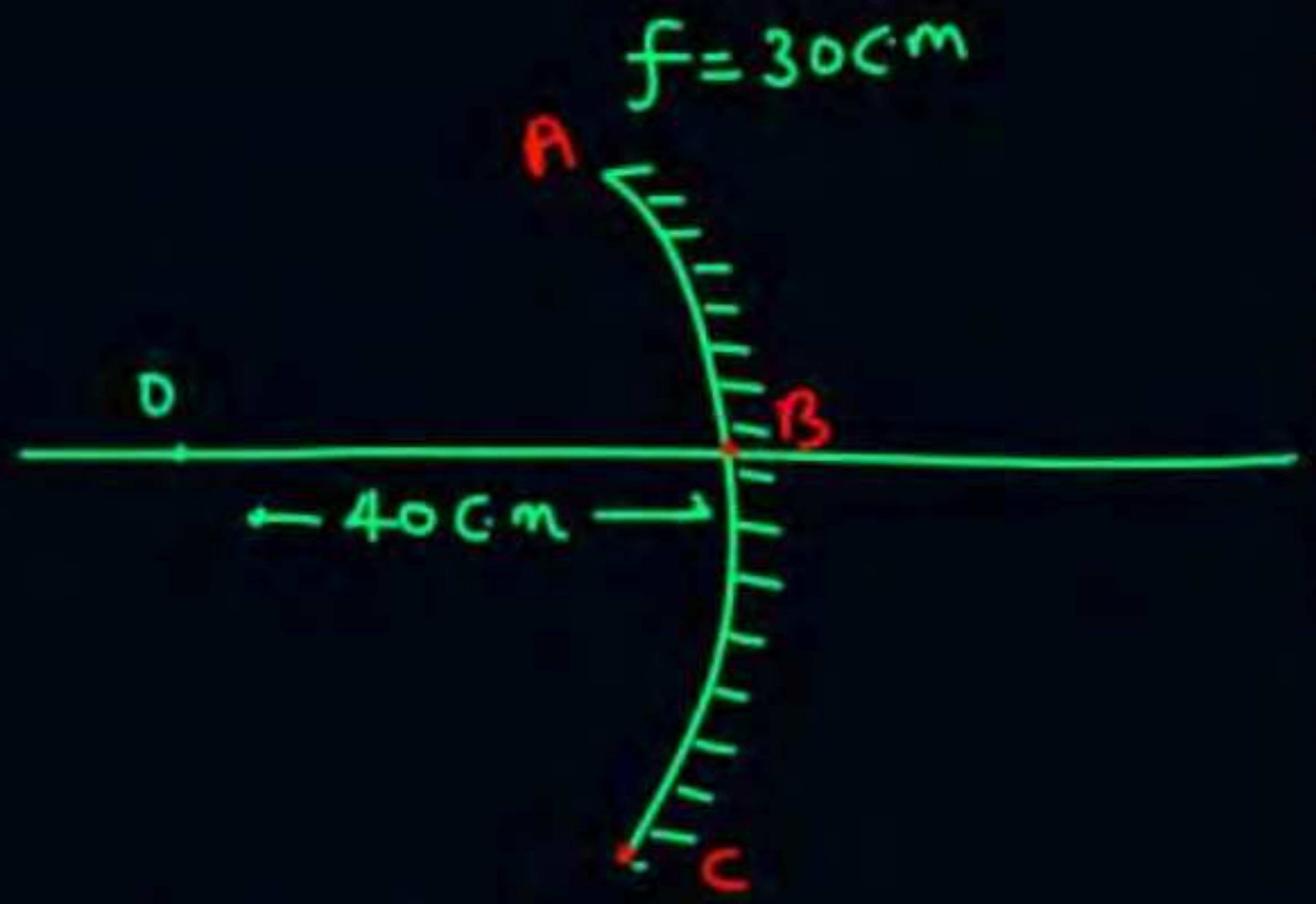
Topics to be covered

1. # mirror formula & application
2. # Velocity of image
3. #
4. #

Q



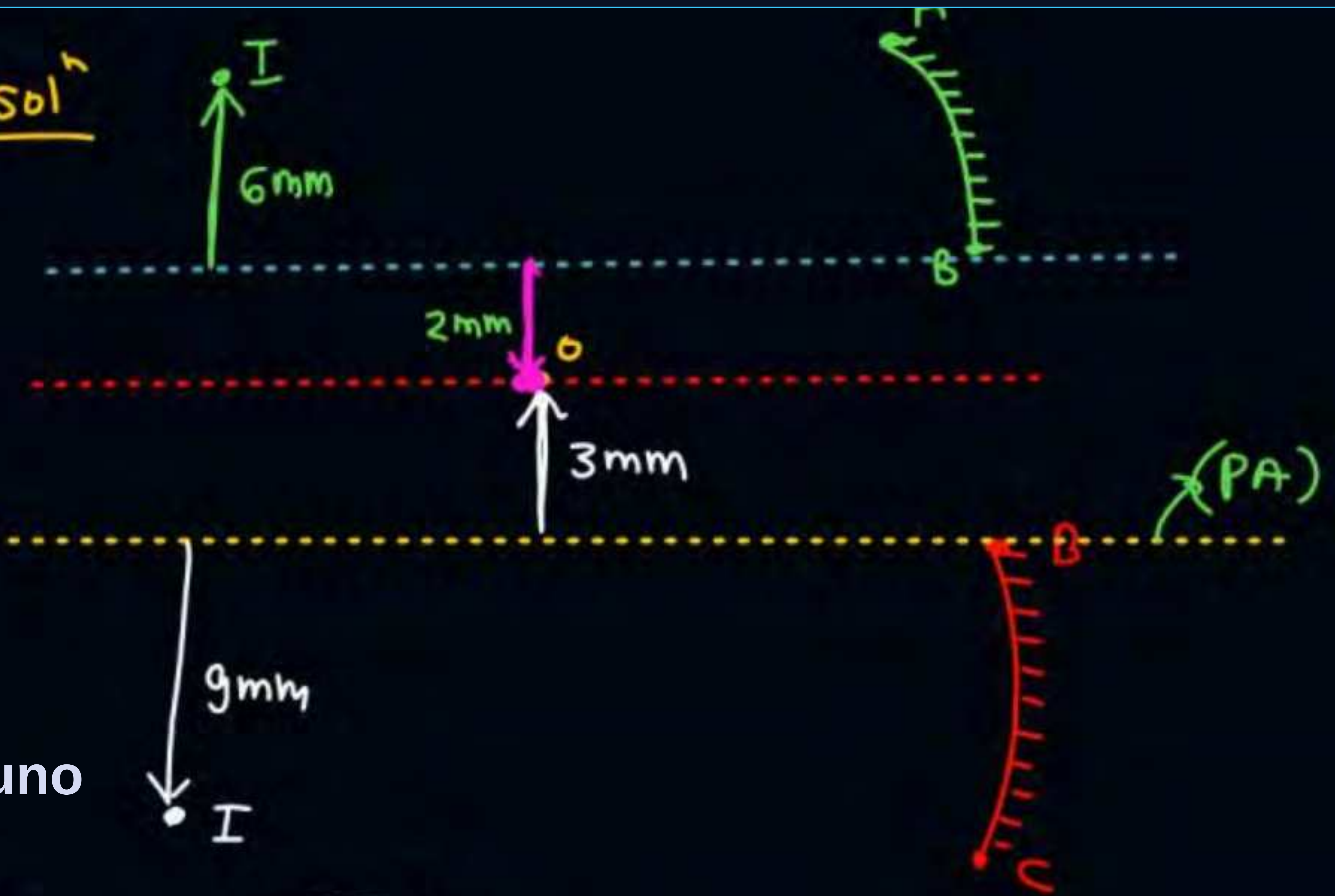
mirror is cut at 'B'
& upper part is shifted up by 2mm
& lower part is shifted down by 3mm
find Gap b/w two image

Sol^n

$$v = \frac{1200}{-40-(-30)} = -120$$

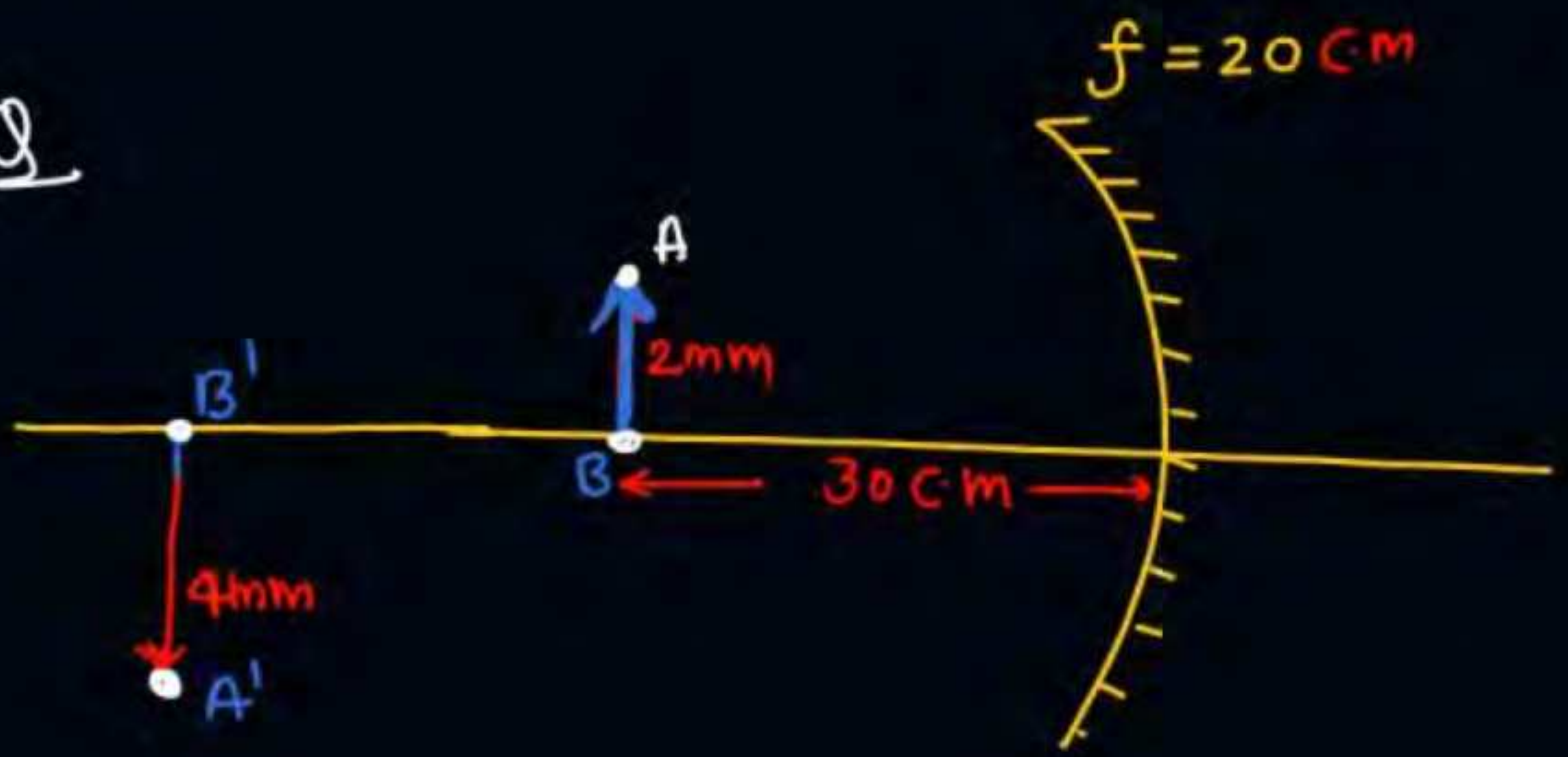
$$m = -\frac{-120}{-40} = -3$$

Sol^n



Ans = 20 mm

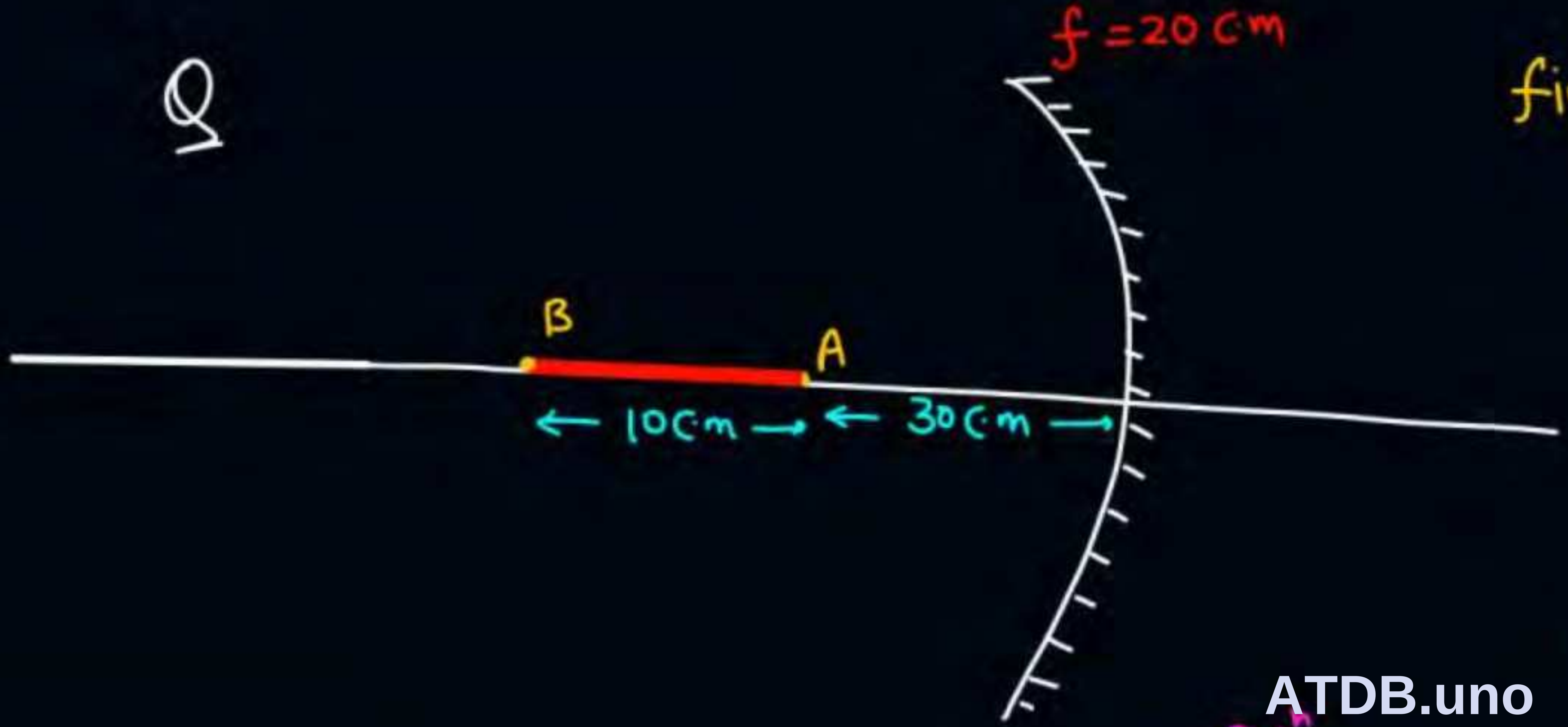
Q



If AB ≡ extended object length = 2mm

A'B' ≡ " image " " = 4mm

Q



find Length of the image = ?

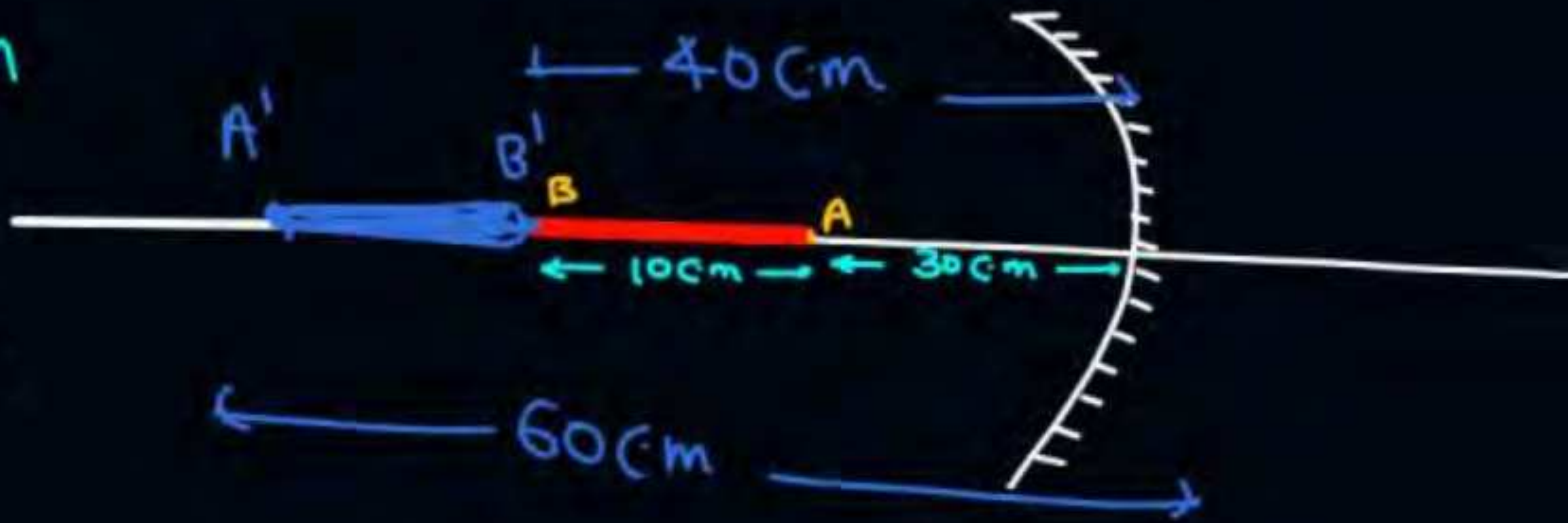
Sol^n

for A'
$$\left.\begin{aligned} u &= -30 \\ f &= -20 \end{aligned}\right\} \; v = -60$$
A'

for B'
$$\left(\begin{aligned} u &= -40 \\ f &= -20 \end{aligned}\right) \Rightarrow v = -40$$

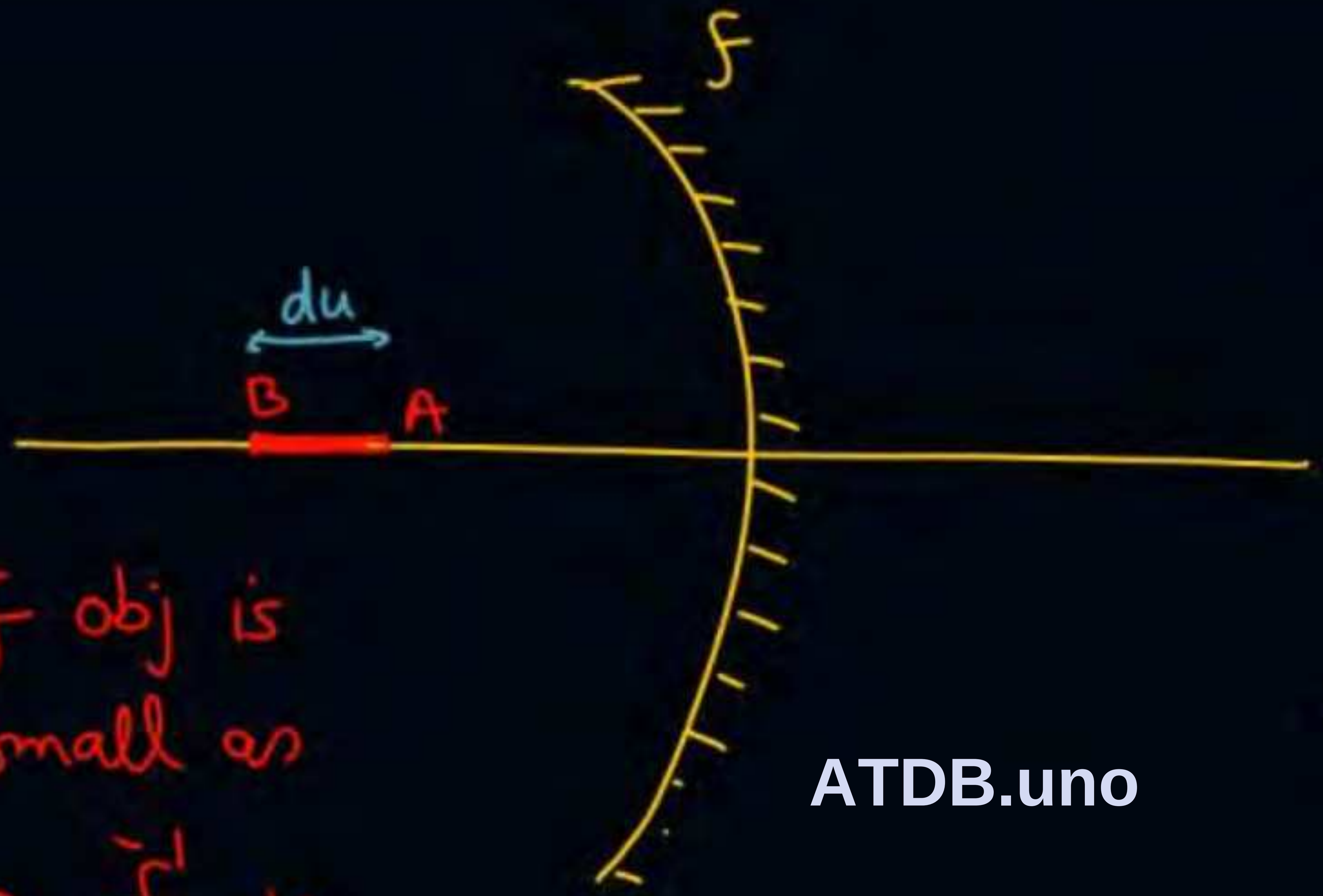
Sol^n

Length of image = $A'B'$ = 20 cm



Longitudinal magnification $= \dfrac{\text{Length of image}}{\text{Length of obj}} = \dfrac{A'B'}{AB}$

$$= \frac{20}{10} = 2$$



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

$$-\frac{1}{u^2}\,du - \frac{1}{v^2}\,dv = 0$$

$$-\frac{1}{u^2}\,du = +\frac{1}{v^2}\,dv$$

$$dv = -\frac{v^2}{u^2}(du)$$

if lenght of obj is very very small as compare to f, u

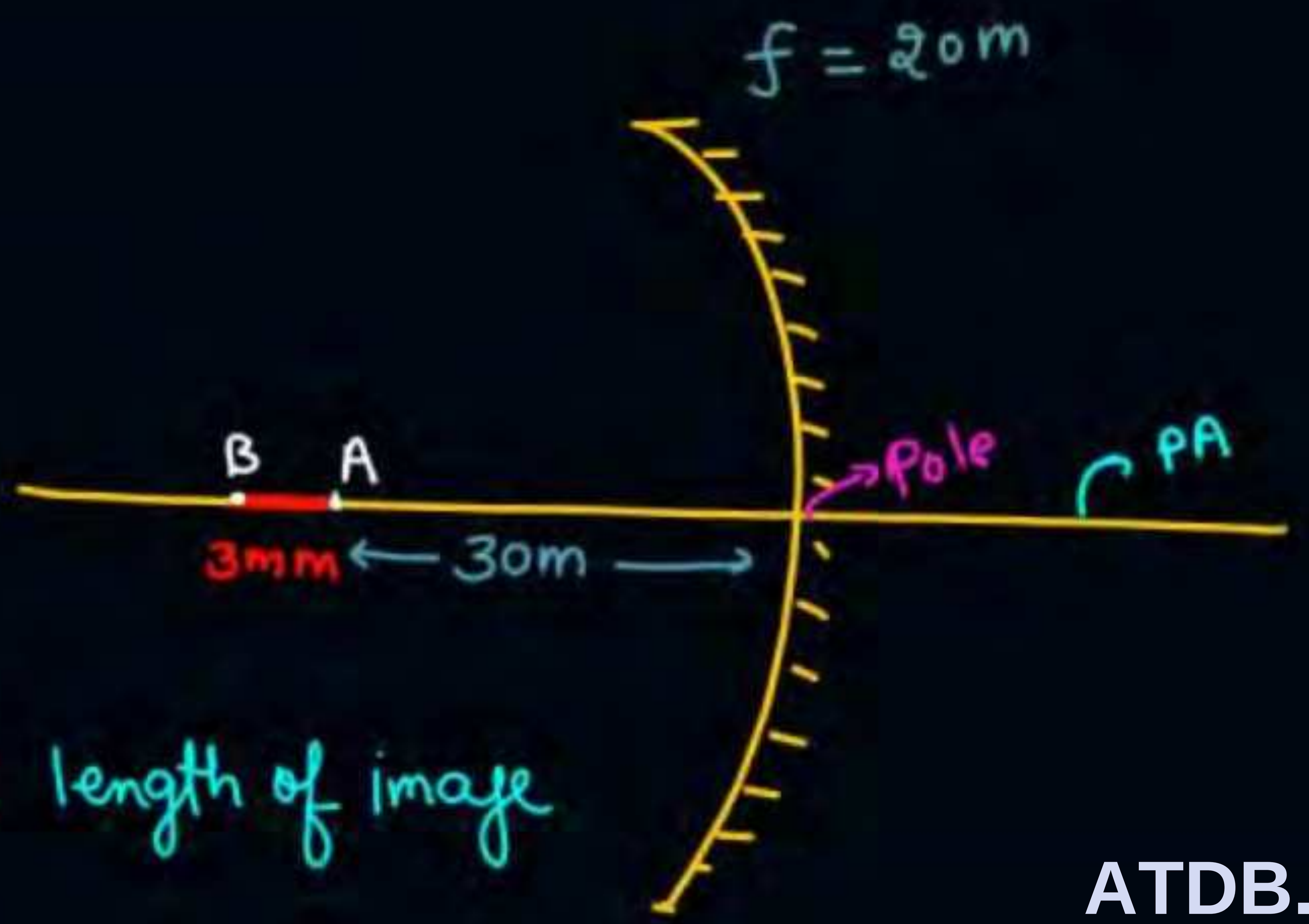
$$m_t = m = -\frac{V}{u}$$

$$m^2 = \frac{V^2}{U^2}$$

length of image = $-m^2$ (length of the obj)

$$\boxed{A'B' = -m^2(AB)}$$

Q



find length of image

Sol^n

$m = -2$

length of image $= m^2 \times AB$

$= 4 \times 3mm = 12mm$

(magnitude)

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

Longnitudenal magnification $m = \frac{\text{Lenght of image on PA}}{\text{'' '' obj on PA}}$

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

differentiate wrt 't'

