



Department of Physics
University of California San Diego

Modern Physics (2D)
Prof. V. Sharma
Quiz # 2 (Jan 24)

Problem 1 : Calculating Planck's Constant [10 pts]

When light of wavelength 450 nm shines on potassium, photoelectrons with stopping voltage of 0.52V are emitted. If the wavelength of the incident light is changed to 300 nm, the stopping voltage is 1.90V. Using *only* these numbers together with the values of speed of light and the electron charge, (a) find the work function of potassium, (b) compute a value for the Planck's constant.

Problem 2: Xtreme Pool ! [10 pts]

In a Compton scattering event, a 0.10 nm photon strikes a free electron in a head-on collision and knocks it into the forward direction. The rebounding photon recoils directly backwards. (a) Sketch this process (b) Write down the conservation of energy and momentum equations for this scattering (c) Determine the kinetic energy of the electron.



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Some Relevant Formulae, Constants and Identities

$$p = \gamma m u$$

$$E = KE + mc^2 = \gamma mc^2$$

$$\text{Centripetal Acc.} = \frac{u^2}{r}$$

$$E^2 = (pc)^2 + (mc^2)^2$$

$$E = hf = \Phi + KE_{\max}$$

$$n\lambda = 2d \sin \theta$$

$$\Delta\lambda = \left(\frac{h}{m_e c} \right) (1 - \cos \theta) = (0.0243 \text{ \AA}) (1 - \cos \theta)$$

$$\text{Coulomb's Constant } k = 8.988 \times 10^9 \text{ N.m}^2/\text{C}^2$$

$$\text{Planck's Constant } h = 6.626 \times 10^{-34} \text{ J.s} = 4.136 \times 10^{-15} \text{ eV.s}$$

$$1 \text{ eV} = 1.60 \times 10^{-19} \text{ J}$$

$$\text{Electron Mass} = 9.1 \times 10^{-31} \text{ kg} = 0.511 \text{ MeV}$$

$$\text{Speed of Light in Vacuum } c = 2.998 \times 10^8 \text{ m/s}$$

$$\text{Electron Charge} = 1.602 \times 10^{-19} \text{ C}$$

Pl. write you answer in the Blue Book in indelible ink. Make sure your code number is prominently displayed on each page.

Physics 2D Quiz 3 Solns

$$\underline{1a)} \quad eV_1 = hf_1 - \phi, \text{ where } V_1 = 0.52\text{V}, f_1 = \frac{c}{450\text{nm}}$$

$$eV_2 = hf_2 - \phi, \text{ where } V_2 = 1.9\text{V}, f_2 = \frac{c}{300\text{nm}}.$$

Now, we do not know what h is, so we need to eliminate it to find ϕ .

Multiply the 2nd eqn. by $\frac{f_1}{f_2}$ and subtract from the 1st to get

$$eV_1 - e\frac{f_1}{f_2}V_2 = -\phi + \frac{f_1}{f_2}\phi$$

$$\Rightarrow \phi = \frac{e(V_1 - \frac{f_1}{f_2}V_2)}{\left(\frac{f_1}{f_2} - 1\right)}. \quad \text{But } \frac{f_1}{f_2} = \frac{\lambda_2}{\lambda_1}, \text{ so}$$

$$\phi = \frac{e\left(V_1 - \frac{\lambda_2}{\lambda_1}V_2\right)}{\left(\frac{\lambda_2}{\lambda_1} - 1\right)} = e \frac{\left(0.52\text{V} - \frac{300}{450}(1.9\text{V})\right)}{\left(\frac{300}{450} - 1\right)}$$

$$= e(2.24\text{V}) = \boxed{2.24\text{eV}}$$

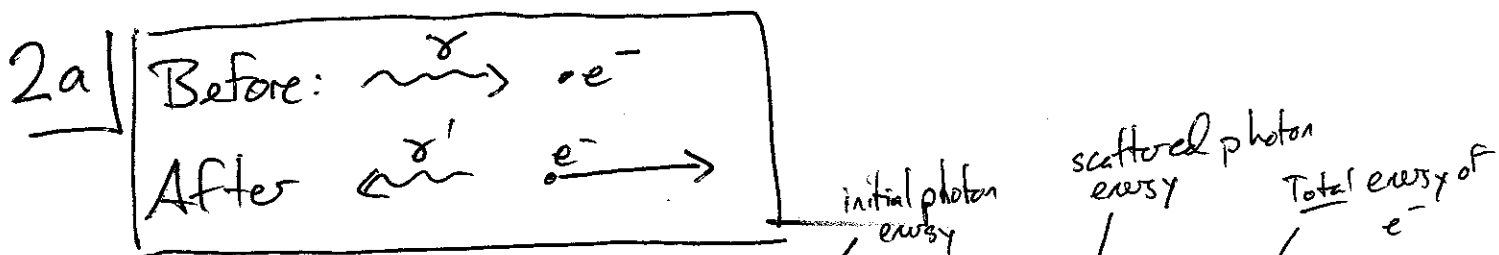
$$b) e(V_2 - V_1) = h(f_2 - f_1)$$

$$\text{So } h = \frac{e(V_2 - V_1)}{f_2 - f_1} = \frac{e(V_2 - V_1)}{c\left(\frac{1}{300\text{nm}} - \frac{1}{450\text{nm}}\right)}$$

$$\Rightarrow \boxed{h = 6.624 \times 10^{-34} \text{ J}\cdot\text{s}}$$

or use ϕ from part (a) to get

$$h = \frac{eV_1 + \phi}{f_1} = 6.624 \times 10^{-34} \text{ J}\cdot\text{s}$$



$$b) E_i = E_\gamma + m_e c^2 \Rightarrow \boxed{E_\gamma + m_e c^2 = E_{\gamma'} + E_{e^-}}$$

$E_f = E_{\gamma'} + E_{e^-}$
 \uparrow Total electron energy

$$P_i = P_\gamma$$

$$P_f = P_e - P_{\gamma'}$$

$$\Rightarrow \boxed{P_\gamma = P_e - P_{\gamma'}}$$

\uparrow initial photon mom. \uparrow electron mom. \uparrow final photon mom.

$$c) \quad KE = E_{\gamma} - E_{\gamma'}$$

$$\text{We know } E_{\gamma} = \frac{hc}{0.10 \text{ nm}}$$

$$\text{To get } E_{\gamma'}, \text{ use } \lambda' = \lambda + \frac{h}{m_e c} (1 - \cos \theta)$$

$$= \lambda + \frac{2h}{m_e c} = 0.10 \text{ nm} + 2(0.0243 \text{ \AA}) \\ = 1.0486 \text{ \AA}$$

$$\text{So } E_{\gamma'} = \frac{hc}{0.10486 \text{ nm}}$$

$$E_{\gamma} - E_{\gamma'} = \boxed{575 \text{ eV} = 9.20 \times 10^{-17} \text{ J}}$$