PRAYAS

JEE 2025

Lecture – 06

Physics

Ray Optics

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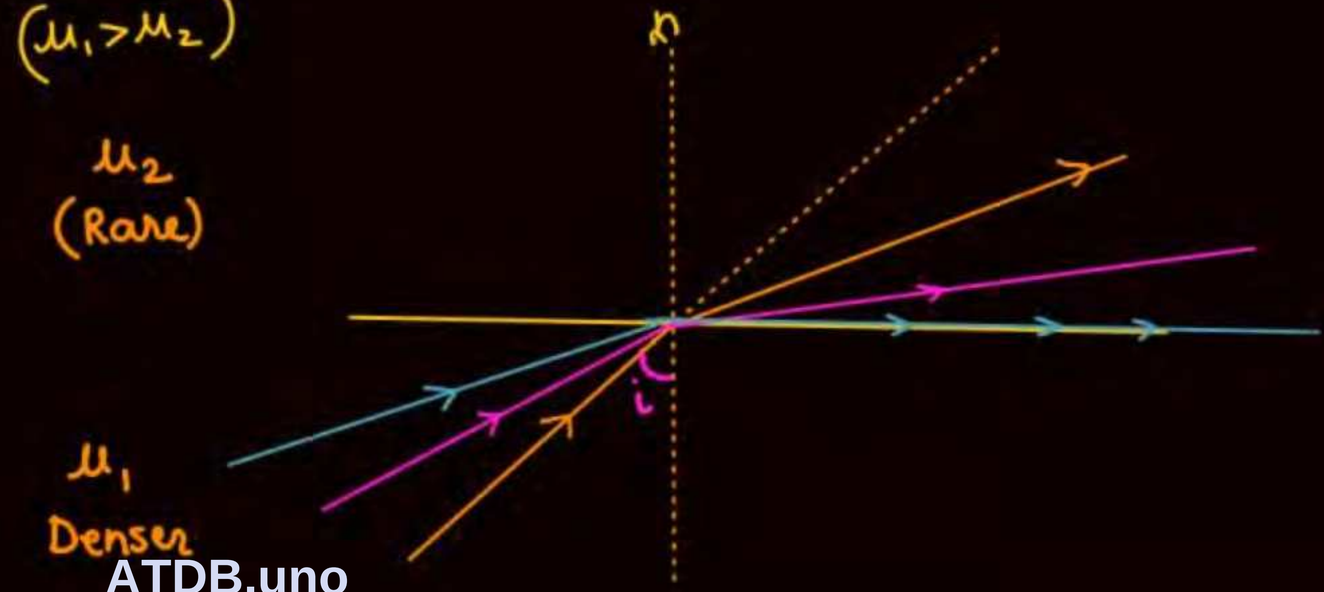
Topics *to be covered*

1. TIR, Curved Refraction

ATDB.uno

$(\mu_1 > \mu_2)$

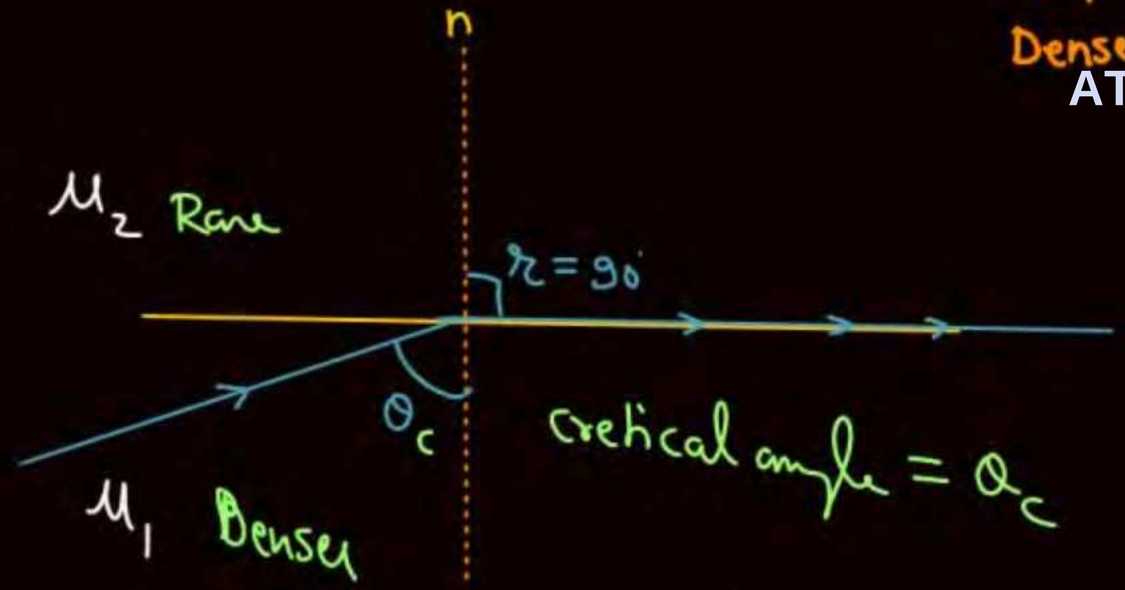
μ_2
(Rare)



μ_1
Denser

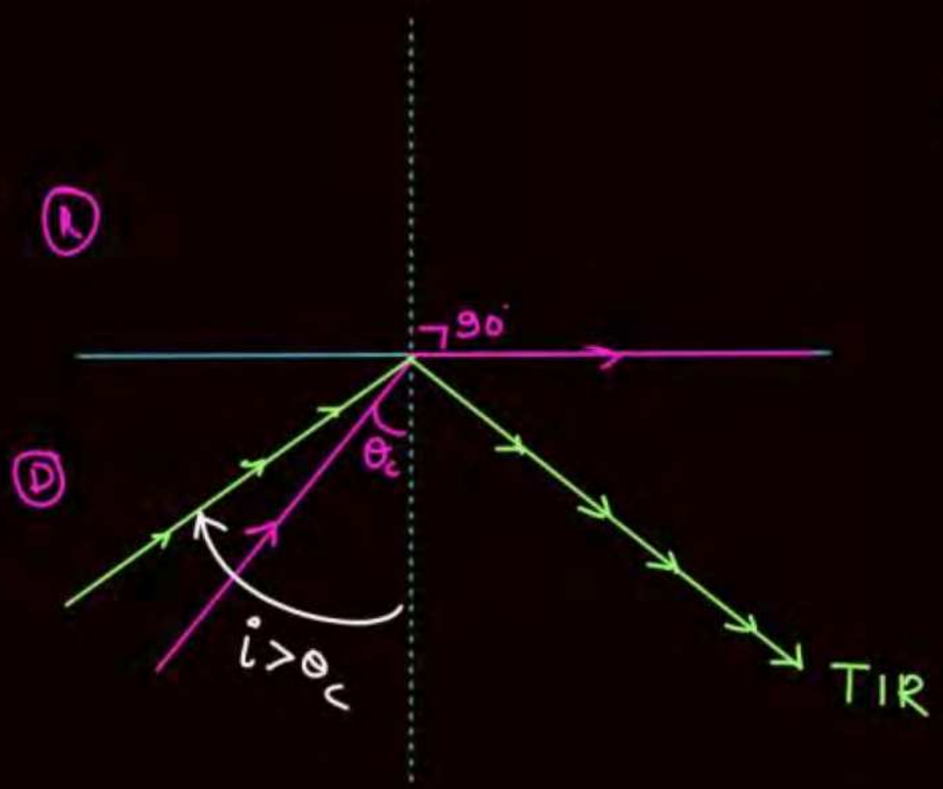
$\mu_1 \sin i = \mu_2 \sin r$

* If $\angle i \uparrow \Rightarrow r \uparrow$



$$\mu_1 \sin\theta_c = \mu_2 \sin 90^\circ$$

$$\sin\theta_c = \frac{\mu_2}{\mu_1} = \frac{\mu_R}{\mu_D}$$



* when a light ray move from denser to rare medium than angle of incidence for which $\angle r = 90$ is called critical angle.

वो $\angle i$ जिस पर $\angle r = 90$ मिला

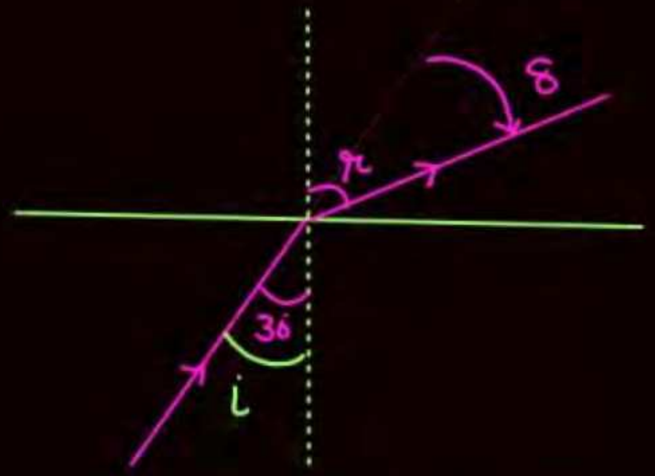
$\angle i = \theta_c \rightarrow$ critical angle.

* If $i > \theta_c \longrightarrow$ TIR (Behaving like mirror)

$i < \theta_c \longrightarrow$ Refraction

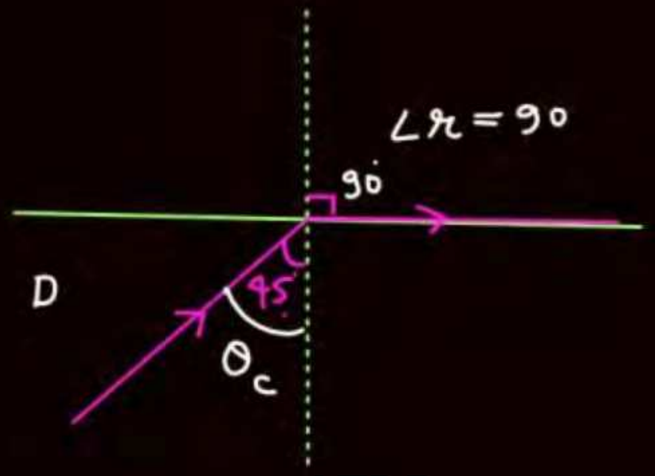
$i = \theta_c \longrightarrow \angle r = 90$

Let $\theta_c = 45^\circ$ meas

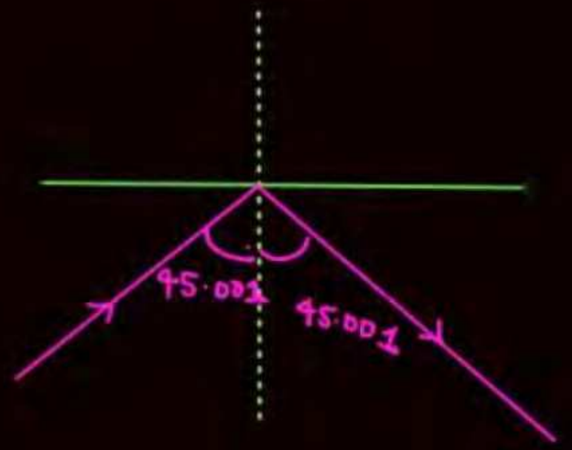


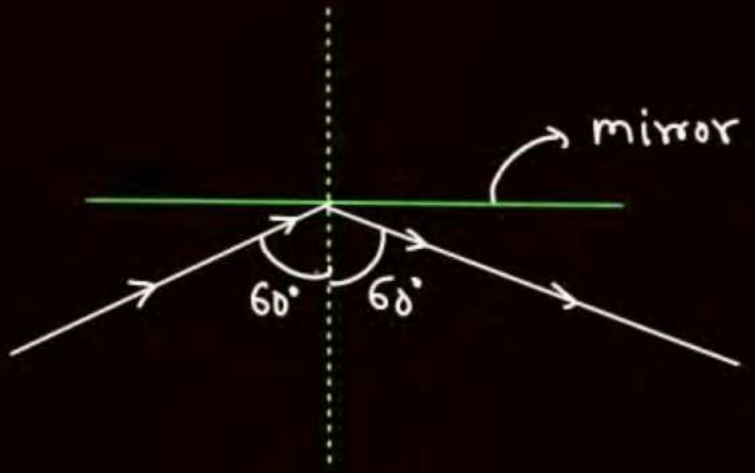
$i < \theta_c$ (Refraction)

$\delta = r - i$

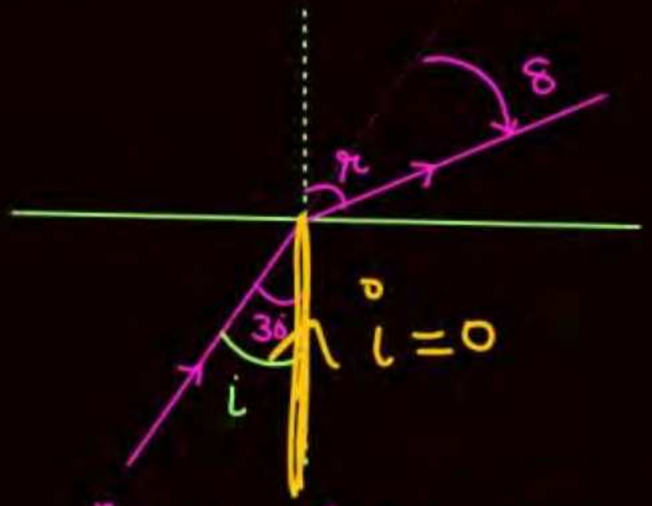


$\delta = 90 - \theta_c$





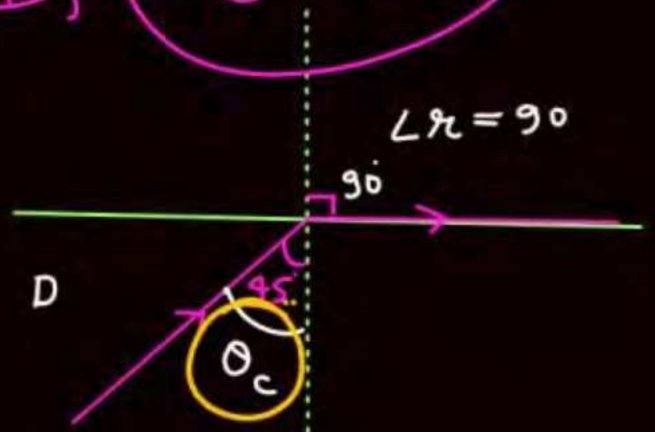
Let $\theta_c = 45^\circ$ meas



$i < \theta_c$ (Refraction)

