Physics 111 Homework Solutions Collected on Monday 11/10

Wednesday, November 5, 2014

Chapter 24

Questions

24.2 In a photoelectric experiment the intensity refers to the number of photons incident on the metal surface per second. Let a beam of green light with intensity I be incident on the surface and note that it produces a photocurrent. If we switch to blue light of the *same intensity I*, the energy of the individual photons is greater and thus the maximum kinetic energy of the ejected photoelectrons is greater. The intensity is a constant, which is the total energy of the photons in the beam of light. The total energy is a product of the energy of each photon multiplied by the total number of photons. If the energy of each individual photon increases then the number of photons in the beam decreases since we want the total energy of the beam (which is proportional to the intensity) to remain constant. Since the number of photons decreases the number of photoelectrons decreases and the photocurrent decreases.

24.4 If for a particular wavelength of green light we find a stopping potential of −1.5V, this allows us to determine the work function φ, or the minimum energy needed to eject a photoelectron. Now, if we switch to a blue light the wavelength is shorter than that of green light and the maximum kinetic energy of the ejected photoelectrons will thus be greater using blue light as opposed to green light.

Multiple-Choice

24.2 B
24.3 C
24.4 D
24.6 C

Problems

24.8 Photoelectric effect in cesium

We are given the work function for cesium is $\phi = 2.9\ eV = 4.64x10^{-19}\ J$.

a. The maximum wavelength corresponds to the minimum frequency. Therefore, $KE_{\min} = hf_{\min} - \phi = 0$ which gives $f_{\min} = \dfrac{\phi}{h} = \dfrac{4.64\times10^{-19}\,J}{6.63\times10^{-34}\,Js} = 7.0\times10^{14}\,s^{-1}$. From $c = f_{\min}\lambda_{\max} \rightarrow \lambda_{\max} = \dfrac{c}{f_{\min}} = \dfrac{3\times10^{8}\,\frac{m}{s}}{7.0\times10^{14}\,s^{-1}} = 4.28\times10^{-7}\,m = 428nm$.

b. If *400nm* photons are used, their energy is given by

$$E=\frac{hc}{\lambda}=\frac{6.63\times10^{-34}Js\times3\times10^{8}\,\frac{m}{s}}{400\times10^{-9}m}=4.97\times10^{-19}J\times\frac{1eV}{1.6\times10^{-19}J}=3.11eV\,.$$

Therefore the maximum kinetic energy is given as

$$KE_{\max}=hf-\phi=3.11eV-2.9eV=0.21eV\times\frac{1.6\times10^{-19}J}{1eV}=3.33\times10^{-20}J\,.$$

c. A *1 W* beam of photons corresponds to *1 J of photons incident per second*. In *1 J* of photons there are $\frac{1J}{4.97\times10^{-19}\,\frac{J}{photon}}=2.01\times10^{18}$ photons. If the photo ejection of an electron is 100% efficient, then for each photon lost, one electron is produced. Thus the photocurrent is the amount of charge produced each second, where *1* electron has $1.6x10^{-19}$ *C* of charge. This corresponds to a total charge of $Q=2.01\times10^{18}\times1.6\times10^{-19}C=0.322C$ of charge in *1 second*. Therefore the photocurrent is *0.322 A = 322 mA*.

d. If green photons are used with a wavelength of *500 nm*, this corresponds to an energy of

$$E=\frac{hc}{\lambda}=\frac{6.63\times10^{-34}Js\times3\times10^{8}\,\frac{m}{s}}{500\times10^{-9}m}=3.98\times10^{-19}J\times\frac{1eV}{1.6\times10^{-19}J}=2.49eV\,.$$

The maximum *f* that will allow for photo ejection of electrons is the one where the electrons are ejected with a maximum kinetic energy equal to zero. Therefore $KE_{\min}=hf_{\min}-\phi=0$, and solving for ϕ we obtain $hf_{\min}=\phi=2.49eV$.

