

4. Monochromatic light of wavelength 632.8 nm is produced by a helium neon laser. The power emitted is 9.42 mW.

- Find the energy and momentum of each photon in the light beam.
- How many photons per second, on the average, arrive at a target irradiated by this beam? (Assume the beam to have uniform cross-section which is less than the target area), and
- How fast does a hydrogen atom have to travel in order to have the same momentum as that of the photon?

Sol. Given,

$$\text{Wavelength, } \lambda = 632.8 \text{ nm} = 632.8 \times 10^{-9} \text{ m}$$

$$\text{Frequency, } \nu = \frac{c}{\lambda} = \frac{3 \times 10^8}{632.8 \times 10^{-9}} = 4.74 \times 10^{14} \text{ Hz}$$

a. $E = h\nu$

$$= 6.63 \times 10^{-34} \times 4.74 \times 10^{14}$$

$$= 3.14 \times 10^{-19} \text{ J}$$

$$\text{Also, } p \text{ (momentum)} = \frac{h}{\lambda} = \frac{6.63 \times 10^{-34}}{632.8 \times 10^{-9}} = 1.05 \times 10^{-27} \text{ kg ms}^{-1}$$

b. Power emitted, $P = 9.42 \text{ mW} = 9.42 \times 10^{-3} \text{ W}$

$$P = nE$$

$$n = \frac{P}{E} = \frac{9.42 \times 10^{-3}}{3.14 \times 10^{-19}} = 3 \times 10^{16} \text{ photons/sec}$$

c. Velocity of hydrogen atom

$$= \frac{\text{Momentum 'p' of } H_2 \text{ atom}}{\text{Mass of } H_2 \text{ atom}}$$

$$\Rightarrow v = \frac{1.05 \times 10^{-27}}{1.673 \times 10^{-27}} = 0.63 \text{ ms}^{-1}$$