$\delta = r - i$

If $\theta_c = 45^\circ$

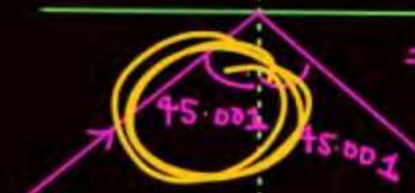


$\delta = 90 - \theta_c$

$\delta = 45^\circ$

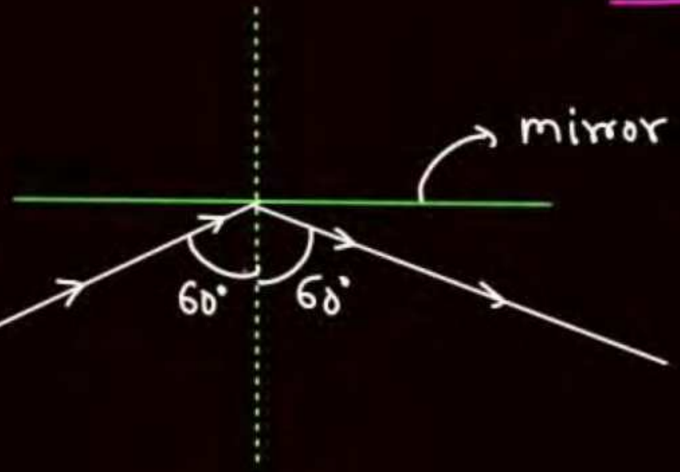
$\delta = 180 - 2i$

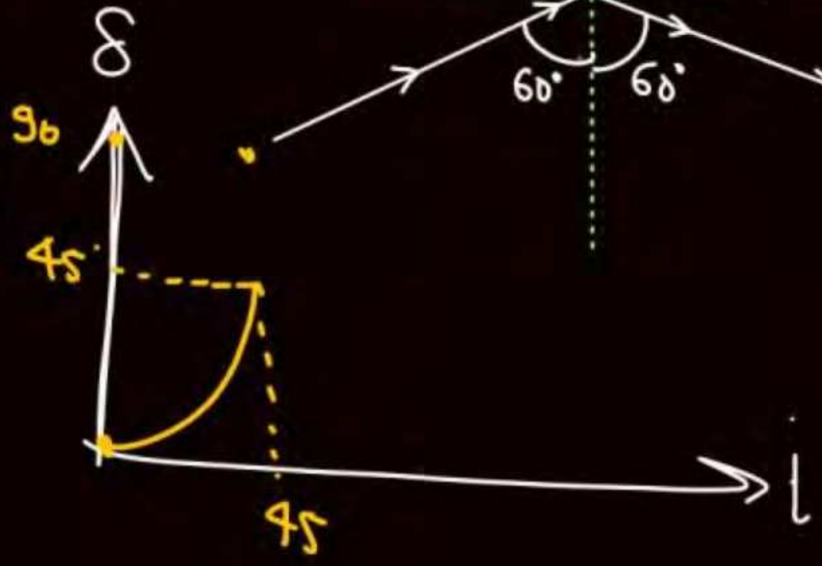
$= 180 - 2 \times (45 \cdot 001)$

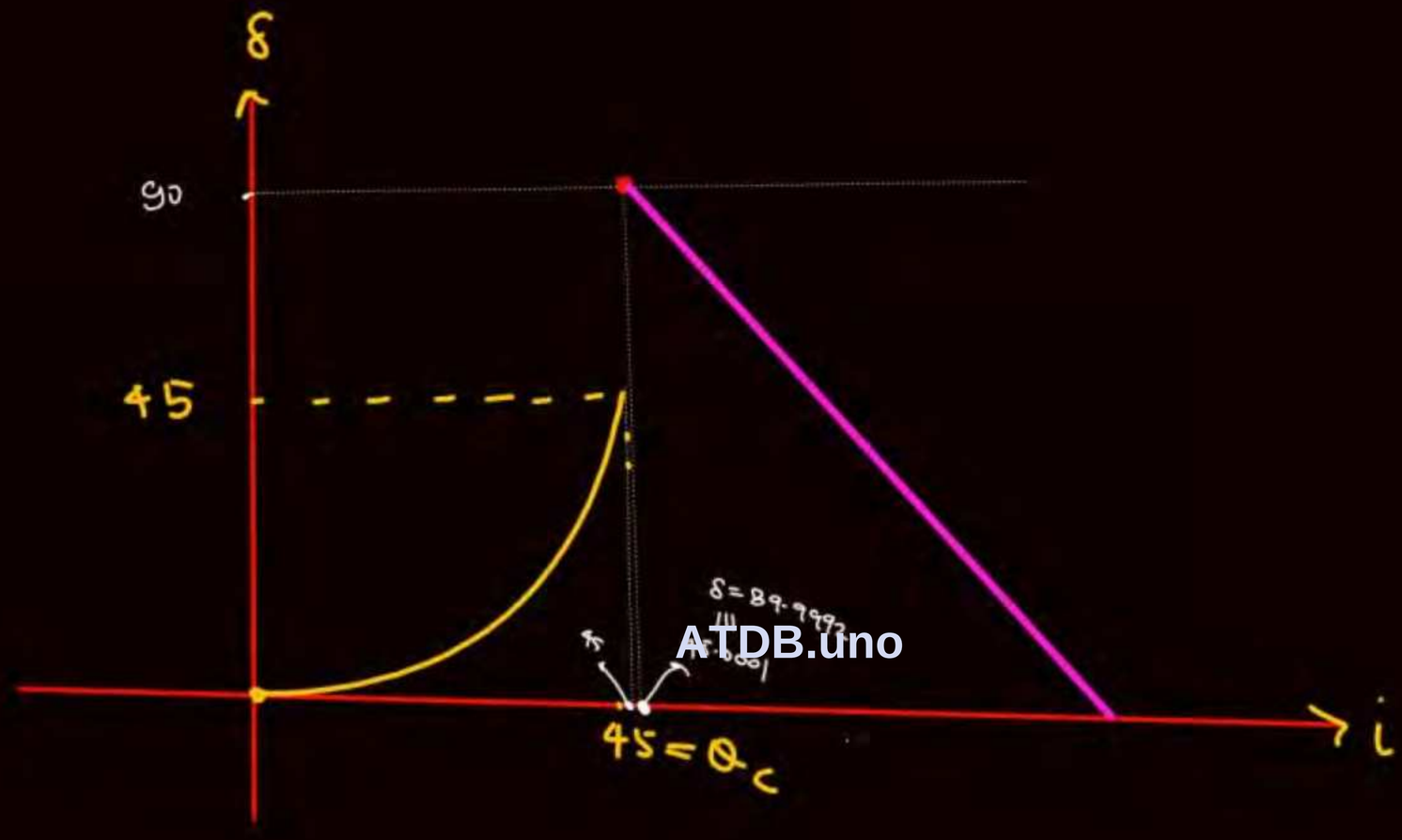


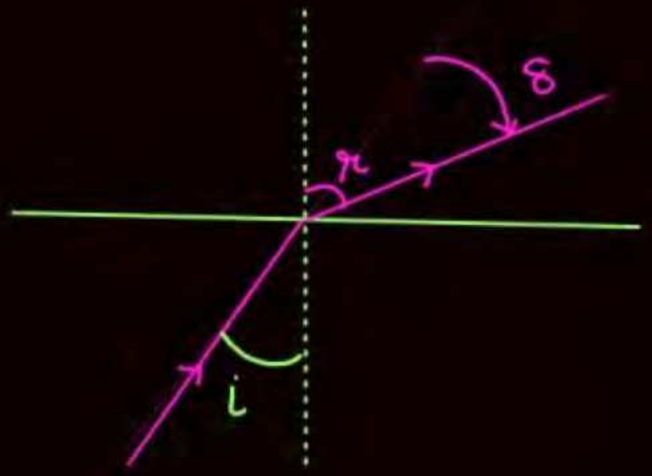
$= 180 - 90 \cdot 002$

$= 89 \cdot 998$



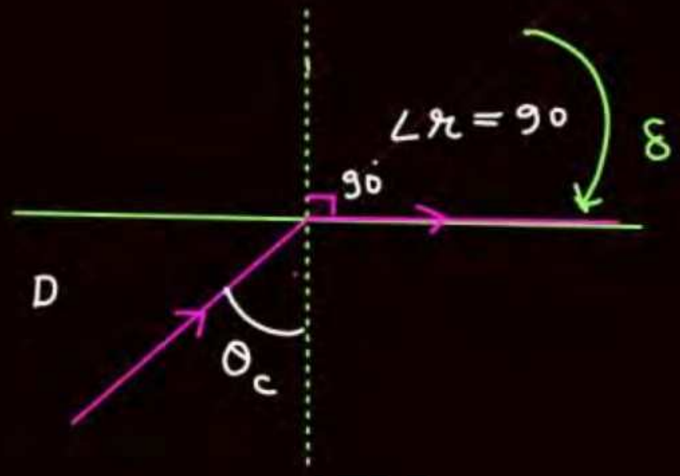




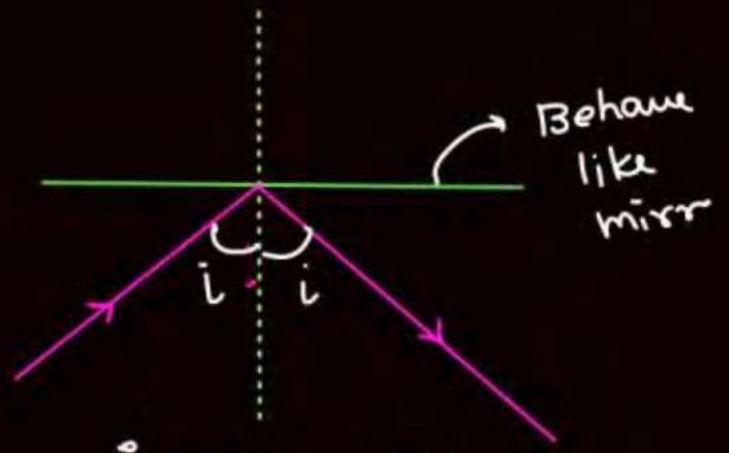


$i < \theta_c$ (Refraction)

$\delta = r - i$



$\delta = 90 - \theta_c$



$i > \theta_c$ = TIR

$\delta = 180 - 2i$

Graph b/w δ Vs i°

① $i < \theta_c$ (Refraction)

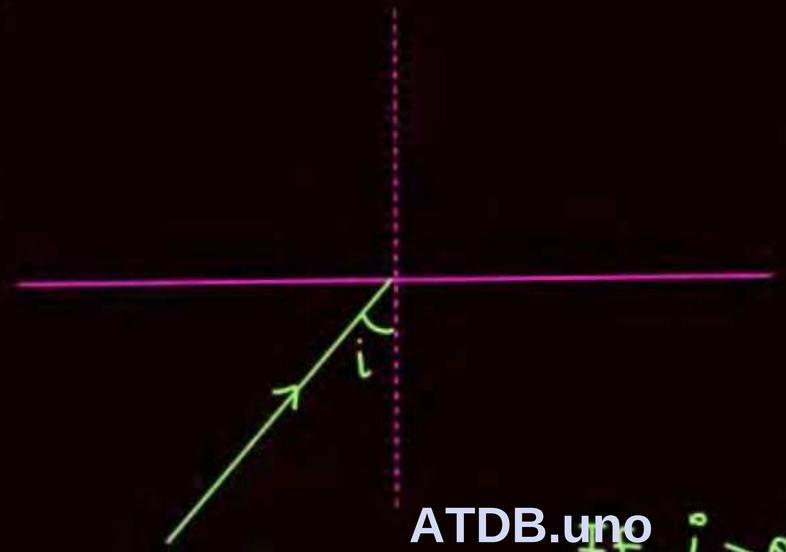
$$\mu_1 \sin i = \mu_2 \sin r$$

$$\delta = r - i$$

$$\sin r = \frac{\mu_1}{\mu_2} \sin i$$

$$r = \sin^{-1}\left(\frac{\mu_1}{\mu_2} \sin i\right)$$

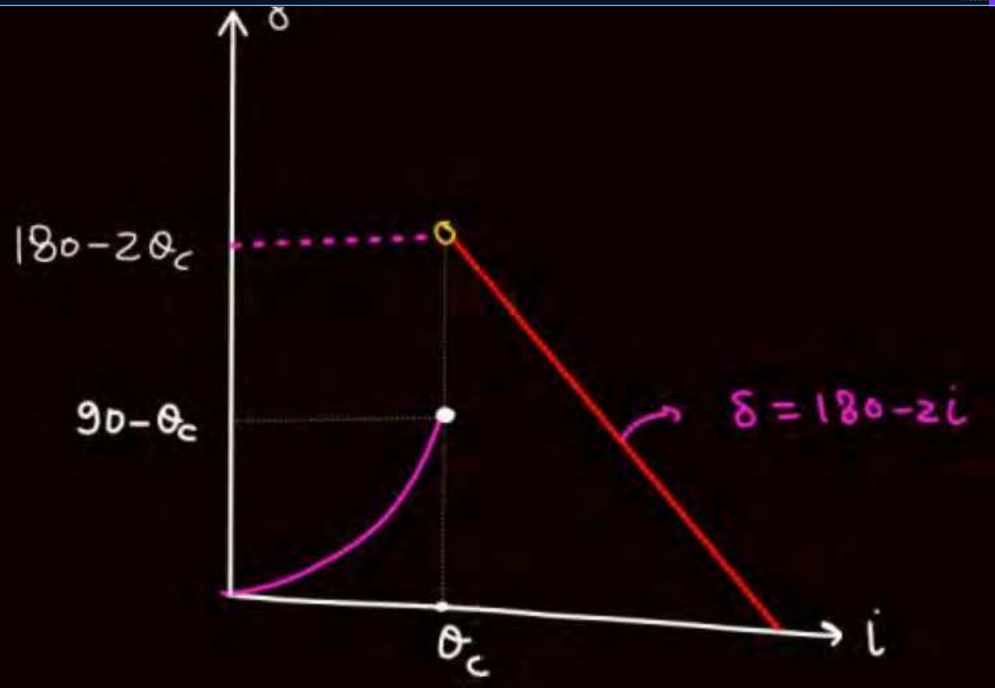
$$\boxed{\delta = \sin^{-1}\left(\frac{\mu_1}{\mu_2} \sin i\right) - i}$$



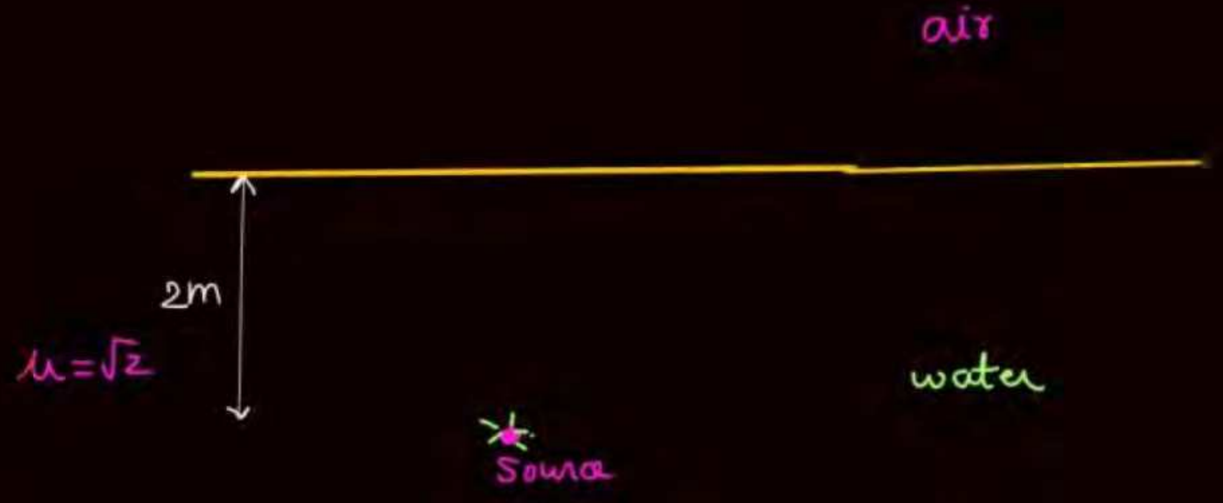
If $i > \theta_c$

(TIR)

