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

a. Find the energy and momentum of each photon in the light beam.
b. 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
c. How fast does a hydrogen atom have to travel in order to have the same momentum as that of the photon?

Sol. Given,

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

Frequency, $\nu = \frac{c}{\lambda} = \frac{3\times10^{8}}{632.8\times10^{-9}} = 4.74 \times 10^{14}Hz$

a. E = hν

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

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

Also, p (momentum) $= \frac{h}{\lambda} = \frac{6.63\times10^{-34}}{632.8\times10^{-9}} = 1.05 \times 10^{-27}kg\ ms^{-1}$

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

P = nE

$n = \frac{P}{E} = \frac{9.42\times10^{-3}}{3.14\times10^{-19}} = 3 \times 10^{16}photons/\sec$

c. Velocity of hydrogen atom

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

$\Rightarrow v = \frac{1.05\times10^{-27}}{1.673\times10^{-27}}$ = 0.63 ms^{-1}