ODM EDUCATIONAL GROUP
Changing your Tomorrow

Total Internal Reflection, Applications, Optical Fibre

XII- SCIENCE

SUBJECT : PHYSICS
CHAPTER NUMBER: 9
CHAPTER NAME : RAY OPTICS

CHANGING YOUR TOMORROW

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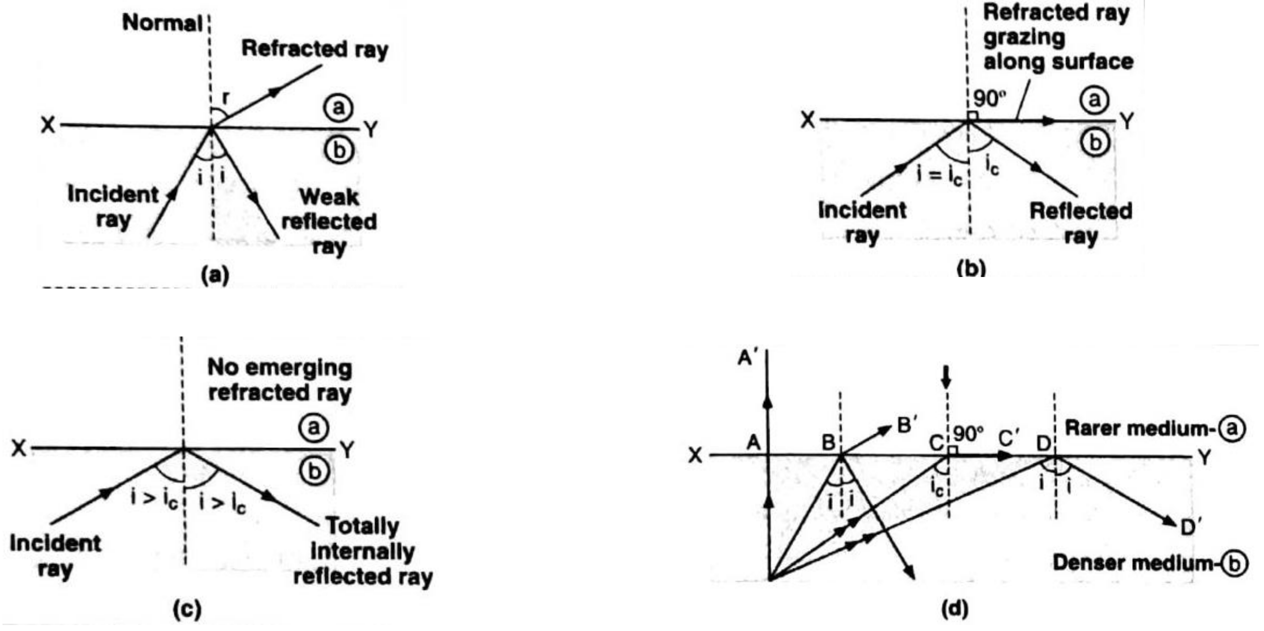
TOTAL INTERNAL REFLECTION

- In the figure give below a ray meets the surface XY separating a denser medium (b) and a rarer medium (a) at a small angle of incidence i.
- The angle of refraction r is greater than the angle of incidence i.
- If the angle of incidence is increased, it will reach a critical value, where the angle of refraction is just 90" and the refracted ray grazes along the surface of denser medium.



TOTAL INTERNAL REFLECTION

- **The critical angle (i_c) between two media is the angle of incidence in the optically denser medium for which the angle of refraction is 90°.**
- When $i > i_c$, no light emerges and all the light is totally internally reflected. This phenomenon is called total internal reflection.
- **The total internal reflection (TIR) is the phenomenon in which a ray of light travelling from an optically denser medium into an optically rarer medium at an angle of incidence greater than the critical angle for the two media is totally reflected hack into the same medium.**
- Thus, the conditions for TIR are :
- (a) Light is travelling from optically denser to optically rarer medium.
- (b) The angle of incidence at the surface is greater than the critical angle for the pair of media.