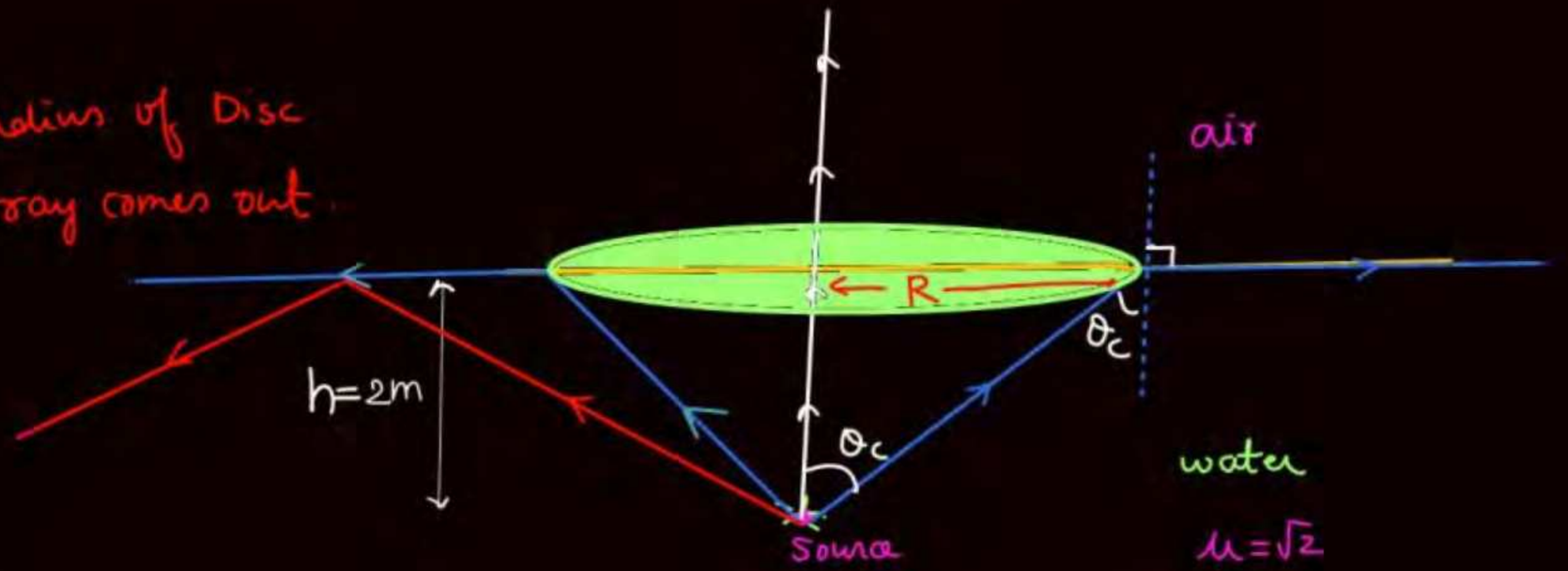
$$\delta = 180 - 2i$$



Q



Q find 'R' radius of Disc so that no ray comes out



$$\sin\theta_c = \frac{1}{\sqrt{2}}$$

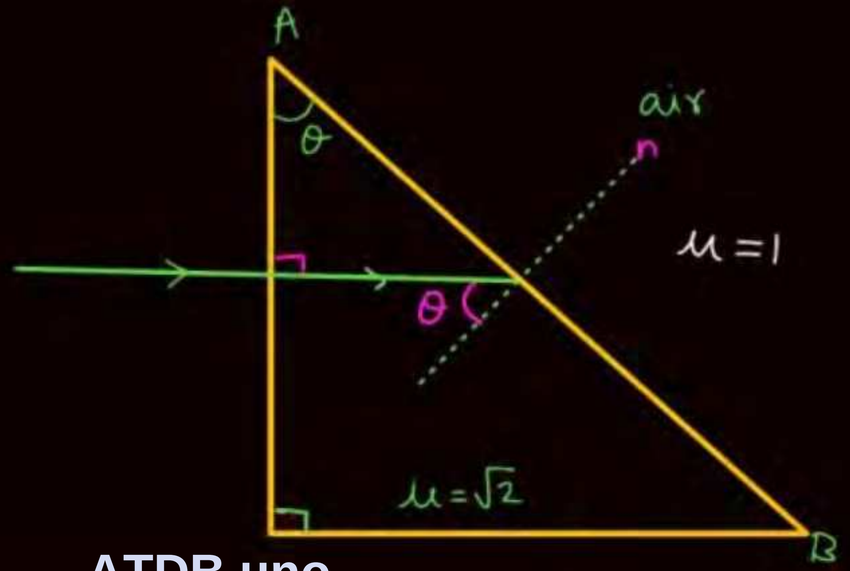
$$\boxed{\theta_c = 45^\circ}$$

$$\tan\theta_c = \frac{R}{h}$$

$$\tan 45^\circ = \frac{R}{2}$$

$$\boxed{R = 2m}$$

Q find value of θ so that ray will not get outside AB.



$\theta > \theta_c$

$\sin\theta > \sin\theta_c$

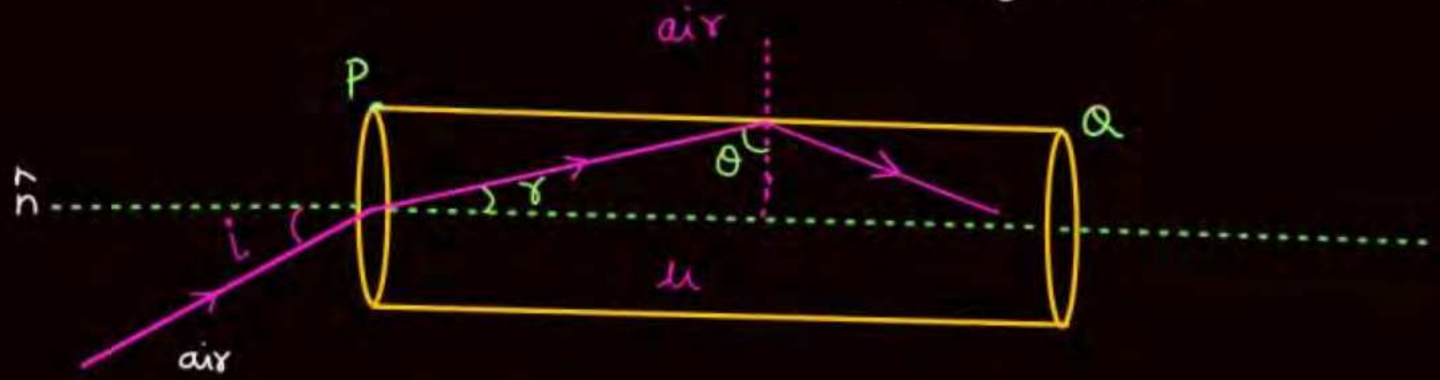
$\sin\theta > \frac{1}{\sqrt{2}}$

$\boxed{\theta > 45^\circ}$

JM / JH

Q

find range of μ so that all the ray will show TIR at PQ



$\sin\theta_c = \frac{1}{\mu}$

Soln

$\theta_{min} > \theta_c$

$(90 - r)_{min} > \theta_c$

$90 - r_{max} > \theta_c$

$90 - \theta_c > \theta_c$

$90 > 2\theta_c$

$\theta_c < 45^\circ$

$\theta_c < 45$

$\sin\theta_c < \sin 45$

$\frac{1}{\mu} < \frac{1}{\sqrt{2}}$

$\mu > \sqrt{2}$

$\theta \longrightarrow$ min

$r \longrightarrow$ max

$i \longrightarrow$ max $\equiv i_{max} = 90^\circ$

$\gamma + \theta = 90^\circ$

$\mu_1 \sin i = \mu_2 \sin\gamma$

$1 \times \sin 90 = \mu \sin\gamma$

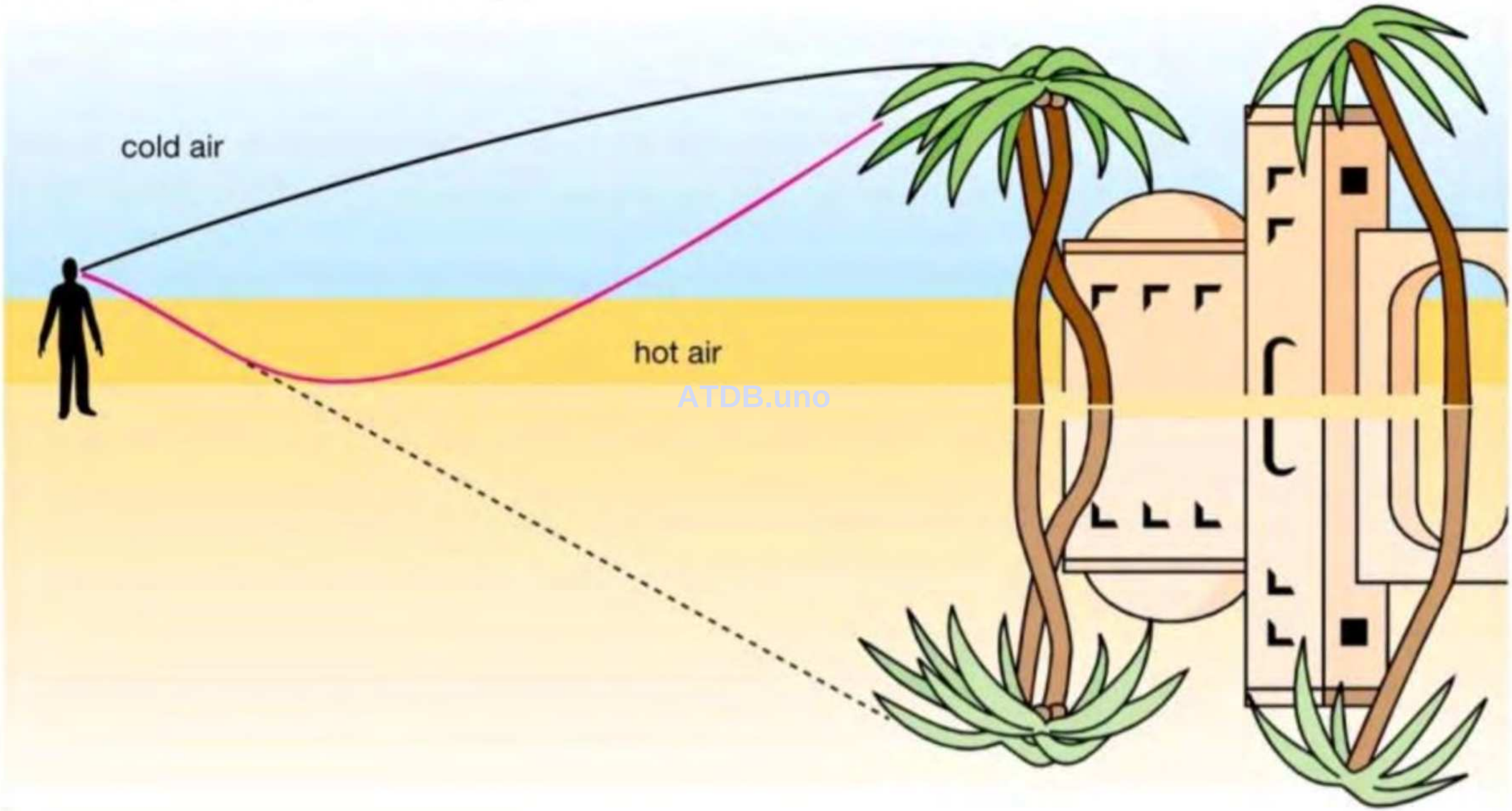
$\sin r = \frac{1}{\mu}$

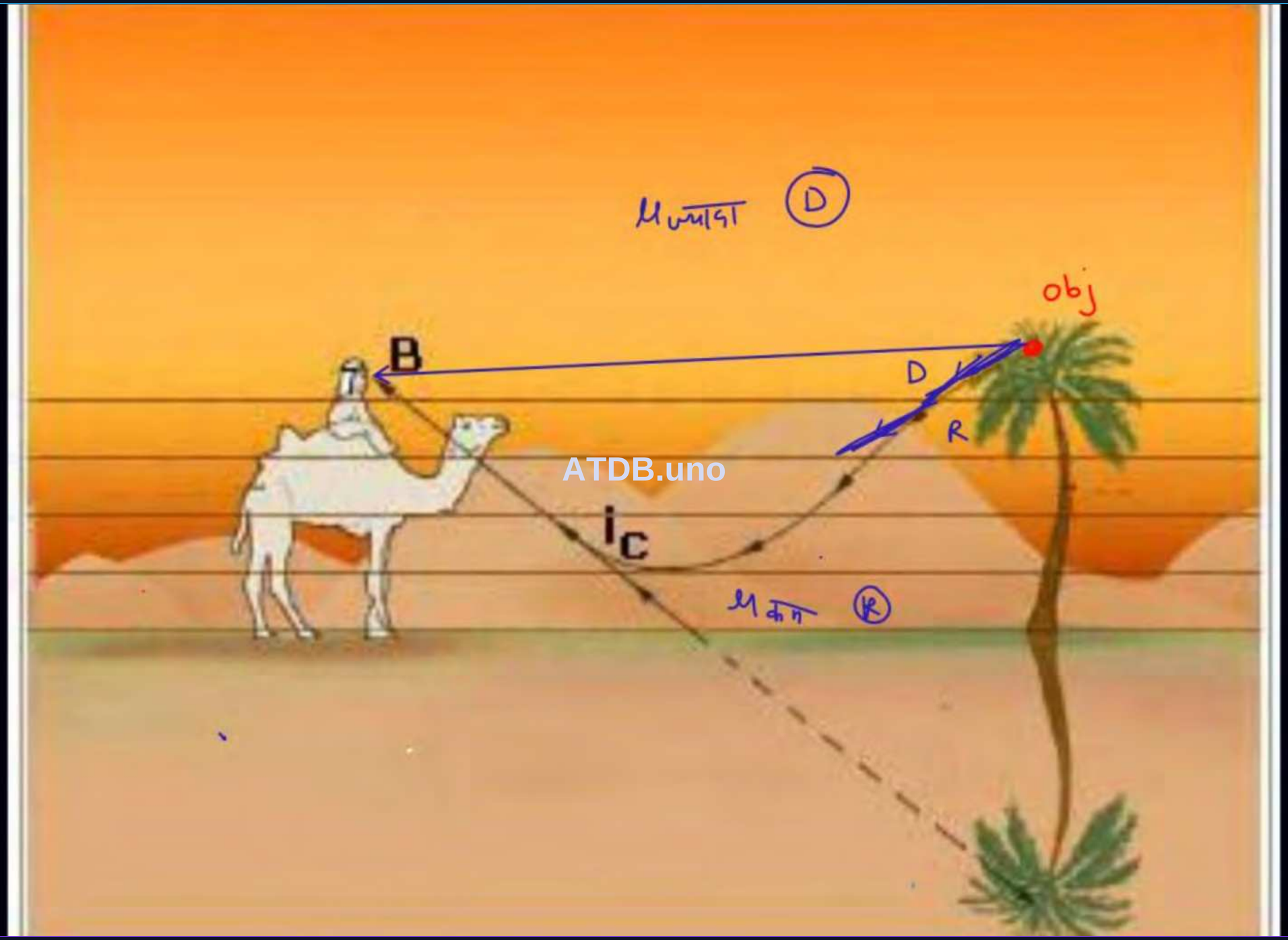
$r = \theta_c$ (max)

