THE DROWNING CHILD, LIFEGUARD AND SNELL'S LAW

Consider a rectangular swimming pool PQSR; see figure here. A lifeguard sitting at G outside the pool notices a child drowning at a point C. The guard wants to reach the

child in the shortest possible time. Let SR be the side of the pool between G and C. Should he/she take a straight line path GAC between G and C or GBC in which the path BC in water would be the shortest, or some other path GXC? The guard knows that his/her running speed v_1 on ground is higher than his/her swimming speed v_2 .

Suppose the guard enters water at X. Let $GX = l_1$ and $XC = l_2$. Then the time taken to reach from G to C would be

$$t = \frac{l_1}{v_1} + \frac{l_2}{v_2}$$

P Q L C R G M

To make this time minimum, one has to

differentiate it (with respect to the coordinate of X) and find the point X when *t* is a minimum. On doing all this algebra (which we skip here), we find that the guard should enter water at a point where Snell's law is satisfied. To understand this, draw a perpendicular LM to side SR at X. Let \angle GXM = *i* and \angle CXL = *r*. Then it can be seen that *t* is minimum when

$$\frac{\sin i}{\sin r} = \frac{v_1}{v_2}$$

In the case of light v_1/v_2 , the ratio of the velocity of light in vacuum to that in the medium, is the refractive index *n* of the medium.

In short, whether it is a wave or a particle or a human being, whenever two mediums and two velocities are involved, one must follow Snell's law if one wants to take the shortest time.

9.4 TOTAL INTERNAL REFLECTION

When light travels from an optically denser medium to a rarer medium at the interface, it is partly reflected back into the same medium and partly refracted to the second medium. This reflection is called the *internal reflection*.

When a ray of light enters from a denser medium to a rarer medium, it bends away from the normal, for example, the ray AO_1 B in Fig. 9.12. The incident ray AO_1 is partially reflected (O_1C) and partially transmitted (O_1B) or refracted, the angle of refraction (r) being larger than the angle of incidence (i). As the angle of incidence increases, so does the angle of refraction, till for the ray AO_3 , the angle of refraction is $\pi/2$. The refracted ray is bent so much away from the normal that it grazes the surface at the interface between the two media. This is shown by the ray AO_3 D in Fig. 9.12. If the angle of incidence is increased still further (e.g., the ray AO_4), refraction is not possible, and the incident ray is totally reflected.