Ray Optics - 13

Critical Angle & Total Internal Reflection (TIR)

\[ \frac{C}{D} \]

Grazing Emergence

Refracted Ray

\[ \gamma = 90^\circ \]

Critical Angle

\[ \gamma = 90^\circ \]

If \( i > C \) \Rightarrow Refraction Stops

Total Internal Reflection (TIR)

\[ i < \gamma \]

(without any mirror)

Conditions for TIR:

1) Rays should travel from denser to rarer medium
2) \( i > C \)

Calculation for \( C \):

\[ \begin{align*}
\mu_1 & \text{ rarer} \quad \gamma = 90^\circ \\
\mu_2 & \text{ denser}
\end{align*} \]

\[ \mu_2 \sin C = \mu_1 \sin 90^\circ \]

\[ \mu_2 \sin C = \mu_1 \]

\[ \sin C = \frac{\mu_1}{\mu_2} \]

\[ \mu_1 \quad \rightarrow \text{Rarer} \]

\[ \mu_2 \quad \rightarrow \text{Denser} \]
\[ \mu_1 < \mu_2 \]

\[ \sin c = \frac{\mu_1}{\mu_2} \rightarrow \text{Rarer} \rightarrow \text{Chota wala} \]
\[ \mu_2 \rightarrow \text{Denser} \rightarrow \text{Bada wala} \]

\[ \frac{\mu_1}{\mu_2} < 1 \text{ should be as } \sin \theta < 1 \text{ always} \]

If rarer medium \( \mu_1 \) is air (\( \mu_1 = 1 \))

\[ \frac{\sin c}{\mu_1} = \frac{1}{\mu_1} = \frac{1}{1.5} = \frac{2}{3} \]

\[ c = \sin^{-1}\left(\frac{2}{3}\right) \approx 42^\circ \]

Remember: \( i < c \) Refraction \( i = c \) Amazing emergence \( i > c \) TIR

Q) Find critical angle for glass-air interface.

\[ \text{R.S. of glass} = 1.5 \]

\[ \sin c = \frac{1}{\mu_1} = \frac{1}{1.5} = \frac{2}{3} \]

\[ c = \sin^{-1}\left(\frac{2}{3}\right) \approx 42^\circ \]

Q) Complete the path of ray: \( c = 42^\circ \) for glass
Solution

\[ \sin^{-1} \left( \frac{2}{4} \right) = 49^\circ \]

\[ \theta = \frac{3}{2} \]

\[ \alpha = 42^\circ \]

\[ \mu \cdot \sin 30^\circ = \mu \cdot \sin \theta \]

\[ \frac{\mu}{2} \times \frac{1}{2} = 1 \times \sin \theta \]

\[ \frac{2}{\theta} = \sin \theta \]

\[ \alpha = \sin^{-1} \left( \frac{3}{4} \right) = 49^\circ \]
Solution:

\[ Mg \sin 30^\circ = Ma \sin \alpha \]
\[ \frac{3}{2} \times \frac{1}{2} = 1 \times \sin \theta \]
\[ \frac{3}{4} = \sin \theta \]
\[ \theta = \sin^{-1} \left( \frac{3}{4} \right) \approx 49^\circ \]
2) Find the refractive index of liquid.

\[ \text{if } \mu_g = \sqrt{2} \]

\[ \mu_e = ? \]

Solution:

\[ \Rightarrow 60^\circ \text{ is Critical angle} \]

\[ \mu_g \sin c = \mu_e \sin 30^\circ \]

\[ \sqrt{2} \times \sin 60^\circ = \mu_e \times 1 \]

\[ \frac{\sqrt{2} \times \sqrt{3}}{2} = \mu_e \]

\[ \sqrt{\frac{3}{2}} = \mu_e \]

Circle of Illumination:

\[ \tan c = \frac{\gamma}{h} \]

\[ \gamma = h \tan c \]
\[ \sin c = \frac{1}{\mu} \]

\[ \Rightarrow \tan c = \frac{1}{\sqrt{\mu^2 - 1}} \]

\[ r = h \tan c \]

\[ r = h \frac{1}{\sqrt{\mu^2 - 1}} \]

\[ r = \frac{h}{\sqrt{\mu^2 - 1}} \]

Area of Circle = \( \pi r^2 \)

Of Illumination = \( \pi \left( \frac{h}{\sqrt{\mu^2 - 1}} \right)^2 \)

3. A point source of light is kept below a glass slab of \( \mu_g = 5 \). The thickness of slab is 8 cm. Find the area through which light emerges out.

Solution

\[ \tan c = \frac{r}{8} \]

\[ \sin c = \frac{1}{\mu} \]

\[ \sin c = \frac{3}{5} \]

\[ \frac{x}{8} = \frac{3}{4} \]

\[ x = \frac{3}{4} \times 8 = 6 \]

\[ \gamma = 6 \text{ cm} \]

Area = \( \pi (6)^2 \)

\[ A = 36 \pi \text{ cm}^2 \]
Mirage: On a hot summer noon in deserts, the layers of air near Earth's surface are warmer & clearer as compared to layers above.

Optical Fibre:

* Core (n1, µ1)
* Cladding (n2, µ2)

Uses:
1) Transmission of audio & video signals
2) Transmission of electric signals

Electric signal → Transducer → Optical signal

Electric signal ← Transducer → Optical fibre