$m = -\frac{v}{u}$

$m^2 = \frac{v^2}{u^2}$

$$-\frac{1}{u^2}\frac{du}{dt} + \left(-\frac{1}{v^2}\frac{dv}{dt}\right) = 0$$

$$-\frac{1}{v^2}\frac{dv}{dt} = \frac{1}{u^2}\frac{du}{dt}$$

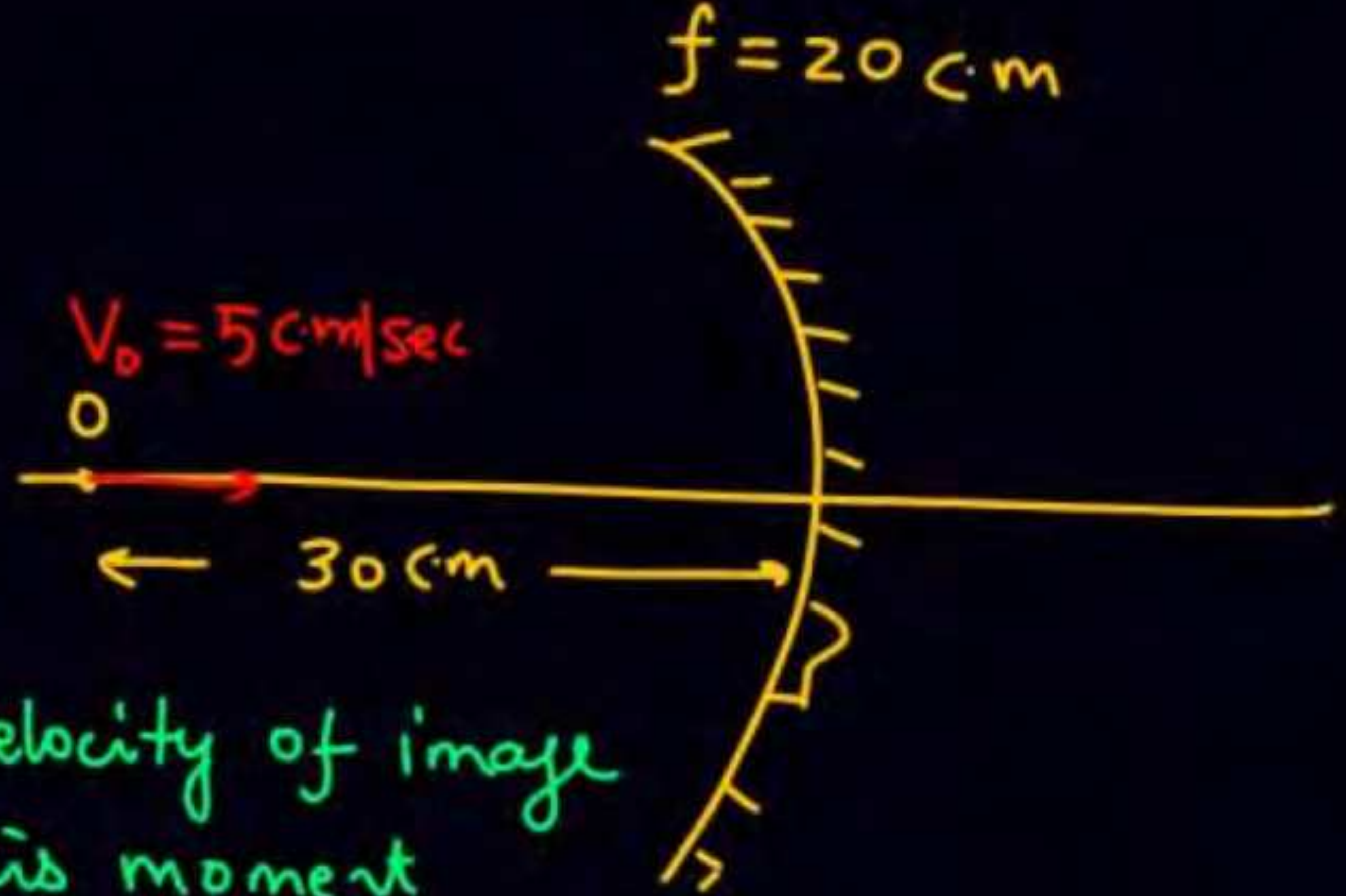
$$\frac{dv}{dt} = -\frac{v^2}{u^2}\frac{du}{dt}$$

$$V_I = -m^2 V_o$$

$$\boxed{\vec{V}_I = -m^2 \vec{V}_o}$$ (Along P.A) (wrt mirror)

$$\boxed{\vec{V}_{I/m} = -m^2 \vec{V}_{o/m}}$$

Q



find velocity of image at this moment

Solⁿ

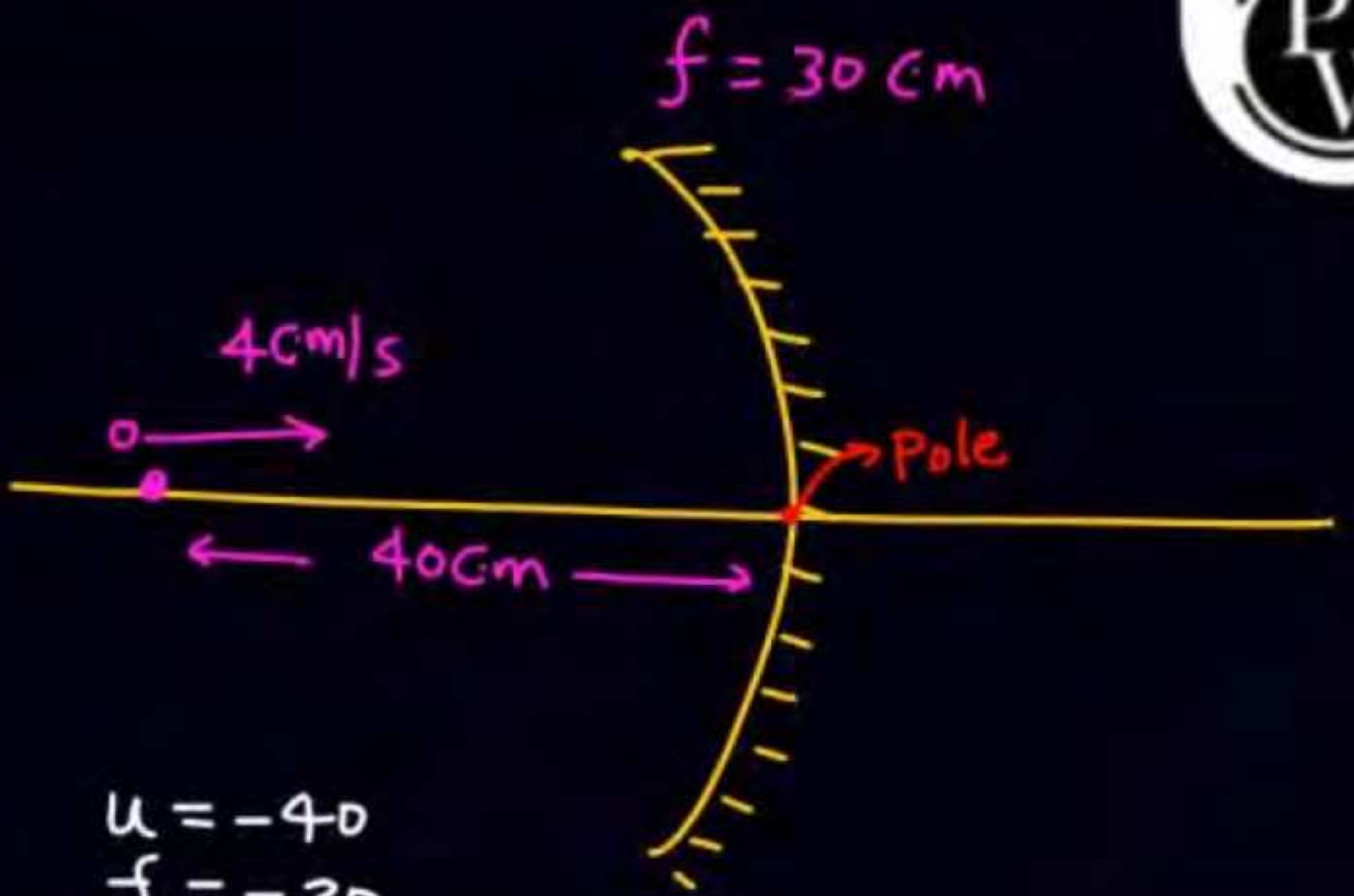
$$\left.\begin{array}{l} u = -30 \\ f = -20 \end{array}\right\} v = \frac{600}{-30+20} = -60$$

$$m = -\frac{v}{u} = -\frac{-60}{-30} = -2$$

$$\vec{V}_I = -m^2 \vec{V}_0 \Rightarrow \vec{v}_I = -4 \times 5\hat{i}$$

$$= -20\hat{i}$$

Q



Sol

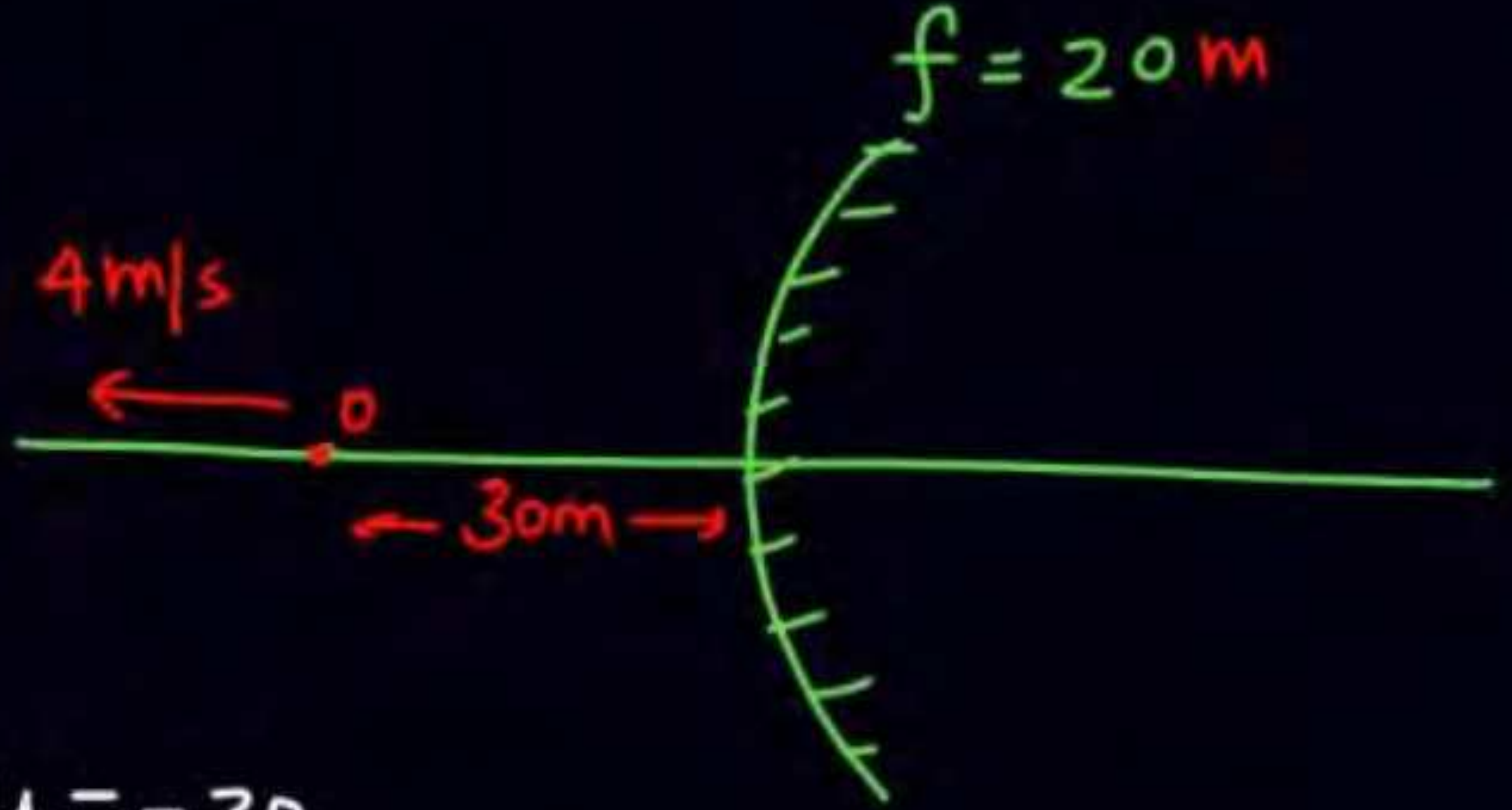
$$u = -40$$
$$f = -30$$
$$v = -120$$

$$m = -\frac{V}{u} = -\frac{-120}{-40} = -3$$

$$V_I = -m^2 V_0$$

$$\vec{V}_I = -9 \times 4\hat{i} = -36\hat{i}$$

Q



$u = -30$

$f = +20$

$$v = \frac{-600}{-30-20} = 12$$

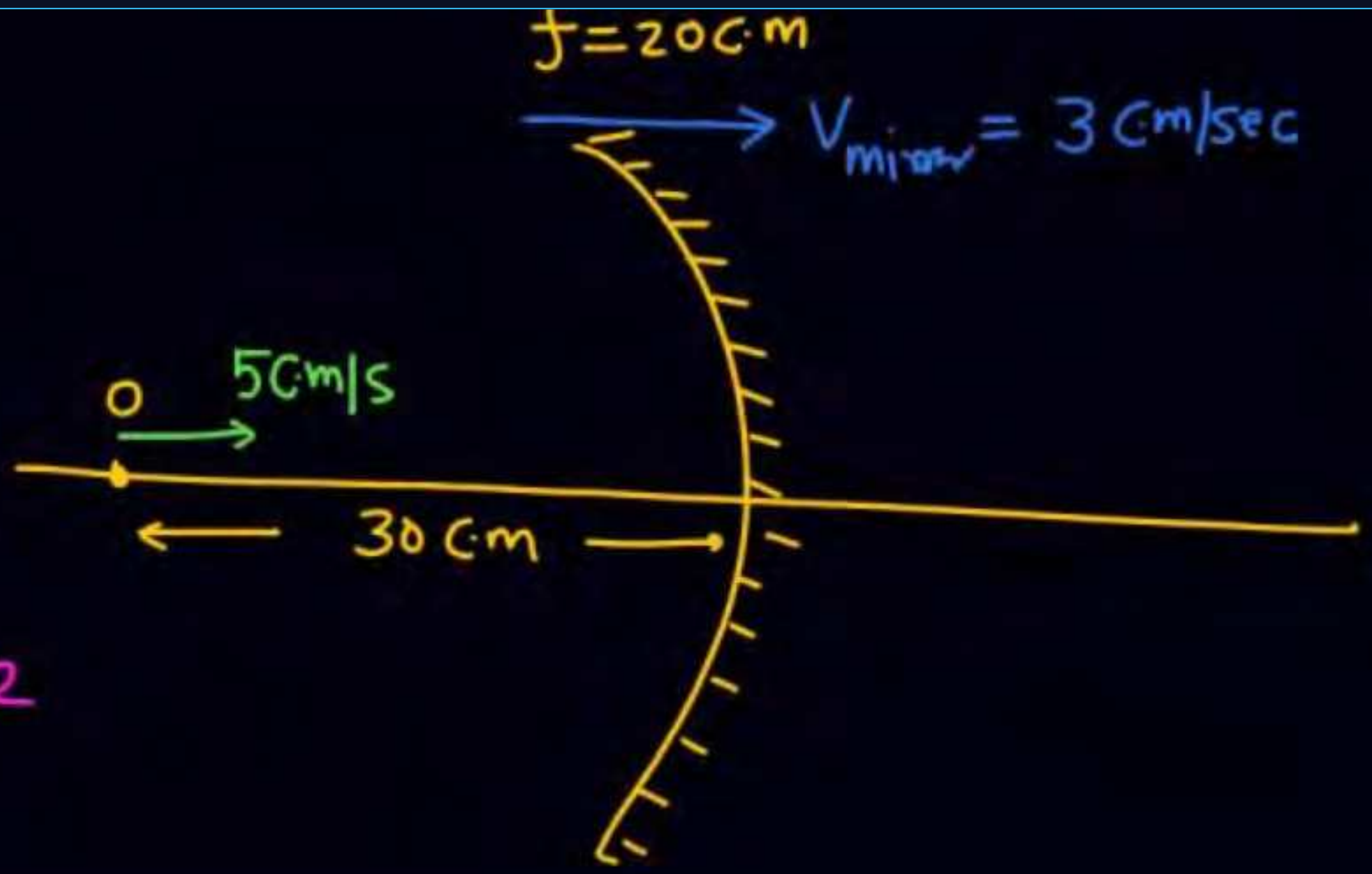
$$m = -\frac{12}{-30} = \frac{2}{5}$$

$$V_I = -\left(\frac{2}{5}\right)^2 \times (-4\hat{i})$$

$= \checkmark$

Q

Q



$m = -2$

Sol^n

$$\vec{V}_{I/m} = -m^2 \vec{V}_{O/m}$$

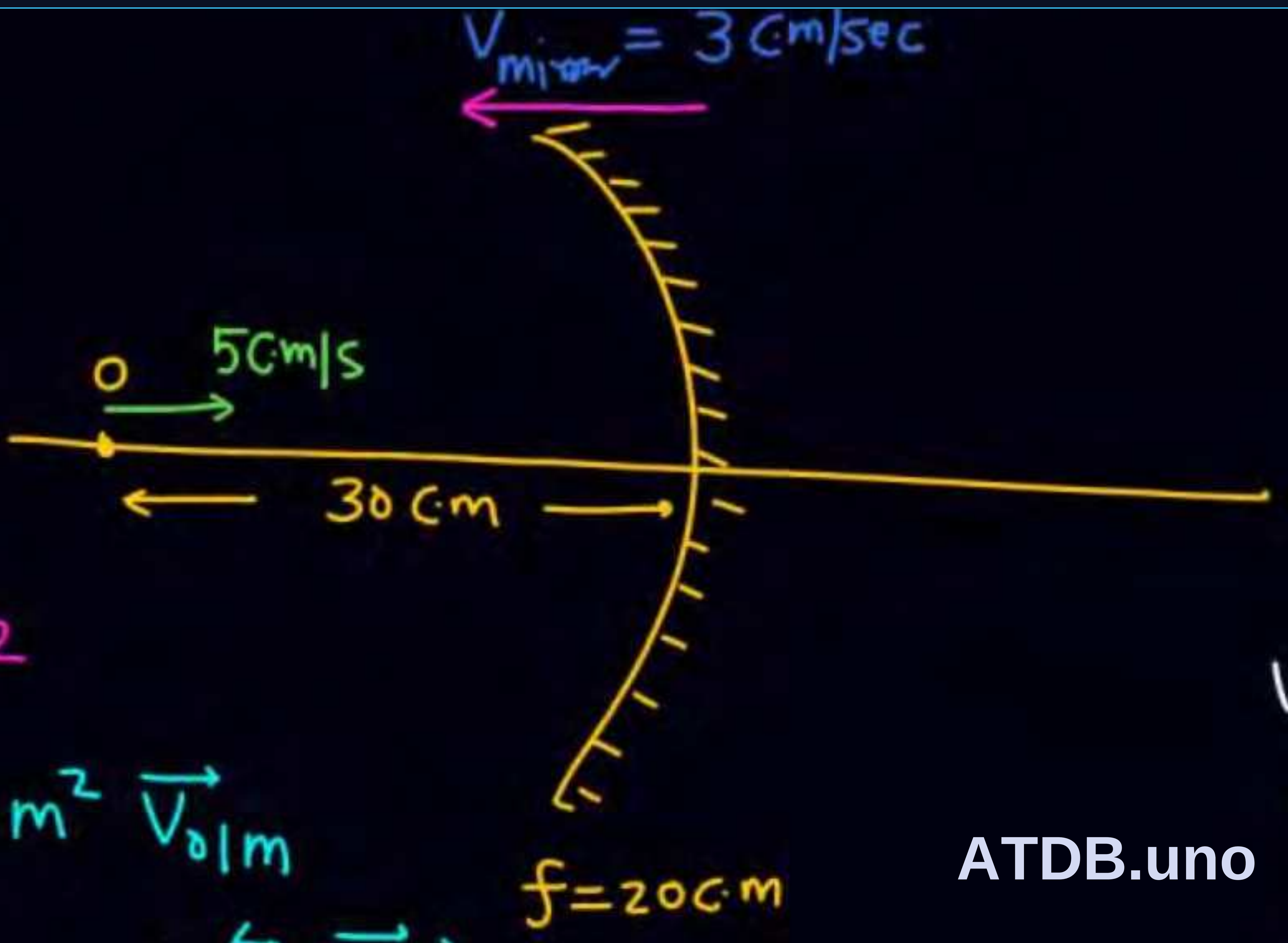
$$\vec{V}_I - \vec{V}_m = -m^2(\vec{V}_O - \vec{V}_m)$$

$$V_I - (+3\hat{i}) = -4(+5\hat{i} - 3\hat{i})$$

$$V_I - 3 = -8$$

$$\boxed{V_I = -5\hat{i}}$$

Q



$m = -2$

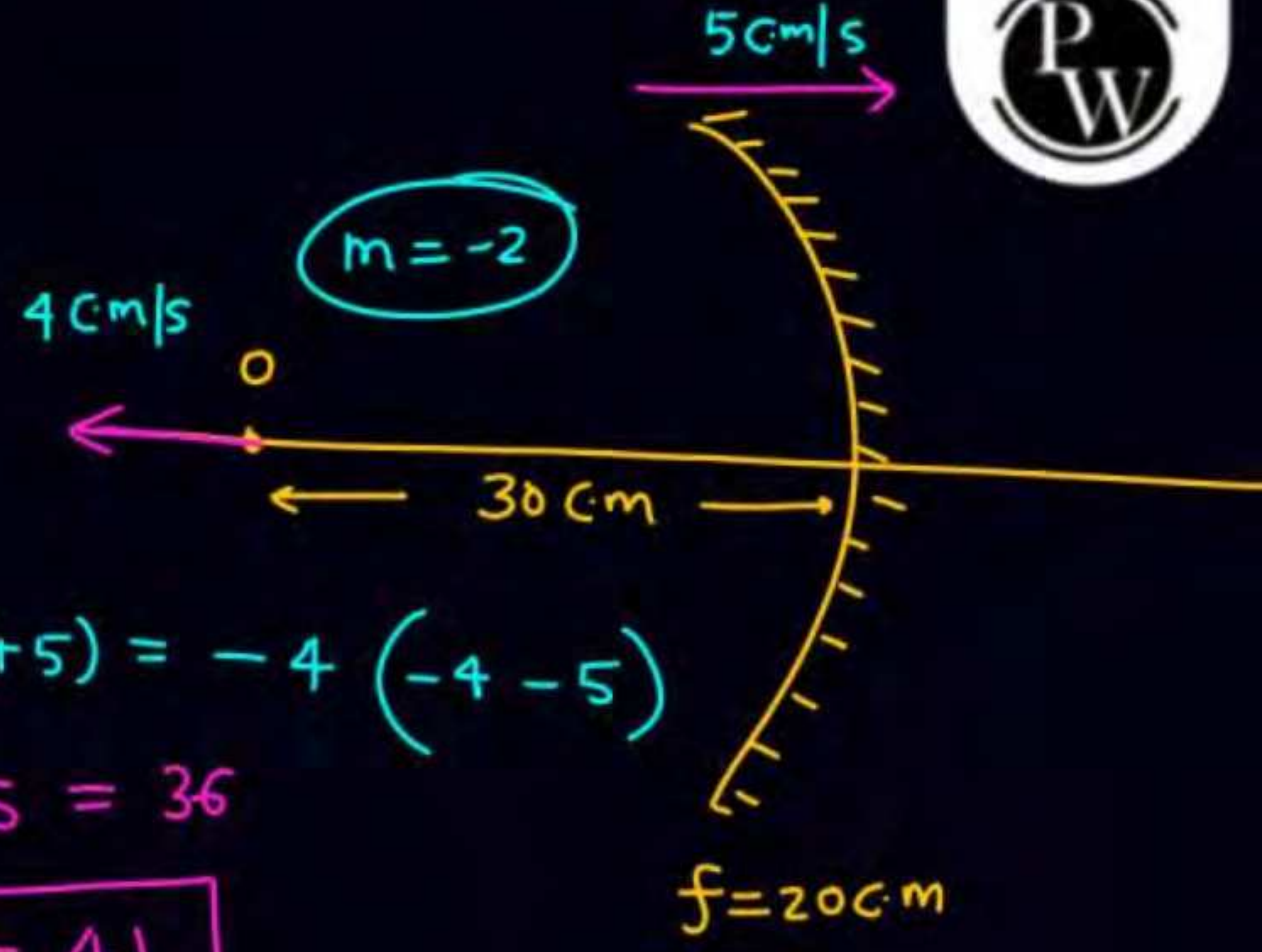
$$\vec{V}_{I/m} = -m^2\, \vec{V}_{o/m}$$

