

## Questions in Quantum Physics — Assignment

Name: Edward Van Welzen, Group No. EE-1, Date: 14/11/2020

(Submit your solutions to all four questions to your tutor in Week 12)

1. The visible intensity threshold of a night-vision device is  $(4.0 \times 10^{-11} \text{ W/m}^2)$  at the wavelength of  $(600 \text{ nm})$ . If the light with this intensity and wavelength enters an eye and the pupil is open to its maximum diameter of  $8.5 \text{ mm}$ , how many photons per second enter the eye? (25 Marks)

$$I = 4 \times 10^{-11}$$

$$\begin{aligned} \text{Surface Area} &= \pi r^2 \\ &= \pi \times \left(\frac{8.5 \times 10^{-3}}{2}\right)^2 \\ &= 5.6745017 \times 10^{-6} \text{ m}^2 \end{aligned}$$

$$\begin{aligned} \text{Energy} &= \frac{hc}{\lambda} = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{600 \times 10^{-9}} \\ &= 3.315 \times 10^{-19} \text{ J} \end{aligned}$$

$$\text{Power} = \text{Intensity} \times \text{Surface Area} \quad (25 \text{ Marks})$$

$$= 5.6745017 \times 10^{-6} \times 4 \times 10^{-11}$$

$$= 2.2698 \times 10^{-16} \text{ W}$$

$$\text{number of photons (s}^{-1}\text{)}$$

$$\Rightarrow \frac{2.2698 \times 10^{-16}}{3.315 \times 10^{-19}} = 684.7 \text{ s}^{-1}$$

~~2.2698~~ 684.7 photons per second

2. A  $0.6 \text{ MeV}$  photon is scattered by a free electron initially at rest. After scattering, the scattering angle of the scattered photon is  $90^\circ$ .

- (i) Determine the energy and the momentum of the scattered photon.  
 (ii) Determine the kinetic energy of the scattered electron.

(i) Compton Effect Equation:  $\rightarrow$  Scatter at  $90^\circ$  w.r.t. normal

$$\lambda' - \lambda_0 = \frac{h}{mc} (1 - \cos \theta) \quad p = \frac{h}{\lambda}$$

$$\lambda' = \frac{h}{mc} (1 - \cos 90^\circ) + \lambda_0$$

$$\theta = 90^\circ \quad \lambda_0 = \frac{hc}{E} = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{0.6 \times 10^6 \times 1.6 \times 10^{19}}$$

$$\lambda' = \frac{h}{mc} + \lambda_0 = 2.4263 \times 10^{-12} \text{ m}$$

$$\begin{aligned} \lambda' &= \frac{6.63 \times 10^{-34}}{9.11 \times 10^{-31} \times 3 \times 10^8} + 2.4263 \times 10^{-12} \\ &= 4.4978 \times 10^{-12} \end{aligned}$$

(25 marks)

$$p' = \frac{6.63 \times 10^{-34}}{4.4978 \times 10^{-12}}$$

$$= 1.474 \times 10^{-22} \text{ kg m s}^{-1}$$

$$E' = \frac{hc}{\lambda'}$$

$$= \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{4.4978 \times 10^{-12}}$$

$$= 4.42 \times 10^{-14} \text{ J}$$

$$= 276385 \text{ eV} = 0.276385 \text{ MeV}$$

(ii) Kinetic energy

$$= \text{Difference in energy} = 0.6 \text{ MeV} - 0.276385 \text{ MeV}$$

$$= 0.323615 \text{ MeV}$$

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**Wolfgang Guggemos**



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