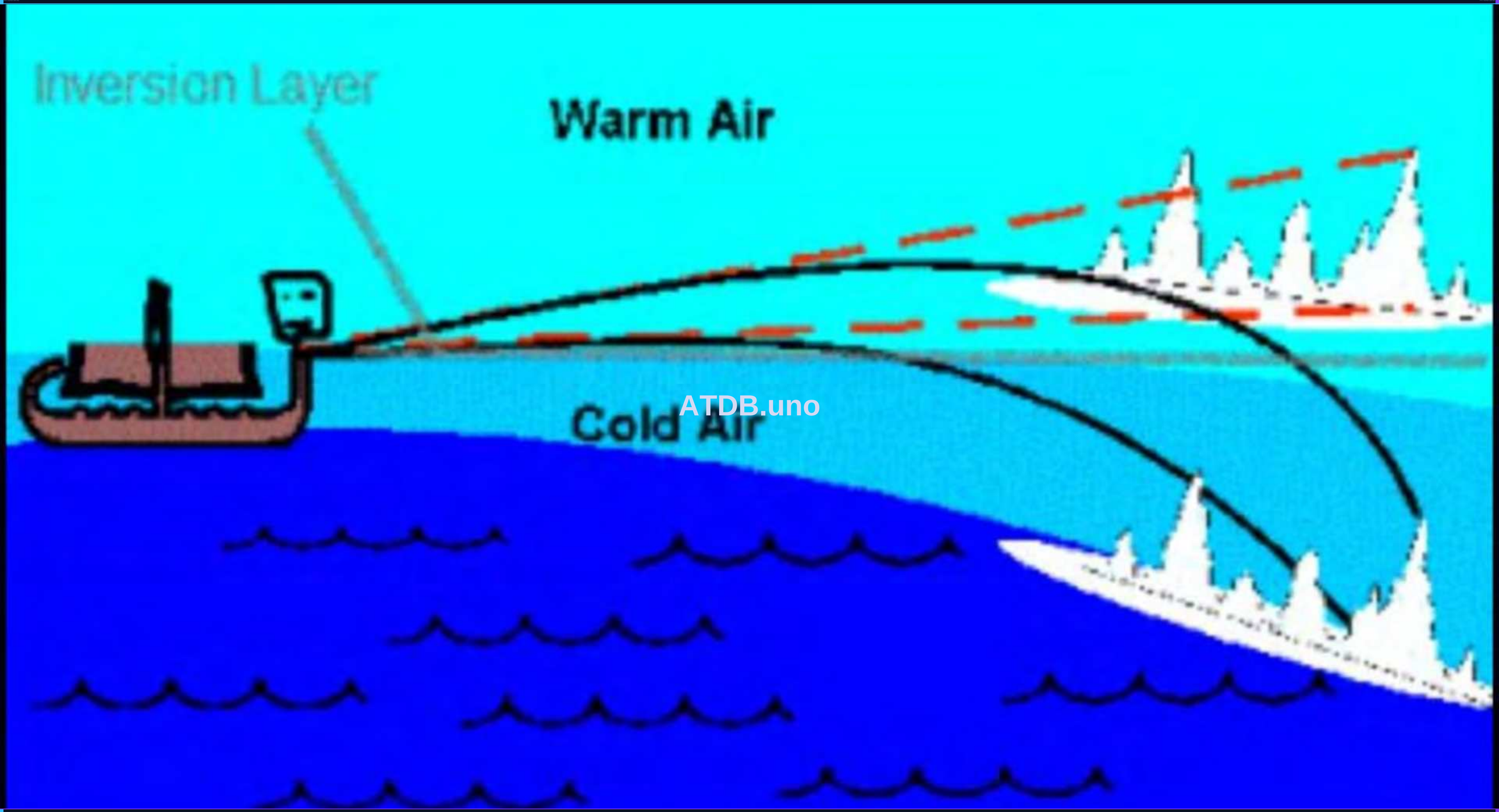
$\sin\theta_c = \frac{1}{\mu}$

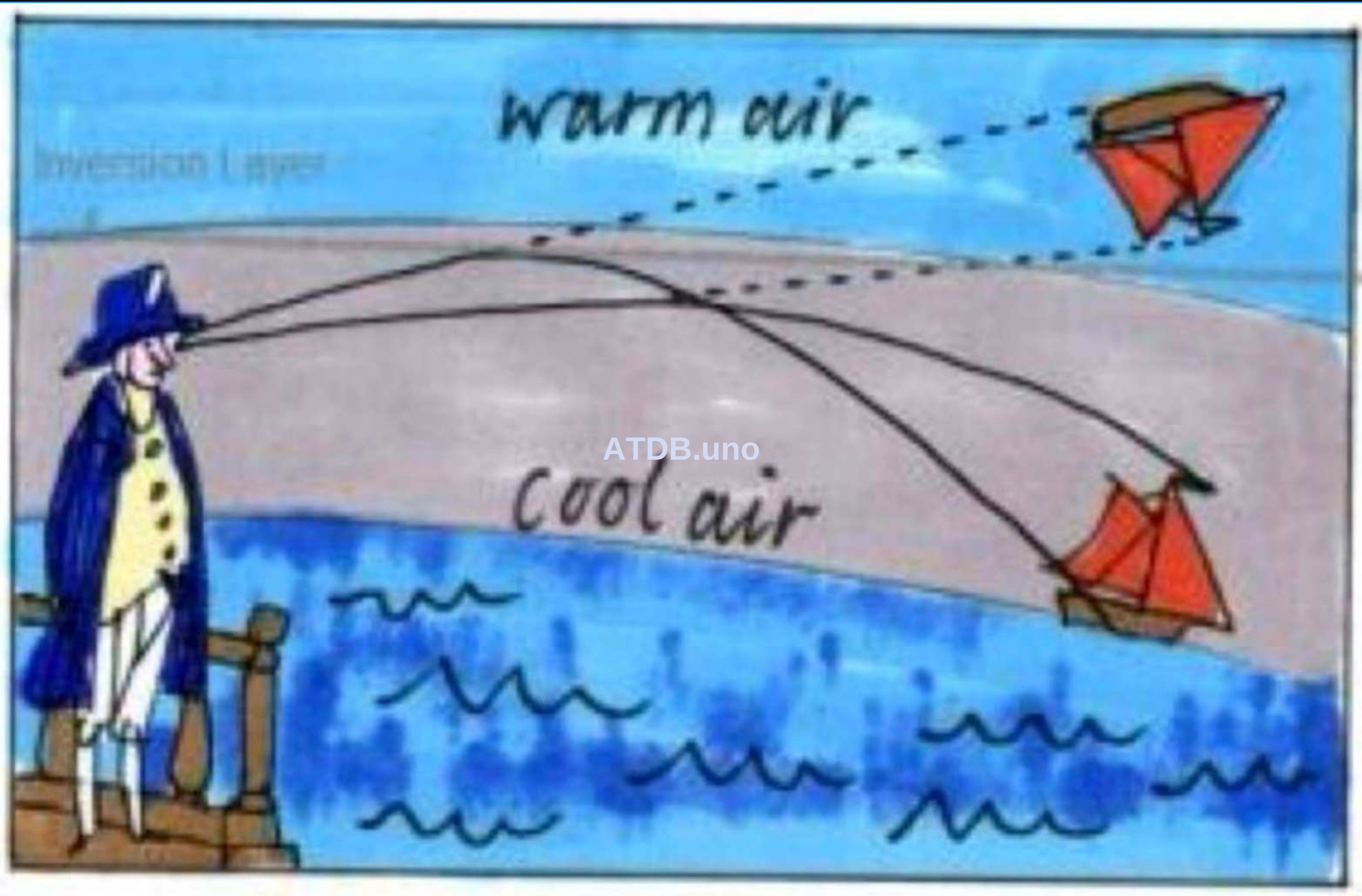
...

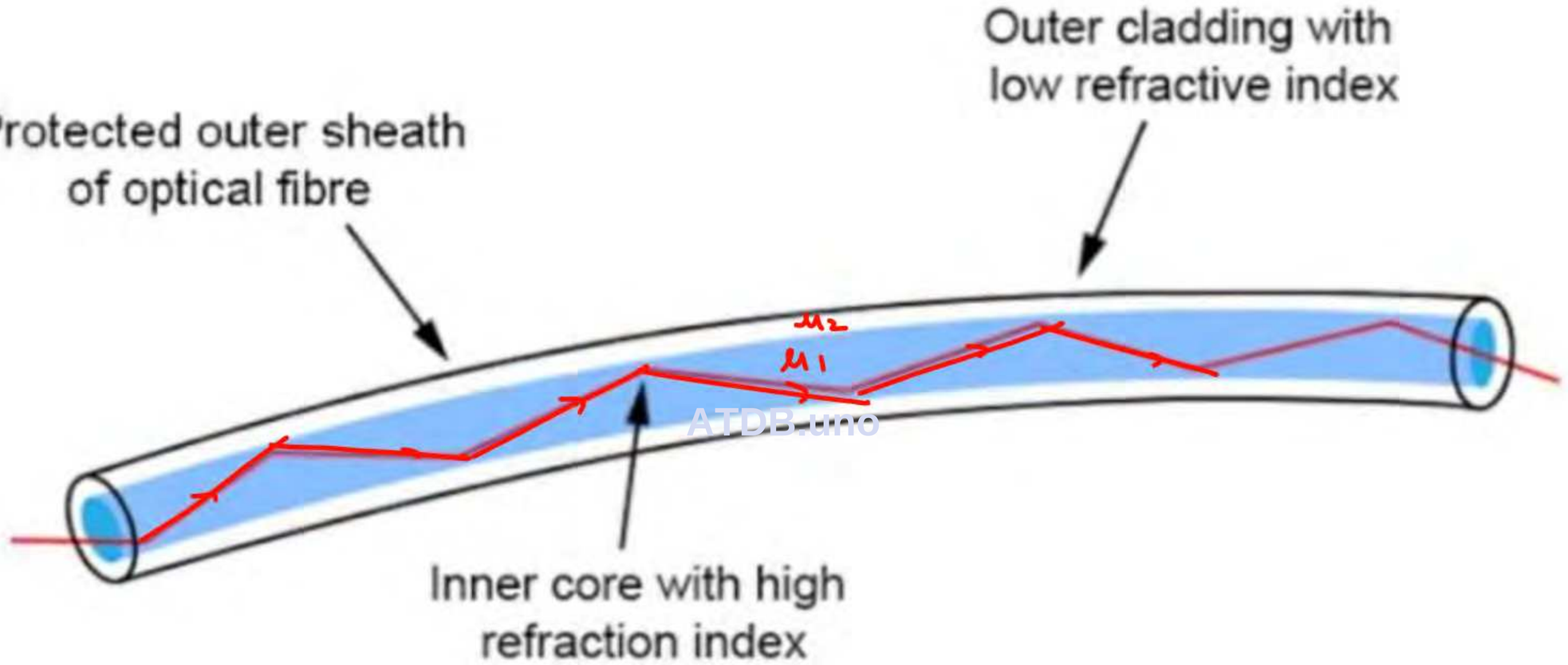
Formation of an inferior image











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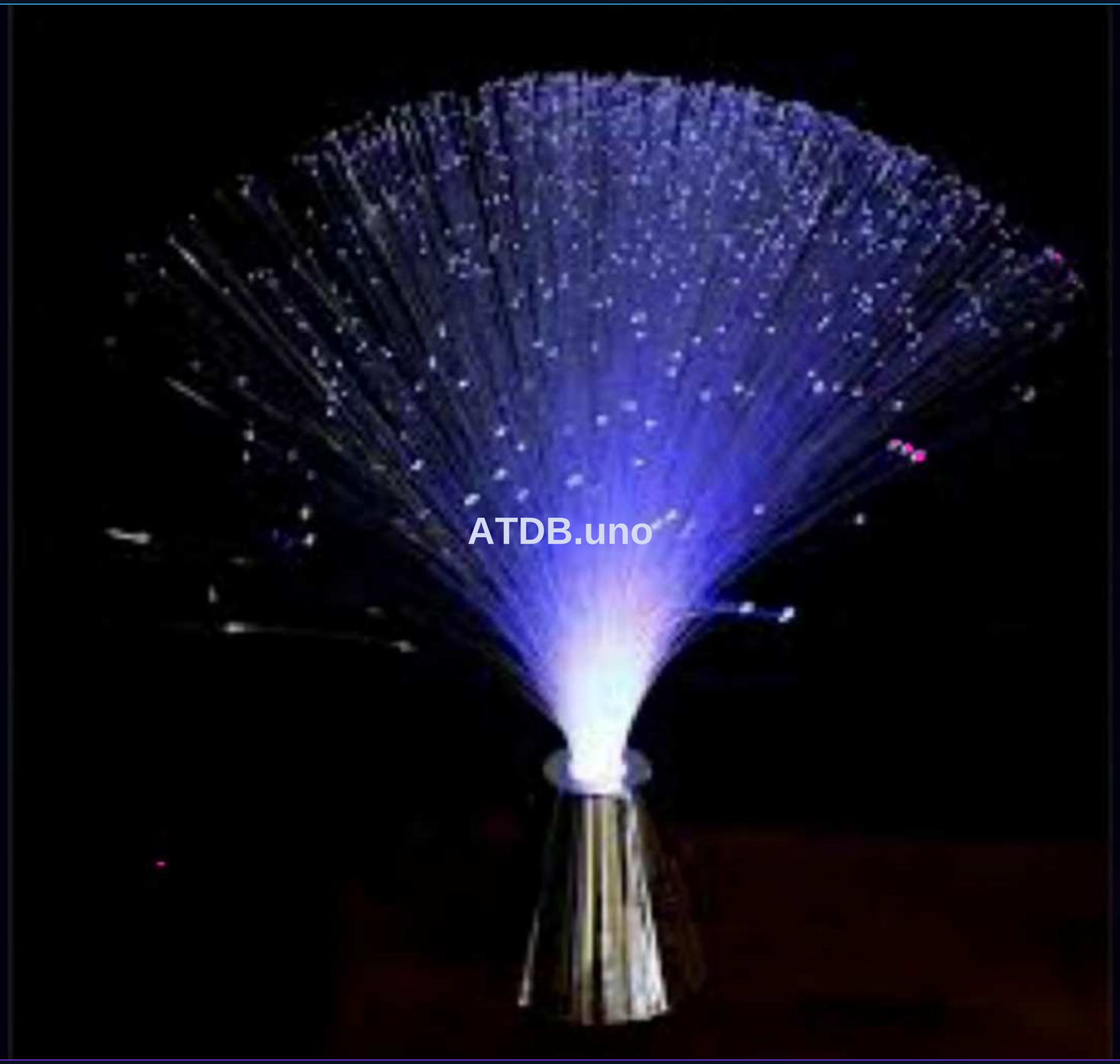


A room contains air in which the speed of sound is 340 m/s. The walls of the room are made of concrete, in which the speed of sound is 1700 m/s. (a) Find the critical angle for total internal reflection of sound at the concrete–air boundary.

$$\sin\theta_c = \frac{340}{1700}$$

Ans. (a) $\sin^{-1}\left(\frac{1}{5}\right)$

A light ray is incident perpendicular to one face of a 90° prism and is totally internally reflected at the glass-air interface. If the angle of reflection is 45°, we conclude that the refractive index n :

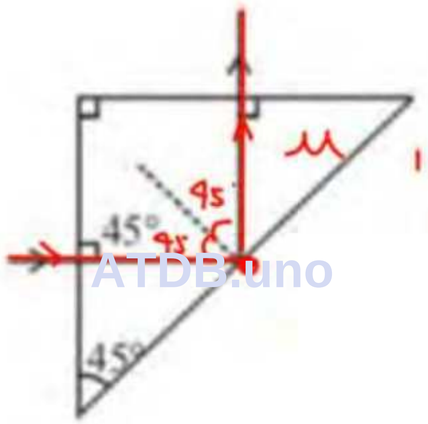
कोई प्रकाश किरण किसी 90° कोण के प्रिज्म के एक फलक पर लम्बवत् आपतित होकर काँच-वायु अन्तरापृष्ठ पर पूर्ण आन्तरिक परावर्तित हो जाती है। यदि परावर्तन कोण 45°, है, तो इससे हम यह निष्कर्ष निकालते हैं कि अपवर्तनांक n :