$$\vec{V}_I - \vec{V}_m = -m^2\left(\vec{V}_o - \vec{V}_m\right)$$

$$V_I - (-3) = -4\left(5 - (-3)\right)$$

$$V_I + 3 = -4(8)$$

$$\boxed{V_I = -35}$$

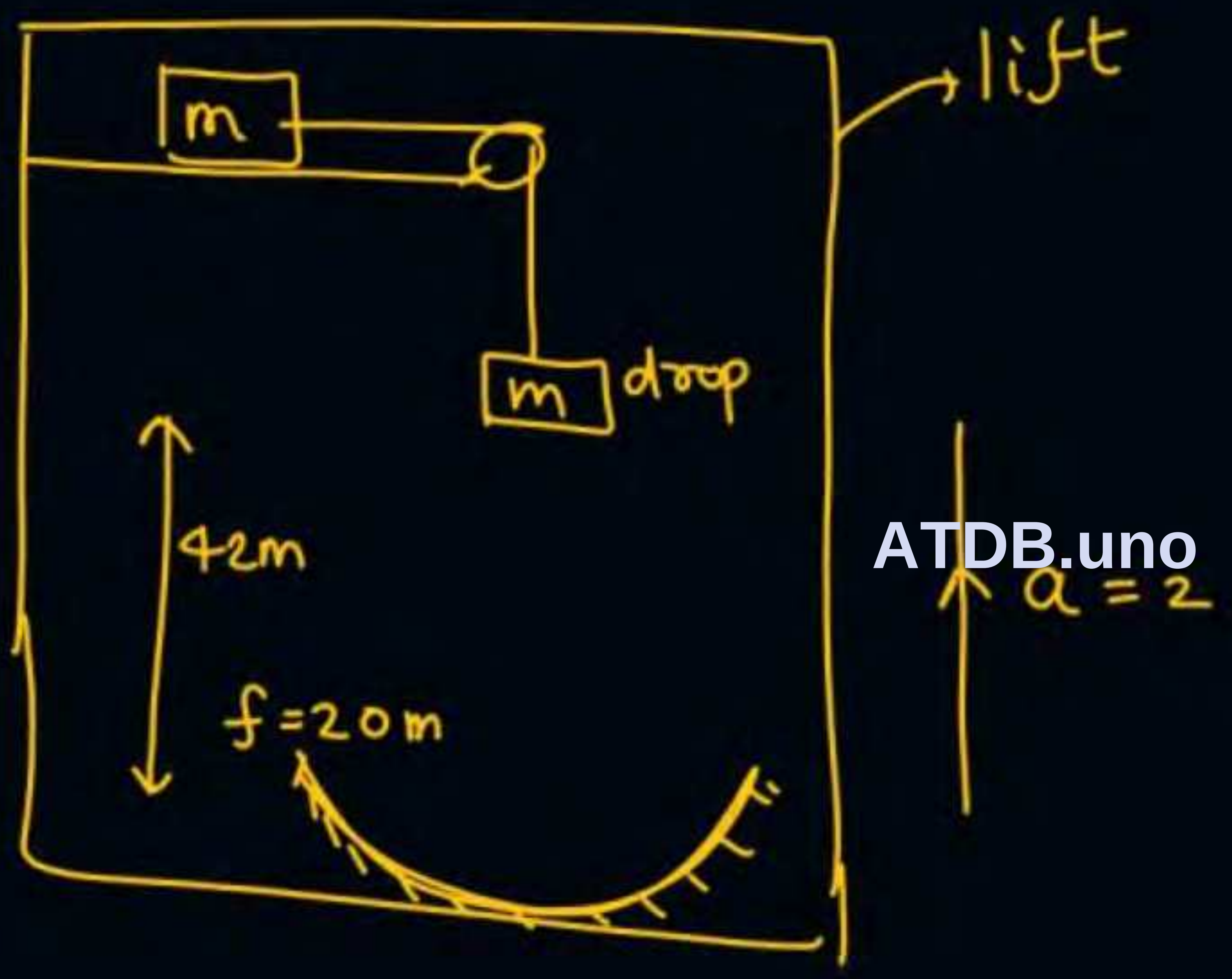


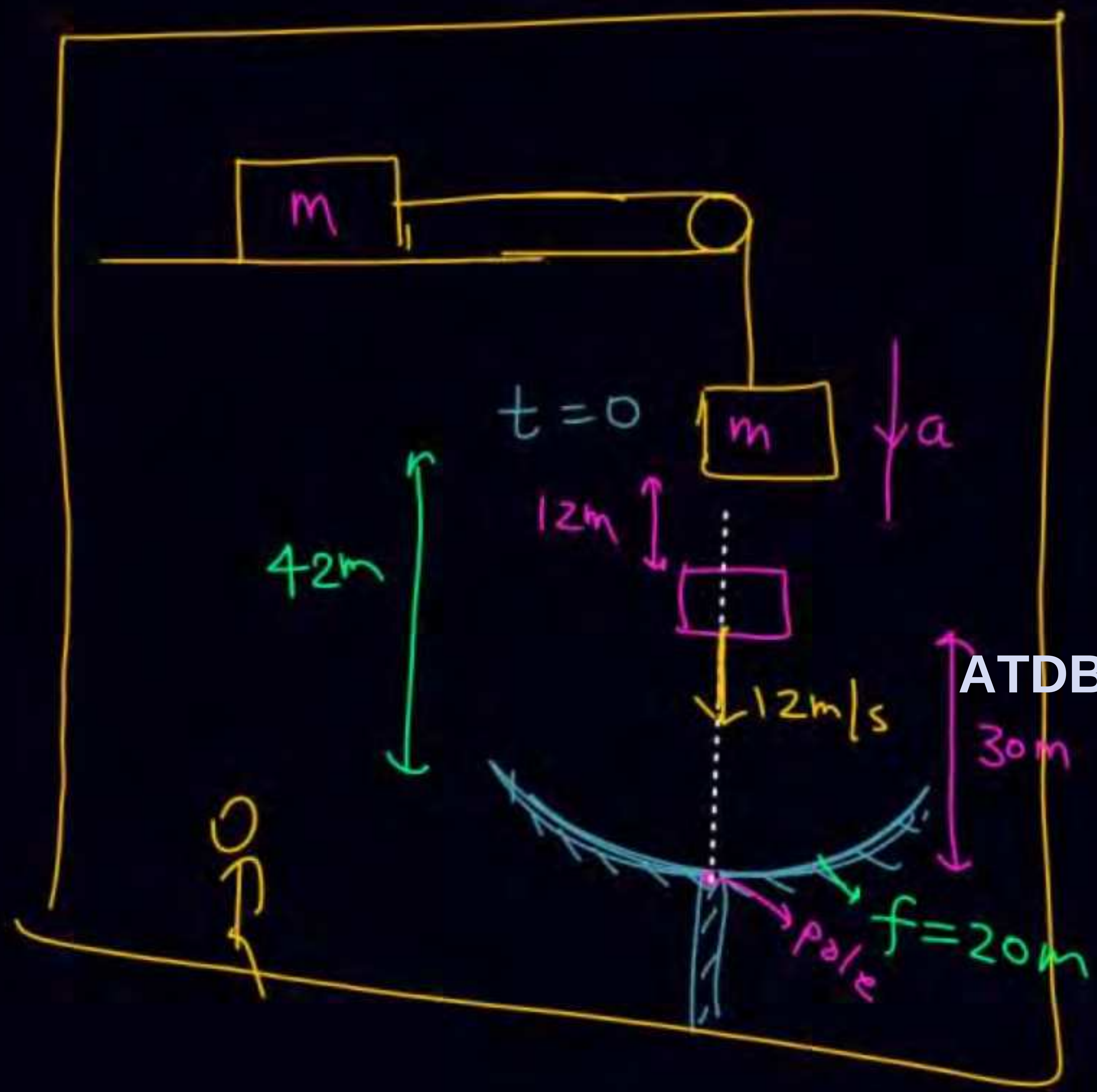
$$V_I - (+5) = -4\left(-4-5\right)$$

$$V_I - 5 = 36$$

$$\boxed{V_I = 41}$$

Q find velocity of image in mirror at t = 2 sec





$$a = \frac{mg-0}{2m} = g/2$$

g_{eff}

$$a = \frac{12}{2} = 6$$

$$a_l = 2$$

find velocity of image at $t = 2\,sec$

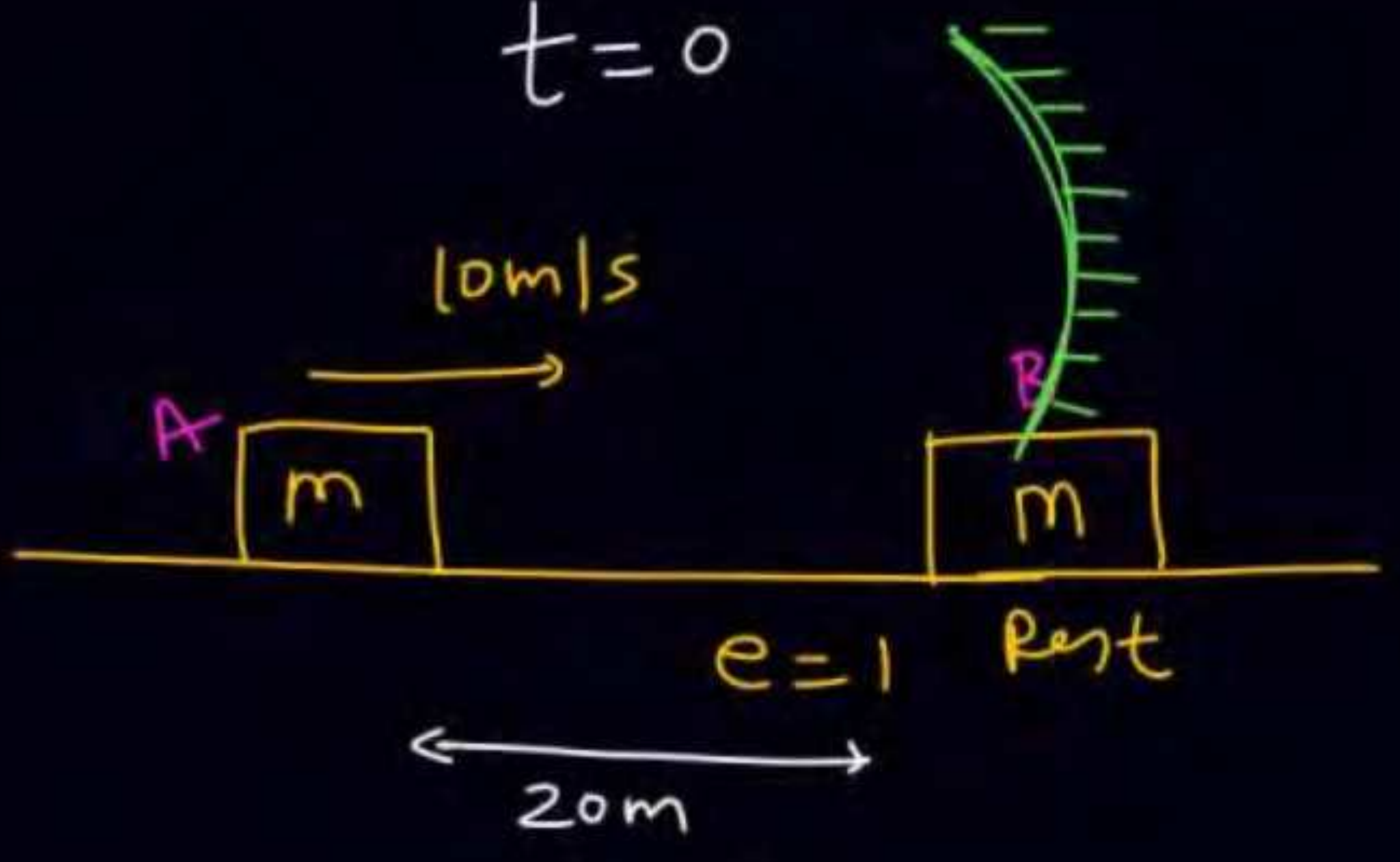
$$s = 0 + \frac{1}{2}\times 6\times 2^2 = 12$$

$$v_I = -m^2 V_0 = -m^2(-12)$$

$$v_I = 48$$

$t = 0$

Q



find

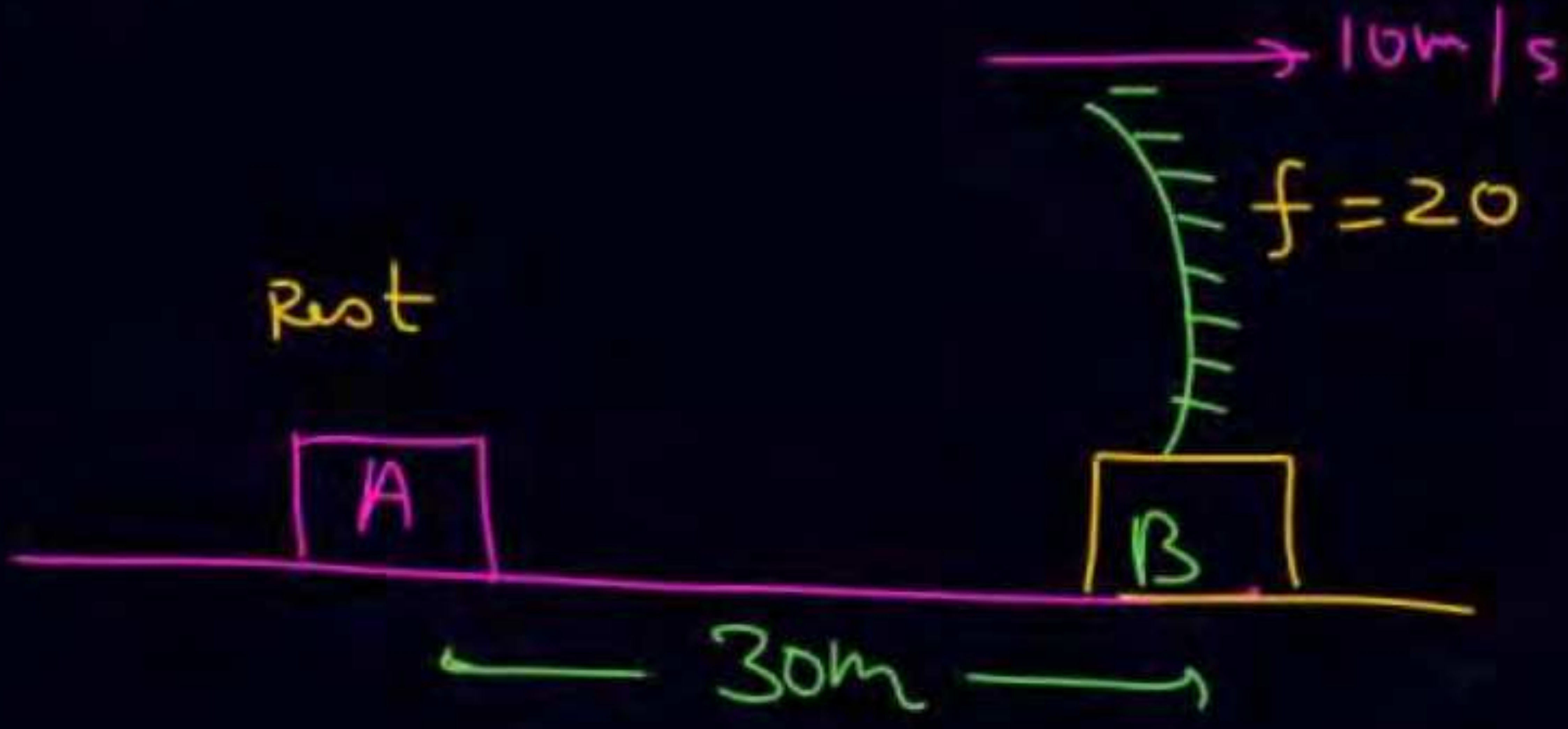
velocity of image at $t = 5\,sec$

sol^n

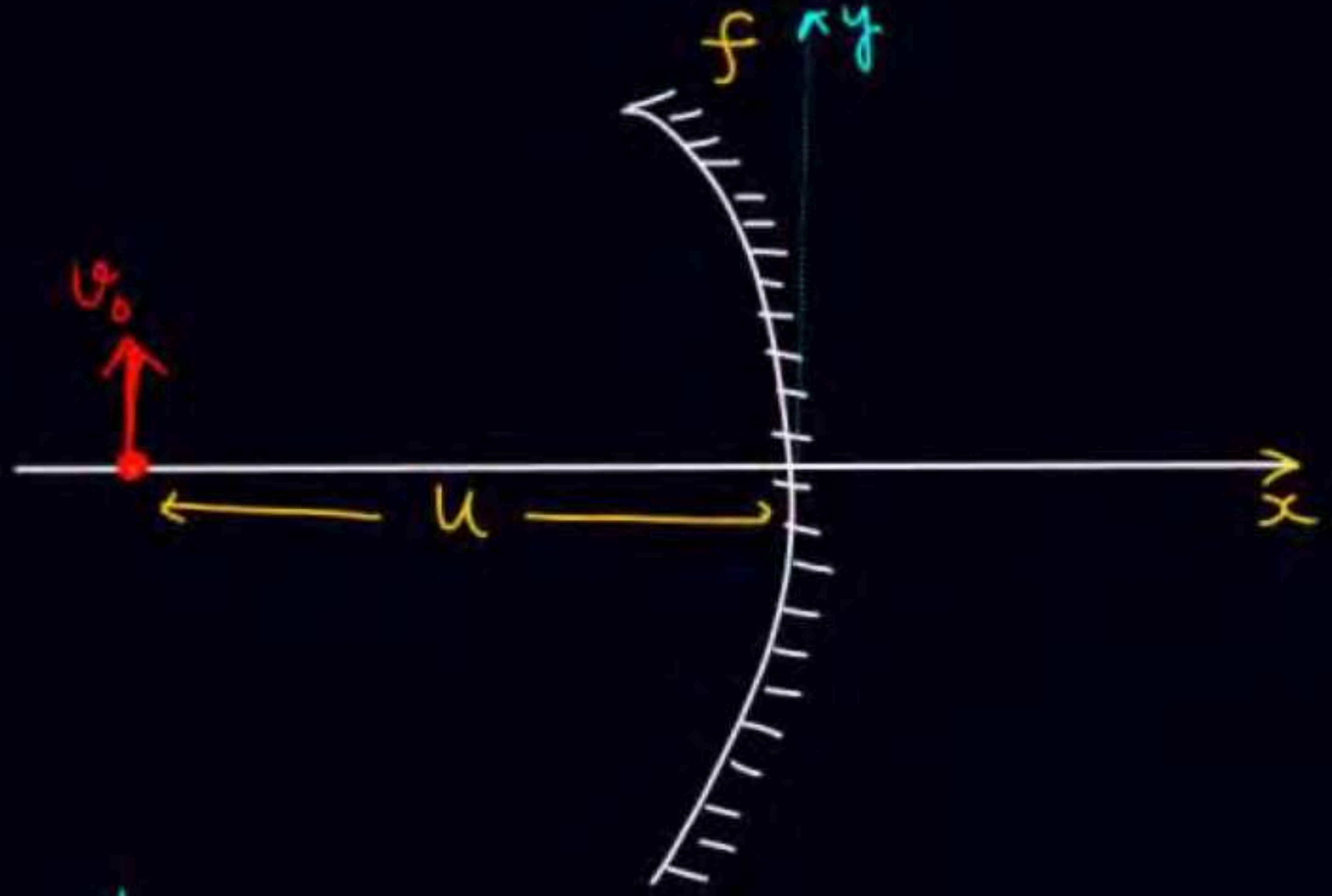
$$\vec{v}_{I/m} = -m^2 \vec{V}_{o/m}$$

$$v_I - (10) = -4(V_o - 10)$$

t =



#



$$\frac{dh_I}{dt} = (v_I)_y = -\frac{v}{u}(v_0)_y$$

$$\vec{v}_I = m\,\vec{v}_0 \quad \text{(perpendicular to the P.A.)}$$

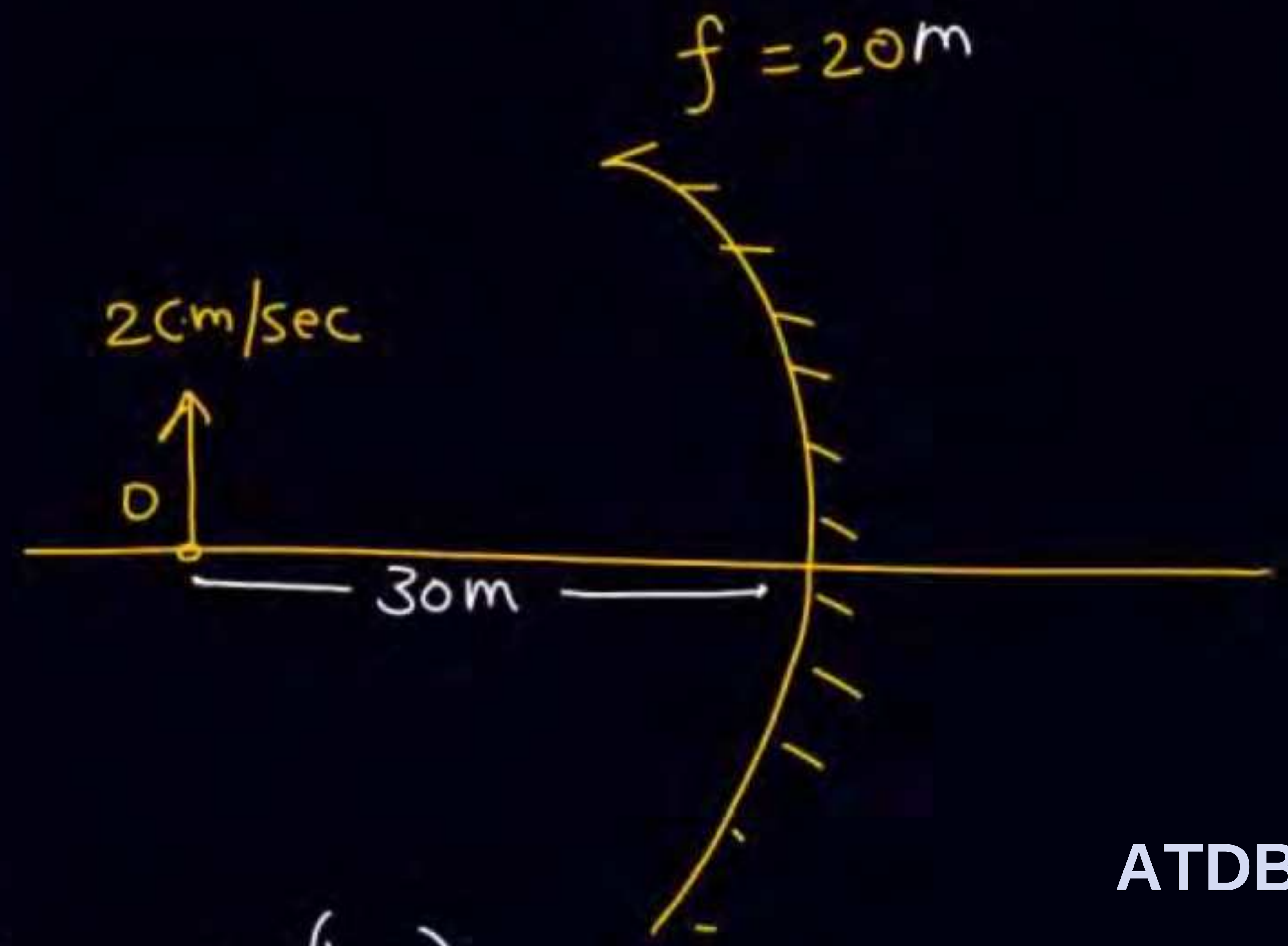
$$\vec{v}_I = -m^2\,\vec{V}_0 \quad \text{(Along P.A)}$$

$$m = \frac{h_I}{h_0}$$

$$h_I = m h_0$$

$$\frac{dh_I}{dt} = m\frac{dh_0}{dt} + \cancelto{0}{h_0\frac{dm}{dt}}$$

Q

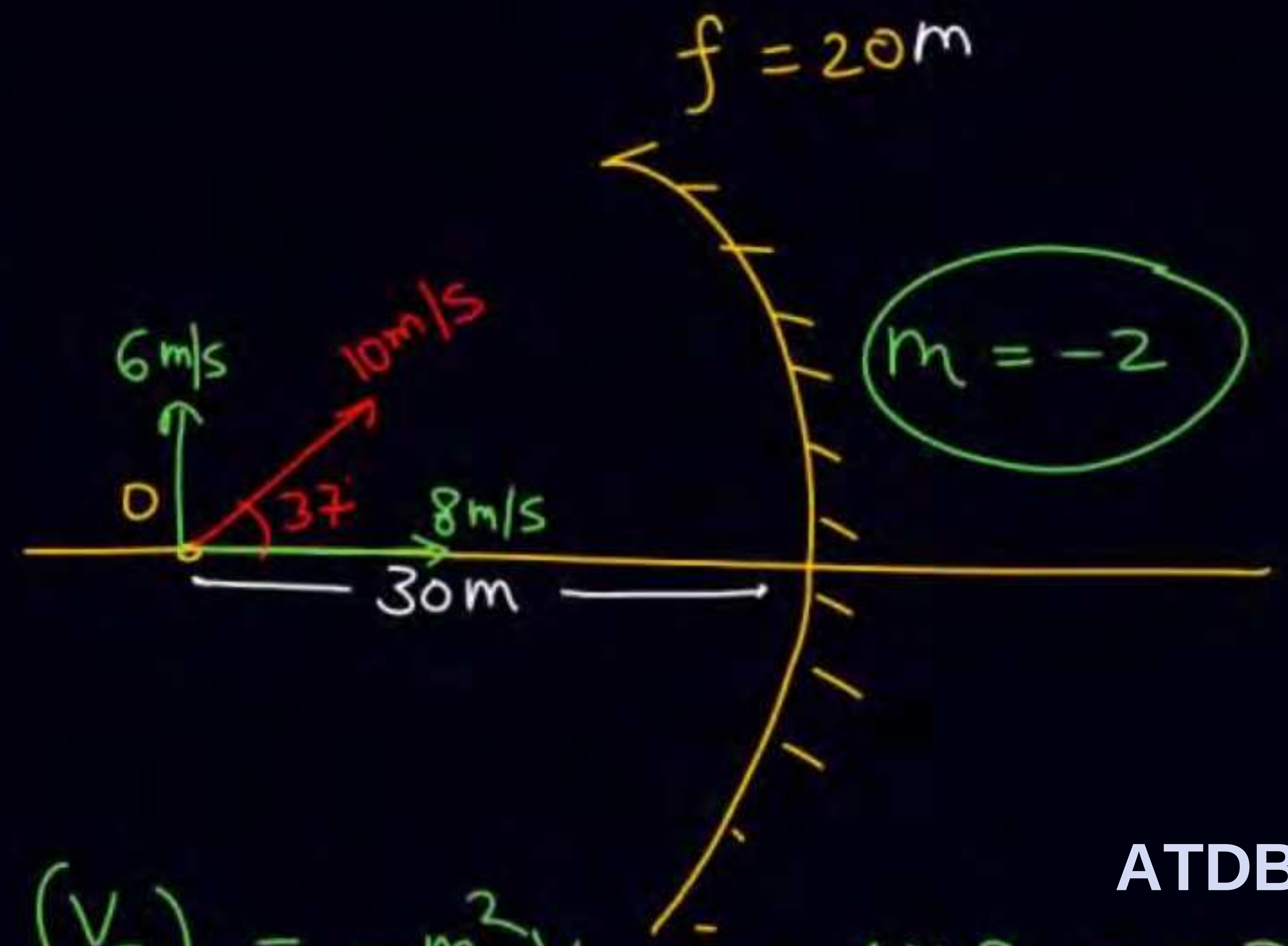


$$(V_I)_y = m(V_O)_y = (-2)(2\ cm/sec)\hat{j}$$

$$= -4\ cm/sec\ \hat{j}$$

नीचे

Q



$m = -2$

$\vec{v}_I = -32\hat{i} - 12\hat{j}$

$(V_I)_x = -m^2 V_0 = -4 \times 8 = -32\hat{i}$

$(v_I)_y = m(V_0)_y = -2 \times (6) = -12\hat{j}$

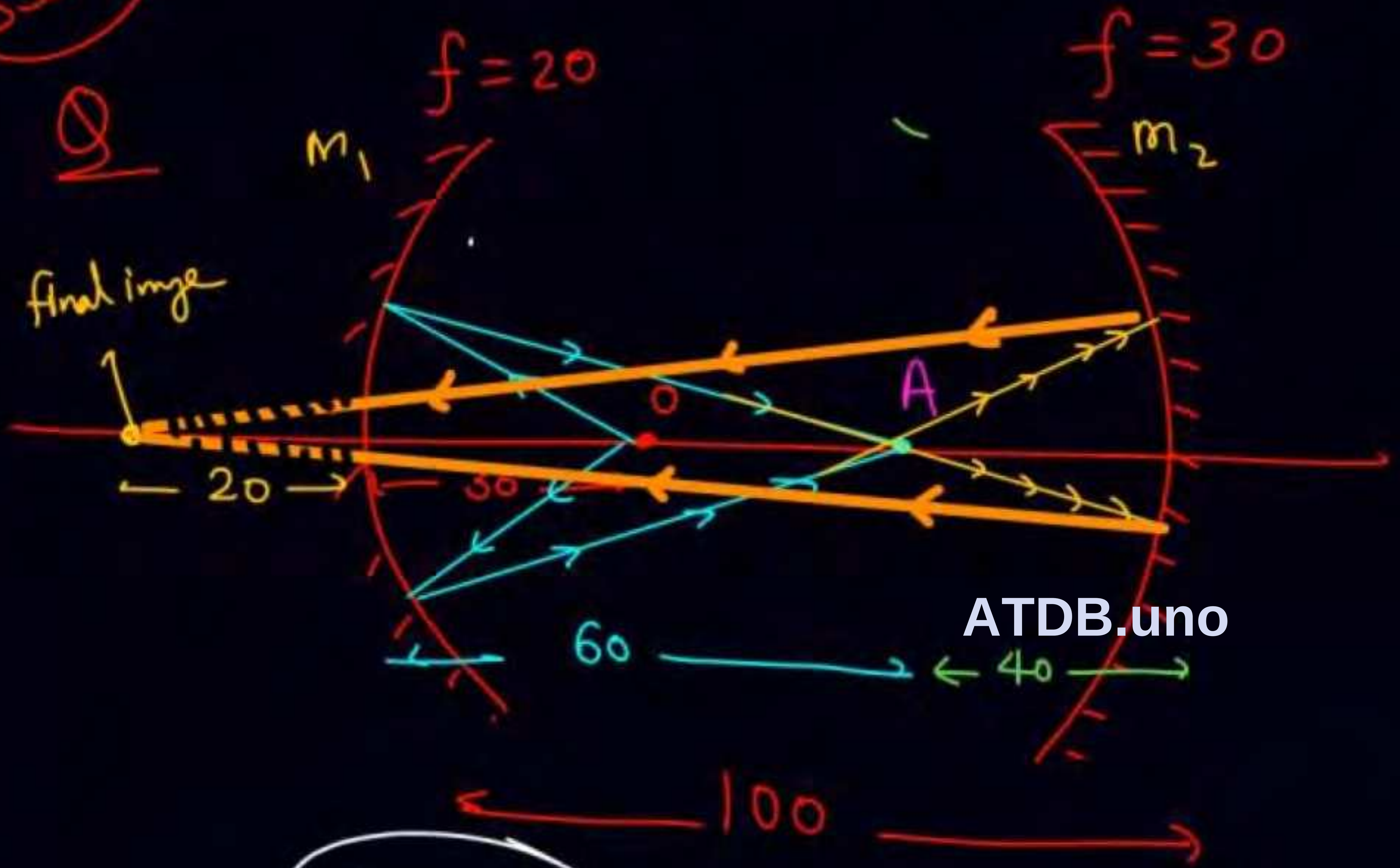
① find location of image after two reflection