Relation between Critical Angle and Refractive Index

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Relation between Critical Angle and Refractive Index

- From Snell's law,
- $\frac{\sin i}{\sin r} = {}_a^b\mu$
- When i=i_c , r= 90^0
- Thus, $\frac{\sin i_c}{\sin 90} = {}_a^b\mu$
- $\sin i_c = {}_a^b\mu = \frac{1}{{}_b^a\mu}$
- When medium (a) is air, then${}_b^a\mu = \mu$
-

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

- **Note:**
- For water, μ = 1.33,
- $\sin i_c$ = 1/ 1.33=0.7519
- i_c = 48.75°
- For crown glass μ = 1.52
- i_c= 41.14°

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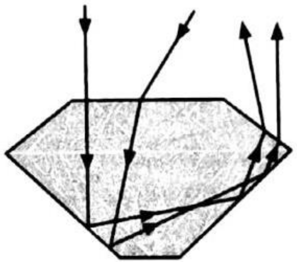
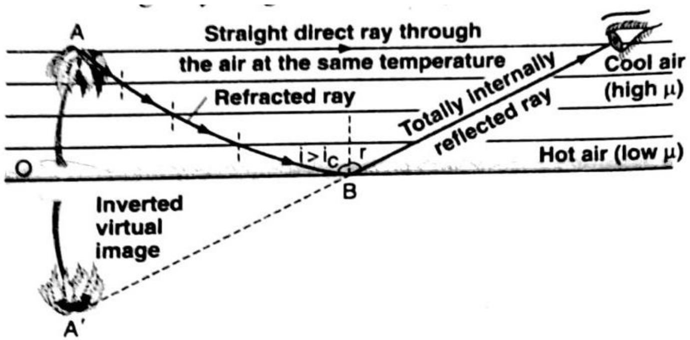
Applications of TIR

- **Sparkling of Diamonds**
- High refractive index (2.41) of diamond leads to its small critical angle in air of 24.5°.
- Diamonds are skillfully cut with many faces in such a way that much of the incident light undergoes multiple total internal reflections within the diamond before passing out again in the air.
- Like a prism, diamond is a dispersive material (that is μvaries somewhat with λ), and so the various colours composing white light travel somewhat different paths and emerge in different directions. Hence, diamond sparkles.



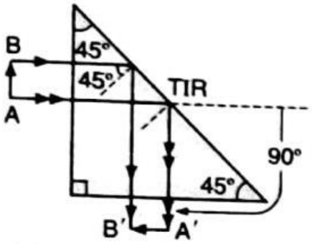
MIRAGE

- The sighting of inverted images on hot still summer days is called mirage as it gives an illusion of water due to inverted images of trees, etc., especially in deserts.
- The phenomenon is on account of the combined effect of:
    - (i) successive refractions at various layers of air having different values of μ
    - (ii) total internal reflection
- The ray of light from the top A of an object progressively bends away from the normal till it reaches point B where the angle of incidence is greater than the corresponding critical angle.
- At this stage, the ray is totally reflected upwards and appears to come from point A' giving rise to an imaginary image OA' of the object OA.

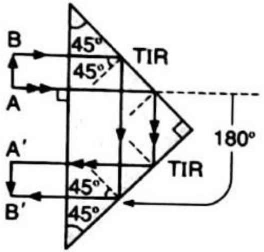


PRISM

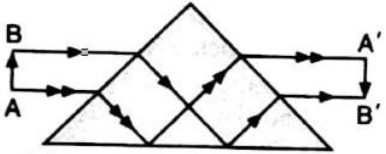
- A prism so designed that its angles are 45^0, 45^0, 90^0; is said to the total reflection prism or totally reflecting prism or the right-angled prism.