$45 > \theta_c$

$\sin 45 > \sin\theta_c$

$\frac{1}{\sqrt{2}} > \frac{1}{\mu}$

$\mu > \sqrt{2}$

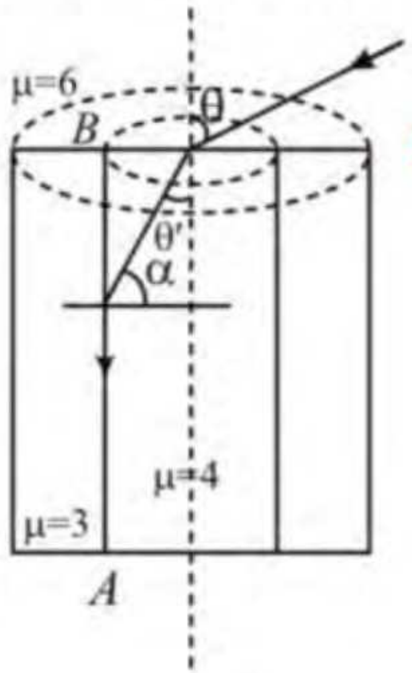


(A) $n < \frac{1}{\sqrt{2}}$ (B) $n > \sqrt{2}$ (C) $n > \frac{1}{\sqrt{2}}$ (D) $n < \sqrt{2}$

Ans. (B)

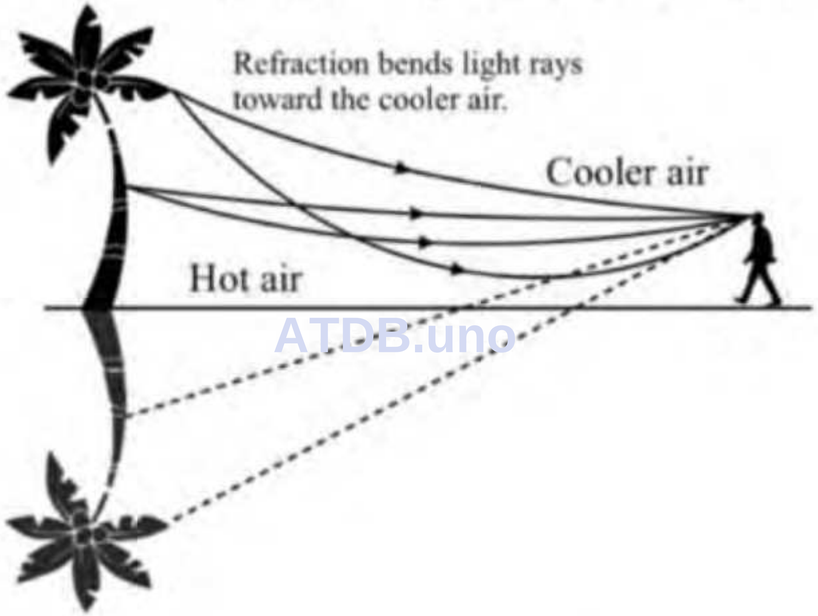
Train Your Brain

Example 25: Find angle θ so that TIR occurs at interface *AB* in the figure shown below:

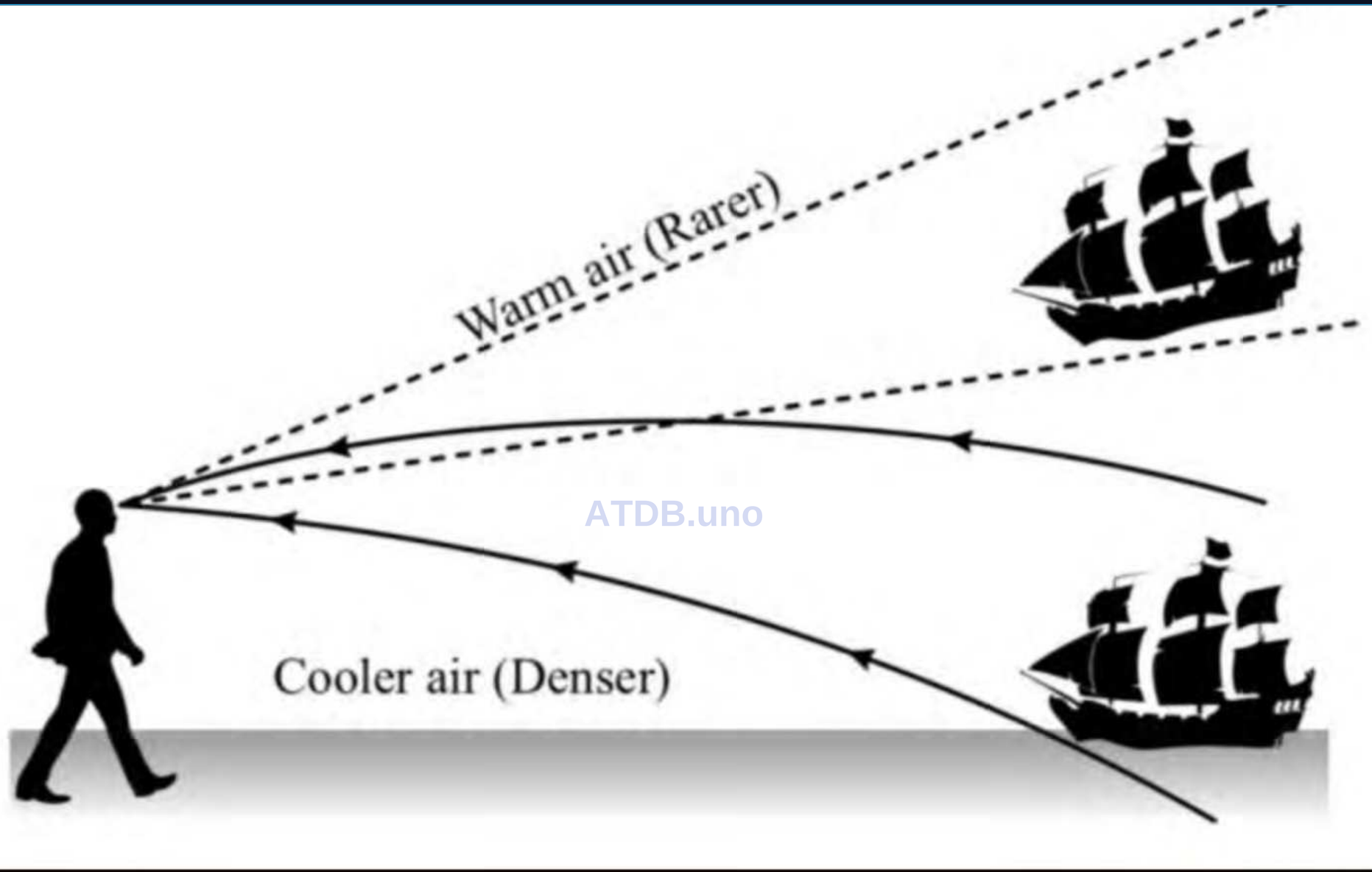


Ans $\sin\theta = \frac{\sqrt{7}}{6}$

8. Mirage: It is an optical illusion created due to phenomenon of total internal reflection. This is seen in hot region. In hot area like deserts surface of earth is very hot, so air in lower region of atmosphere is hot as compared to that of in higher region. This result in variation of density with height and it increases as we go up. In this situation atmosphere can be assumed to be made up of large number of thin layers of air.



A beam of light starting from an object (say tree) and travelling downward find itself going from denser to rarer medium. Therefore its angle of incidence goes on increasing gradually till it surpasses the critical value and reflected back due to total internal reflection. A virtual image of object is seen. Due to disturbance of air the mirage is formed in nature. Thus giving an illusion for the presence of water which is actually not there.



TOTAL INTERNAL REFLECTION AND CRITICAL ANGLE

22. The wavelength of light in two liquids x and y is 3500 Å and 7000 Å. Then the critical angle of x relative to y will be

$\sin\theta_c = \frac{1}{2}$

(a) 60°
(b) 45°
(c) 30°
(d) 15°

23. A light wave travels from glass to water. The refractive index for glass and water are $\frac{3}{2}$ and $\frac{4}{3}$ respectively. The value of the critical angle will be:

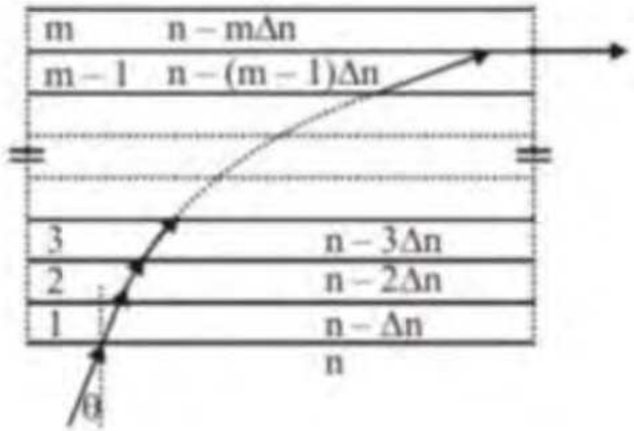
$\sin\theta_c = \frac{4/3}{3/2} = 8/9$

(a) $\sin^{-1}\left(\frac{1}{2}\right)$
(b) $\sin^{-1}\left(\frac{9}{8}\right)$
(c) $\sin^{-1}\left(\frac{8}{9}\right)$
(d) $\sin^{-1}\left(\frac{5}{7}\right)$

17. A monochromatic light is traveling in a medium of refractive index $n = 1.6$. It enters a stack of glass layers from the bottom side at an angle $\theta = 30°$. The interfaces of the glass layers are parallel to each other. The refractive indices of different glass layers are monotonically decreasing as $n_m = n - m\Delta n$, where n_m is the refractive index of the m^{th} slab and $\Delta n = 0.1$ (see the figure). The ray is refracted out parallel to the interface between the $(m-1)^{th}$ and m^{th} slabs from the right side of the stack. What is the value of m ?

एकवर्णी प्रकाश (monochromatic light) अपवर्तनांक $n = 1.6$ वाले माध्यम में प्रगामी है। यह प्रकाश काँच की चीती (stack of glass layers) पर निचले सतह से $\theta = 30°$ कोण पर आपतित होता है। (जैसा कि चित्र में दर्शाया गया है)। काँचों के स्तर परस्पर समांतर है। काँच के चीती के अपवर्तनांक एकदिष्ट $n_m = n - m\Delta n$ क्रम से घट रहे है। यहाँ m स्तर का अपवर्तनांक n_m है और $\Delta n = 0.1$ है। प्रकाश किरण $(m-1)^{th}$ एवं m^{th} स्तर के पृष्ठतल से समांतर दिशा में दाई ओर से बाहर निकलता है। तब m का मान होगा ?

[JEE-Advance-2017]



Ans. 8

12. A parallel beam of light is incident from air at an angle α on the side PQ of a right angled triangular prism of refractive index $n = \sqrt{2}$. Light undergoes total internal reflection in the prism at the face PR when α has a minimum value of 45°. The angle θ of the prism is :

$1 \cdot \sin 45 = \sqrt{2} \sin r$ $\quad \gamma = 30$

वायु से आती प्रकाश की एक समानान्तर किरण-पुंज (parallel beam) एक समकोण त्रिभुजीय प्रिज्म (right angled triangular prism), जिसका अपवर्तनांक $n = \sqrt{2}$ है, के PQ तल पर α कोण से आपतित होती है। जब α का न्यूनतम मान 45° है तो प्रकाश का प्रिज्म की PR सतह पर पूर्ण आंतरिक परावर्तन (total internal reflection) होता है। प्रिज्म का कोण θ क्या होगा ?

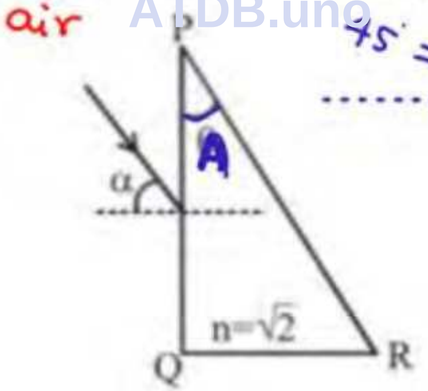
[JEE-Advance-2016]

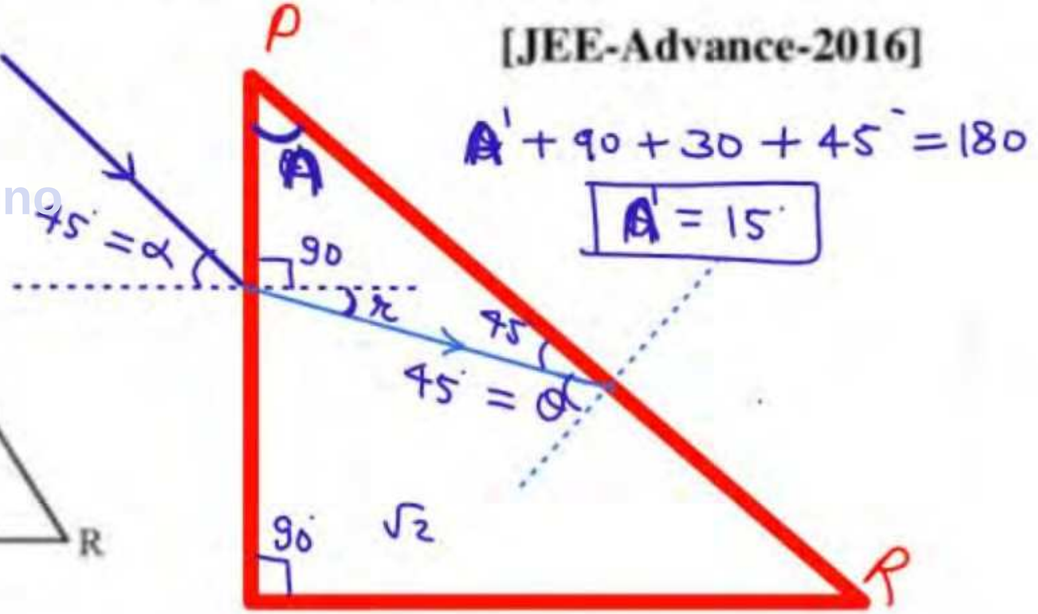
$\theta > \theta_c$

$\theta_{min} > \theta_c$

$\sin\theta_c = \frac{1}{\sqrt{2}}$

$\theta_c = 45°$





$A' + 90 + 30 + 45 = 180$

$A' = 15°$

(A) 15° (B) 22.5° (C) 30° (D) 45°

Ans. (A)

$\theta = ?$

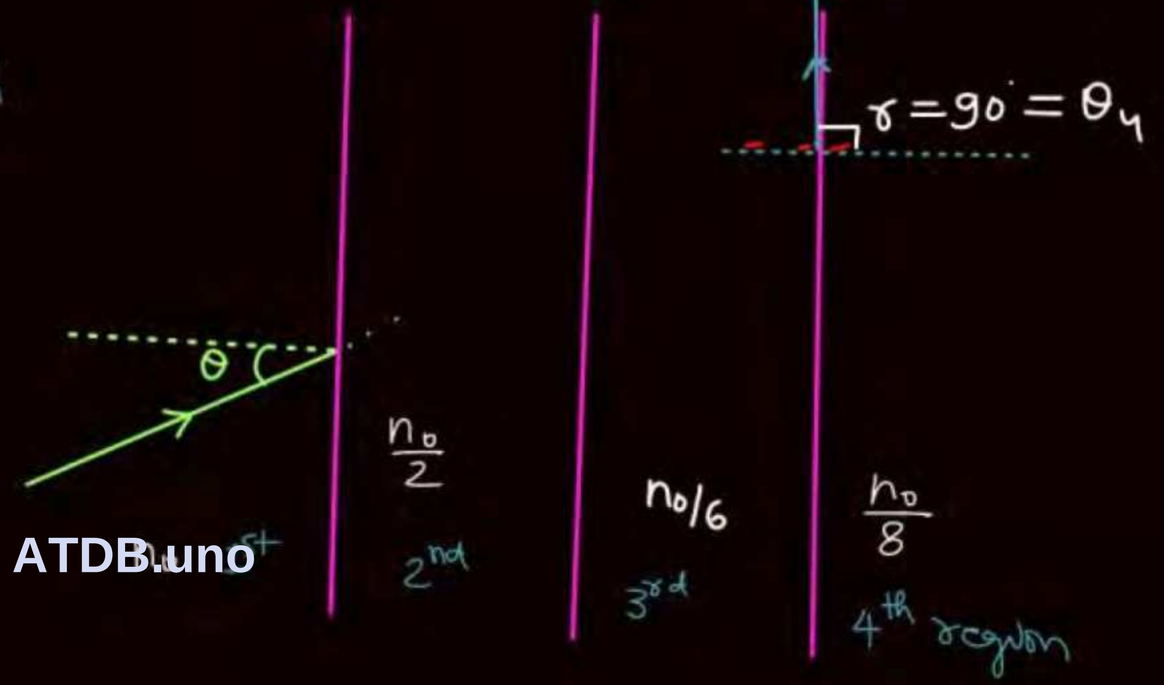
Q Angle of incident for which rays fails to enter Region 4th