Consider 1^{st} reflection at M_1 (left)

Ans 20 cm left to M_1 (left Min)

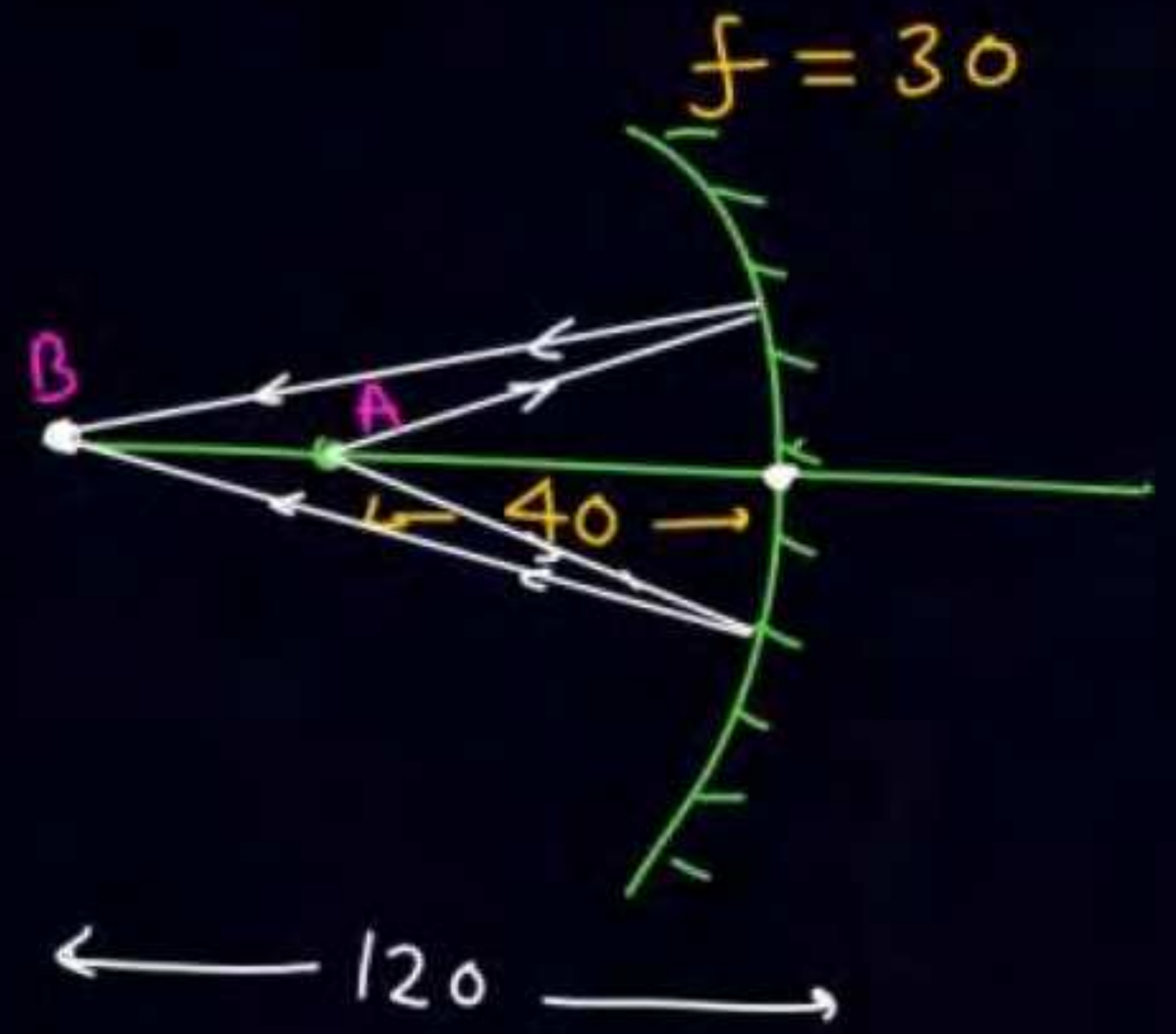
SSSD

Q



$m_1 = -2$

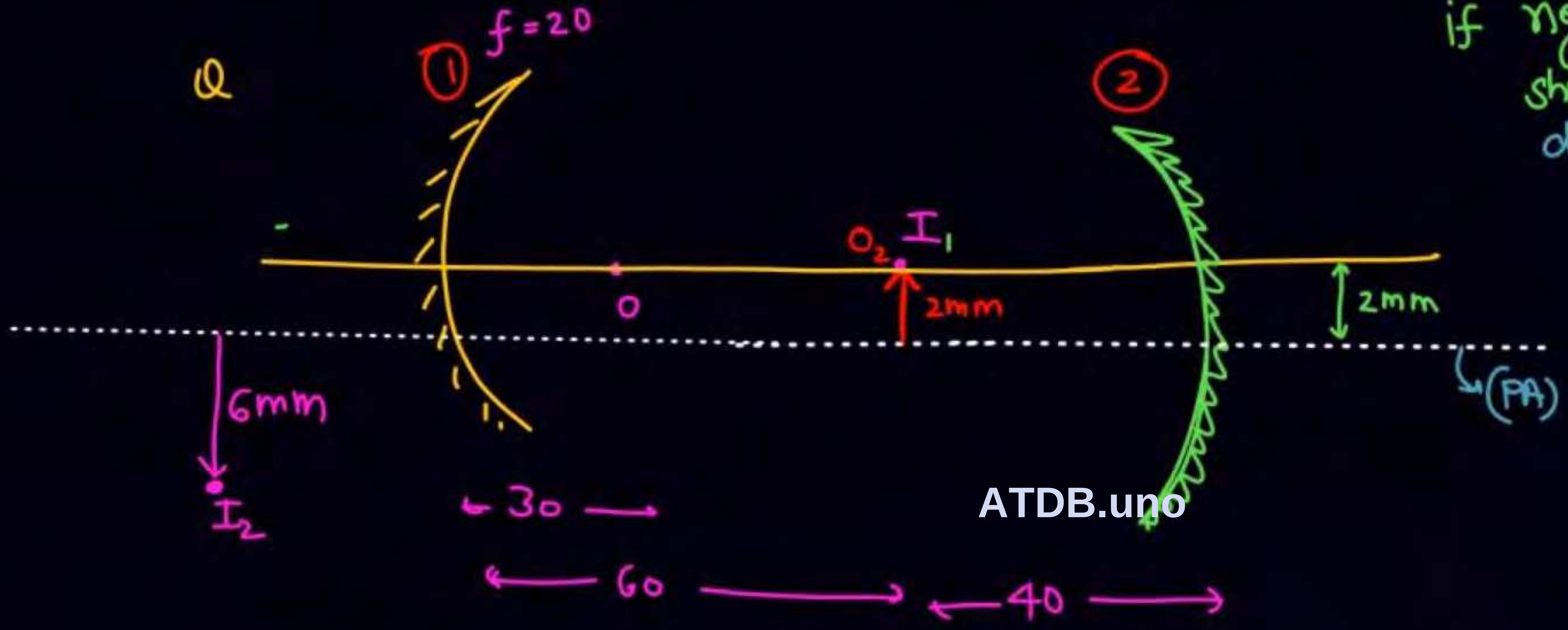
2^{nd} reflection



$$m_2 = -\frac{-120}{-40} = -3$$

f = 20
1
f = 30
40
0
30
60

Q



if right mirror is shifted by 2mm. down

$\underline{2^{nd} \text{ reflection}}$

$h_0 = 2\,mm$

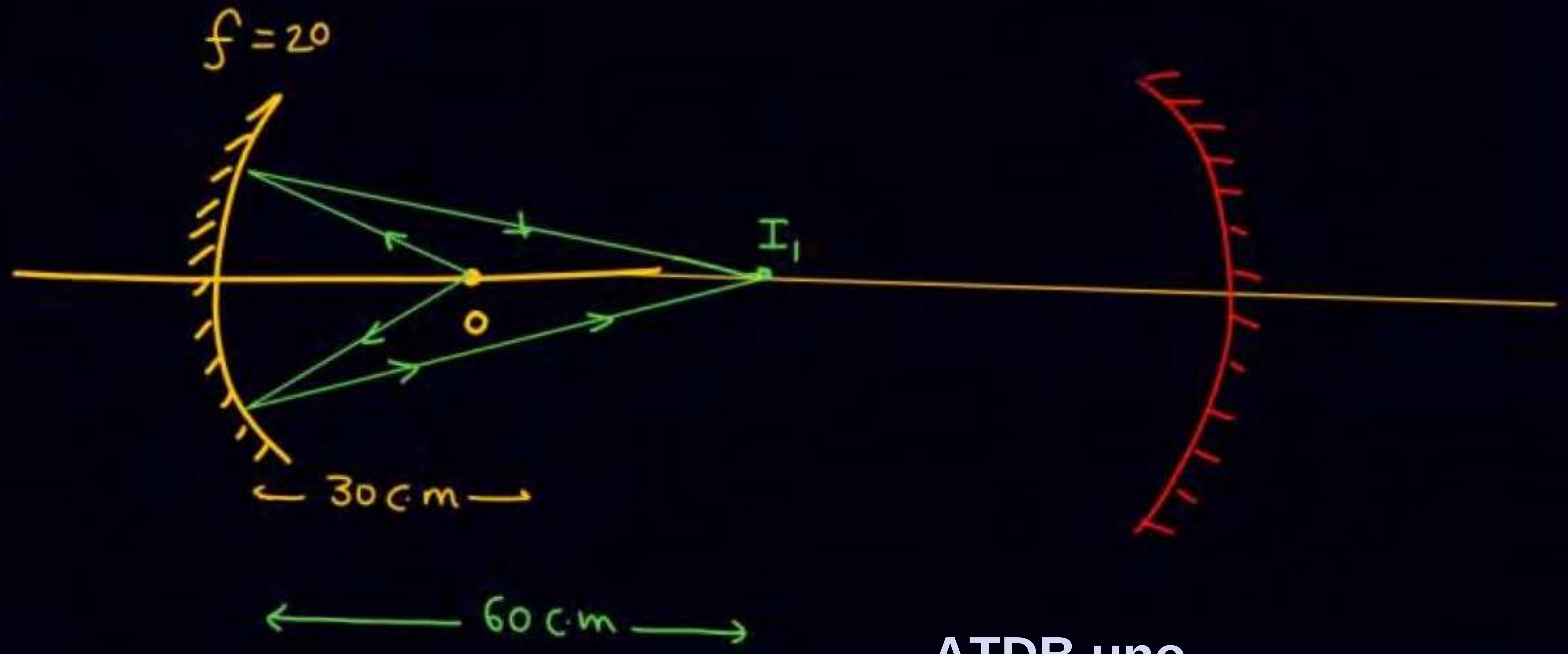
$m_2 = -3$

$V = -120$

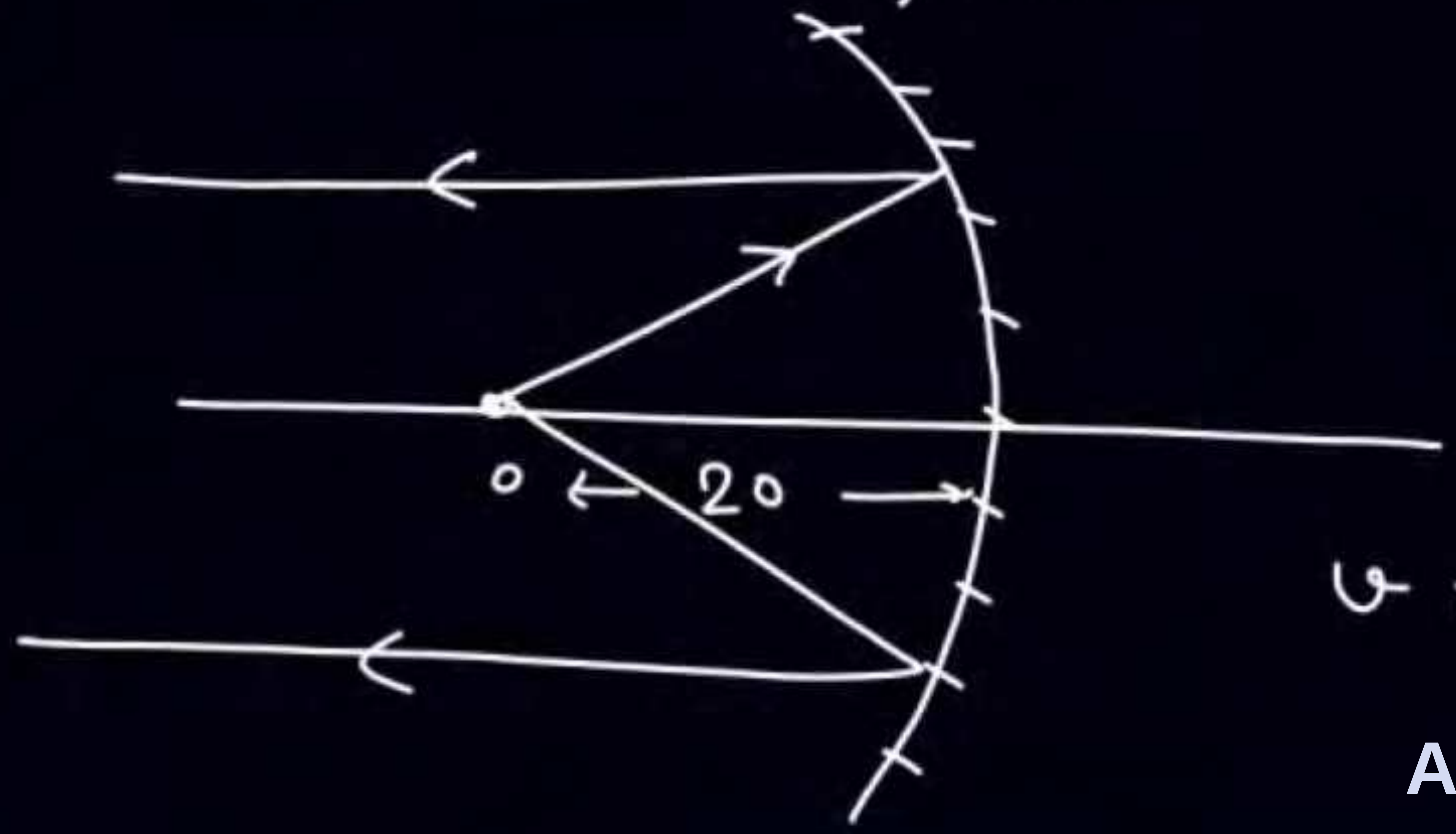
$u = -40$

$m = -\frac{V}{u} = -3$

Q



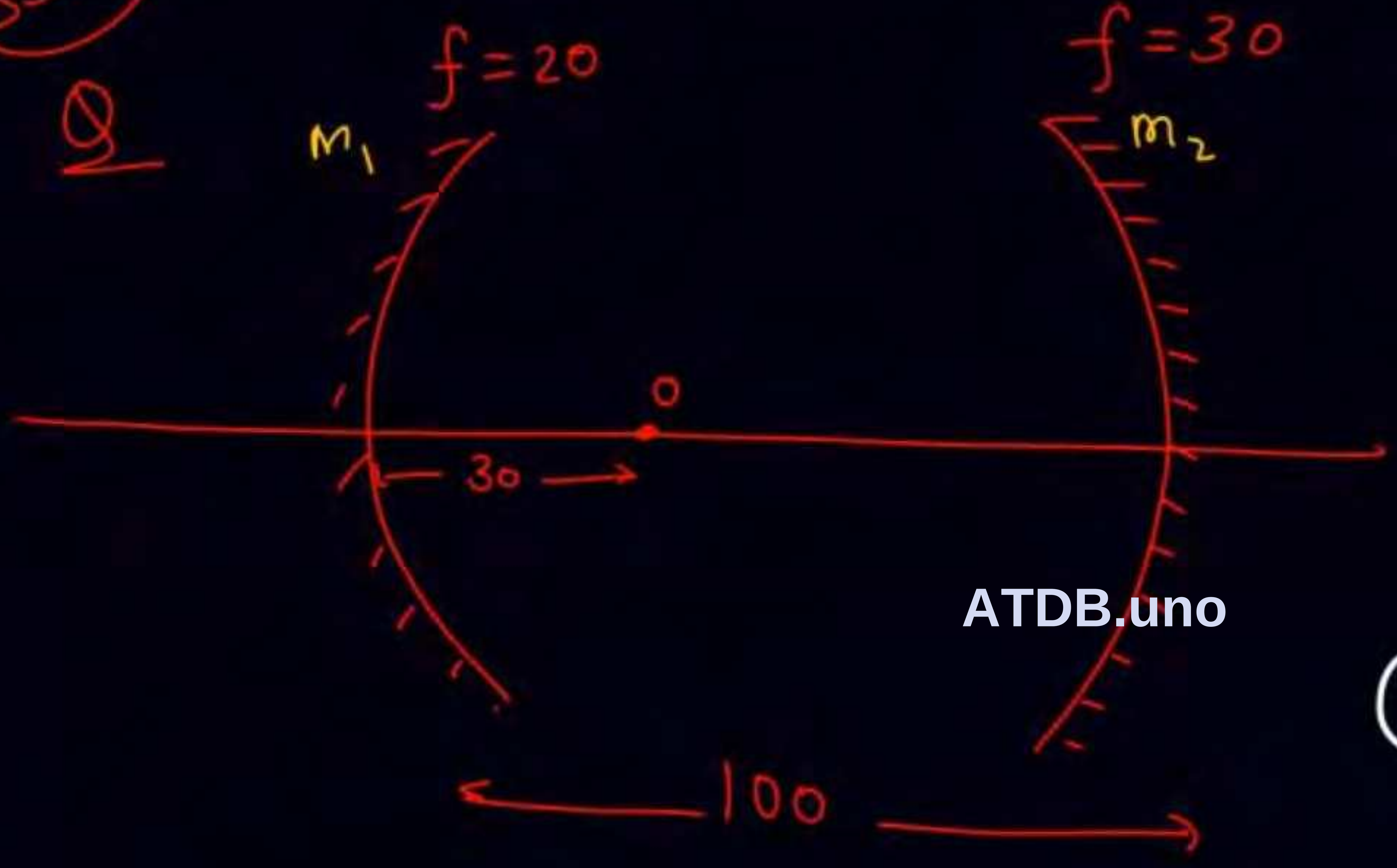
$f = 20$



$$v = \frac{-20 \times -20}{(-20) - (-20)} = \infty$$

SSSD

Q



(1) find location of image after two reflection

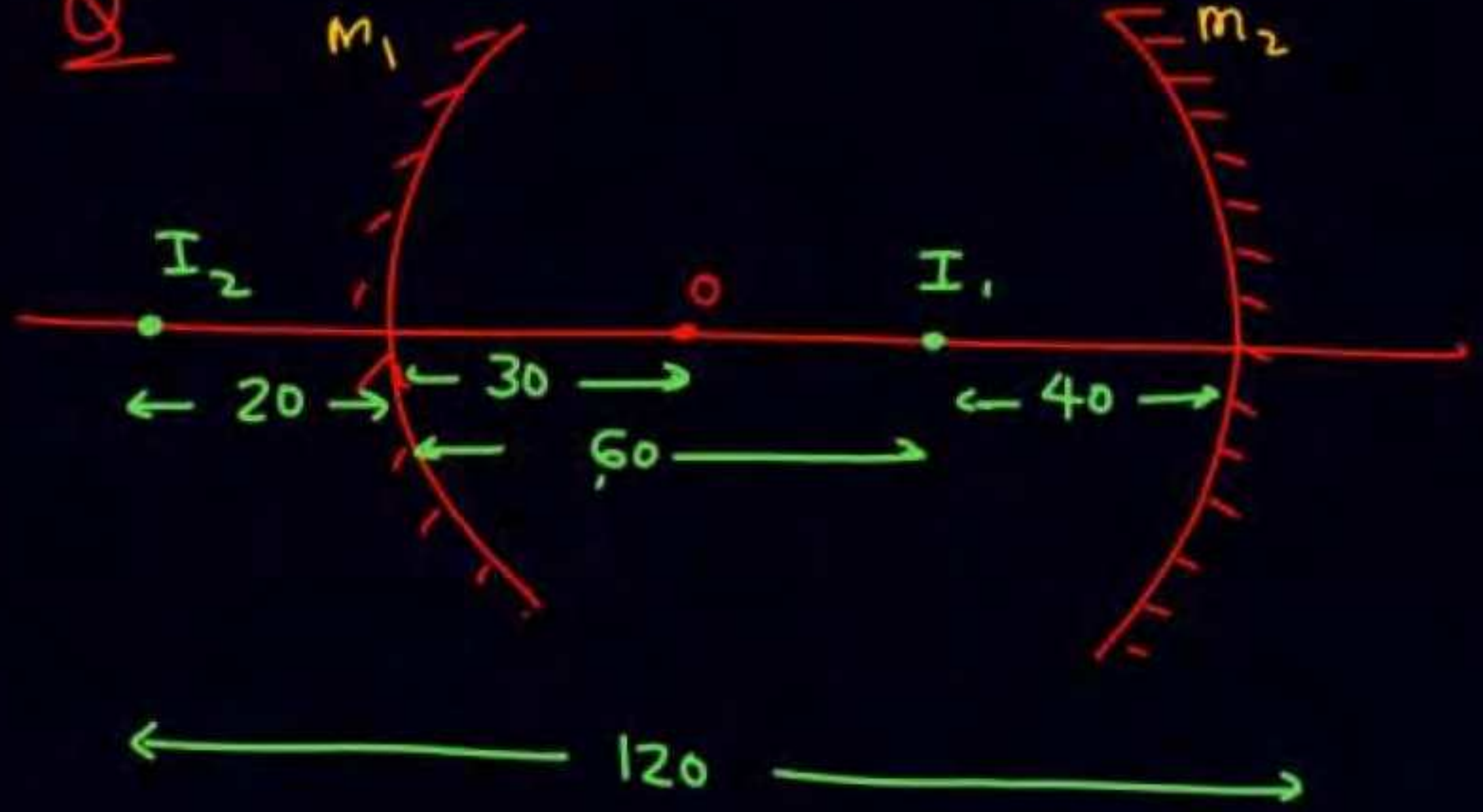
Consider 1^{st} reflection at m_1 (left)

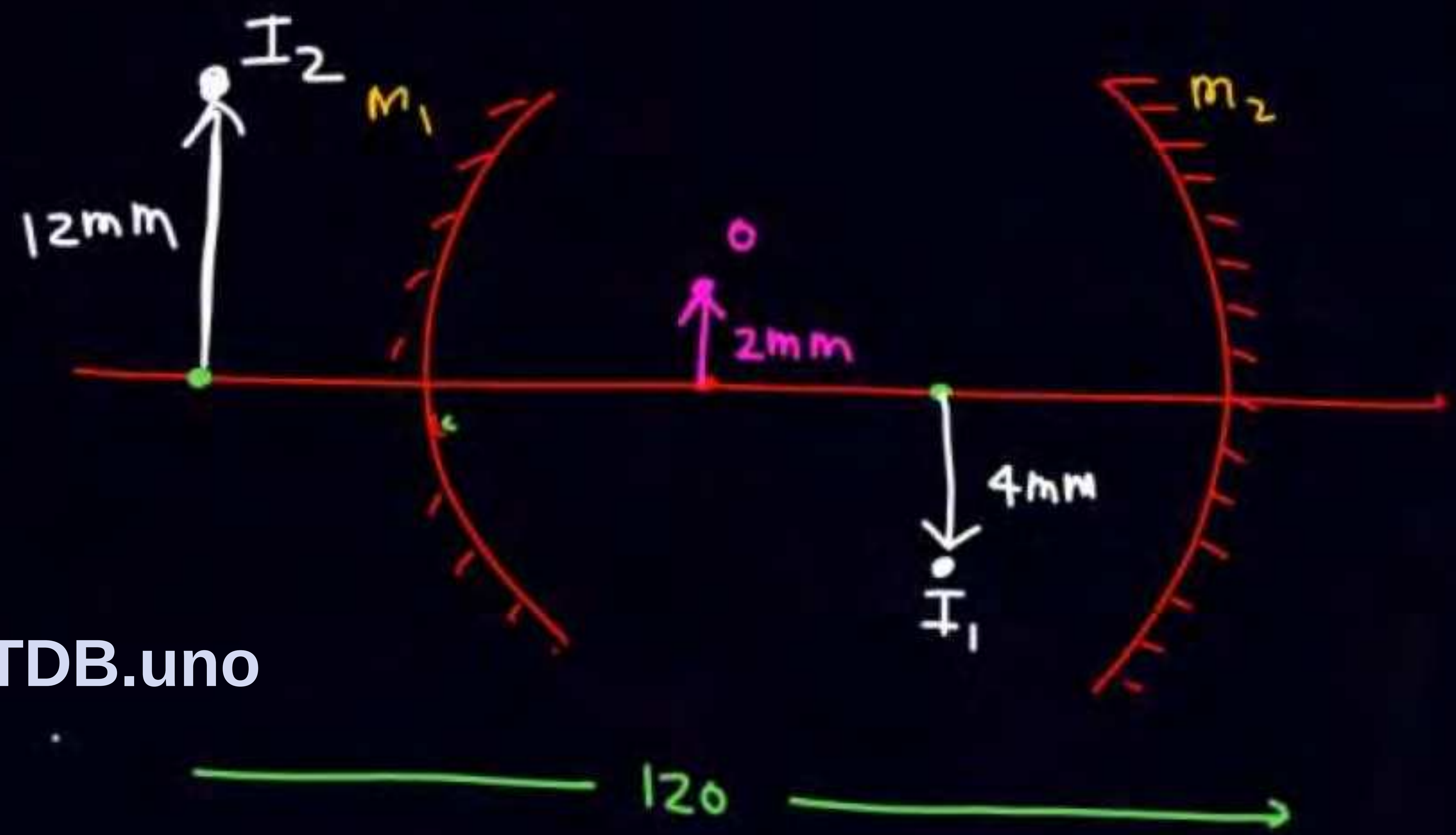
Ans 20 cm left to m_1 (left Mirr)

