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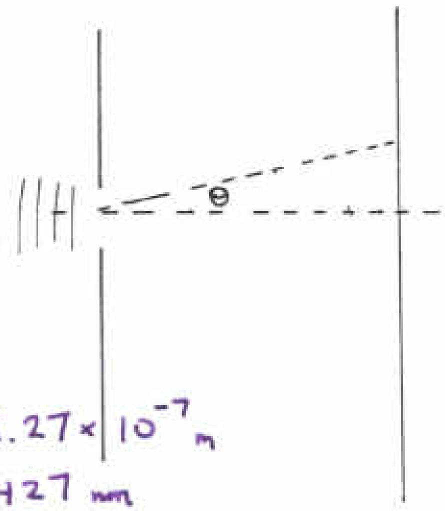
Phys 122 — Section 4
Quiz #6



1. A beam of monochromatic light is incident on a single slit of width 1.50×10^{-4} m. A diffraction pattern appears on a distant screen. It is found that the first dark fringe occurs at an angle of 0.163° away from the central maximum.

a) What is the wavelength of the incident light?

At the first dark fringe, $\sin\theta = (1)\,\lambda/_W$

Solve for λ:

$$\lambda = w \sin\theta = (1.50\times 10^{-4}\,\text{m})\sin(0.163^\circ) = 4.27\times 10^{-7}\,\text{m}$$

$$= 427\ \text{nm}$$

b) What is the frequency of this light?

$$f = \frac{c}{\lambda} = \frac{2.998\times 10^{8}\,\frac{\text{m}}{\text{s}}}{4.27\times 10^{-7}\,\text{m}} = 7.03\times 10^{14}\ \text{s}^{-1}$$

c) What is the momentum of a single photon of this light?

$$p = \frac{h}{\lambda} = \frac{6.63\times 10^{-34}\ \text{J}\cdot\text{s}}{4.27\times 10^{-7}\,\text{m}} = 1.55\times 10^{-27}\ \frac{\text{kg}\cdot\text{m}}{\text{s}}$$

2. Find the De Broglie wavelength of an electron which has a speed of $4.28 \times 10^5 \frac{\text{m}}{\text{s}}$.

Electron has momentum

$$p = mv = (9.11\times 10^{-31}\,\text{kg})(4.28\times 10^{5}\,\tfrac{\text{m}}{\text{s}}) = 3.90\times 10^{-25}\ \frac{\text{kg}\cdot\text{m}}{\text{s}}$$

So its wavelength is

$$\lambda = \frac{h}{p} = \frac{6.63\times 10^{-34}\ \text{J}\cdot\text{s}}{3.90\times 10^{-25}\ \frac{\text{kg}\cdot\text{m}}{\text{s}}} = 1.70\times 10^{-9}\ \text{m}$$

$$= 1.70\ \text{nm}$$

3. The He^+ ion has a series of emission lines with wavelengths given by

$$\frac{1}{\lambda} = (4.388 \times 10^7 \text{ m}^{-1}) \left(\frac{1}{3^2} - \frac{1}{n^2} \right)$$

for $n = 4, 5, 6, \ldots$.

a) Find the wavelengths for the first two "lines" in this series.

With $n=4$, $\frac{1}{\lambda} = (4.388 \times 10^7 \text{m}^{-1})(\frac{1}{9} - \frac{1}{16}) = 2.13 \times 10^6 \text{ m}^{-1} \rightarrow \lambda = 4.69 \times 10^{-7} \text{ m} = 469 \text{ nm}$

With $n=5$, $\frac{1}{\lambda} = (4.388 \times 10^7 \text{m}^{-1})(\frac{1}{9} - \frac{1}{25}) = 3.12 \times 10^6 \text{ m}^{-1} \rightarrow \lambda = 3.20 \times 10^{-7} \text{ m} = 320 \text{ nm}$

b) Find the photon energies for the lines in part (a). Express the answers in eV's (electron Volts).

For the $n=4$ photon,

$$E = hf = \frac{hc}{\lambda} = \frac{(6.63 \times 10^{-34} \text{ J.s})(2.998 \times 10^8 \frac{\text{m}}{\text{s}})}{4.69 \times 10^{-7} \text{ m}} = 4.24 \times 10^{-19} \text{ J}$$

$$= (4.24 \times 10^{-19} \text{ J})\left(\frac{1 \text{ eV}}{1.602 \times 10^{-19} \text{ J}}\right) = 2.64 \text{ eV}$$

For the $n=5$ photon,

$$E = hf = \frac{hc}{\lambda} = \frac{(6.63 \times 10^{-34} \text{ J.s})(2.998 \times 10^8 \frac{\text{m}}{\text{s}})}{3.20 \times 10^{-7} \text{ m}} = 6.20 \times 10^{-19} \text{ J}$$

$$= (6.20 \times 10^{-19} \text{ J})\left(\frac{1 \text{ eV}}{1.602 \times 10^{-19} \text{ J}}\right) = 3.87 \text{ eV}$$

You must show all your work!

$1 \text{ eV} = 1.602 \times 10^{-19} \text{ J}$ $\quad m_e = 9.11 \times 10^{-31} \text{ kg}$ $\quad h = 6.63 \times 10^{-34} \text{ J} \cdot \text{s}$

$c = 2.998 \times 10^8 \frac{\text{m}}{\text{s}}$ $\quad \frac{h}{m_e c} = 2.43 \times 10^{-12} \text{ m}$ $\quad k = 1.38 \times 10^{-23} \frac{\text{J}}{\text{K}}$

$\lambda f = c$ $\quad$ Dark fringe: $\sin\theta = m\frac{\lambda}{w}$ $\quad m = 1, 2, 3, \ldots$

$E = hf$ $\quad E_{\text{phot}} = hf = \text{KE}_{\text{max}} + W_0$ $\quad p = \frac{h}{\lambda}$ $\quad \lambda = \frac{h}{p}$ $\quad \lambda' - \lambda = \frac{h}{mc}(1 - \cos\theta)$

$(\Delta p_y)(\Delta y) \geq \frac{h}{2\pi}$ $\quad \text{PE} = mgh$ $\quad \text{PE} = \frac{1}{2}kx^2$ $\quad \text{KE} = \frac{1}{2}mv^2$ $\quad p = mv$