Sol^n

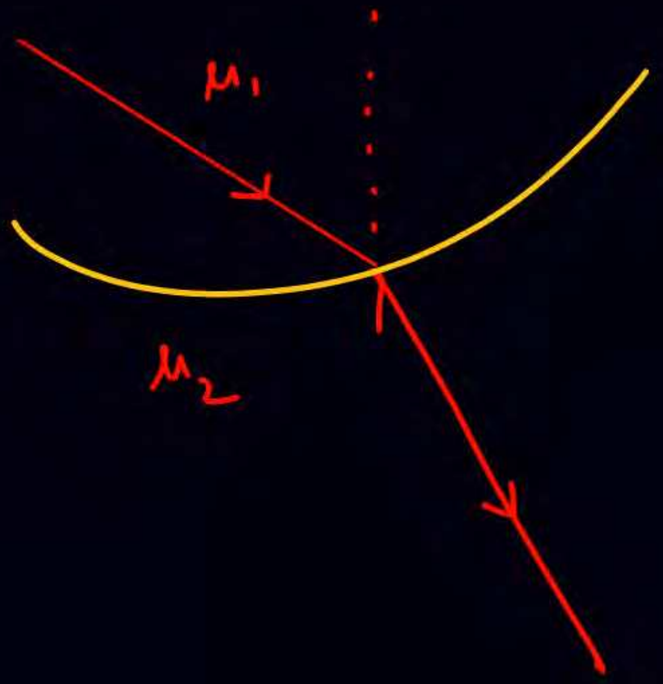
$$n_0 \sin\theta = \mu_4 \sin\theta_4$$

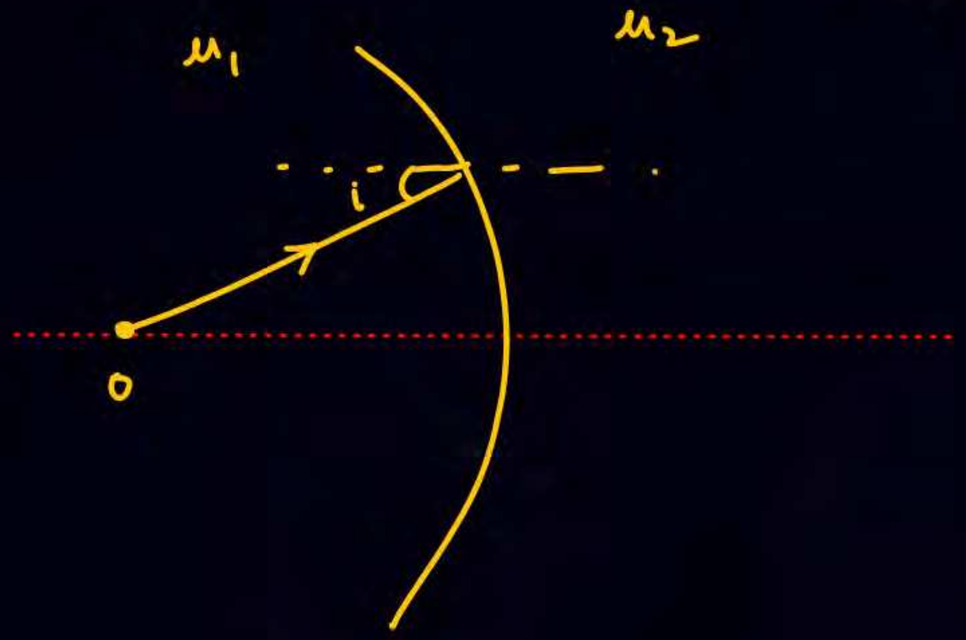
$$n_0 \sin\theta = \frac{n_0}{8} \sin 90^\circ$$

$$\theta = \sin^{-1}\left(\frac{1}{8}\right)$$

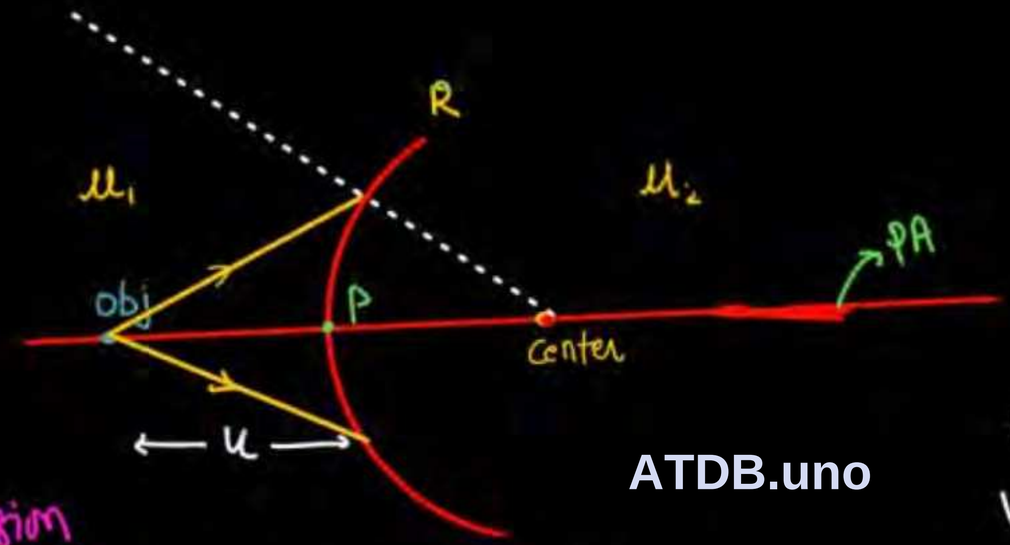


JEE Adv 2008





ATDB.uno



$$\frac{\mu_2}{V} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$$

- Valid for parallaxial
- u, V, R ⟶ with sign put करना है

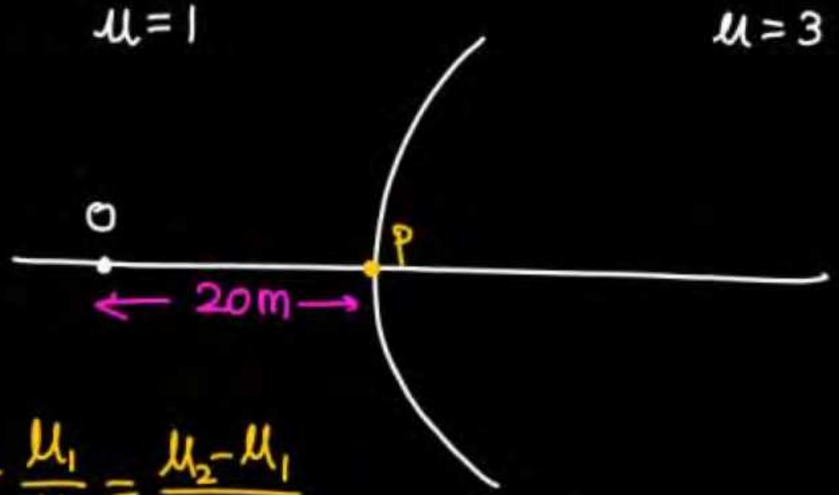
u ⟶ distance of obj from 'P' along PA
V ⟶ " " image " 'P' " "
R ⟶ Radius of curvature
μ_1 ⟶ जहाँ से rays आ रही है _ incident ray है
μ_2 ⟶ " rays जा रही है, refracted ray.

Sign Convension

- Direction of incident ray taken as positive
- सारे measurement pole से करने है.
- 'R' के sign के लिए 'P' से Center की तरफ चलो.

find location of image of obj.

(1)



$$\frac{\mu_2}{V} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$$

$$\frac{3}{V} - \frac{1}{-20} = \frac{3-1}{+10}$$

$$\frac{3}{V} + \frac{1}{20} = \frac{2}{10}$$

$$\boxed{V = +20\,m}$$

Sol^n

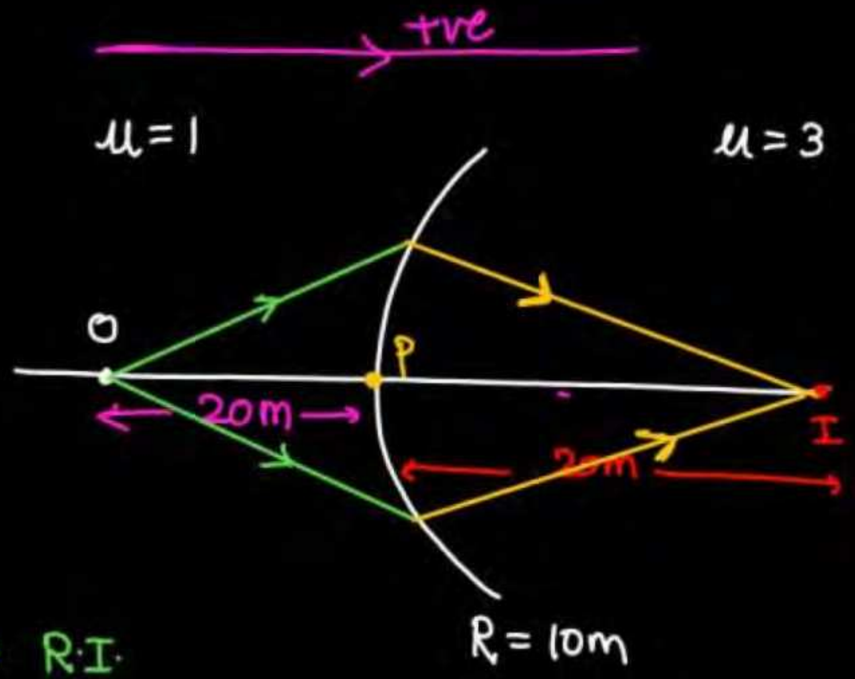
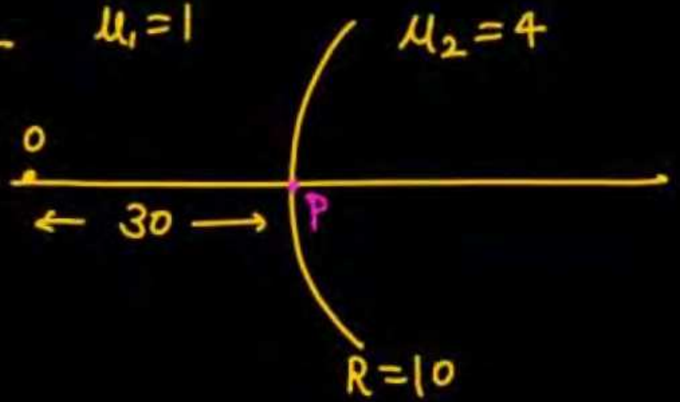
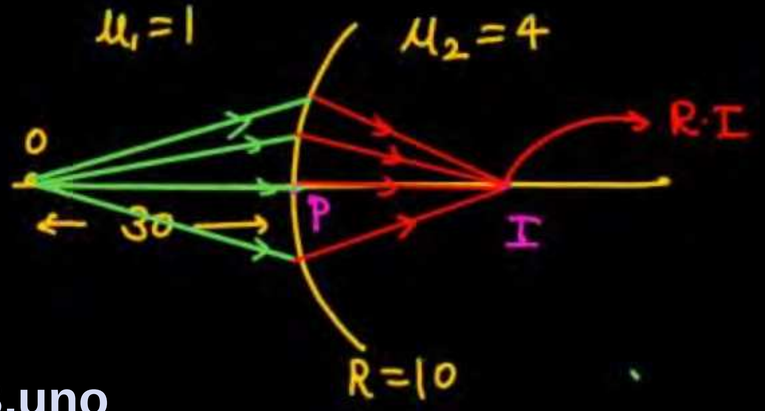


Image ≡ R.I.

Q





$$\frac{\mu_2}{V} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$$

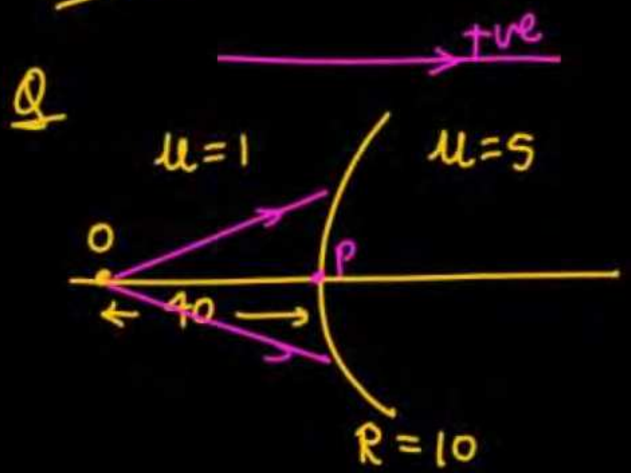
$$\frac{4}{V} - \frac{1}{-30} = \frac{4-1}{+10}$$

$$\frac{4}{V} + \frac{1}{30} = \frac{3}{10} = \frac{9}{30}$$

$$\frac{4}{V} = \frac{8}{30}$$

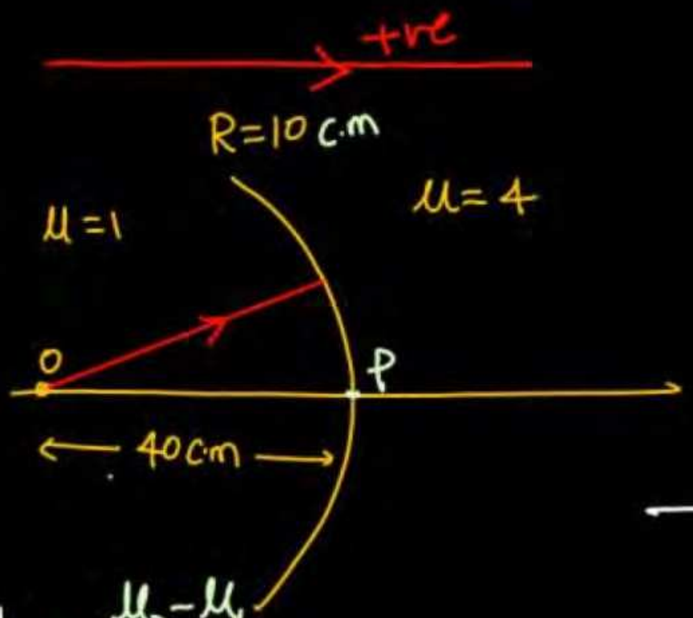
$$\boxed{V = +15}$$

All Unit cm



$$\frac{\mu_2}{V} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$$

$$\frac{5}{V} - \frac{1}{-40} = \frac{5-1}{+10}$$



$$\frac{\mu_2}{V} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$$

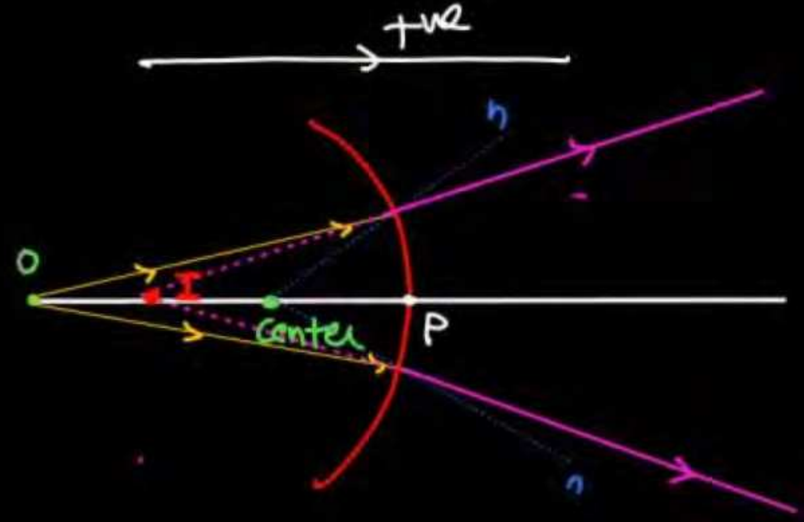
$$\frac{4}{V} - \frac{1}{-40} = \frac{4-1}{-10}$$

