

Phys 243 Midterm Solutions

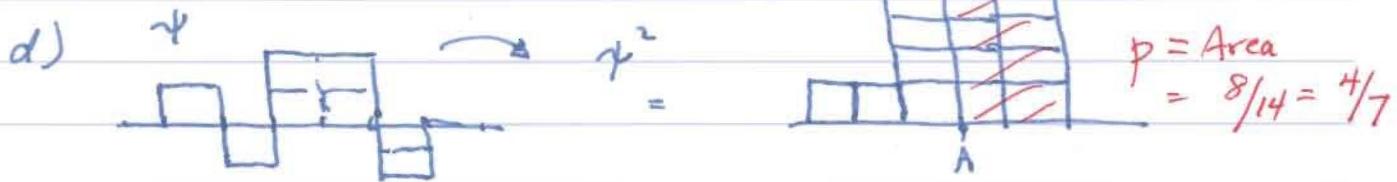


1) a) $\phi = \frac{h}{\lambda} \quad \therefore \lambda = \frac{h}{\phi} = \frac{6.63 \times 10^{-34} \text{ Js}}{1.28 \times 10^{-28} \text{ kg m/s}} = \underline{\underline{5.2 \times 10^{-6} \text{ m}}}$

b) $\Delta E = E_5 - E_2 = 13.6 \left(\frac{1}{4} - \frac{1}{25} \right) = 2.86 \text{ eV}$

c) $\lambda = \frac{c}{f} \quad f = \frac{E}{h} \quad \therefore \lambda = \frac{hc}{E} = \frac{1240 \text{ eV nm}}{2.86 \text{ eV}} = \underline{\underline{434 \text{ nm}}}$

This is blue (Hydrogen- γ in the Balmer spectrum!)



e) Use $K_{\max} = \frac{hc}{\lambda} - W_0 \quad hc = 1240 \text{ eV nm}$

$$\therefore 0.500 \text{ eV} = \left(\frac{1240}{425} \right) - W_0 \quad \therefore W_0 = \underline{\underline{2.42 \text{ eV}}}$$

2) a) Light shows both wave & particle properties.

1) Wave: interference, diffraction, polarization, ← EM theory "predicts it"

2) Particle: Photoelectric Effect and Compton Scattering!

No way to "reconcile" \Rightarrow instead develop understanding that quanta are neither wave/particle but exhibit wave-like and particle-like properties according to how you interact with them.

b) Use de Broglie wavelength $\lambda = \frac{h}{p}$ $p^2 = k = \frac{h^2}{2m\lambda^2}$

$$\therefore \lambda = \frac{h}{\sqrt{2mk}} \quad \text{Since the electron and proton are accelerated through the same potential } K_p = K_e$$

$$\therefore \lambda_e = \frac{h}{\sqrt{2mk_e}} \quad \lambda_p = \frac{h}{\sqrt{2mk_p}} \quad \therefore \frac{\lambda_e}{\lambda_p} = \frac{\sqrt{m_p}}{\sqrt{m_e}} \approx 43$$

Protons have a much smaller wavelength.

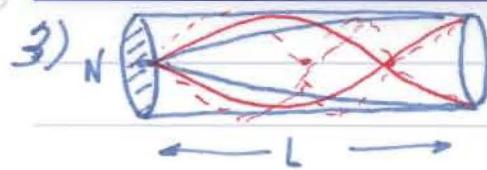
c) Use Planck Law $E = \frac{nhc}{\lambda}$

$$A = 1.0 \text{ cm}^2 = 10^{-4} \text{ m}^2 \quad E = (IA)\Delta t = (10 \text{ W})(10^{-4} \text{ m}^2)(5 \text{ s})$$

$$= \frac{5 \times 10^{-3} \text{ J}}{\lambda} = n \frac{hc}{\lambda} = n \frac{(1240 \text{ eV} \cdot \text{nm})}{600 \text{ nm}} = n 2.1 \text{ eV} = n(3.3 \times 10^{-19} \text{ J})$$

$$\therefore n = \frac{5 \times 10^{-3} \text{ J}}{3.3 \times 10^{-19} \text{ J}} = 1.5 \times 10^{16} \text{ photons} \quad \therefore \Delta L = n \hbar$$

$$= (1.5 \times 10^{16})(1.05 \times 10^{-34}) \\ = \underline{\underline{1.6 \times 10^{-18} \text{ kg m}^2/\text{s}}}$$



$$\left. \begin{array}{l} \lambda_1 = 4L \\ \lambda_3 = \frac{4}{3}L \\ \lambda_5 = \frac{4}{5}L \end{array} \right\} \quad \lambda_n = \frac{4L}{n}, \quad n=1, 3, 5, \dots$$

a)

b) $f = \frac{v}{\lambda} \quad \therefore f_n = n \frac{v}{4L}; \quad n=1, 3, 5, \dots \quad \therefore f_1 = \frac{v}{4L} > f_3 = \frac{3v}{4L}$

