Q- A ray of sunlight hits the ice on a frozen lake at a 56^0 angle of incident.

(a) At what angle does the refracted ray penetrate the water beneath the ice?

(b) What is the speed of light for the refracted beam in the water?

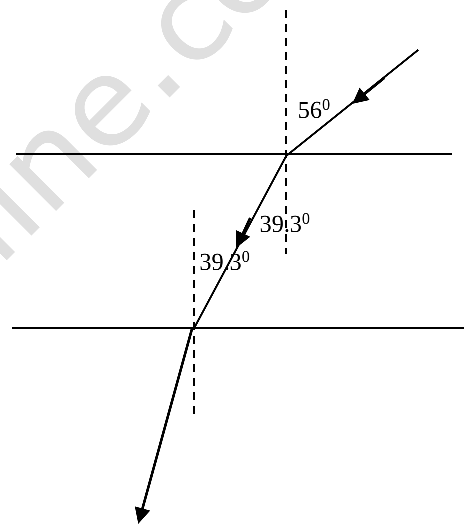
(Refractive index: Ice 1.039, Water 1.333)

(a) The relation between the angle of incidence (i) and angle of refraction (r) is given by Snell's law and according to that

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

Here μ is a constant and called the refractive index of second medium with respect to the first medium.

Refractive index of ice (with respect to vacuum or air) is 1.309 hence we have for the refraction at air ice interface we have



$$\frac{\sin 56}{\sin r} = 1.309$$

Gives $\sin r = \frac{\sin 56^0}{1.309} = \frac{0.829}{1.309} = 0.633$

So $r = \sin^{-1} 0.633 = 39.297^0$

Now as the two interfaces are parallel the normal at the two surfaces will be parallel and hence the angle of incidence at the ice water interface will also be 39.297^0.

The light at second interface is going from ice to the water hence hear we have to take refractive index of water with respect to ice which is given by

$${}_i\mu_w = \frac{\mu_w}{\mu_i} = \frac{1.333}{1.309} = 1.0183$$

Hence according to the Snell's law the angle of refraction (r') at ice water interface is given by

$$\frac{\sin 39.297}{\sin r'} = 1.0183$$

Gives $\sin r' = \frac{\sin 39.297}{1.0183} = 0.622$

Hence $r' = \sin^{-1} 0.622 = 38.43^0$

This is the required angle.

(b) The speed of light in a medium of refractive index μ is given by $c_m = \frac{c_0}{\mu}$

Where c_0 is the speed of light in free space (vacuum)

Hence speed of light in water will be

$$c_w = \frac{c_0}{\mu_w} = \frac{3*10^8}{1.333} = 2.2506*10^8 \text{ m/s}$$