PH1130 **In-class problems** **9/18/07**

Prob. 1 A certain material is illuminated with light of wavelength 450 nm, and a certain stopping potential V_s is measured. When light with half this wavelength strikes the same material, the stopping potential is observed to triple. From this information, determine the work function of the material in units of eV?

$$(1) \quad eV_s = h\nu - W$$
$$(2) \quad 3eV_s = 2h\nu - W$$

multiply eq (1) by 3, subtract eq's

$$0 = h\nu - 2W$$

$$\therefore W = \frac{1}{2}h\nu = \frac{1}{2}\frac{hc}{\lambda} = \frac{1240 \text{ eV}\cdot\text{nm}}{2(450 \text{ nm})} = \boxed{1.38 \text{ eV}}$$

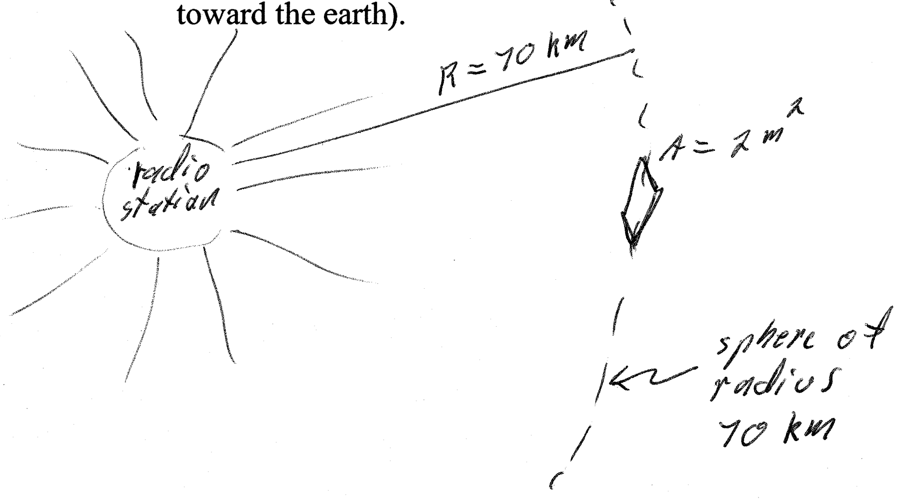
Prob. 2 A Boston radio station operates at a frequency of 1.03 MHz. How many photons per second is it emitting if its power output is 50 kW?

$$h\nu = (6.63\cdot10^{-34})(1.03\cdot10^{6}) = 6.83\cdot10^{-28} \text{ J}$$

$$P = \eta\cdot h\nu \quad \text{where} \quad \eta \equiv \frac{\#\text{ photons}}{\text{sec}}$$

$$\eta = \frac{P}{h\nu} = \frac{5\cdot10^{4} \text{ W}}{6.83\cdot10^{-28} \text{ J}} = \boxed{7.3\cdot10^{31} \ \frac{\text{photons}}{\text{s}}}$$

Prob. 3 You are listening to the radio station mentioned in prob. 2, and your radio antenna in Worcester (70 km from Boston) has an effective area of about 2 square meters. How many photons per second are you detecting, assuming that your antenna is perfectly effective over those 2 m^2, and that the radio station emits photons equally in all directions (including down toward the earth).



$$\frac{P_{received}}{P_{transmitted}} = \frac{2 \text{ m}^2}{4\pi(70\cdot10^{3} \text{ m})^2} = 3.25\cdot10^{-11}$$

so rate of photons detected is

$$\eta_{det} = (7.3\cdot10^{31})(3.25\cdot10^{-11}) = \boxed{2.37\cdot10^{21} \ \frac{\text{photons}}{\text{s}}}$$

Prob. 4 A photon of wavelength 0.005 nm scatters off an electron, which is initially at rest. If the photon changes its direction by 180°,

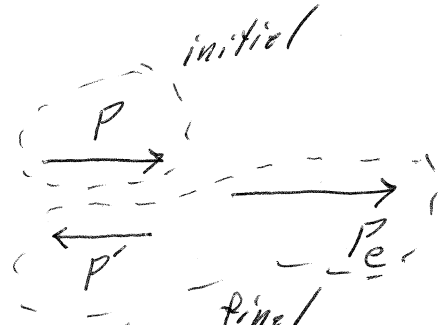
a) What is the wavelength of the scattered photon?

$$\lambda' = \lambda + \lambda_c (1 - \cos\theta)$$

if $\theta = 180°$, $1 - \cos\theta = 2$

$$\lambda' = \lambda + 2\lambda_c = .005 + (.00243)^{\times 2} = \boxed{.00986 \text{ nm}}$$

b) What is the momentum of the electron after the interaction?



For photon, $p = \frac{E}{c} = \frac{h\nu}{c} = \frac{h}{\lambda}$

$p' = \frac{h}{\lambda'}$ (magnitude)

$p = P_e - p'$ cons. momentum in x direction

$$P_e = p + p' = \frac{h}{\lambda} + \frac{h}{\lambda'} = 6.63 \cdot 10^{-34} \left[\frac{1}{5 \cdot 10^{-12} \text{ m}} + \frac{1}{9.86 \cdot 10^{-12} \text{ m}} \right]$$

$$\boxed{P_e = 2.0 \cdot 10^{-22} \ \frac{\text{kg} \cdot \text{m}}{\text{s}}}$$

c) What is the energy of the electron after the interaction?

Cons. energy: $h\nu = h\nu' + E_K$

$$E_K = h\nu - h\nu' = hc\left(\frac{1}{\lambda} - \frac{1}{\lambda'}\right) = 1240 \text{ eV} \cdot \text{nm} \times \left(\frac{1}{.005 \text{ nm}} - \frac{1}{.00986 \text{ nm}}\right)$$

$$\boxed{E_K = 1.22 \cdot 10^{5} \text{ eV}} = 1.95 \cdot 10^{-14} \text{ J}$$

Note: rest energy $E_0 = m_e c^2 = 511$ keV

so need relativity here. $E_K \neq \frac{P_e^2}{2m_e}$