

Q- A small ideal mirror of mass 10 mg is suspended by a light thread of length 10 cm. Find the angle through which the thread will be deflected when a short laser pulse of energy 15 J is shot on the mirror horizontally and normally to the surface of the mirror and reflected completely.

Solution: Momentum of a small pulse of laser P is given by

$$P = U/c$$

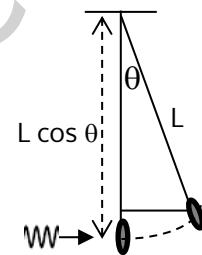
Here U is the energy of the pulse and c is the speed of light

If the pulse is reflected completely the momentum imparted to the mirror will be 2P and hence the velocity v of the mirror just after reflecting the pulse will be

$$v = \frac{2P}{m} = \frac{2U}{mc}$$

Kinetic energy acquired by the mirror will be

$$KE = \frac{1}{2} mv^2 = \frac{1}{2} m \left(\frac{2U}{mc}\right)^2 = \frac{2U^2}{mc^2}$$



If the maximum deflection of the mirror is θ then according to law of conservation of energy we get

$$\text{Loss in KE} = \text{gain in PE}$$

$$\text{Or } \frac{2U^2}{mc^2} = mgL (1 - \cos \theta) \quad (\text{L is the length of string})$$

$$\text{Or } \frac{2U^2}{mc^2} = mgL 2\sin^2\left(\frac{\theta}{2}\right)$$

$$\text{Or } \sin^2\left(\frac{\theta}{2}\right) = \frac{U^2}{m^2c^2gL} = mgL$$

if θ is very small and it is measured in radians we can approximate $\sin \theta = \theta$ and thus

$$\left(\frac{\theta}{2}\right)^2 = \frac{U^2}{m^2c^2gL}$$

$$\text{Or } \theta = \frac{2U}{mc\sqrt{gL}} = \frac{2*15}{10*10^{-6}*3*10^8\sqrt{9.8*0.1}}$$

$$\text{Or } \theta = \frac{30}{3*10^3\sqrt{9.8*0.10}} = 0.101 \text{ rad} = 0.579 \text{ deg}$$