(b) If obj is shifted above PA by 2mm find location of image & net magnification

SSSD

Q



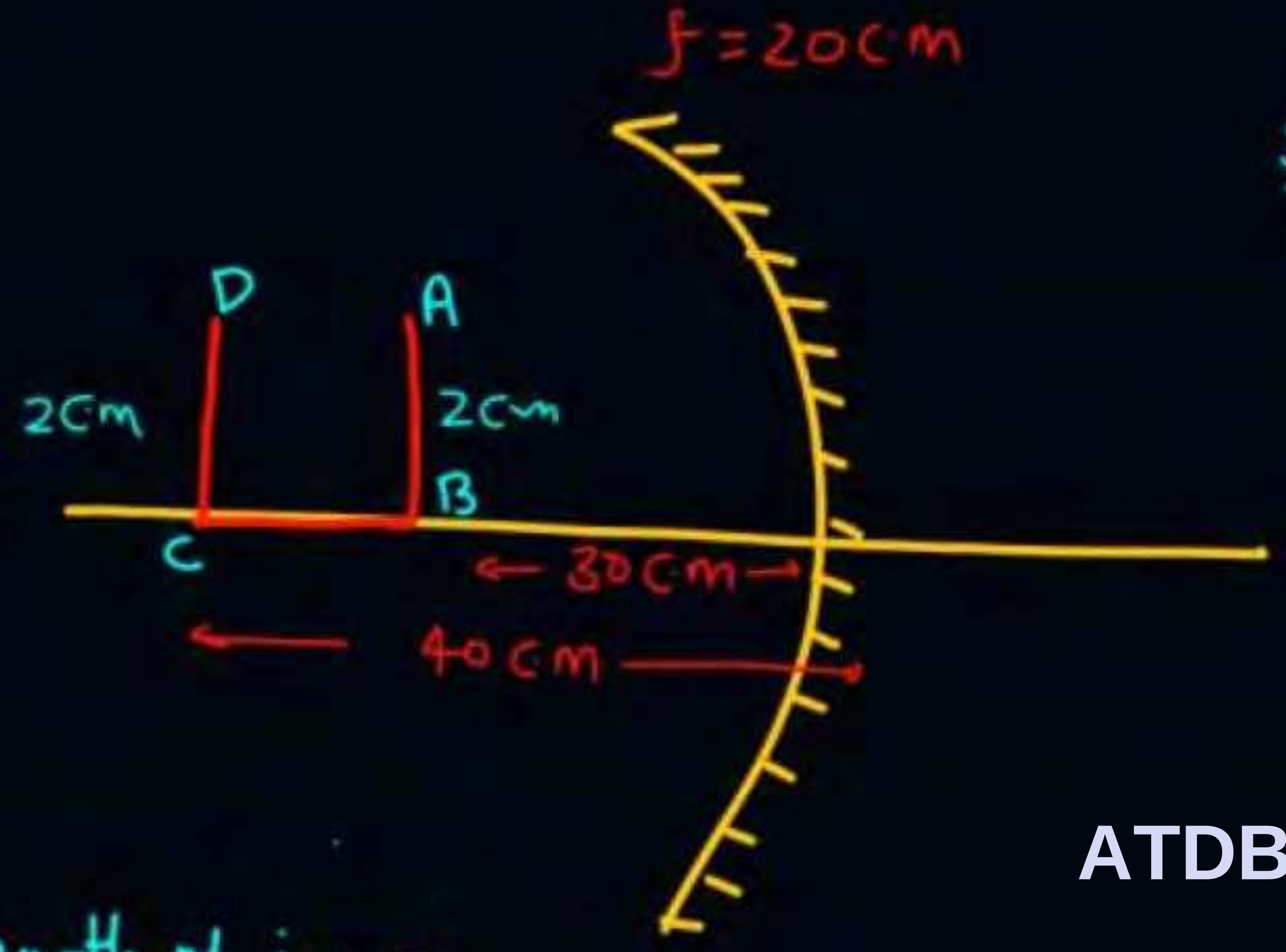


$$\left.\begin{aligned} m_1 &= -2 \\ m_2 &= -3 \end{aligned}\right\} \text{magnifical}$$

$$m_{nt} = m_1 \times m_2$$
$$= (-2) \times (-3) = +6$$

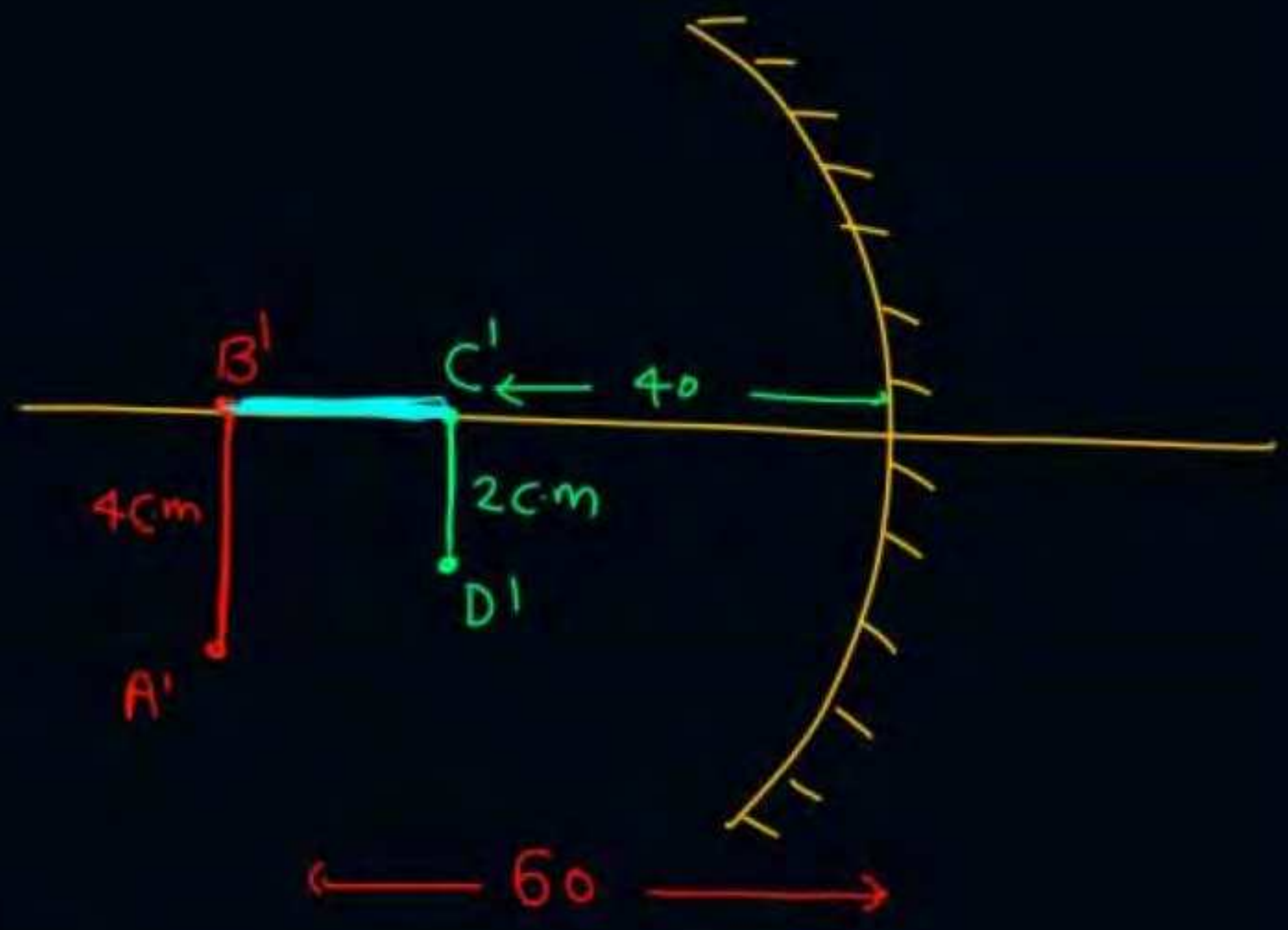
Assume paraxial rays concept

Q

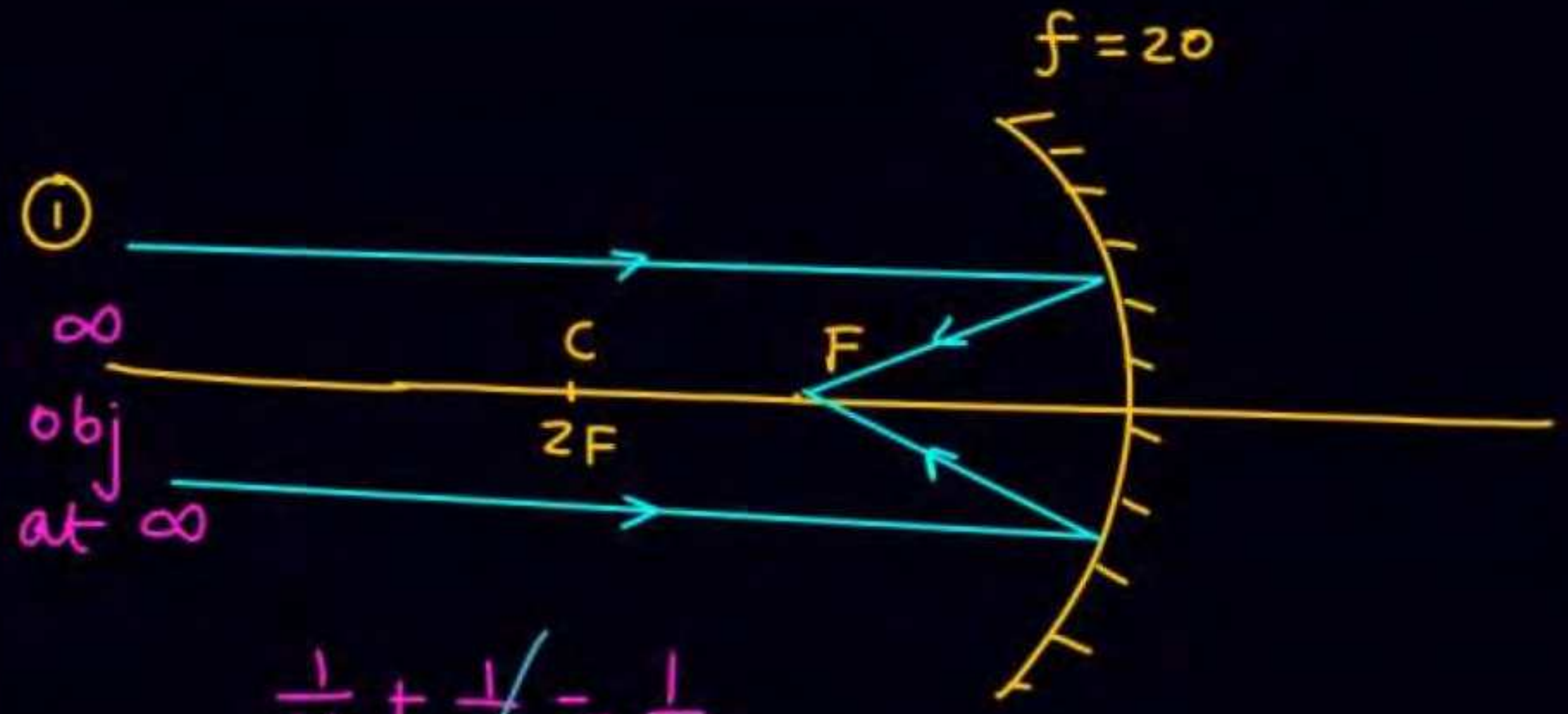


Find length of image

Sol^n



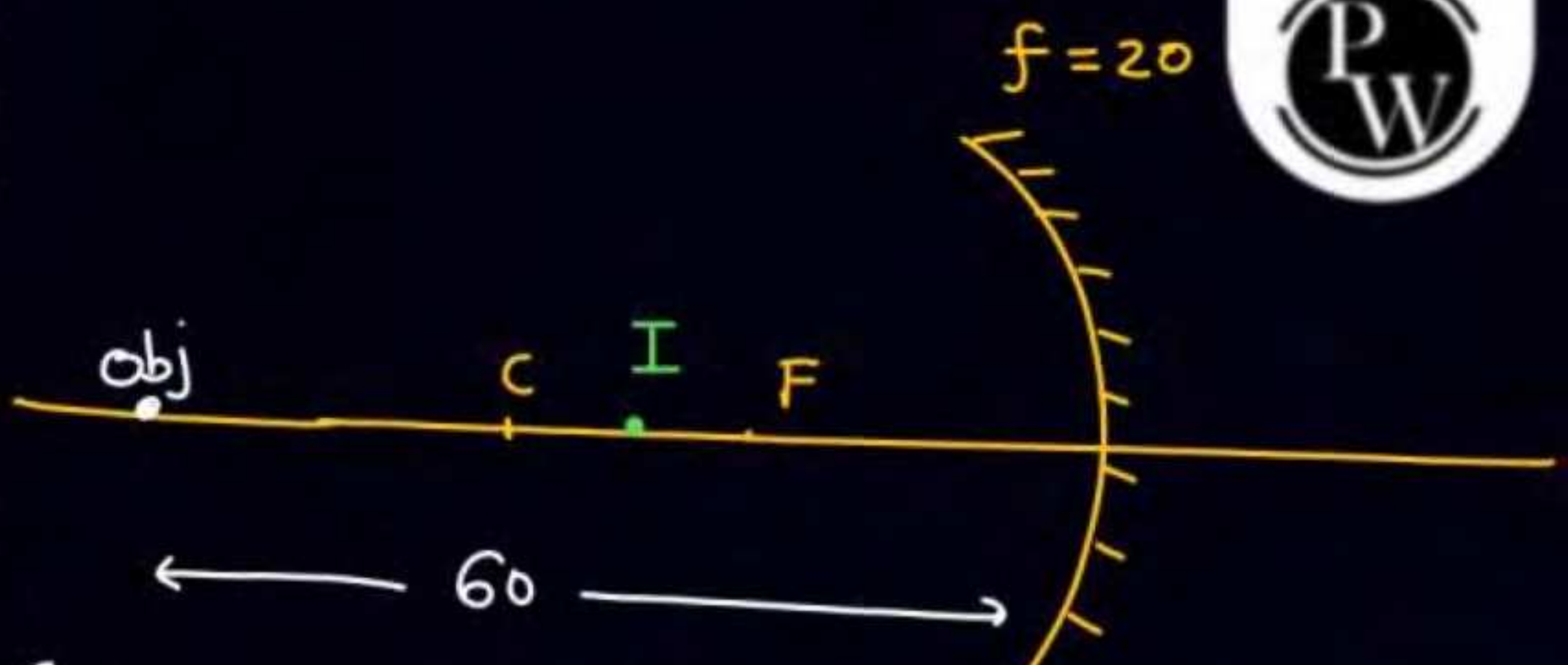
Length of image = $4 + 20 + 2 = 26$ cm



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

$\cancel{\frac{1}{u}} \to 0$

$$\boxed{V = -20}$$



(Obj. b/w −∞ & coc)

R.O. $v = \frac{1200}{-60-(-20)} = -30$

$$m = -\frac{v}{u} = -\frac{-30}{-60} = -\frac{1}{2}$$

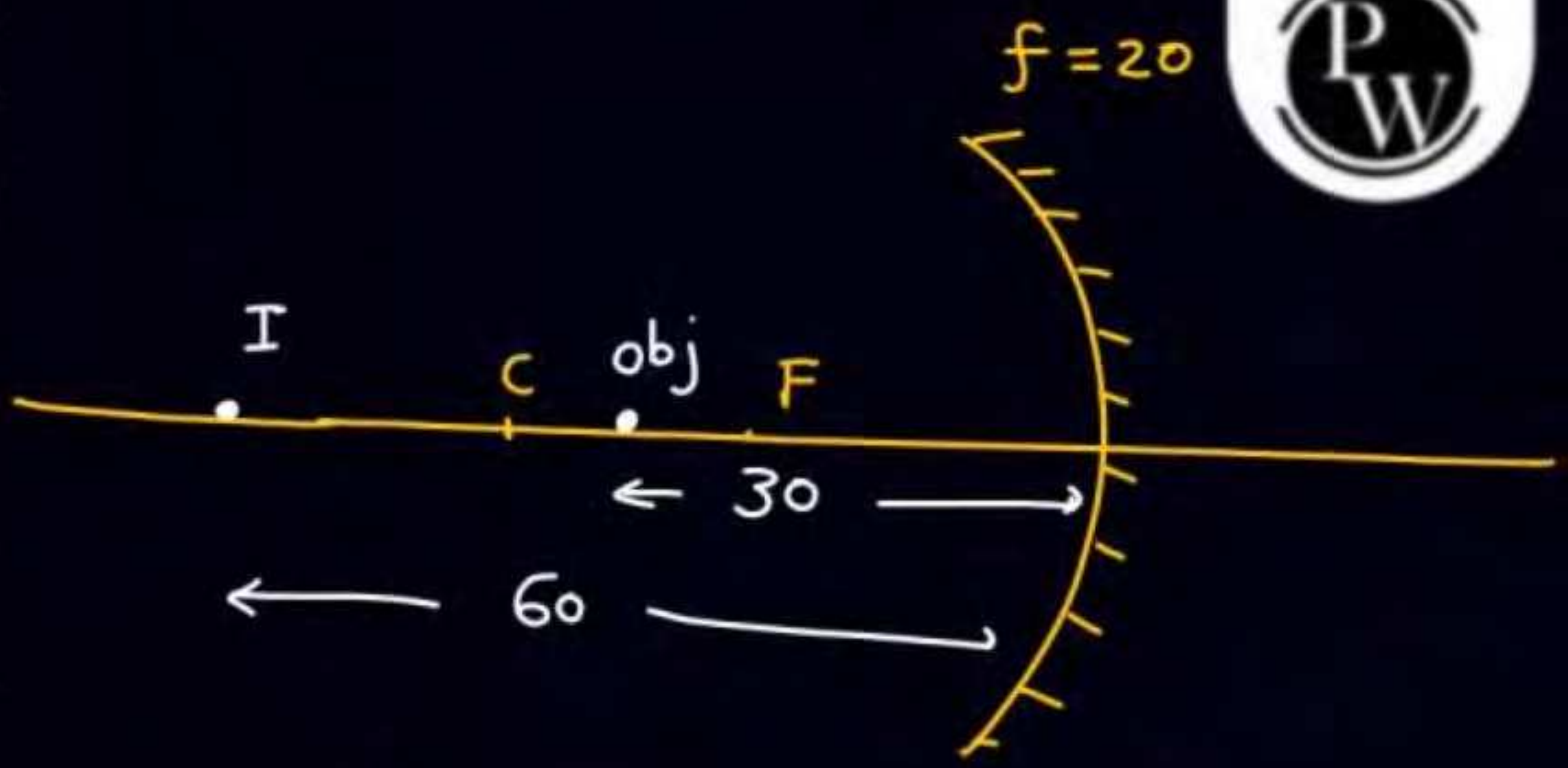
(Obj. b/w −∞ & coc) ⇒ RO, RI, diminish, inverted

image b/w F & C

(1)

obj (coc) $\Rightarrow$ I $\equiv$ (coc)

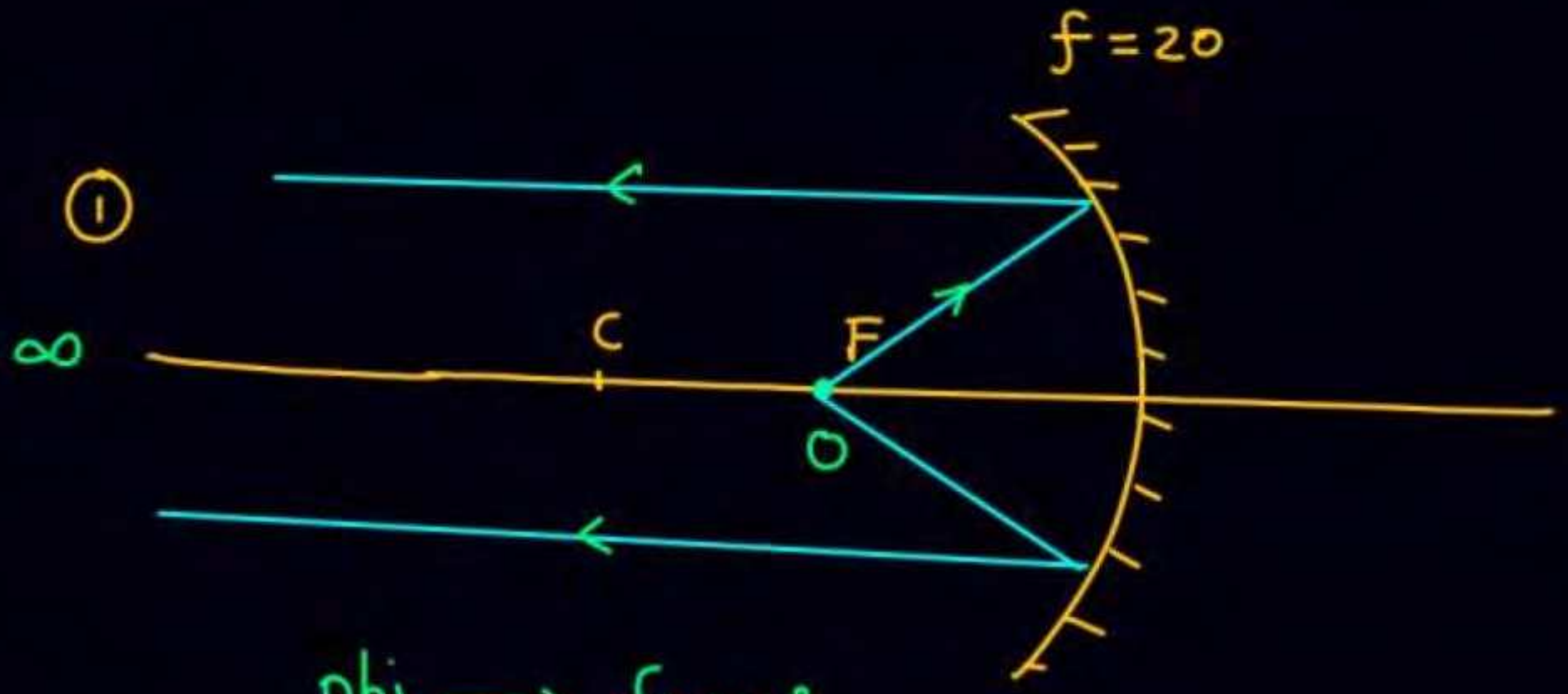
$m = -1$



obj $\Rightarrow$ (b/w F & C)