$\therefore f_1 = \frac{344 \text{ m/s}}{4(0.10 \text{ m})} = \underline{\underline{860 \text{ Hz}}}, \quad f_3 = \frac{3 \cdot 344 \text{ m/s}}{4(0.10 \text{ m})} = 3f_1 = \underline{\underline{2580 \text{ Hz}}}$

c)

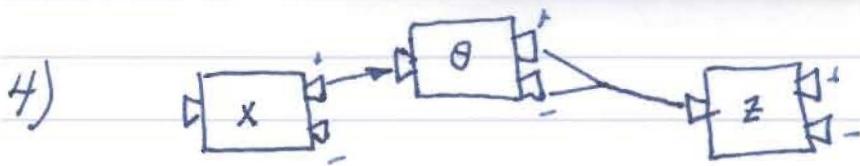


$\lambda = 2L$ is the maximum wavelength the quantum can have. $\hbar = 1 \text{ nm} \quad \therefore \lambda = 2 \text{ nm}$

Use $p = \frac{\hbar}{\lambda} \quad \therefore K = \frac{p^2}{2m} \Rightarrow K = \frac{(\frac{\hbar}{2L})^2}{2m} = \frac{\hbar^2}{8mL^2}$

The electron must have at least this K so cannot be at rest!

d) $K = \frac{\hbar^2}{8mL^2} = 6.0 \times 10^{-20} \text{ J} = 0.38 \text{ eV}$



a) you should expect $P = \frac{1}{2}$ for each of the Z-channels. The combination of outputs from the Θ device essentially makes this step "un-necessary" in the calculation. $\frac{1}{2}$ of the photons will emerge from each channel.

b) The -channel photon can be found from superposition of 2 paths : -++ or --+ (reading from $r \rightarrow L$)

$$\therefore \langle -z | \theta+ \rangle \langle +\theta | +x \rangle \text{ and } \langle -z | -\theta \rangle \langle -\theta | +x \rangle$$

$$\therefore \text{amp/rach} = ([0, 1] \cdot \begin{bmatrix} \cos \frac{1}{2}\theta \\ \sin \frac{1}{2}\theta \end{bmatrix}) ([\cos \frac{1}{2}\theta, \sin \frac{1}{2}\theta] \begin{bmatrix} \sqrt{\frac{1}{2}} \\ \sqrt{\frac{1}{2}} \end{bmatrix}) + ([0, 1] \begin{bmatrix} -\sin \frac{1}{2}\theta \\ \cos \frac{1}{2}\theta \end{bmatrix}) (\begin{bmatrix} -\sin \frac{1}{2}\theta, \cos \frac{1}{2}\theta \end{bmatrix} \begin{bmatrix} \sqrt{\frac{1}{2}} \\ \sqrt{\frac{1}{2}} \end{bmatrix})$$

$$= \frac{1}{\sqrt{2}} (\sin \frac{1}{2}\theta) \cdot (\cos \frac{1}{2}\theta + \sin \frac{1}{2}\theta) + \frac{1}{\sqrt{2}} (\cos \frac{1}{2}\theta) (-\sin \frac{1}{2}\theta + \cos \frac{1}{2}\theta) = \frac{1}{\sqrt{2}} (\sin^2 \frac{1}{2}\theta + \cos^2 \frac{1}{2}\theta) = \frac{1}{\sqrt{2}}$$

$$\therefore P = \left(\frac{1}{\sqrt{2}}\right)^2 = \frac{1}{2}$$

c) If you block the $-\theta$ channel then you only have the upper prob. amp/rach

$$= \frac{1}{\sqrt{2}} \sin \frac{1}{2}\theta (\cos \frac{1}{2}\theta + \sin \frac{1}{2}\theta) \quad \therefore P = \frac{1}{2} (\sin \frac{1}{2}\theta)^2 (\cos \frac{1}{2}\theta + \sin \frac{1}{2}\theta)^2$$

$$P = \frac{1}{2} \sin^2 \frac{1}{2}\theta (\cos^2 \frac{1}{2}\theta + \sin^2 \frac{1}{2}\theta + 2 \sin \frac{1}{2}\theta \cos \frac{1}{2}\theta) = \frac{1}{2} \sin^2 \frac{1}{2}\theta (1 + \sin \theta)$$

For a large range of θ this will work out $> \frac{1}{2}$ (if try $\theta = \frac{3}{4}\pi$ for example $\Rightarrow P = 0.729$)

This happens because there are no "cancellation" effects from the other paths now (similar to cutting out the effects of wave interference)