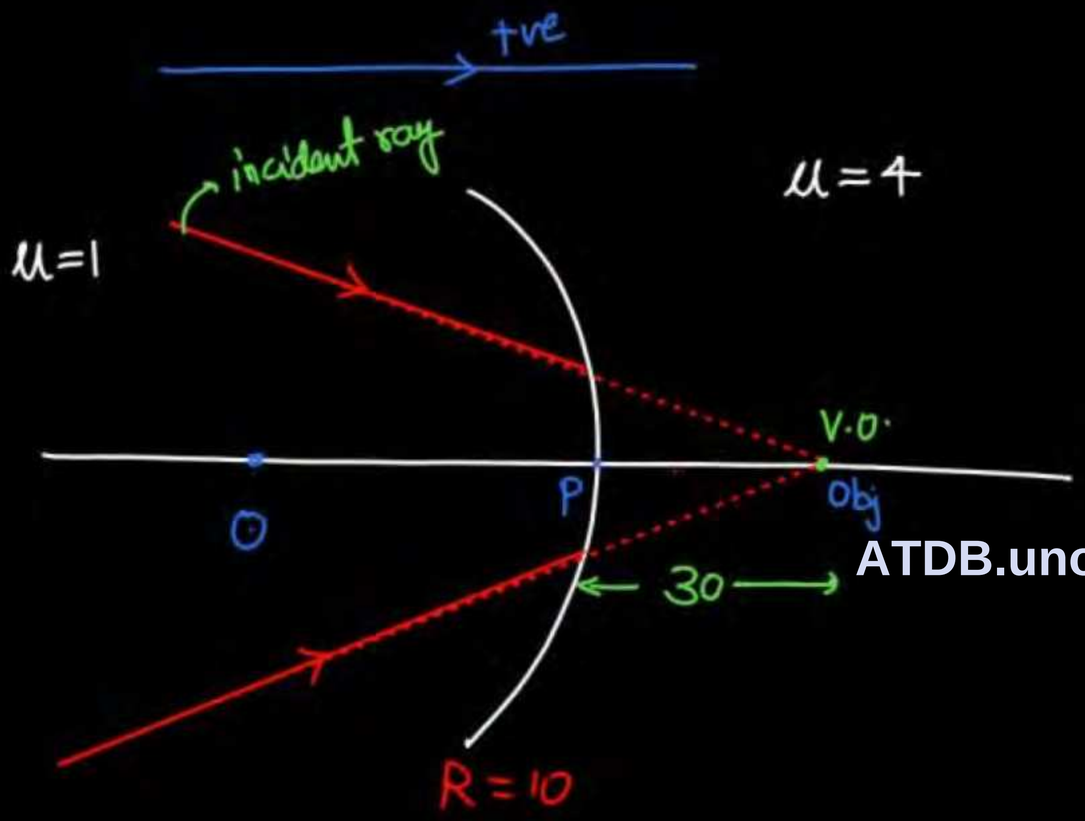
$$\frac{4}{V} + \frac{1}{40} = -\frac{3}{10}$$

$$\frac{4}{V} = -\frac{3}{10} - \frac{1}{40} = \frac{-13}{40}$$

$$V = \frac{-160}{13} = -12.3$$

V.I.





$$\frac{\mu_2}{V} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$$

$$\frac{4}{V} - \frac{1}{+30} = \frac{4-1}{-10}$$

$$\frac{4}{V} - \frac{1}{30} = -\frac{3}{10}$$

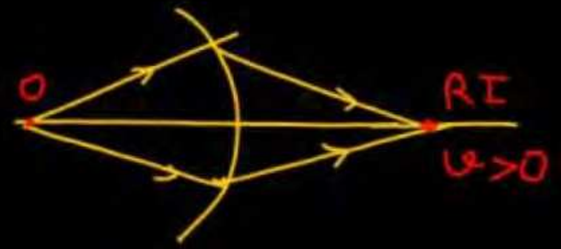
$$V = -15 \text{ (check)}$$ (Virtual)

$u<0 \longrightarrow$ R·O·

$u>0 \longrightarrow$ V·O

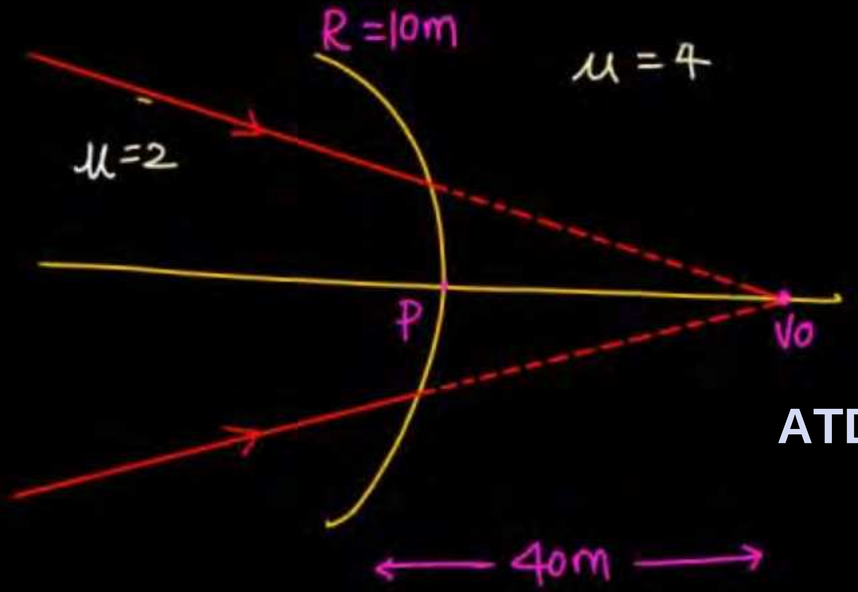
$u>0 \longrightarrow$ R·I

$u<0 \longrightarrow$ V·I



(1)

Q

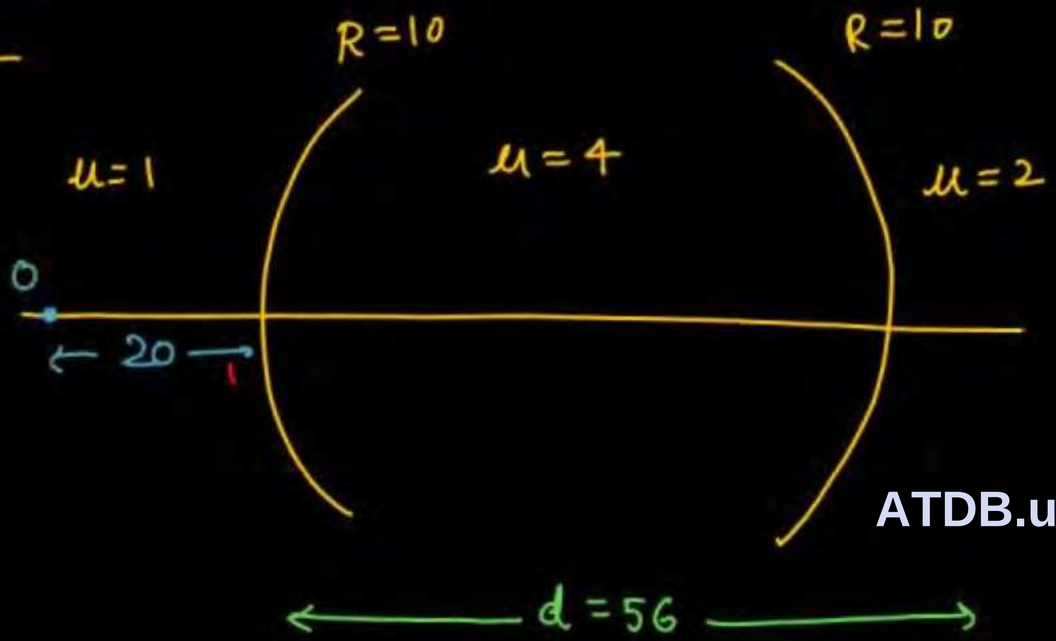


$$\frac{\mu_2}{V} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$$

$$\frac{4}{V} - \frac{2}{+40} = \frac{4-2}{-10}$$

find image location will be

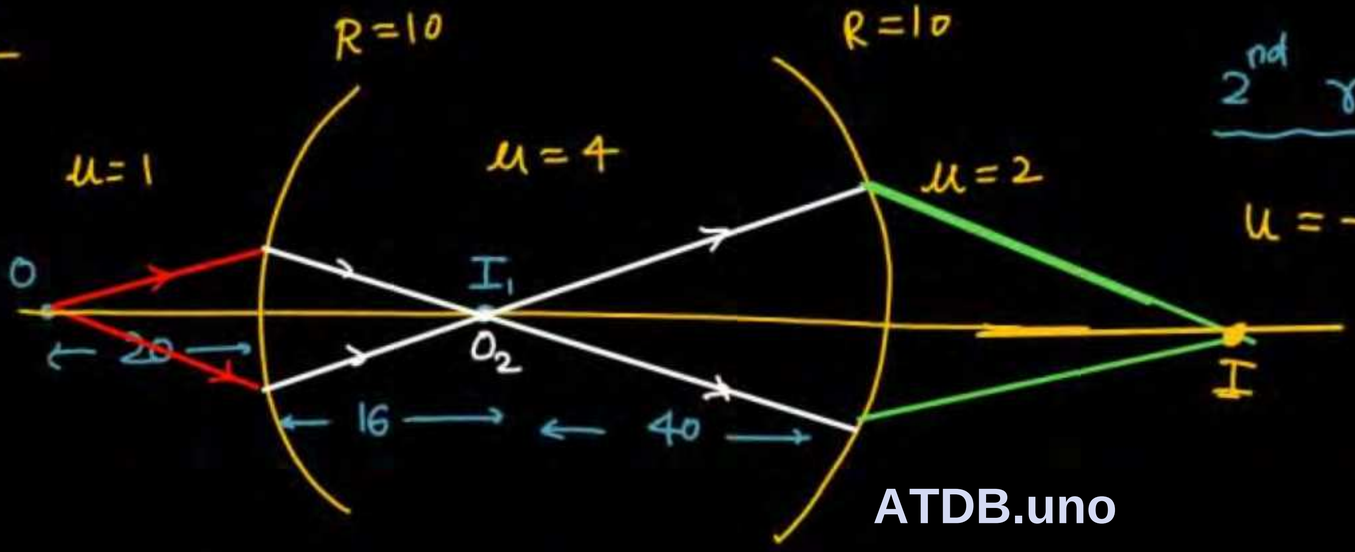
Q



1

final image location will be

Q



Sol^n (1^{st} refraction) $\longleftarrow d = 56 \longrightarrow$

$$\frac{4}{V} - \frac{1}{-20} = \frac{4-1}{+10}$$

$$V = +16$$

2^{nd} refraction

$u = -40, \quad \mu_1 = 4, \quad \mu_2 = 2$

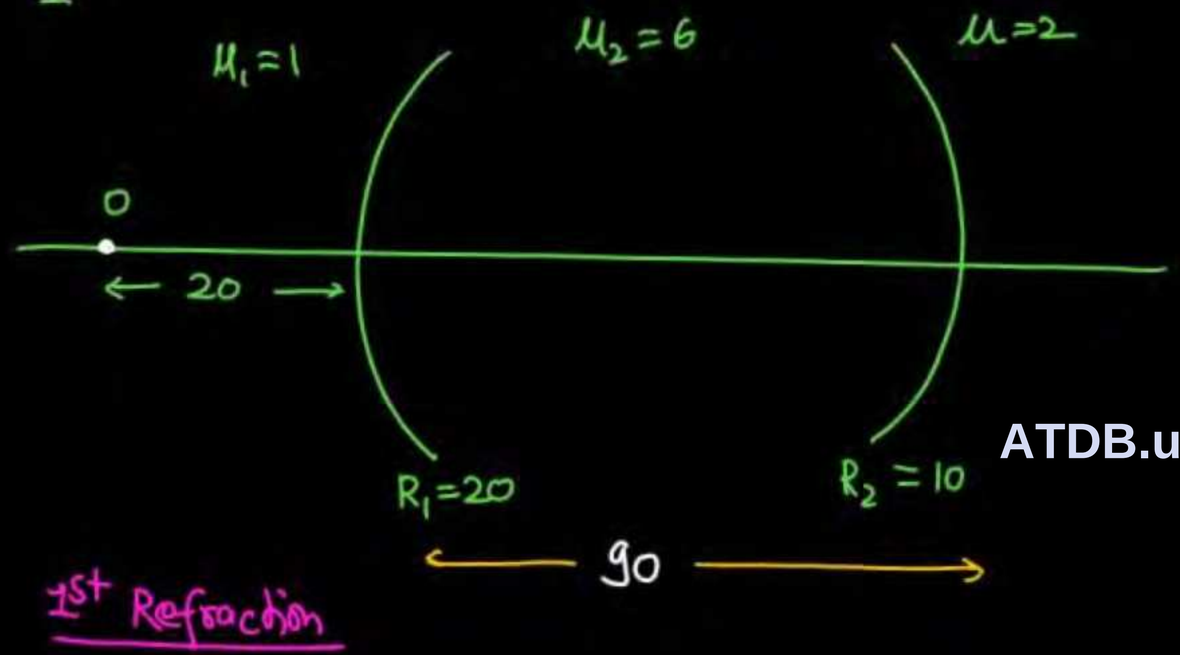
$R = -10$

$$\frac{2}{V_f} - \frac{4}{-40} = \frac{2-4}{-10}$$

$$V_f = +20 \quad (R \cdot I)$$

All unit are in Cm.