24.9 The maximum KE is given by the product of the stopping potential (0.82V) and the electron's charge (e^-). Thus the maximum $KE=eV_{stop}=0.82eV$. This is equal to the energy of the photons incident minus the work function (the minimum energy needed to eject a photoelectron). In symbols,

$$KE_{\max}=hf-\phi=\frac{hc}{\lambda}-\phi$$

$$\rightarrow 0.82eV=\left(\frac{6.63\times10^{-34}Js\times3\times10^{8}\,\frac{m}{s}}{400\times10^{-9}m}\right)\times\frac{1eV}{1.6\times10^{-19}J}-\phi\rightarrow\phi=2.29eV$$

24.10 A photoelectric effect experiment

a. The maximum kinetic energy is given by

$$KE_{\max}=hf-\phi=\frac{hc}{\lambda}-\phi$$

$$KE_{\max}=\left(\frac{6.63\times10^{-34}Js\times3\times10^{8}\,\frac{m}{s}}{410\times10^{-9}m}\right)\times\frac{1eV}{1.6\times10^{-19}J}-2.28eV$$

$$KE_{\max}=3.03eV-2.28eV=0.75eV$$

In order to calculate the speed, we use the expression for the relativistic kinetic energy. We have

$$KE = 0.75eV = (\gamma - 1)m_e c^2 = (\gamma - 1)0.511MeV$$

$$\gamma = 1 + \frac{0.75eV}{0.511\times10^6 eV} = 1 + 0000\,015 = 1.0000\,015$$

and the speed is therefore $\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}} \rightarrow v^2 = 2.94\times10^{-6}c^2 \rightarrow v = 0.0017c$

b. Based on the speed calculated in *part a*, the electron is not relativistic.

c. The minimum frequency corresponds to an electron ejected with a kinetic energy equal to zero. Therefore, $KE_{\min} = hf_{\min} - \phi = 0$ which gives

$$f_{\min} = \frac{\phi}{h} = \frac{2.28eV \times \frac{1.6\times10^{-19}J}{1eV}}{6.63\times10^{-34}Js} = 5.5\times10^{14}s^{-1}.$$

d. The minimum frequency corresponds to the maximum wavelength. Therefore we have $c = f_{\min}\lambda_{\max} \rightarrow \lambda_{\max} = \frac{c}{f_{\min}} = \frac{3\times10^8 \frac{m}{s}}{5.5\times10^{14}s^{-1}} = 5.45\times10^{-7}m = 545nm$.

e. For *700nm* photons we have the maximum kinetic energy given as

$$KE_{\max} = hf - \phi = \frac{hc}{\lambda} - \phi$$

$$KE_{\max} = \left(\frac{6.63\times10^{-34}Js \times 3\times10^8 \frac{m}{s}}{700\times10^{-9}m}\right) \times \frac{1eV}{1.6\times10^{-19}J} - 2.28eV$$

$$KE_{\max} = 1.78eV - 2.28eV = -0.50eV$$

Or, we have that no photoelectrons are produced. In addition we know that the maximum wavelength for photo production is 545nm, and we are well beyond this, so no photocurrent would be produced.

2.12 X-rays on a foil target

a. The energy is given by $E = \frac{hc}{\lambda} = \frac{(6.63\times10^{-34}Js)(3\times10^8 \frac{m}{s})}{0.012\times10^{-9}m} = 1.66\times10^{-14}J = 0.104MeV$.

b. The scattered wavelength is given by

$$\lambda_f - \lambda_i = \frac{h}{mc}(1-\cos\phi) = \frac{2h}{mc} = \frac{2(6.63\times10^{-34}Js)}{(9.11\times10^{-31}kg)(3\times10^8 \frac{m}{s})} = 4.86\times10^{-12}m.$$ Thus,

$\lambda_f = 4.86\times10^{-12}m + 1.2\times10^{-11}m = 1.686\times10^{-11}m$. The energy is given by the formula in part a, and is $1.18\text{x}10^{-14}$ J = 0.0741 MeV.

c. The energy given to the foil is

$$\Delta E_{foil} = E_{incident} = E_{backscattered} = 0.104MeV - 0.0741MeV = 0.03MeV = 30keV.$$

Thursday, November 6, 2014
Chapter 24
Questions
- none

Multiple-Choice
- none

Problems
- none