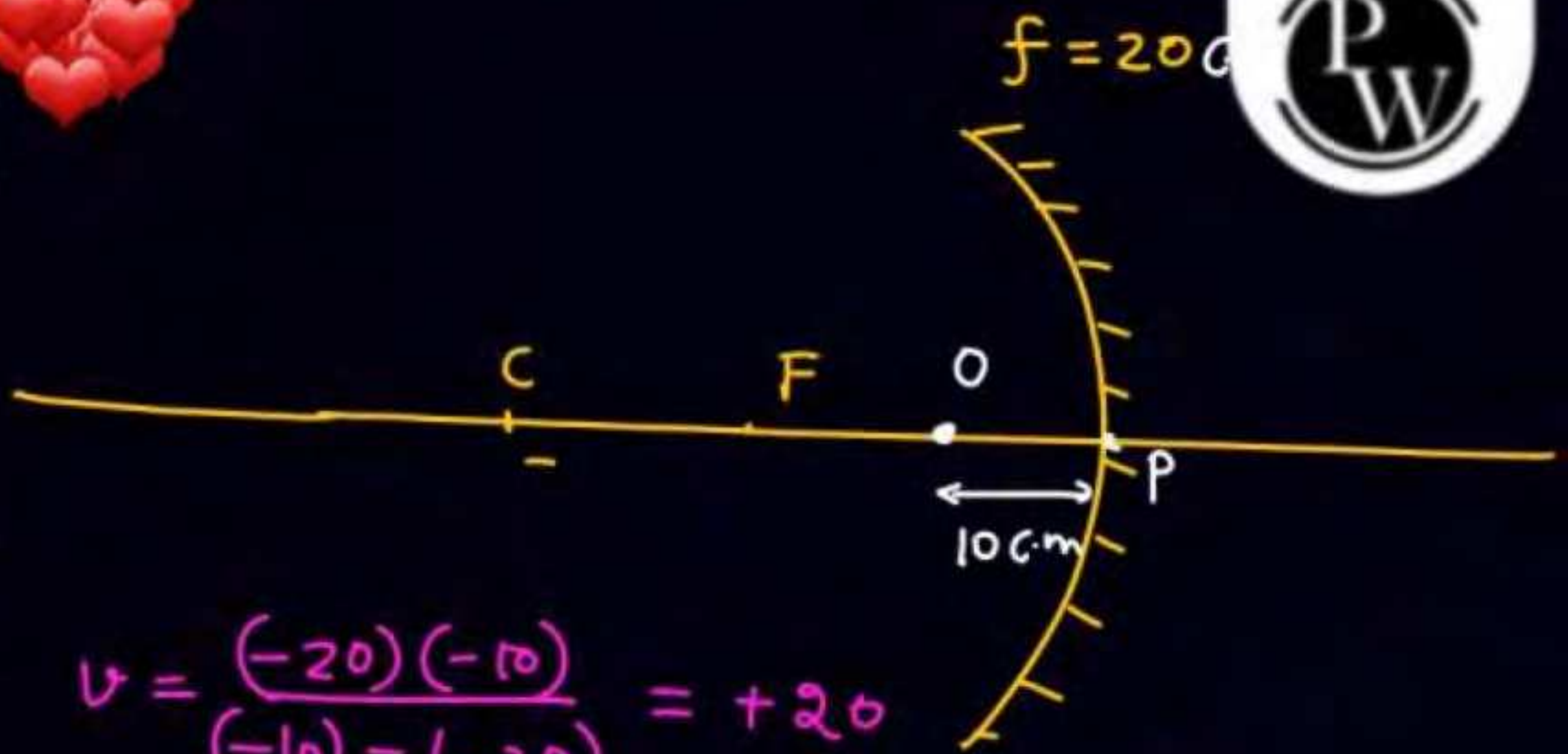
Imge $\Rightarrow$ (b/w $-\infty$ & C) $m = -2$

enlarge, inverted



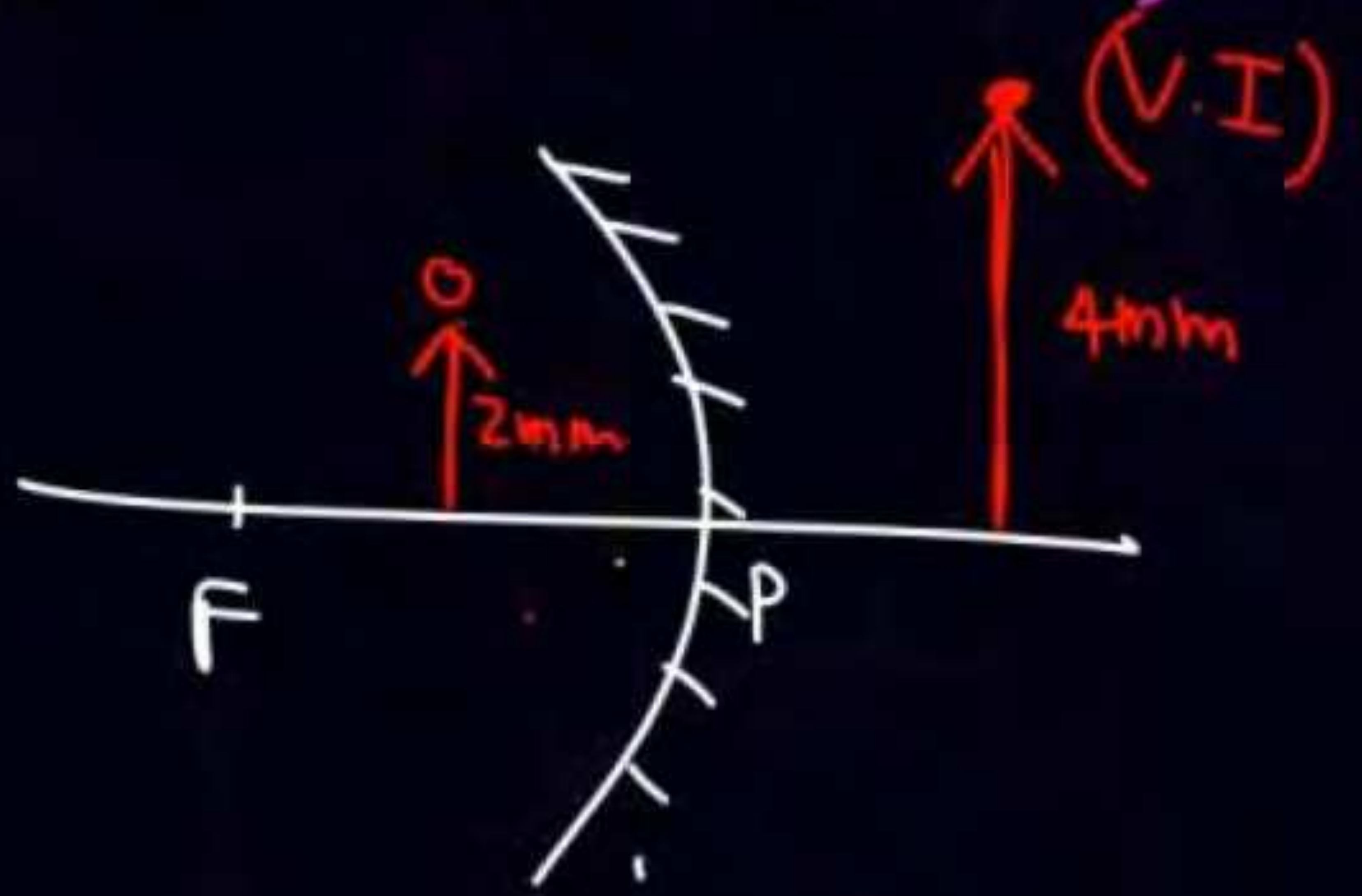
obj ⟶ focus

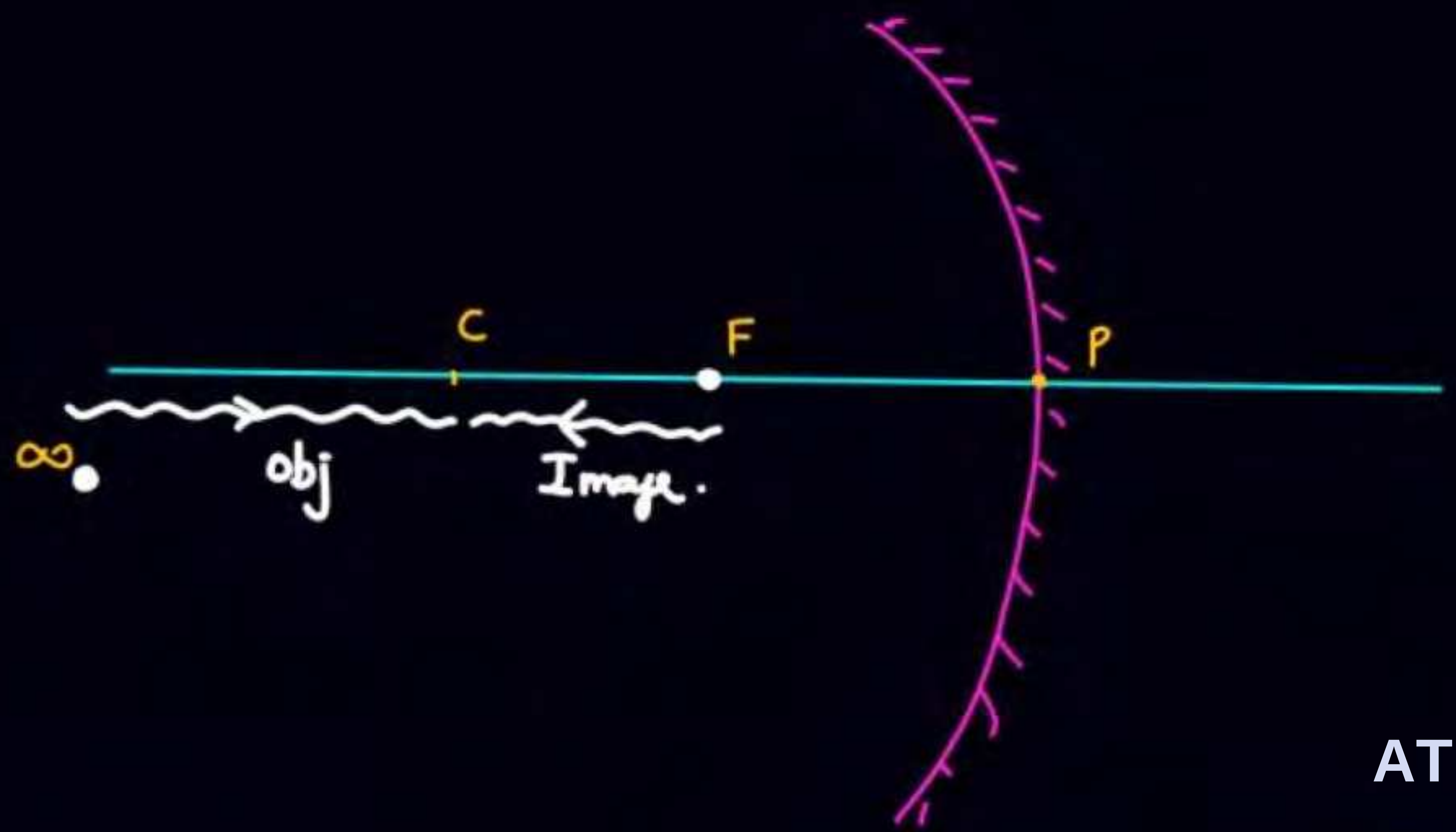
image ⟶ ∞

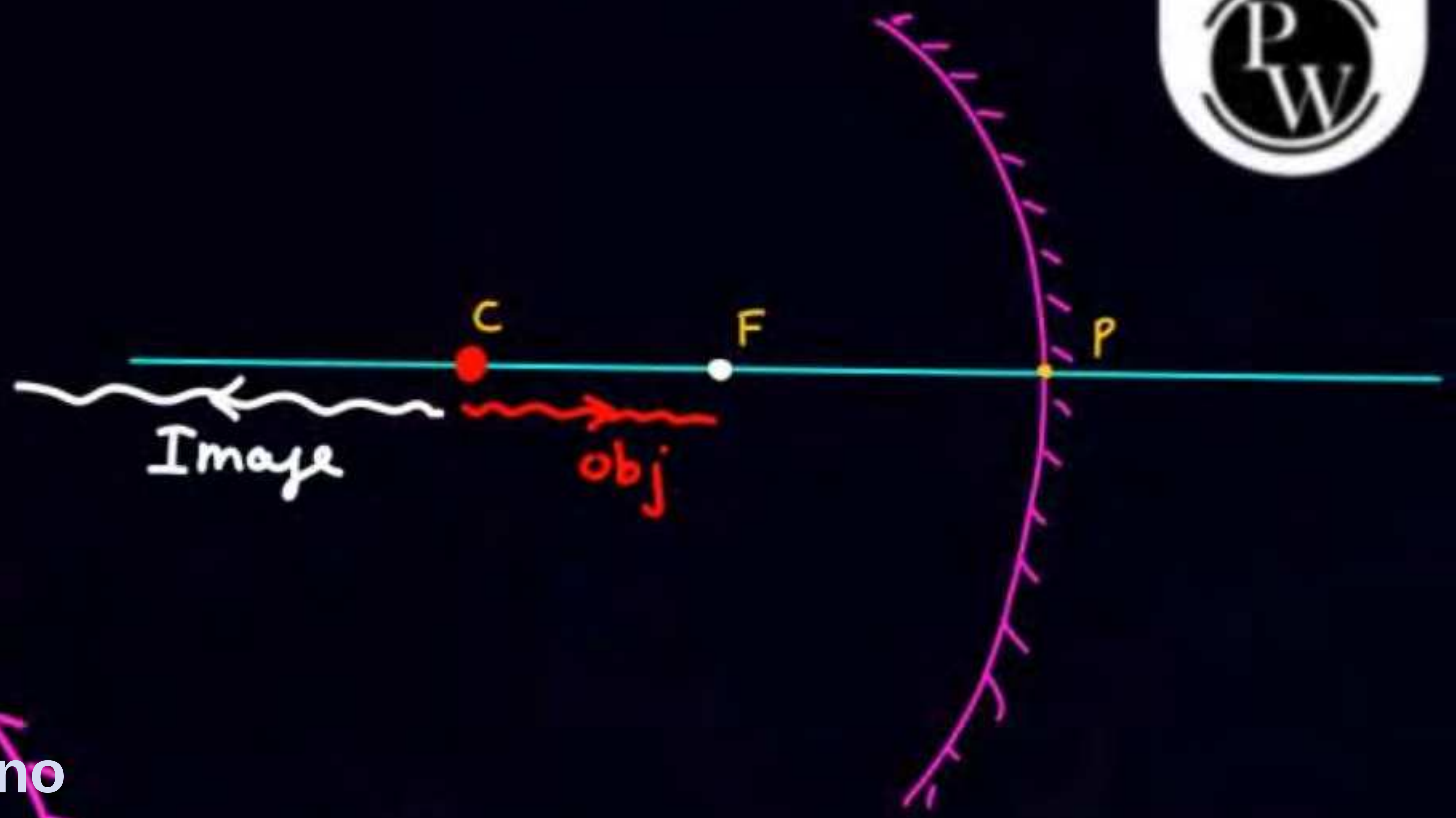


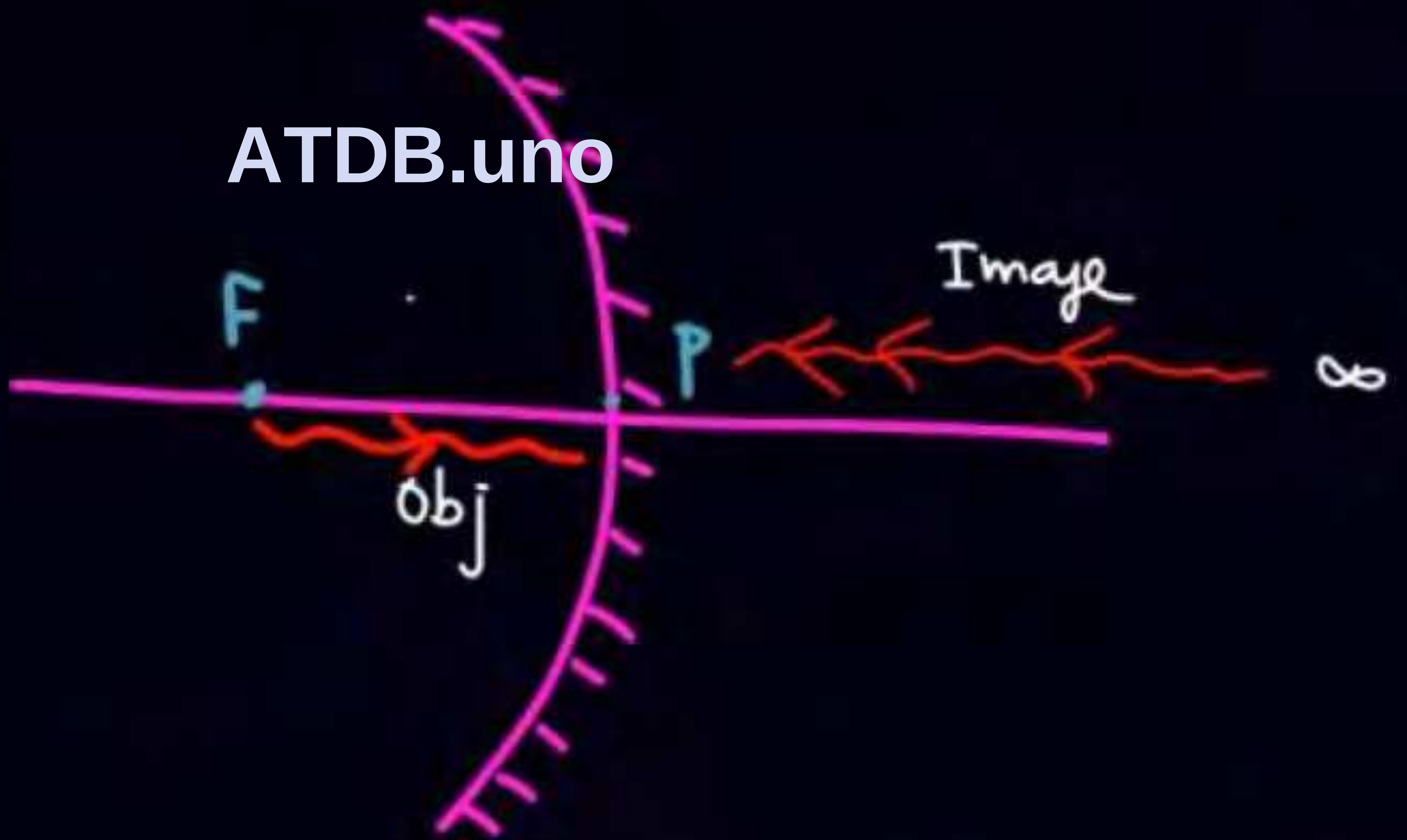
$$v = \frac{(-20)(-10)}{(-10)-(-20)} = +20$$

$$m = -\frac{20}{-10} = +2 \text{ (erect, enlarge)}$$




C
F
P
∞
obj
Image.


C
F
P
Image
obj


F
P
Image
∞
obj


F
O
∞
I

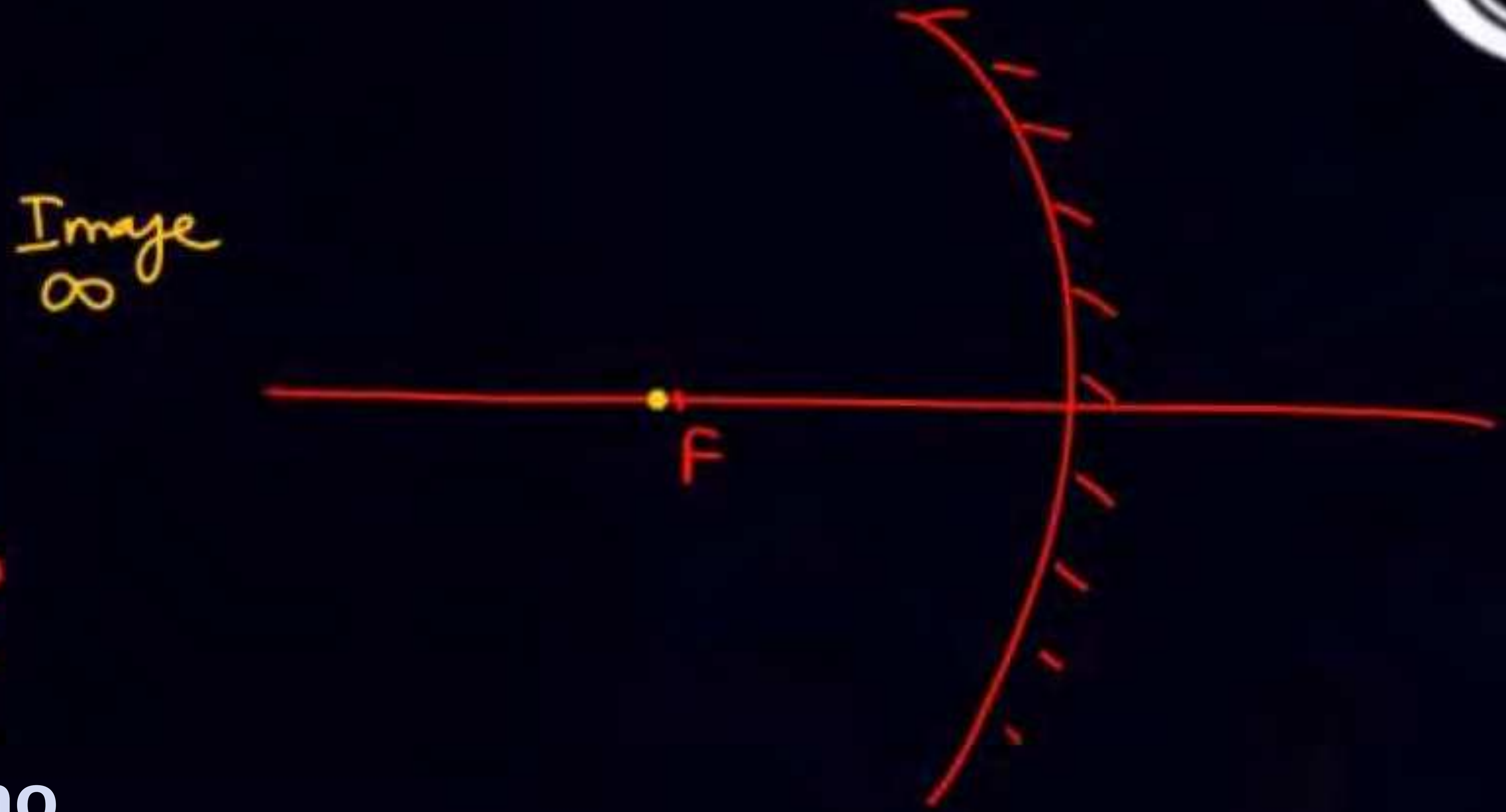


Image
∞
F

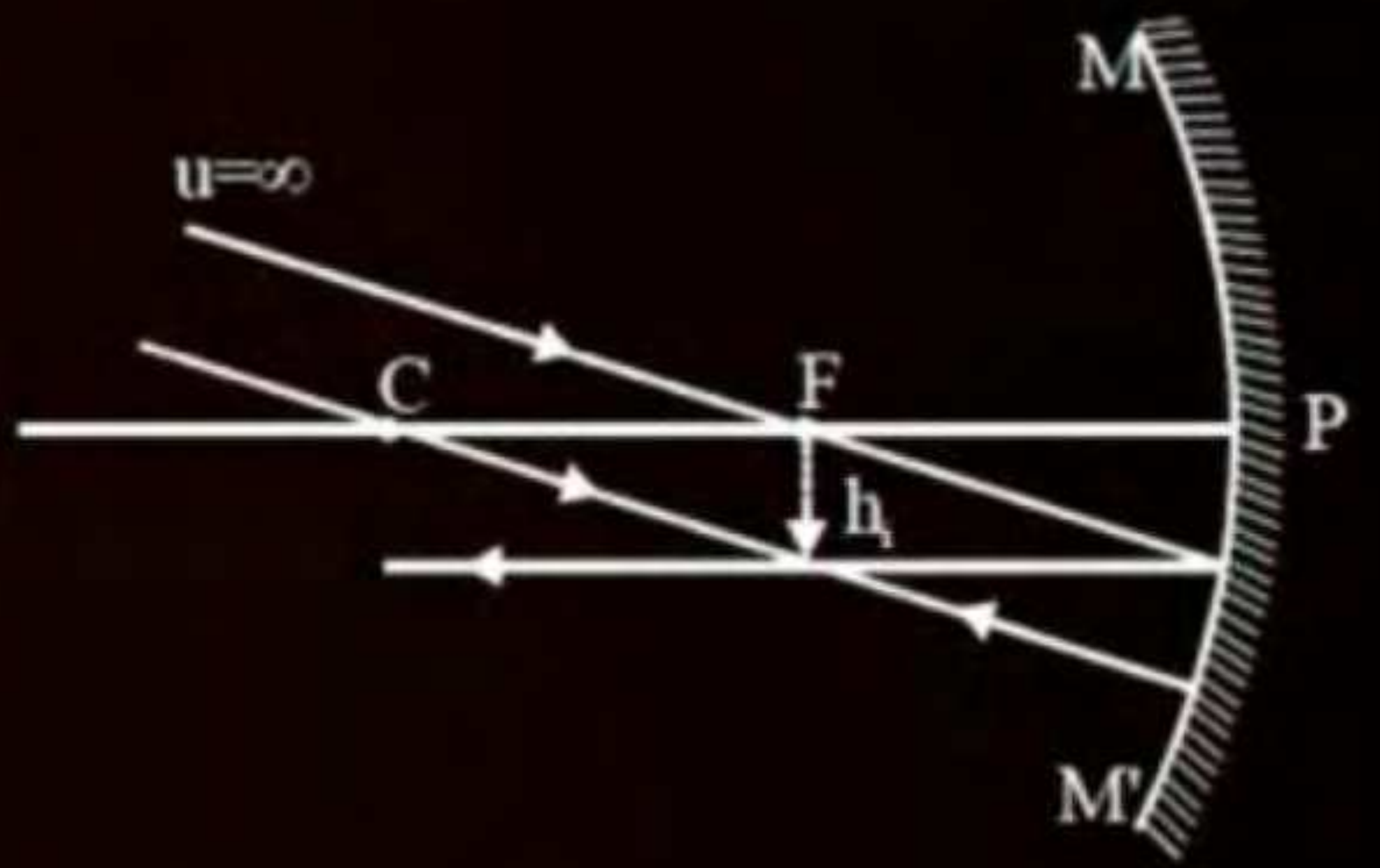
Image Formation by Spherical Mirrors

Concave mirror:

(i) Object : Placed at infinity

Image : real, inverted, diminished at F

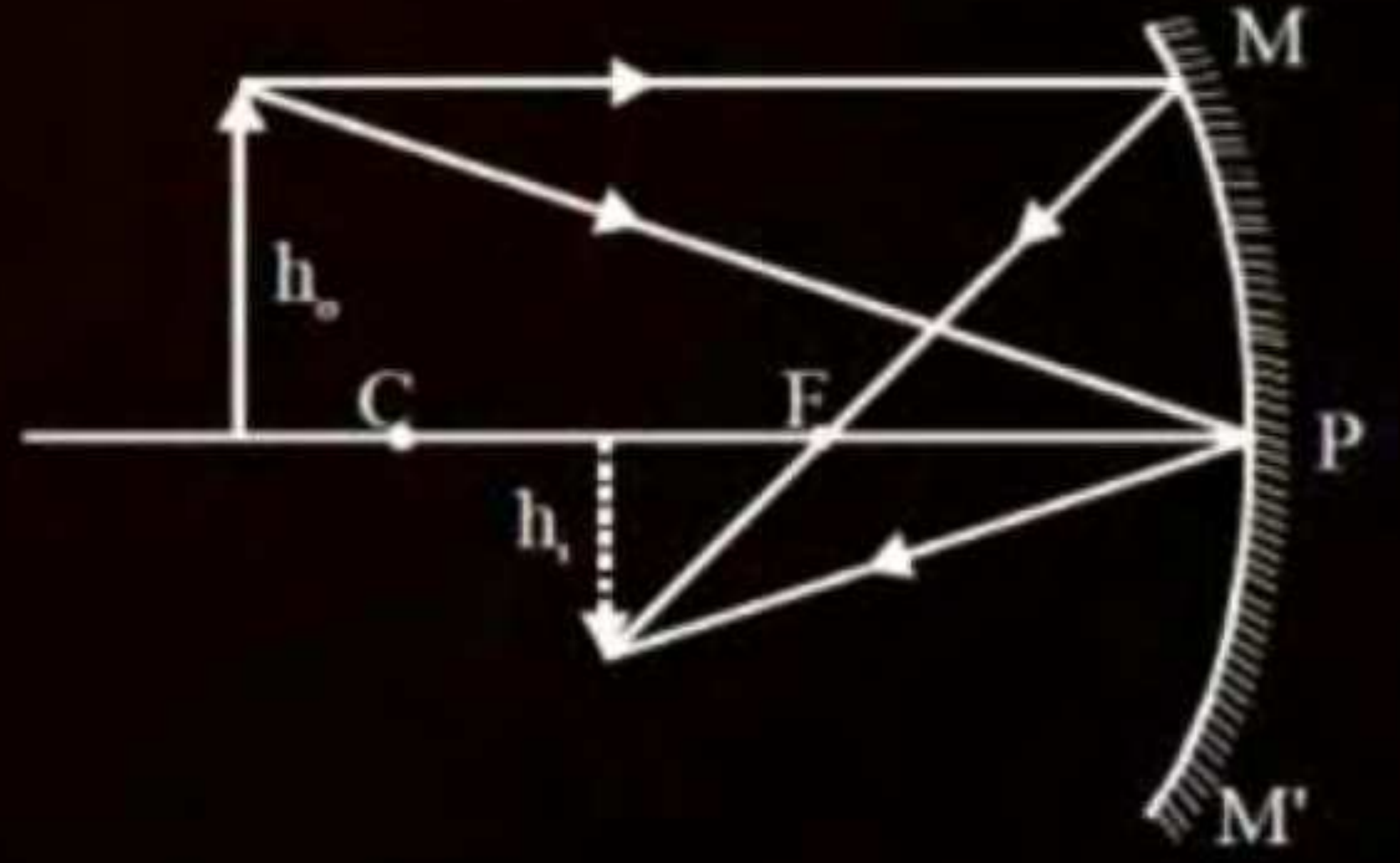
$|m| << 1$ and $m < 0$



(ii) Object : Placed in between infinity and C

Image : real, inverted, diminished in between C and F

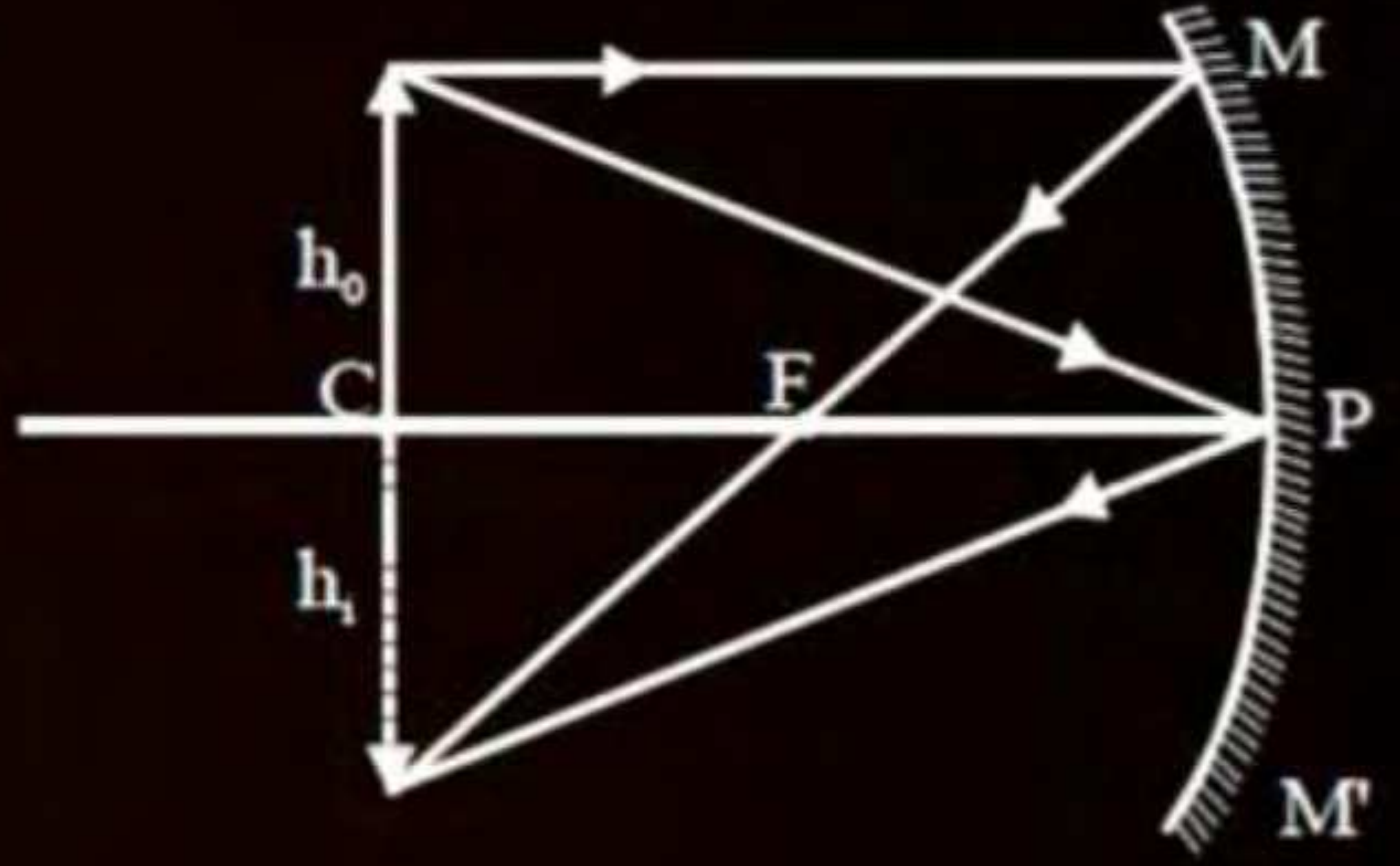
$|m| << 1$ and $m < 0$



(iii) Object : Placed at C

Image : real, inverted, equal at F

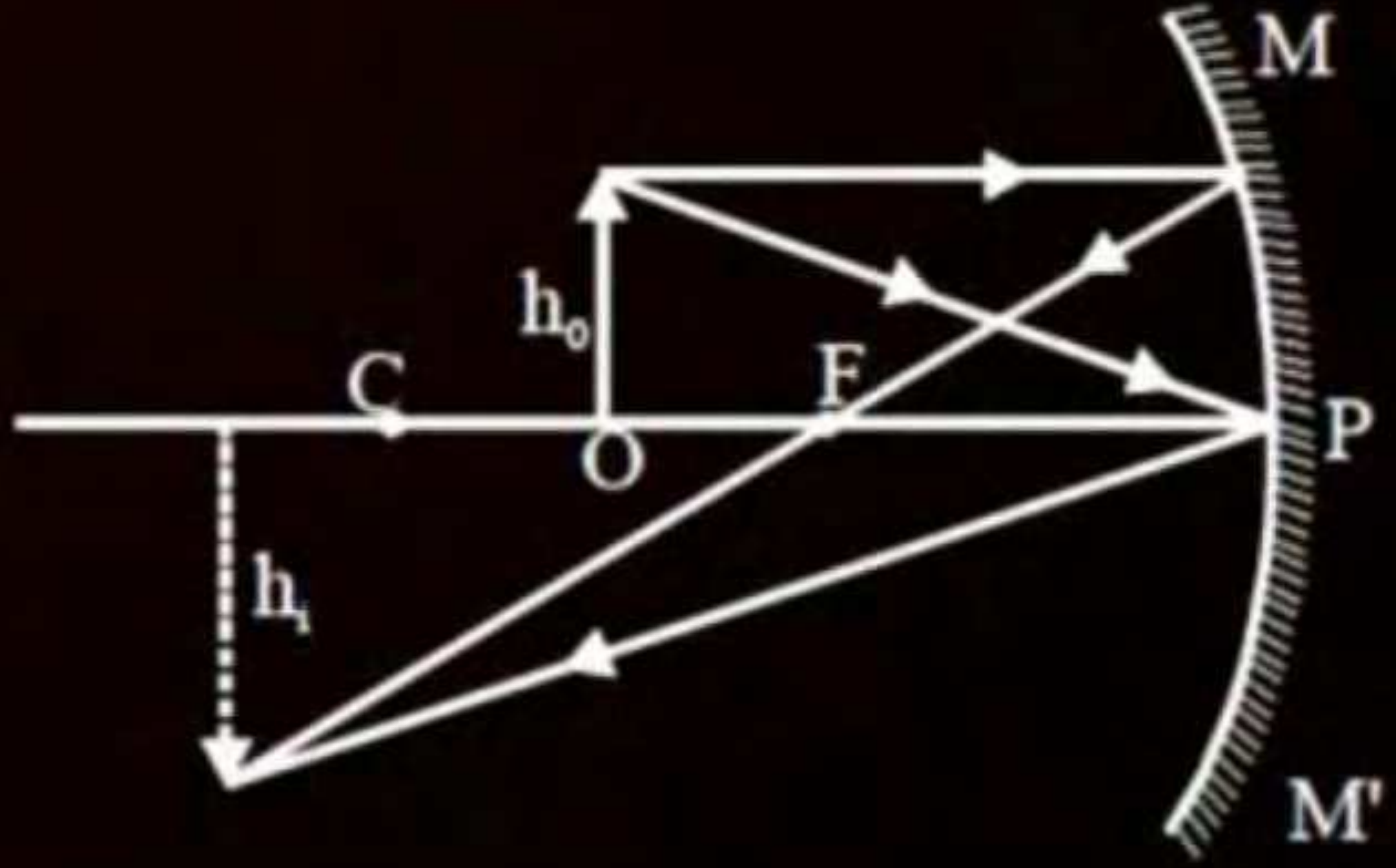
$(m = -1)$



(iv) Object : Placed in between F and C

Image : real, inverted, enlarged beyond C

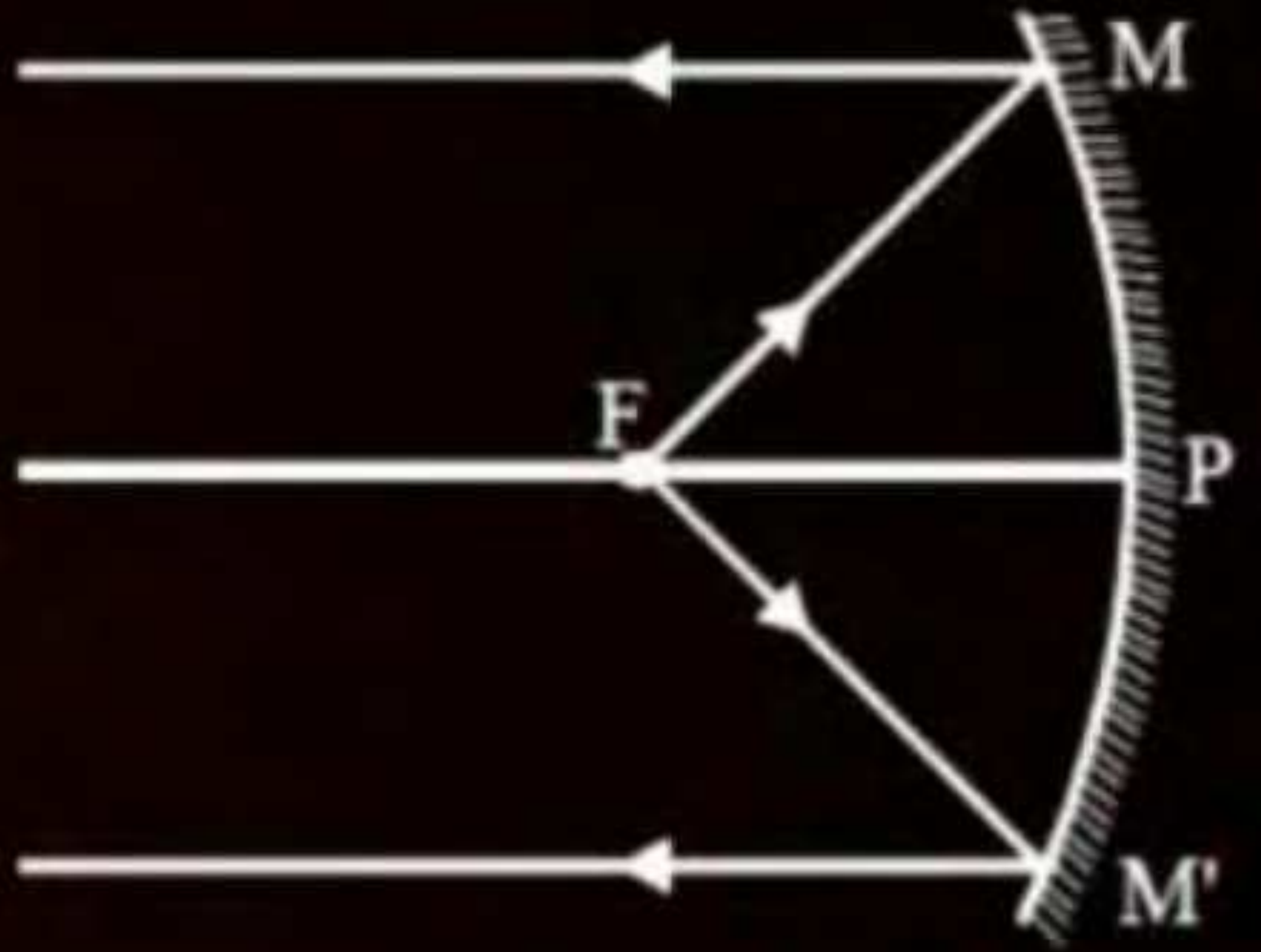
$|m| > 1$ and $m < 0$



(v) Object : Placed at F

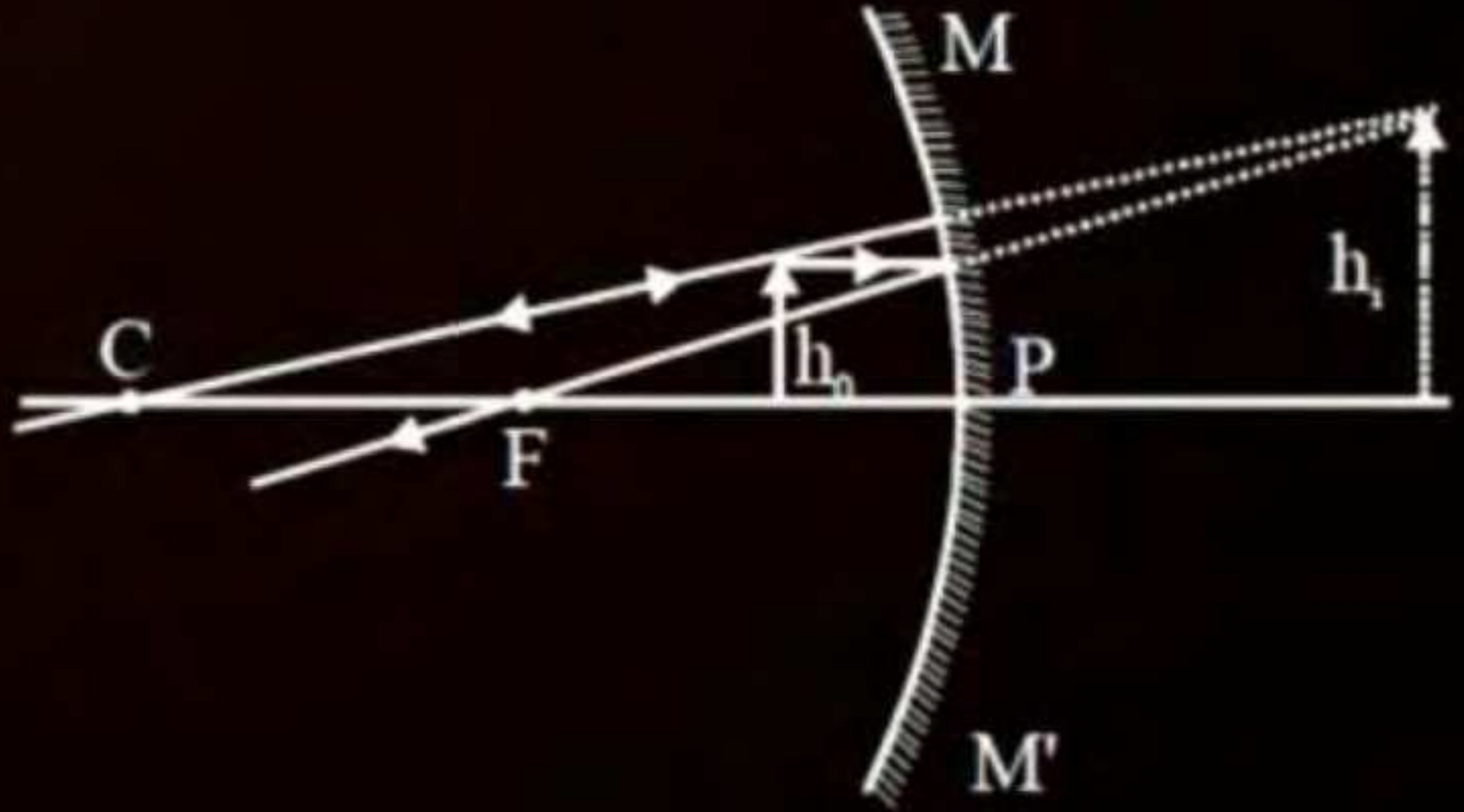
Image : real, inverted, very large (assumed at infinity

(m << –1)



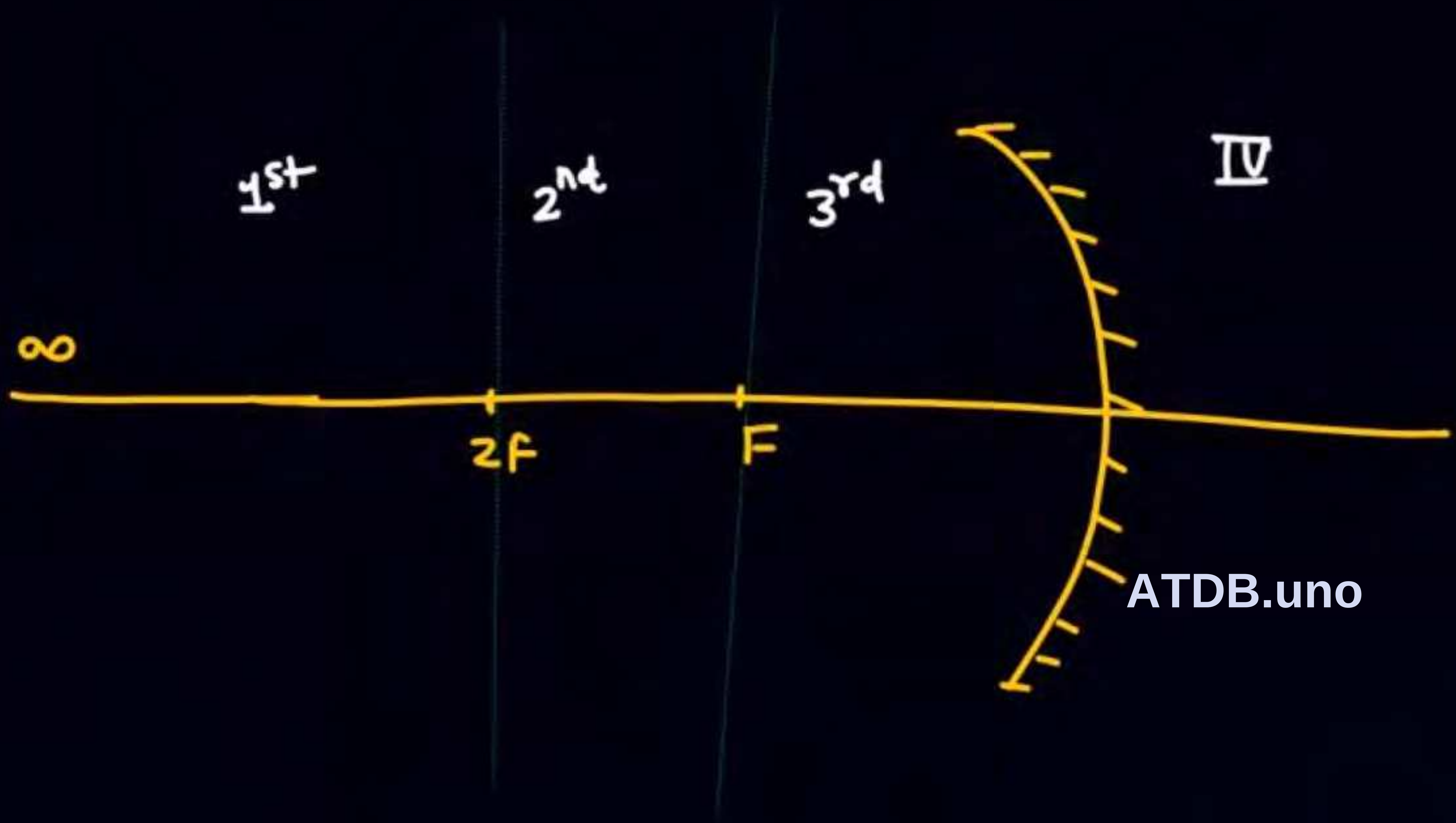
(vi) Object : Placed in between F and P

Image : virtual, erect, enlarged and behind the mirror (m > +1)



FOR CONCAVE MIRROR

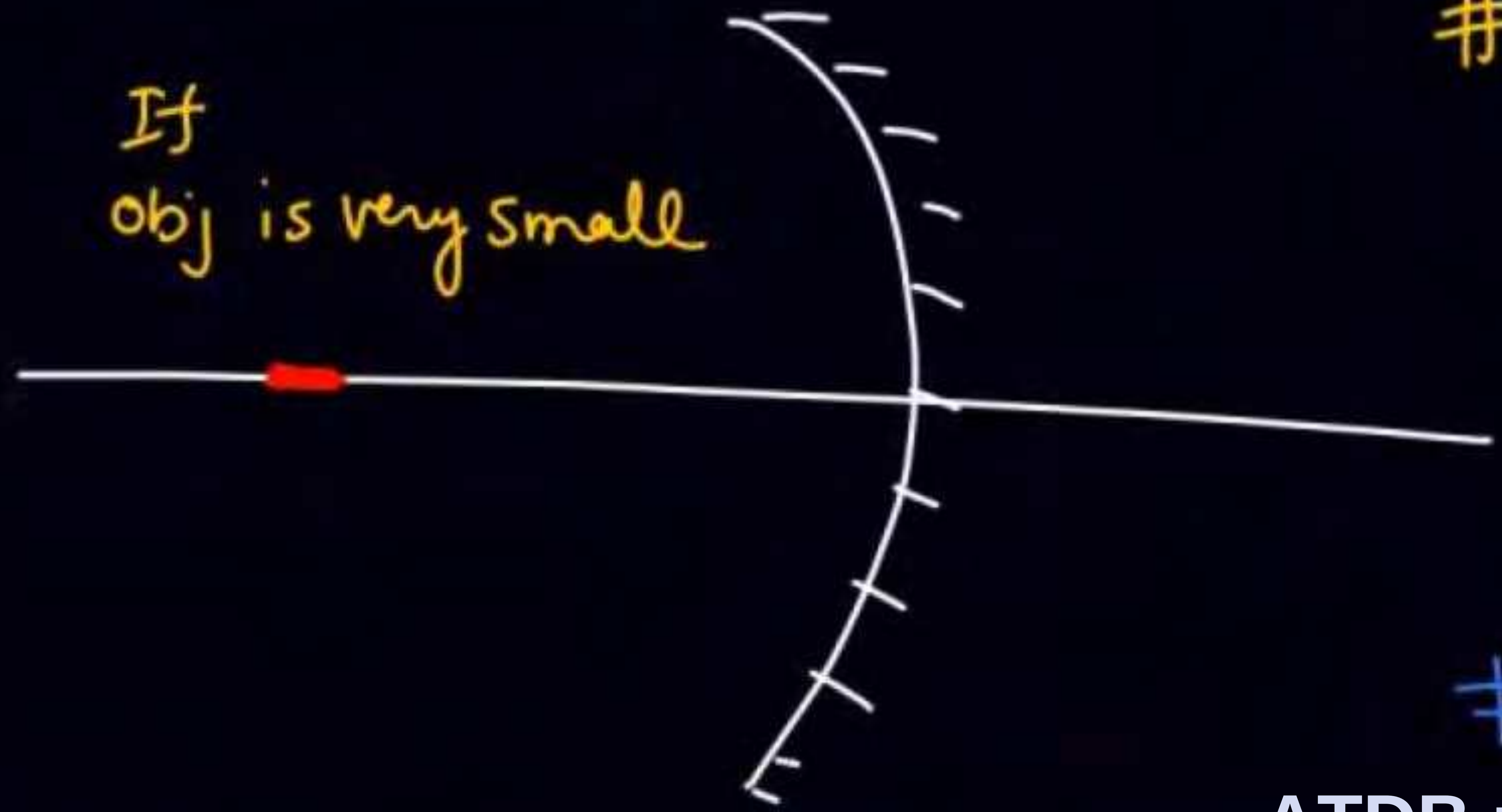
Object	Image	Magnification
$-\infty$	F	$\lvert m \rvert << 1$ & $m<0$
$-\infty - C$	$C - F$	$\lvert m \rvert < 1$ & $m<0$
C	C	$m = -1$
$C - F$	$-\infty - C$	$\lvert m \rvert > 1$ & $m<0$
Just before F towards C	$-\infty$	$m << -1$
Just after F towards P	$+\infty$	$m >> 1$



Obj	Image	
1	2	Real, inverted, Small
2	1	Real, inverted बड़ा
3	4	Virtual, erect बड़ा
4	3	Real, inverted small

#

If
obj is very small



$$\text{Length of image} = m^2(\text{Length of obj})$$

#

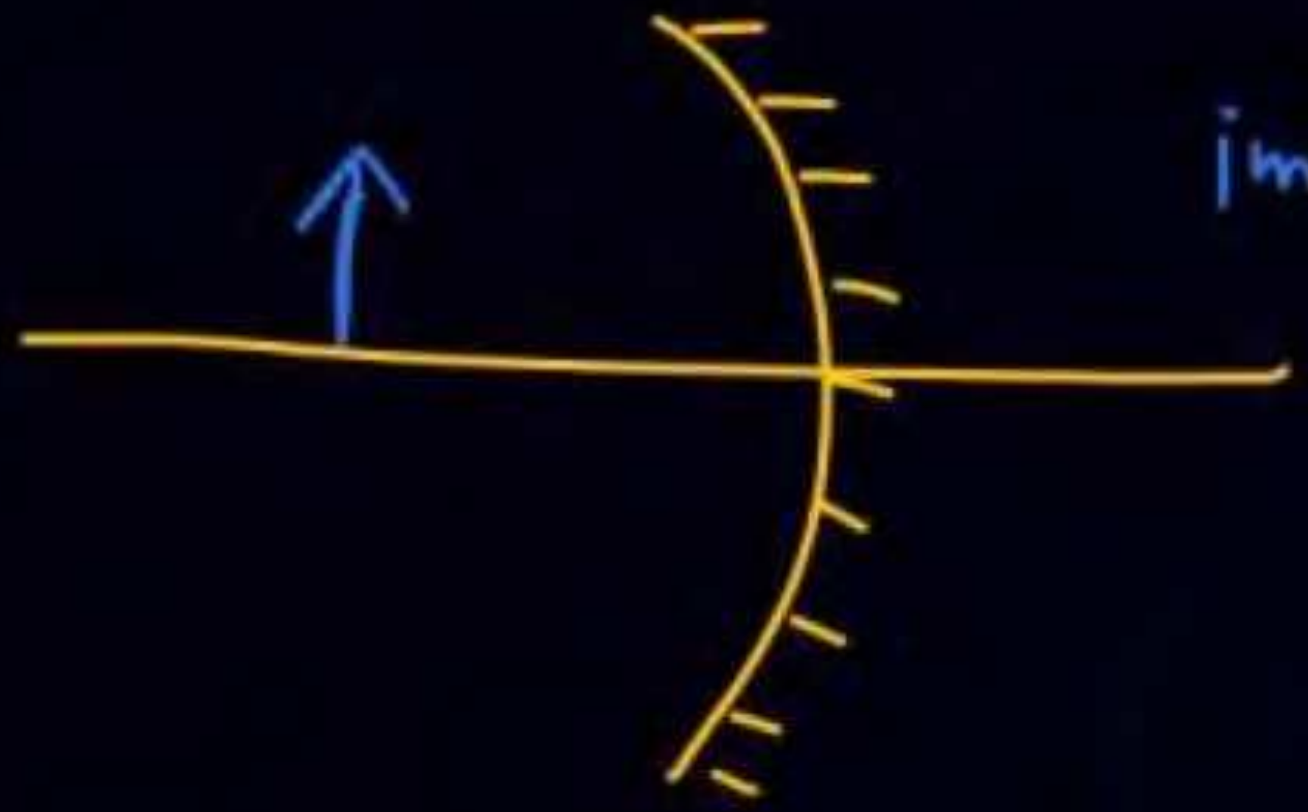


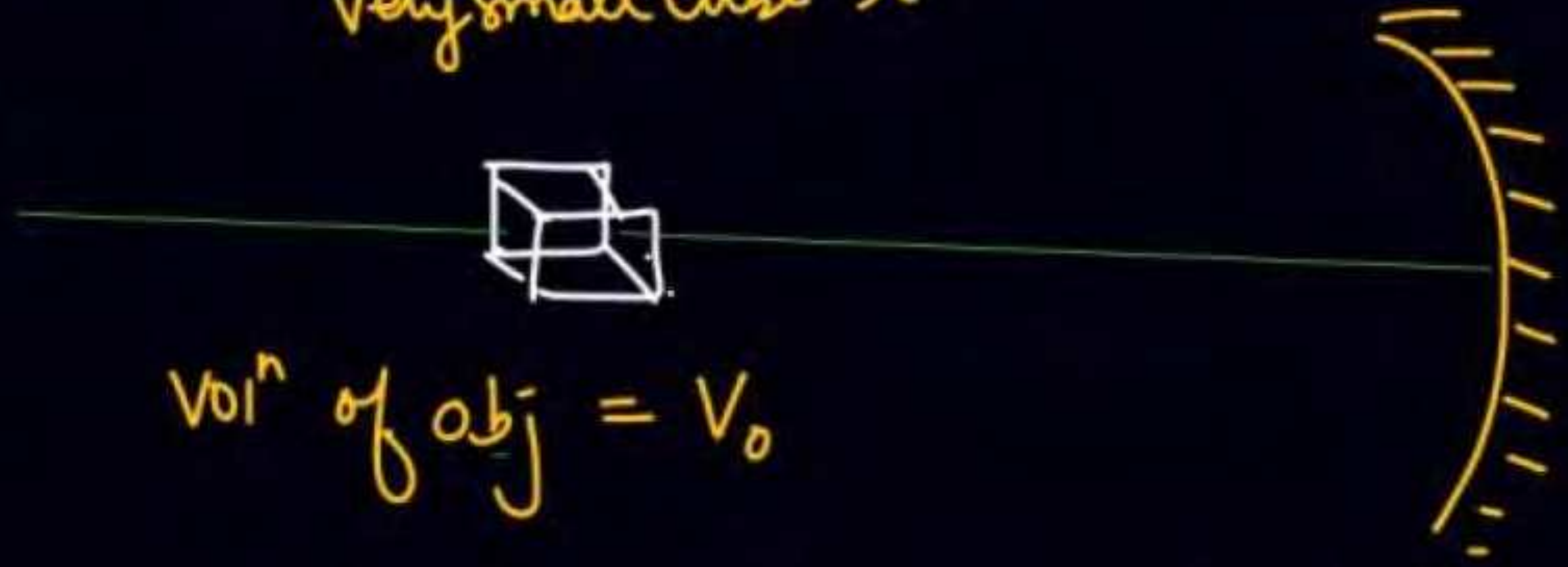
image की length 'm' times हो जाती है

#

Area of obj $= A_o$

Area of image $= m^2 A_o$

\# very small cube 'l'



