PHYS 2D
PROBLEM SESSION

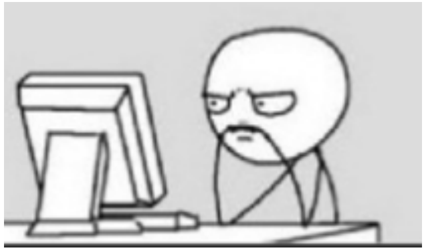
2012/4/26

2.12

- Solution for b is incorrect

Q: e^- with speed 0.75c, find speed of proton with 1. same E_k, 2. same momentum

- e^-: $\gamma_e=1.512$, $E_{ke}=(\gamma_e-1)m_ec^2=0.262MeV$, $p_e=\gamma_e m_e v_e=0.579MeV/c$
- proton:
  - 1. $E_{kp}=(\gamma_p-1)m_pc^2=E_{ke}=0.262MeV$, $\gamma_p=0.262/931.5+1=1.000281$, $v_p=0.0237c$
  - 2. $p_p=\gamma'_p m_p v'_p=p_e=0.579MeV/c$, $v'_p\gamma'_p=v'_p/(1-(v'_p/c)^2)^{1/2}=c*0.579/931.5=a$ $v'^2_p=a^2c^2/(1+a^2)$, $v'_p=6.216*10^{-4}c$
- Solution just used γ_p from 1 for γ'_p (wrong)



3.14

Q: Shine 350nm light on potassium (φ=2.24eV), find K_e & cutoff λ

- $E_{photon}=\varphi+K_e$
- $E_{photon}=hc/\lambda=6.626*10^{-34}*3*10^{8}/(350*10^{-9})J$
  $=5.68*10^{-19}J=3.55eV$
- $K_e=3.55-2.24=1.31eV$
- Cutoff λ : E_{photon} is now a variable
- Cutoff happens at $K_e=0$
- $E_{photon}=\varphi=hc/\lambda=2.24eV$
- λ=555nm

3.14

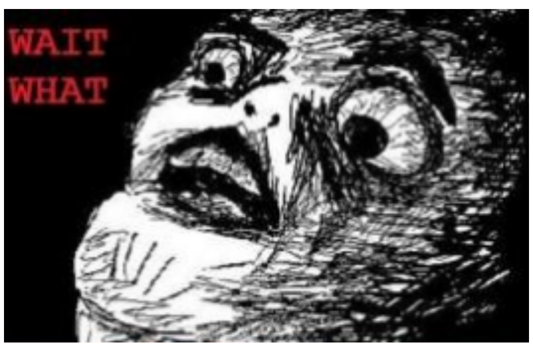
- Solution has errors in formula

$$K = hf - \phi = \frac{hc}{\lambda - \phi}$$

$$\phi = \frac{hc}{\lambda - K}$$

$$K = hf - \phi = \frac{hc}{\lambda} - \phi$$

$$\phi = \frac{hc}{\lambda} - K$$



3.24

Q: 0.2nm X-ray scattered by e^- at 90°, find Δλ & K_e

- Compton formula: $\lambda' - \lambda_0 = \frac{h}{m_e c}(1-\cos\theta)$

- cos(90°)=0
- $\Delta\lambda = h/m_e c = 0.00243\text{nm} > 0$
- $\lambda' > \lambda_0$
- $E_\lambda = E_{\lambda'} + K_e$
- $K_e = hc/\lambda_0 - hc/\lambda' = 1.19*10^{-14}\text{J} = 74.6\text{eV}$

3.26

Q: 0.04nm X-ray scattered at θ, find λ' & K_e

- $\lambda' - \lambda_0 = \frac{h}{m_e c}(1 - \cos\theta)$

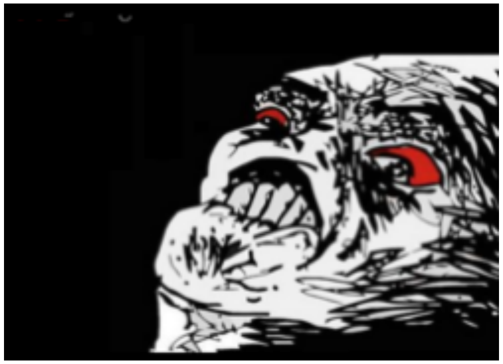
- $h/m_e c = 0.00243$nm
- $K_e = hc/\lambda_0 - hc/\lambda'$

Q: Which θ produces largest K_e?