(a) Deviation through 90°



(b) Deviation through 180°
Inverted image

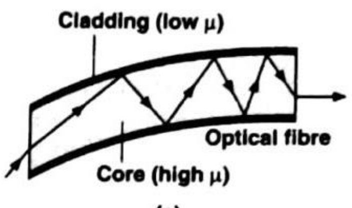


(c) Deviation through 0°
Image inverted
Erecting prism

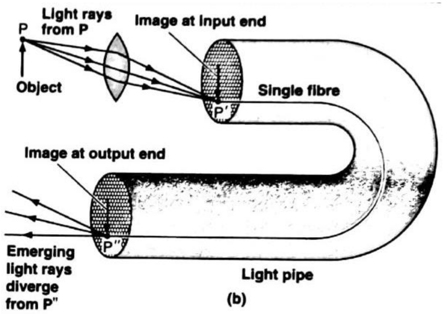
- The critical angle of glass is about 41^0. In such a prism, the rays are so directed that the angle of incidence at the surface where TIR occurs is 45^0.
- Hence, the ray of light will be totally reflected.
- A total reflection prism can be used as a mirror producing deviation of 90° or 180° or no deviation at all as in case of the erecting prism.

OPTICAL FIBRE

- An optical fibre is an extremely thin (about 50 μm in diameter) long strand of high quality glass or quartz (called core) which is coated with a thin layer of a material of lower refractive index (called cladding).
- It works on the principle of total internal reflection.



(a)



(b)

- A light ray travelling within the fibre is internally reflected each time it strikes the surface between the core andthe cladding so long its angle of incidence exceeds the critical angle for the core-cladding.
- μ_{core} = 1.6
- $\mu_{cladding}$ = 1.5
- i_c = 70^0
- $\sin i_c = \frac{\mu_{cladding}}{\mu_{core}}$= 0.94
- A bundle of fibres is called a light pipe and may contain about 10^4 fibres.
- Optical Fibres are used in endoscopy, arthroscopic surgery, laser angioplasty etc.

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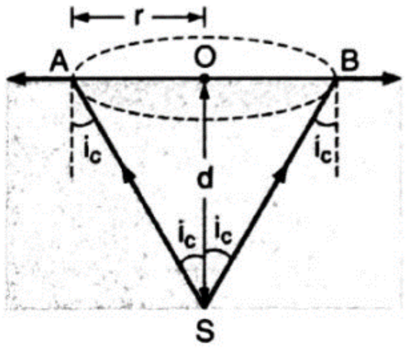
NUMERICALS

- **Question-1:** A small bulb is placed at the bottom of a tank containing water to a depth of 80 cm. What is the area of the surface of water through which light from the bulb can emerge out? Refractive index of water is 1.33. Consider the bulb to be a point source.



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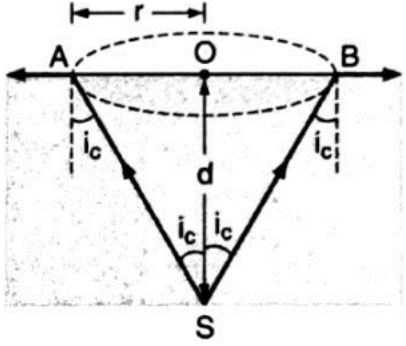
- **Solution:**
- S = small bulb
- SO = d= 80 cm = 0.8 m
- Rays of light incident at an angle greater than i_c, are totally reflected within water and consequently cannot emerge out of the water surface.
- $\sin i_c = \frac{1}{\mu} = \frac{1}{1.33} = 0.75$
- $i_c = 48°36'$
- $\tan i_c = \frac{r}{d}$
- $r = d \tan i_c$
- $r = 0.91\ m$
- Area of the circular path = πr^2 =3.14 x $(0.91\text{m})^2$ = 2.6 m^2



NUMERICALS

- **Question-2:** In the Fig. given below shows a cross-section of a light-pipe made of a glass fibre of refractive index 1.68. The outer covering of the pipe is made of a material of refractive index 1.44.
- (a) What is the range of the angles of the incident rays with the axis of the pipe for which total reflections inside the pipe take place as shown?
- (b) What is the answer if there is no outer covering of the pipe?
- **Solution :** *Left to the Students*

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