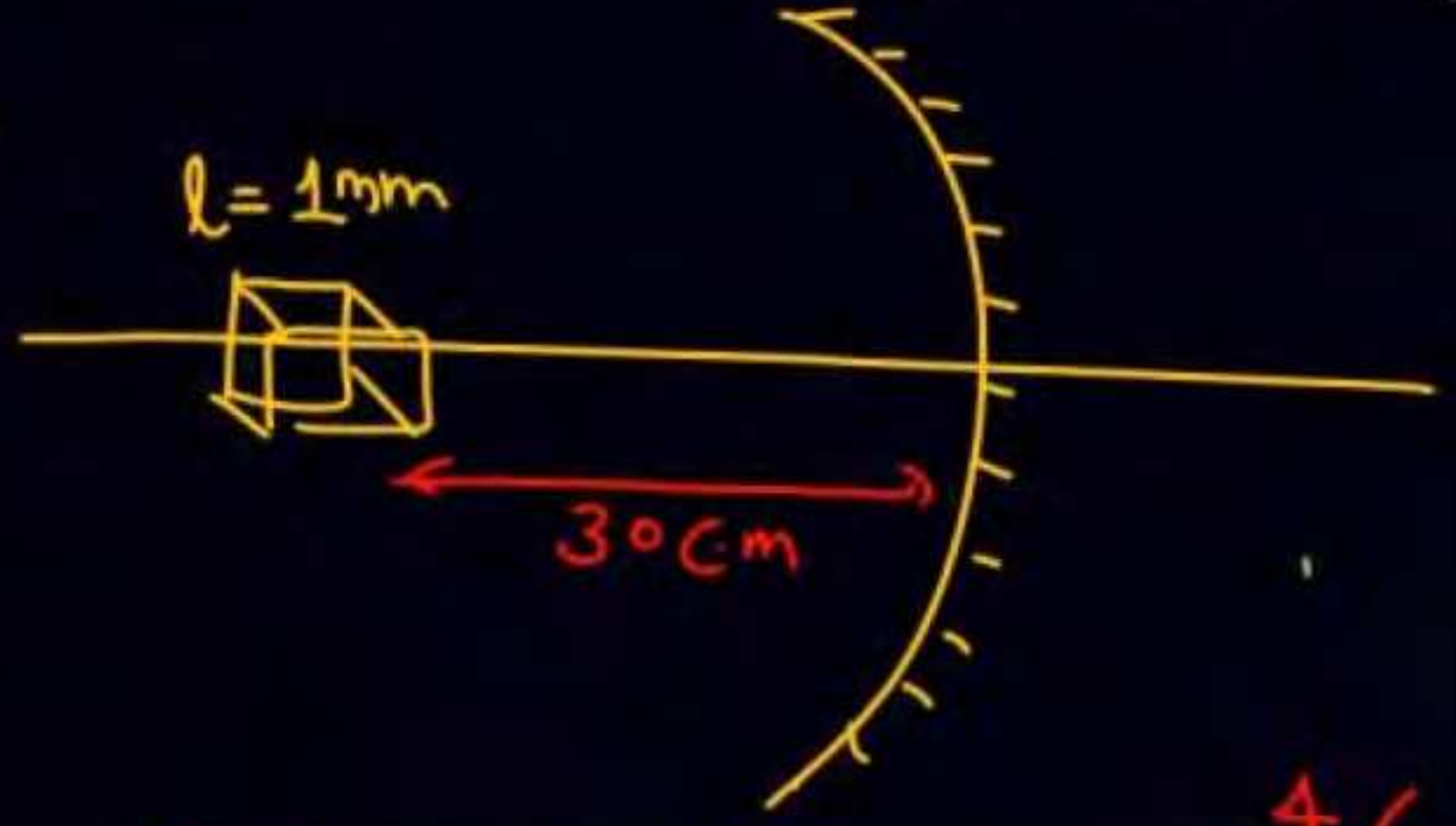
Vol^n of obj $= V_0$

Vol^n of image $= (m \times m \times m^2)(\text{Vol}^n)_{obj}$

$= m^4 (\text{Vol}^n)$ of obj

Q

$f = 20\,cm$



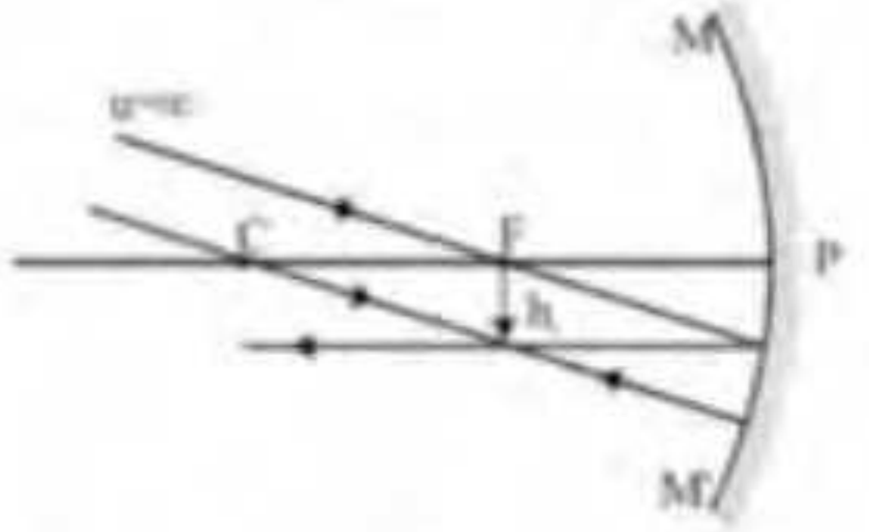
Vol^n of image of cube $= m^4 (\text{Vol}^n \text{ of obj})$

$= 2^4 \times (1\,mm)^3$

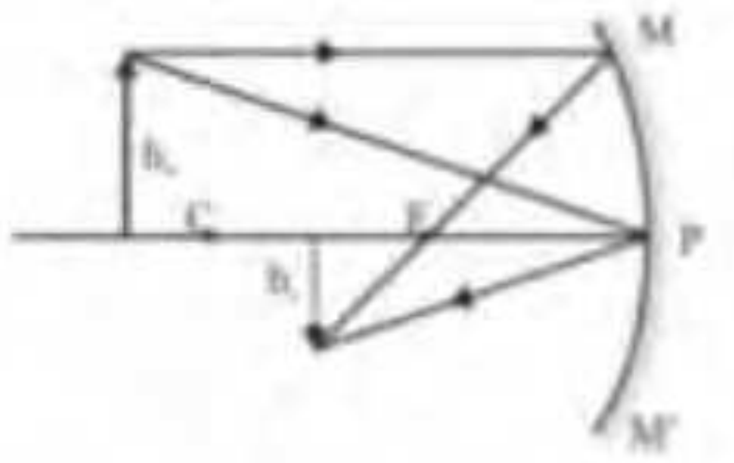
$= \underline{16\,mm^3}$

Concave mirror

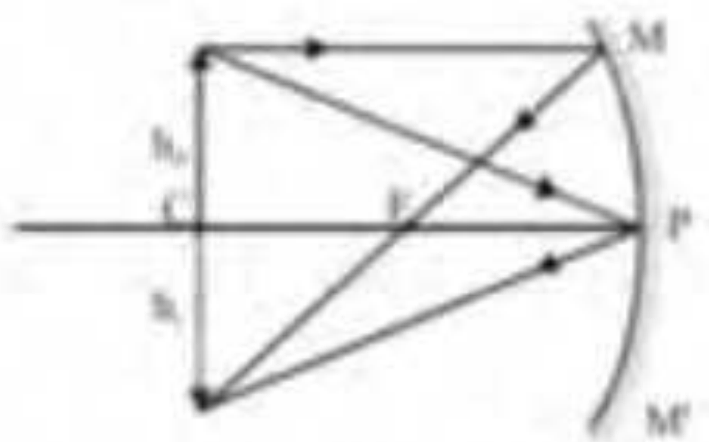
(i) **Object :** Placed at infinity
Image : real, inverted, diminished at F
$|m| << 1$ & $m<0$



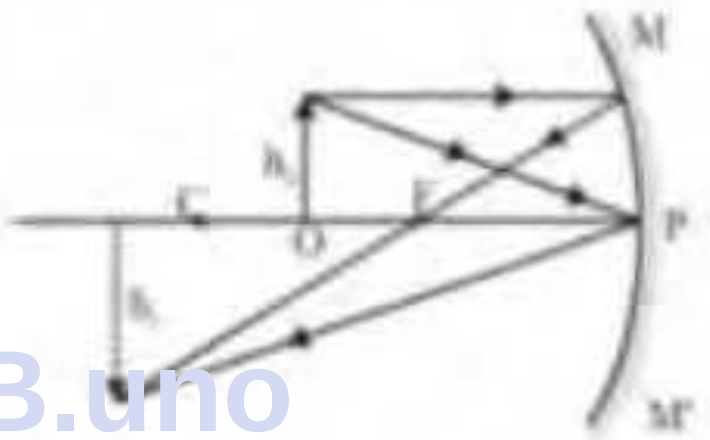
(ii) **Object :** Placed in between infinity and C
Image : real, inverted, diminished in between C and F
$|m| < 1$ & $m<0$



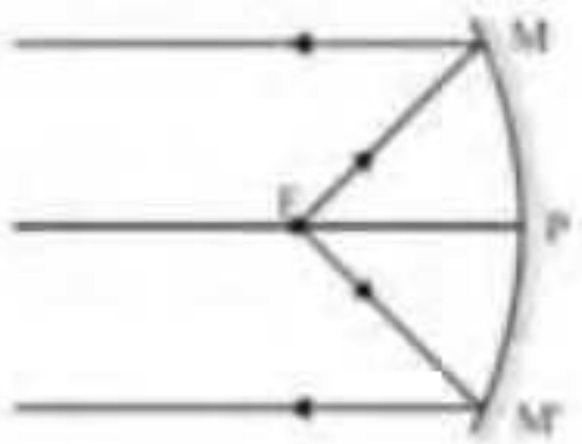
(iii) **Object :** Placed at C
Image : real, inverted, equal at C
($m = -1$)



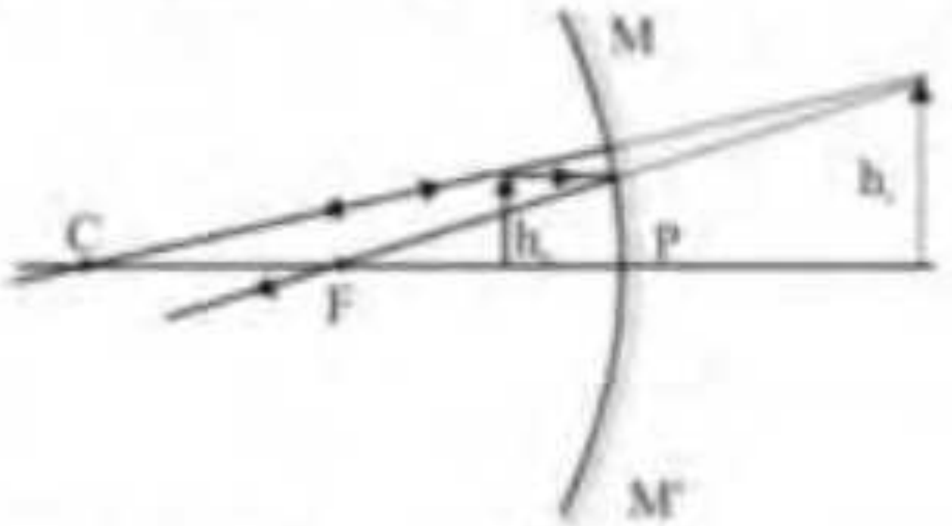
(iv) **Object :** Placed in between F and C
Image : real, inverted, enlarged beyond C
$|m| > 1$ & $m<0$



(v) **Object :** Placed at F
Image : real, inverted, very large (assumed) at infinity ($m << -1$)



(vi) **Object :** Placed between F and P
Image : virtual, erect, enlarged and behind the mirror ($m > +1$)

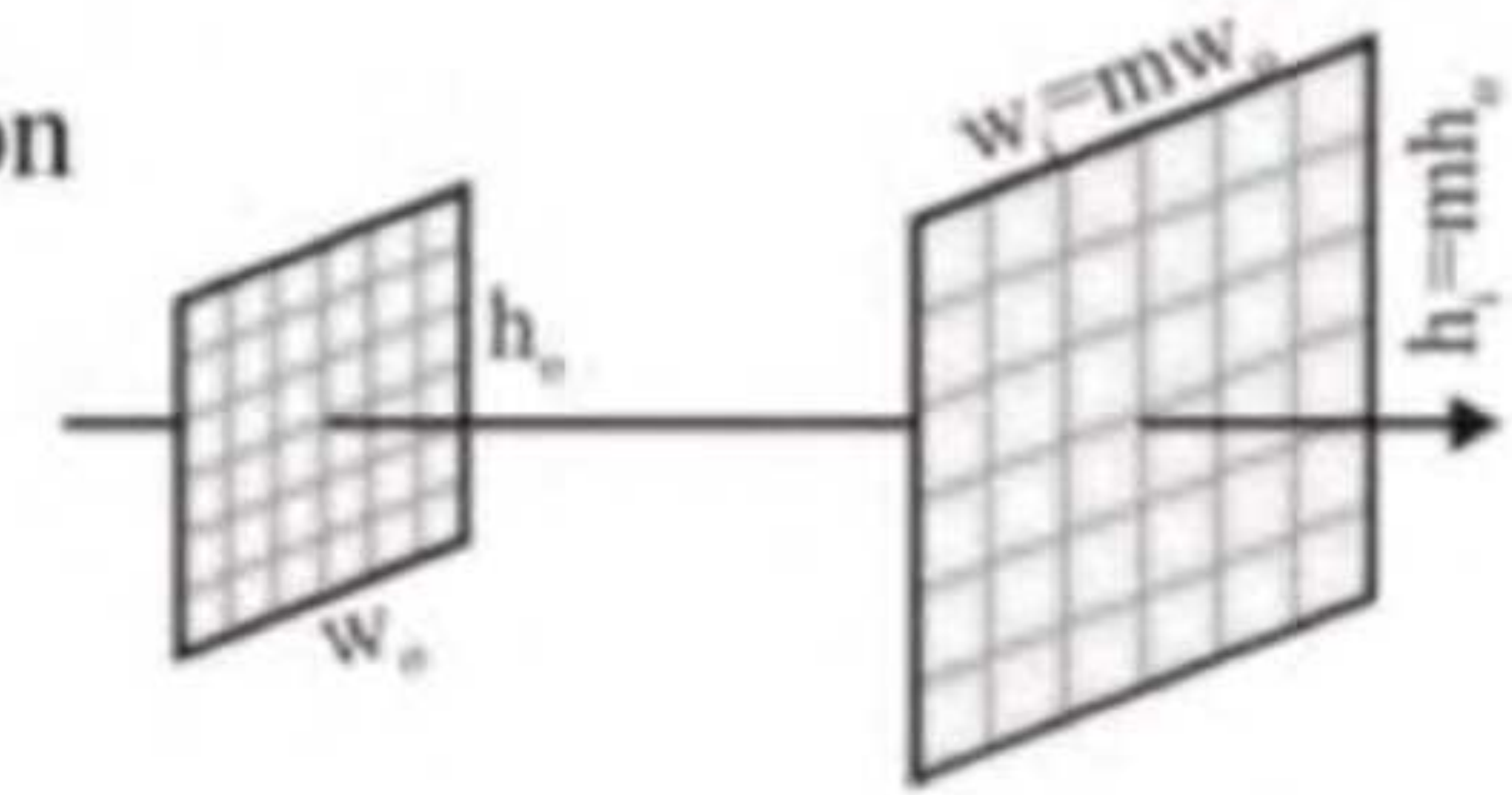


For concave mirror

Object	Image	Magnification
$-\infty$	F	$\lvert m\rvert << 1$ & $m<0$
$-\infty - C$	C – F	$\lvert m\rvert < 1$ & $m<0$
C	C	$m = -1$
C – F	$-\infty - C$	$\lvert m\rvert > 1$ & $m<0$
Just before F towards C	$-\infty$	$m << -1$

Superficial magnification

If two dimensional object placed with its plane perpendicular to principal axis its magnification is known as superficial magnification



Linear magnification $m = \frac{h_i}{h_o} = \frac{w_i}{w_o}$

$h_i = mh_o$, $w_i = mw_o$ and $A_{obj} = h_o \times w_o$

Area of image : $A_{image} = h_i \times w_i = mh_o \times mw_o = m^2 A_{obj}$

superficial magnification $m_s = \frac{\text{area of image}}{\text{area of object}} = \frac{(ma)\times(mb)}{(a\times b)} = m^2$

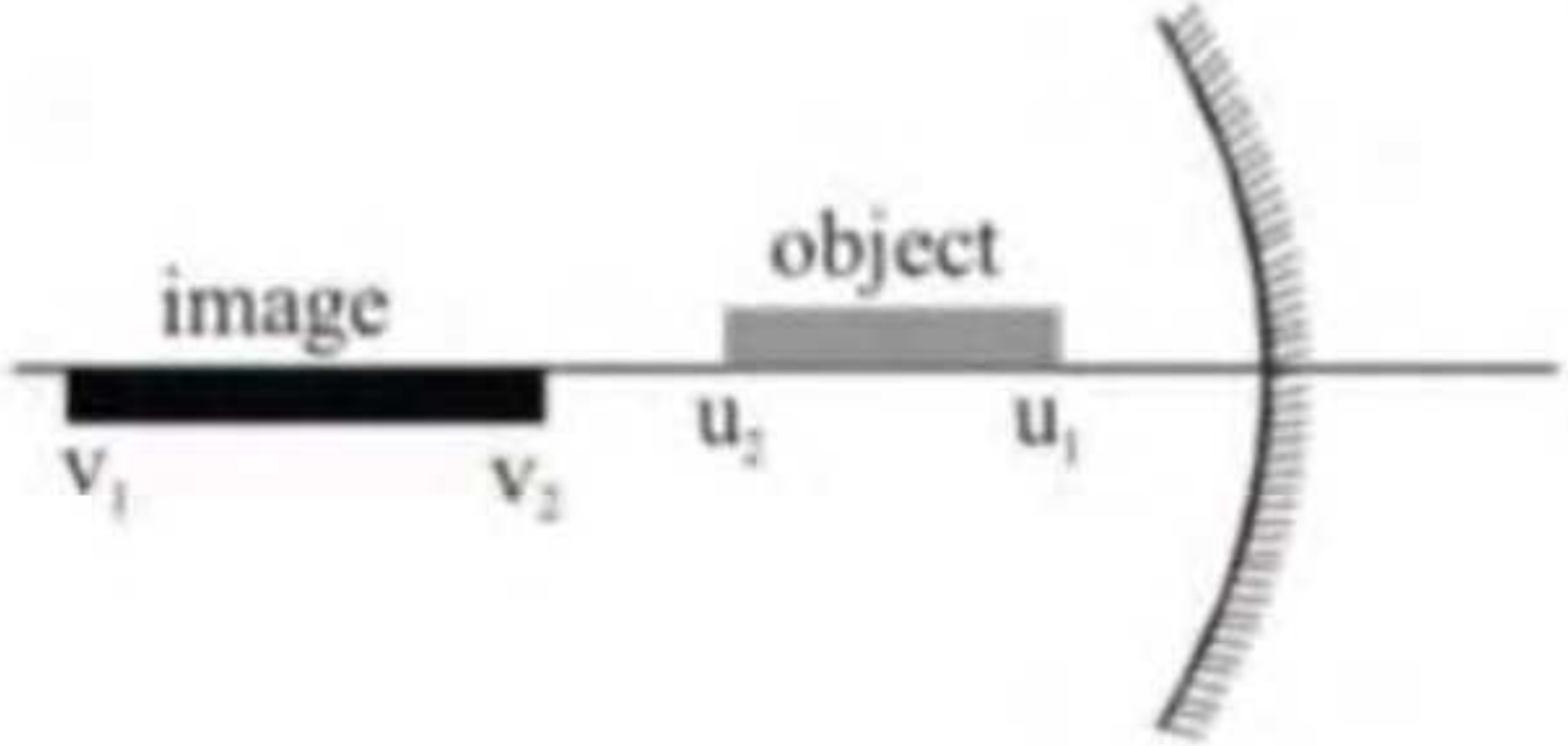
If one dimensional object is placed perpendicular to the principal axis then linear magnification is called transverse or lateral magnification. $\boxed{m = \frac{h_i}{h_o} = -\frac{v}{u}}$

Magnification	Image	Magnification	Image
$\lvert m \rvert > 1$	enlarged	$\lvert m \rvert < 1$	diminished
$m < 0$	inverted	$m > 0$	erect

- **Longitudinal magnification**

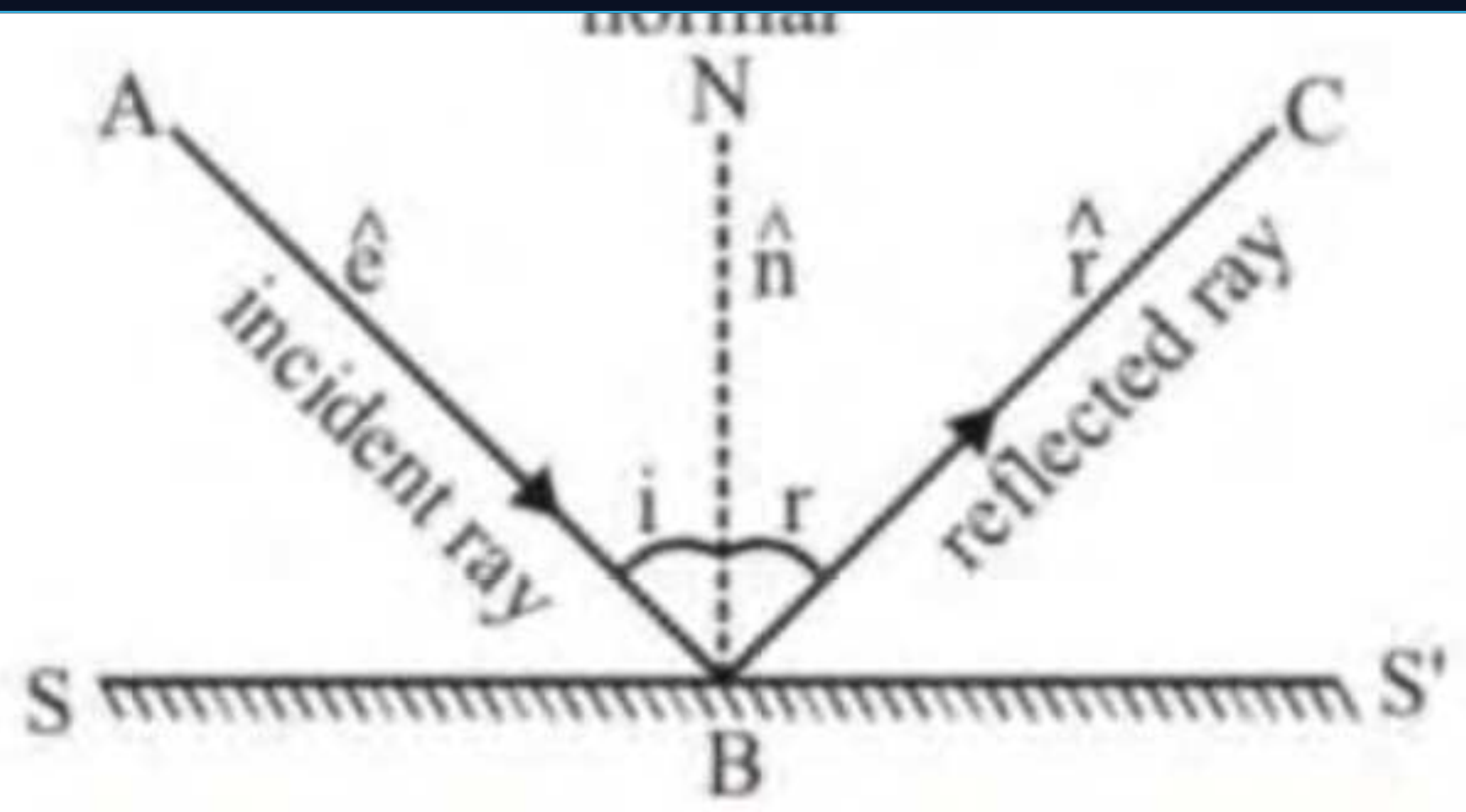
If one dimensional object is placed with its length along the principal axis then linear magnification is called longitudinal magnification.

Longitudinal magnification $m_L = \frac{\text{length of image}}{\text{length of object}} = \frac{|v_2 - v_1|}{|u_2 - u_1|}$



For small objects only : $m_L = -\frac{dv}{du}$

differentiation of $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$ gives us $-\frac{dv}{v^2} - \frac{du}{u^2} = 0 \Rightarrow -\frac{dv}{du} = \left[\frac{v}{u}\right]^2$ so $m_L = -\frac{dv}{du} = \left[\frac{v}{u}\right]^2 = m^2$



In vector form $\boxed{\hat{r} = \hat{e} - 2(\hat{e}.\hat{n})\hat{n}}$


THANK
YOU
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