- 180°
- Largest λ', highest e^- momentum

3.26

- More errors



$$K_e hc\left(\frac{1}{\lambda_0}-\frac{1}{\lambda'}\right)$$

$$K_e = hc\left(\frac{1}{\lambda_0}-\frac{1}{\lambda'}\right)$$

$$K_e = \frac{\left(6.63\times10^{-34}\text{ J s}\right)\left(3\times10^{8}\text{ m/s}\right)}{\frac{1}{0.04\times10^{-9}}-\frac{1}{4.03\times10^{-11}}}$$

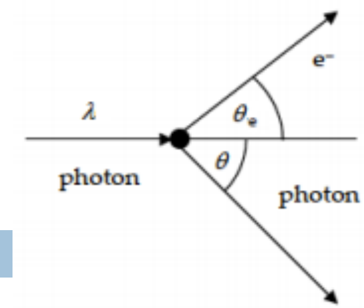
$$K_e = \left(6.63\times10^{-34}\text{ J s}\right)\left(3\times10^{8}\text{ m/s}\right)\left(\frac{1}{0.04\times10^{-9}}-\frac{1}{4.03\times10^{-11}}\right)$$

3.31

Q: 0.1 MeV photon Compton scattered at 60°, find $E_{\lambda'}$, K_e & recoil angle of e^-

- $\Delta\lambda = h/mc(1-0.5) = 0.00121\text{nm}$
- $\lambda = hc/E_\lambda = hc/0.1\text{MeV} = 0.0124\text{nm}$
- $\lambda' = 0.01361\text{nm}$
- $E_{\lambda'} = hc/\lambda' = 0.0911\text{MeV}$
- $K_e = E_\lambda - E_{\lambda'} = 8.89\text{KeV}$
- For the angle, need momentum conservation

3.31



- Momentum conservation in x (direction of incoming photon)

  photon: $E=pc=hc/\lambda$, $p=h/\lambda$

  $p_{before,x}=h/\lambda=p_{after,x}=\cos 60^\circ h/\lambda' + \gamma m_e v \cos\theta_e$
- Momentum conservation in y

  $p_{before,y}=0=p_{after,y}=-\sin 60^\circ h/\lambda' + \gamma m_e v \sin\theta_e$
- $\gamma m_e v \sin\theta_e / \gamma m_e v \cos\theta_e$

  $=(\sin 60^\circ h/\lambda')/(h/\lambda - \cos 60^\circ h/\lambda')$
- $\tan\theta_e=1.451$, $\theta_e=55.4^\circ$

Example

- Calculate the binding energy in MeV per nucleon in the isotope carbon-12, ${}^{12}_{6}C$. The mass of a proton is 1.007276u and the mass of a neutron is 1.008665u where 1 u = 929.494 MeV/c^2.

$$\Delta m = 6m_p + 6m_n - m_C = [6(1.007\,276) + 6(1.008\,665) - 12]\ \text{u} = 0.095\,646\ \text{u}$$

$$\Delta E = (931.49\ \text{MeV/u})(0.095\,646\ \text{u}) = 89.09\ \text{MeV}$$

$$\text{Therefore the energy per nucleon } = \frac{89.09\ \text{MeV}}{12} = 7.42\ \text{MeV}$$

Formulas you might need

- E=pc, E=hf=hc/λ (photon)
- $E^2 = (pc)^2 + (mc^2)^2$ (particle)
- $\sum_i E_i^{before} = \sum_i E_i^{after}$, $\sum_i p_i^{before} = \sum_i p_i^{after}$ (note: p is a vector)
- p=γmu
- $E=K+mc^2=\gamma mc^2$
- Compton: $\lambda' - \lambda_0 = \frac{h}{m_e c}(1-\cos\theta)$
- Photoelectric: $E_{photon}=\varphi+K_e$