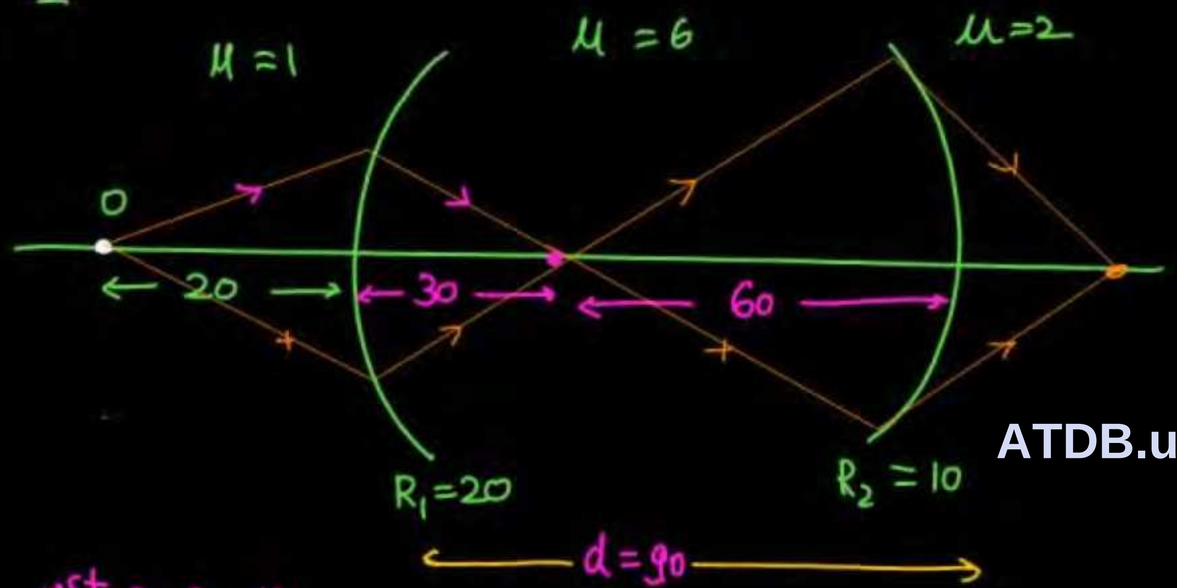
Q



1st Refraction

All unit are in Cm.

Q

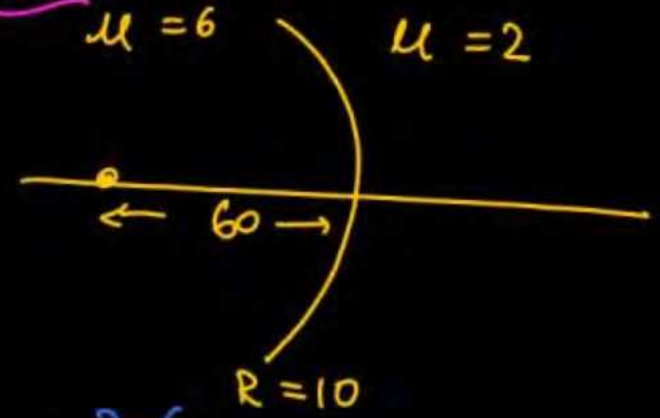


1st Refraction

$$\frac{6}{V} - \frac{1}{-20} = \frac{6-1}{+20}$$

$$\boxed{V = +30}$$

2nd Refraction

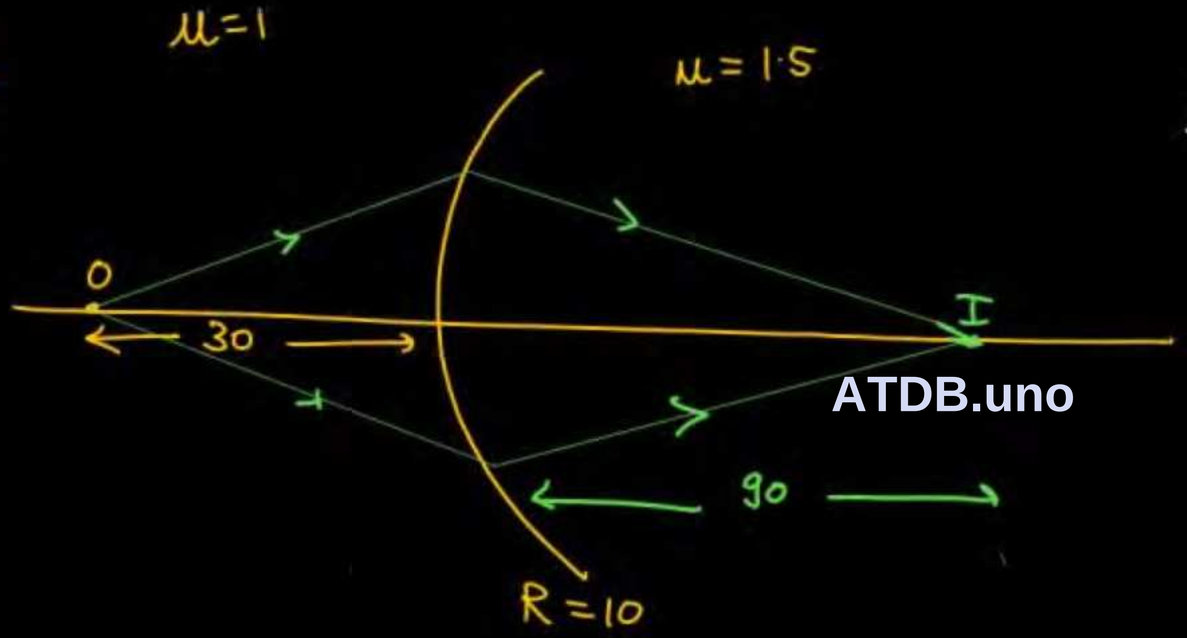


$$\frac{2}{V} - \frac{6}{-60} = \frac{2-6}{-10}$$

$$\frac{2}{V} + \frac{1}{10} = \frac{4}{10}$$

$$\boxed{V = +\frac{20}{3}}$$

Doubt



$$\frac{1.5}{V} - \frac{1}{-30} = \frac{1.5-1}{+10}$$

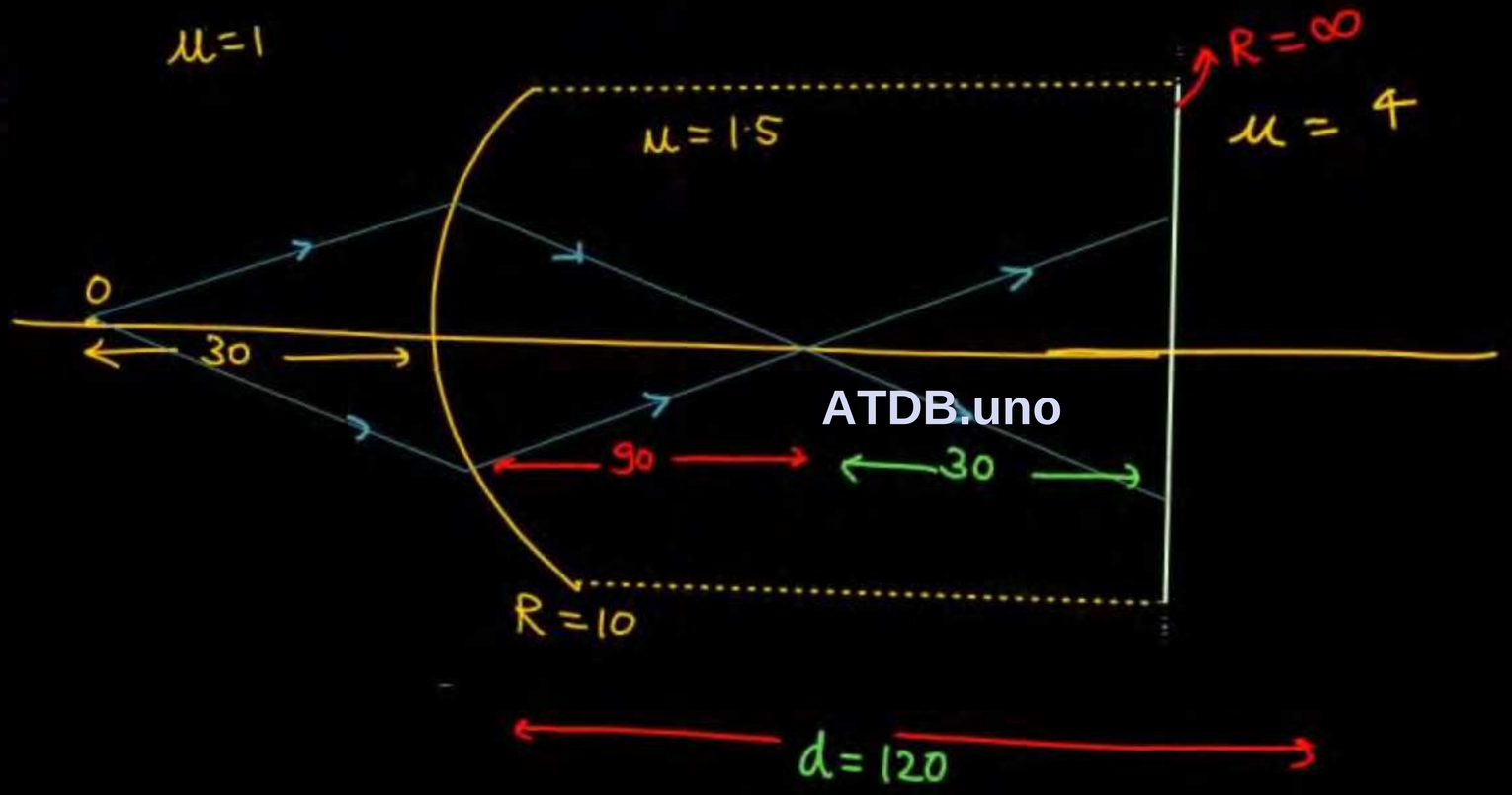
$$\frac{3}{2V} + \frac{1}{30} = \frac{1}{20}$$

$$\frac{3}{2V} = \frac{1}{60}$$

$$\boxed{V = +90}$$

Find location of final Image aftn all possible of refraction.

Q



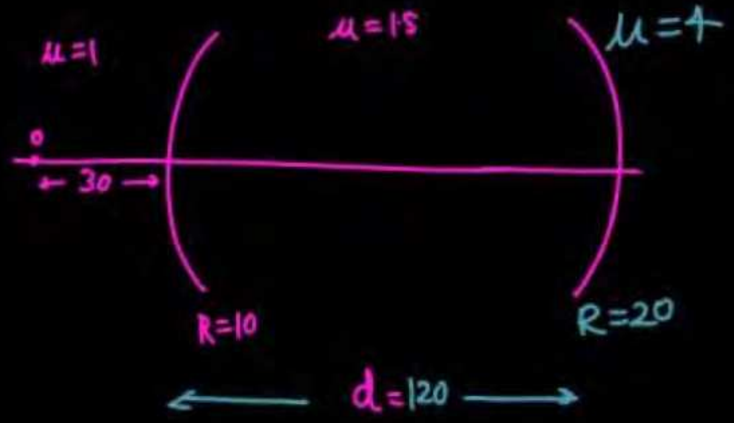
2nd refraction

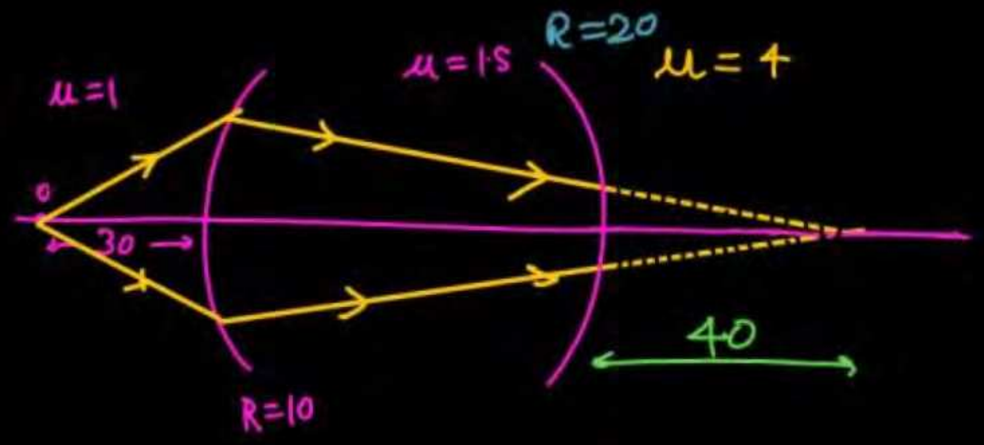
$$\frac{4}{v_f} - \frac{1.5}{-30} = \frac{4-1.5}{\infty}$$

$$\frac{4}{v_f} = \frac{-1.5}{300}$$

$$\boxed{v_f = -80}$$

Q

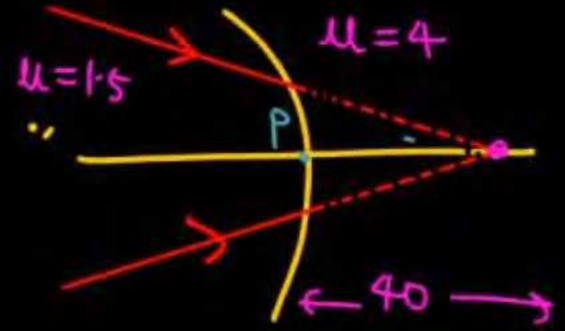




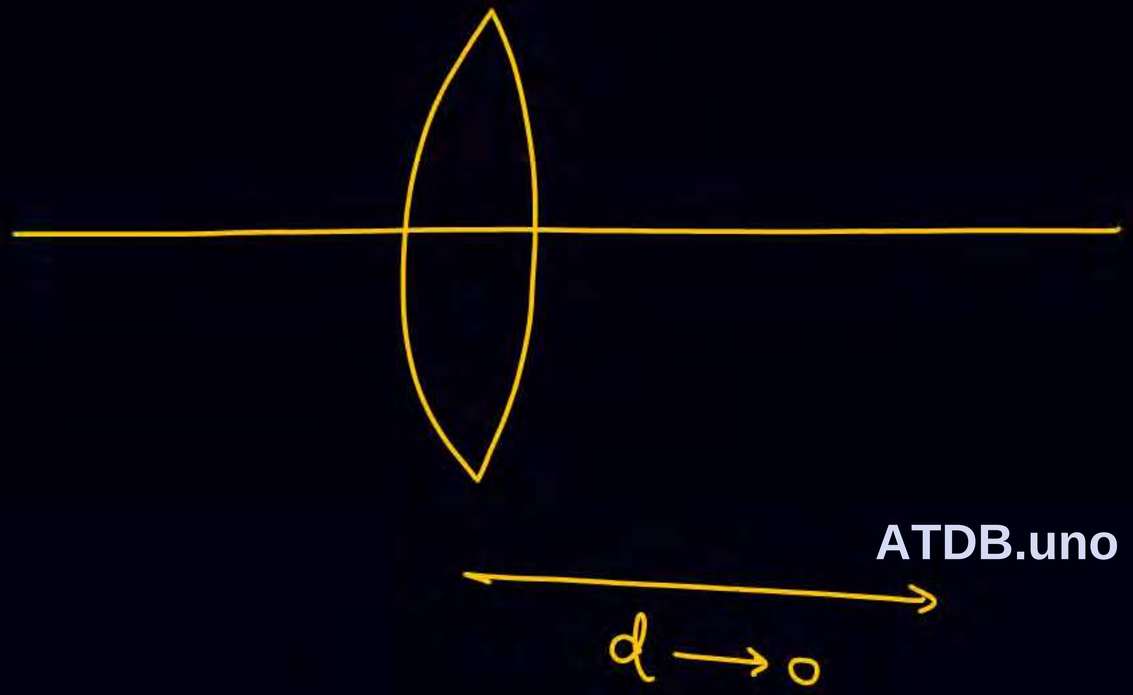
1st refraction

$V = +90$

2nd refraction



$$\frac{4}{V_f} - \frac{1.5}{+40} = \frac{4-1.5}{-20}$$



Homework

HCV ⟶

Solved ex. ⟶ 1, 2, 3, 4,
(Page 401 HCV part 1)

Ex: (1 ⟶ 10), 13, 14, 37, 38, 41, (73 - 79)