Sample Problem 2: *A light ray falls normally on one face of a glass* ($_a\mu_g = \frac{3}{2}$) *prism. After refraction from the second surface it goes along the surface. Calculate the refracting angle of this prism.*

Solution: As shown in the figure for face PQ, $i = r = 0$. Hence the refracted ray BC goes undeviated into glass and strike at point C on the face PR of the prism.

For face PR refracted light goes along the surface. It means $r = 90°$ and it implies that angle of incidence $i = i_c$. For glass air interface, (Fig. 4.45)

$$\sin i_c = \frac{1}{_a\mu_g}$$

$$= \frac{1}{1.5}$$

$$= 0.67$$

$$i_c = 42°.$$

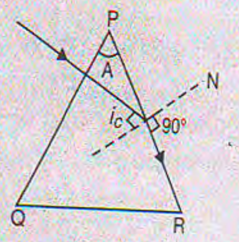

Fig. 4.45

Now from the figure refracting angle $A = i_c = 42°$.

4.16 APPLICATIONS OF TOTAL INTERNAL REFLECTION

(*i*) **Periscope :** In class IX you are told about the action of a periscope. This instrument is basically used in submarines to observe the movement of enemy ships. There we used two plane mirrors to obtain the reflection of light through 90° twice. However a right angle glass prism provides better option for this purpose. As shown in the figure, two right angle prisms P_1 and P_2 are used in periscope to provide two successive 90° rotations in opposite directions. Light rays from the object O fall on the prism P_1 and rotate through 90° because of total internal reflection of the light through the prism. Reflected light falls on the lower prism P_2 and suffer another rotation of 90° but in opposite direction. Light reflected from the prism P_2 moves towards the eyes of the observer and the object O is seen. (Fig.4.46)

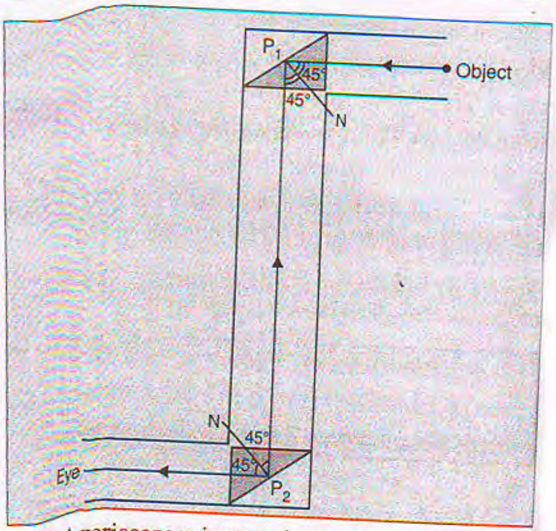

Fig. 4.46. A periscope using two right angle prisms P_1 and P_2

(*ii*) **Mirage formation :** In summer when temperature rises above 40°C while moving in a bus or a car you must have seen the false impression of water on the road. Similarly in deserts an inverted image of tree or some other object is seen that gives the false impression of water under the object. This is called *mirage*. Mirage formation is due to phenomenon of total internal reflection of light. (Fig. 4.47)

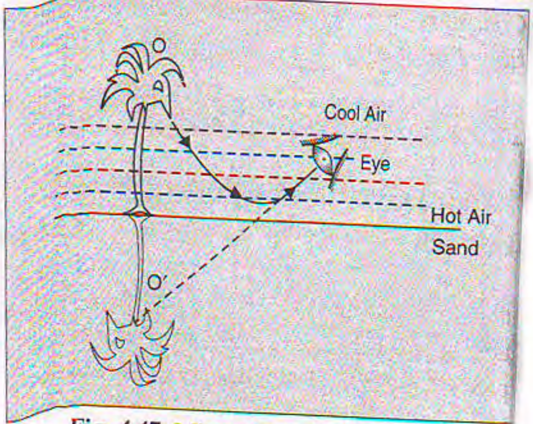

Fig. 4.47. Mirage formation desert.

In summer when sand in the desert or the road is very hot the air in contact to desert or road also becomes hot. However air is bad conductor of heat and as we go up temperature goes down. Thus the layers of air closer to sand or the road are hotter than the layers at some height. This makes the refractive index of the air layer in contact to sand or road least. Refractive index of the higher layers of air increases gradually. Consider a light ray from the tip of a tall object O, like a tree or a building. When this ray moves down towards sand or the road actually moves from various layers of air each being rarer to the preceding layer. After every refraction from each of these layers the ray drifts away from the normal. A condition comes when angle of incidence for a particular layer becomes more than critical angle. Total internal reflection of the light takes place and the ray starts moving upwards. When produced, this ray appears coming from the point O'. Thus O' behave as the virtual image of the object O.

