Name____

Physics 111 Quiz #6, March 4, 2022

Please show all work, thoughts and/or reasoning in order to receive partial credit. The quiz is worth 10 points total.

I affirm that I have carried out my academic endeavors with full academic honesty.

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1. A proton is accelerated from rest to a speed of $v = 0.6c$. Through what potential difference was it accelerated to reach this speed?

$$W = -q\Delta V = \Delta K = K_f = (\gamma - 1)mc^2 \rightarrow \Delta V = \frac{(\gamma-1)mc^2}{-e} = \frac{(1.25-1)\left(937\frac{MeV}{c^2}\right)c^2}{-e} = -234.3MV$$

$$\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}} = \frac{1}{\sqrt{1-\frac{(0.6c)^2}{c^2}}} = 1.25$$

2. What is the momentum of the accelerated proton at this speed?

$$p = \gamma mv = 1.25 \times 937\frac{MeV}{c^2} \times 0.6c = 702.8\frac{MeV}{c} = 3.8 \times 10^{-19}\frac{kgm}{s}$$

3. Suppose that green light ($\lambda_{green} = 545nm$) was incident onto a cesium metal surface ($\phi = 2.1eV$) with an intensity of $S = 1\frac{W}{m^2}$. What is the speed of an ejected electron from the cesium surface?

$$K = \frac{hc}{\lambda_{green}} - \phi = \left[\frac{6.63\times10^{-34}Js\times3\times10^8\frac{m}{s}}{545\times10^{-9}m}\right] \times \frac{1eV}{1.6\times10^{-19}J} - 2.1eV = 2.28eV - 2.1eV = 0.18eV$$

$$K = \frac{1}{2}mv^2 \rightarrow v = \sqrt{\frac{2K}{m}} = \sqrt{\frac{2\times0.18eV}{511000\frac{eV}{c^2}}} = 0.00084c = 2.5 \times 10^5\frac{m}{s}$$

4. In the last problem, green light ejected an electron from the cesium surface. However, shining red light ($\lambda_{red} = 633nm$) onto the same cesium surface, electrons will not be ejected. This is because, according to the photon theory of light, the energy of the red photons of light is lower than the binding energy of the outer valance electron to the cesium nucleus. Suppose that you are not entirely convinced that the photon theory of light is correct. How long would you have to wait to see electrons from red light incident on the cesium surface? To see how long you need to get the red light to interact with the outer valance electron in the $3s$-orbital. This defines the size of the atom to be $r_{Cs} = 343 \times 10^{-12}m.$

$$S = \frac{E}{tA} \rightarrow t = \frac{E}{SA} = \frac{3.14\times10^{-19}J}{1\frac{J}{sm^2}\times\pi(343\times10^{-12}m)^2} = 0.85s$$

$$E = \frac{hc}{\lambda_{red}} = \frac{6.63\times10^{-34}Js\times3\times10^8\frac{m}{s}}{633\times10^{-9}m} = 3.14 \times 10^{-19}J$$

If the wave theory were correct, I'd have to wait about one second to see the phtotocurrent. However, I could wait a lifetime and never see any current, since red light will not eject electrons. In fact, if the light has the correct energy (greater than the binding energy) they electrons are ejected in fractions of a nano-second, or essentially immediately.

5. X-rays with energy $74.969keV$ are incident on stationary electrons in a block of insulating material. If the scattered x-rays have an energy of $72.708keV$, at what angle was the x-ray detector placed with respect to the incident beam direction?

$$\frac{1}{E'} = \frac{1}{E} + \frac{(1-\cos\phi)}{E_{rest}} \rightarrow \cos\phi = 1 - E_{rest}\left(\frac{1}{E'} - \frac{1}{E}\right) = 1 - 511\frac{keV}{c^2}\left(\frac{1}{72.708keV} - \frac{1}{74.969keV}\right)$$

$$\cos\phi = 0.7880 \rightarrow \phi = 38^0$$