(*iii*) **An empty test tube inside water shines like a mirror :** Take an empty test tube of glass and put it obliquely in water in a container. You will find that the surface of the tube shines like a mirror. It is due to internal reflection of light. Consider a light ray AP striking at point P on the test tube at angle of incidence more than the critical angle for water air interface *i.e.* 49°. Total internal reflection takes place and the ray reflects back into the water along the path PB. This makes the surface of test tube shine like a mirror. (Fig. 4.48)

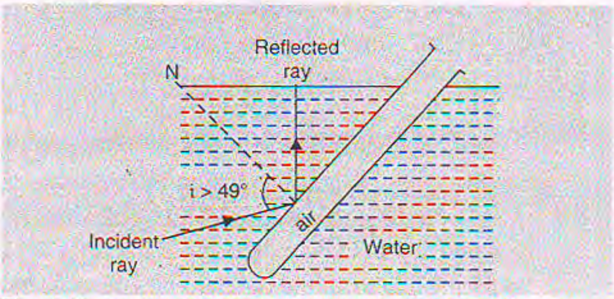

Fig. 4.48. Surface of a test tube shines when dipped in water.

(*iv*) **Optical fibre :** *It is a device based on the phenomenon of total internal reflection to transfer the light energy from one end of the glass quartz cable to another with minimal loss of energy.*

The cable connection used in your T.V. set is made of an optical fibre. Optical fibre is commonly used in a long distance cable communication of light signals. As shown in figure an optical fibre is made of two transparent mediums of different refractive indices. The central part of the fibre is made of a medium of higher refractive index while the part that surrounds the central part is made of a medium of relatively low refractive index. There is a plastic covering outside to protect the fibre. When a light ray from air enters into the central part of the fibre at small angle of incidence it refracts into the central medium even at smaller angle of refraction. This allows the light ray to strike on the surface of second transparent medium at larger angle of incidence *i.e.* more than the critical angle for this interface. This allows total internal reflection of the light from this interface. A large number of such total reflections transmit the light to the other end of the fibre. As you know, total internal reflection of light allows 100% reflection of light energy the energy loss in this process is negligible. (Fig. 4.49)

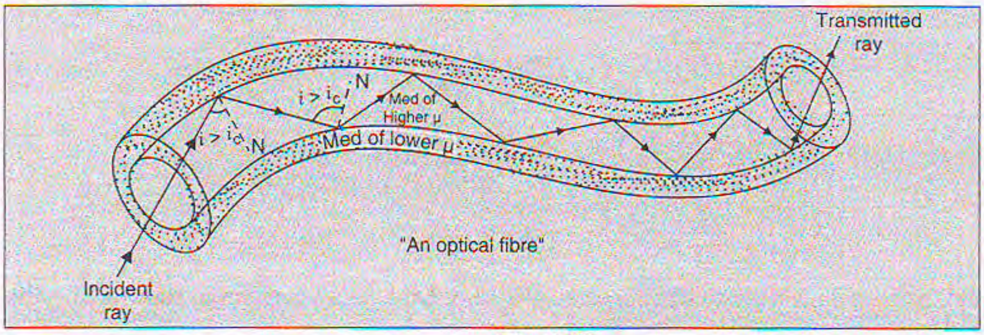

Fig. 4.49

(*v*) **Sparkling of diamond :** A piece of cut diamond sparkles. This sparkling is due to total internal reflection of light. We know that refractive index of diamond is most (${}_a\mu_d$ = 2.41) hence the value of critical angle for diamond air interface is least, i_c=25°. When a light ray from air enters into the piece of diamond at small angle of incidence it refracts even at smaller angle of refraction. This allows a larger value of angle of incidence at diamond air interface. Mostly this value incidence is more than the value of critical angle i_c = 25° and causes total internal reflection of the ray. This process continues and multiple internal reflections of light take place. All points where light ray reflects internally sparkle. Remember if a piece of diamond is put in a dark place for a number of days it stops sparkling due to continuous loss of light energy. (Fig. 4.50)

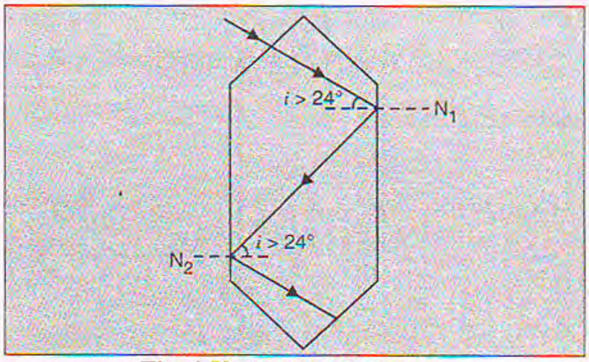

Fig. 4.50. Lusture of diamond.