Homework 4 Solutions

3-9 Use $E = \frac{hc}{\lambda}$ or $\lambda = \frac{hc}{E}$ (where $hc = 1\,240$ eV nm) and the results of Problem 3-7 to find

(a) $\lambda = 600$ nm

(b) $\lambda = 0.03$ m

(c) $\lambda = 10$ m

3-12 As in Problems 3-9 and 3-10,

$$\frac{n}{t} = \frac{P}{hf} = \frac{P\lambda}{hc} = (10\text{ W})\frac{589\times10^{-9}\text{ m}}{1.99\times10^{-25}\text{ J m}} = 3.0\times10^{19}\text{ photons/s}.$$

3-18 (a) $K_{max} = eV_s = s(0.45\text{ V}) = 0.45\text{ eV}$

(b) $\phi = \frac{hc}{\lambda - K} = \frac{1\,240\text{ eV nm}}{500\text{ nm}} - 0.45\text{ eV} = 2.03\text{ eV}$

(c) $\lambda_c = \frac{hc}{\phi} = \frac{1\,240\text{ eV nm}}{2.03\text{ eV}} = 612\text{ nm}$

3-23 $$E = \frac{hc}{\lambda} = \frac{(6.626\times10^{-34}\text{ J s})(3\times10^{8}\text{ m/s})}{(5\times10^{-7}\text{ m})(1.6\times10^{-19}\text{ J/eV})} = 2.48\text{ eV}$$

$$p = \frac{h}{\lambda} = \frac{E}{c} = \frac{(2.48\text{ eV})(1.6\times10^{-19}\text{ J/eV})}{3\times10^{8}\text{ m/s}} = 1.32\times10^{-27}\text{ kg m/s}$$

3-25 $E = 300$ keV, $\theta = 30°$

(a) $$\Delta\lambda = \lambda' - \lambda_0 = \frac{h}{m_e c}(1-\cos\theta) = (0.002\,43\text{ nm})[1-\cos(30°)] = 3.25\times10^{-13}\text{ m}$$
$$= 3.25\times10^{-4}\text{ nm}$$

(b) $$E = \frac{hc}{\lambda_0} \Rightarrow \lambda_0 = \frac{hc}{E_0} = \frac{(4.14\times10^{-15}\text{ eVs})(3\times10^{8}\text{ m/s})}{300\times10^{3}\text{ eV}} = 4.14\times10^{-12}\text{ m; thus,}$$
$$\lambda' = \lambda_0 + \Delta\lambda = 4.14\times10^{-12}\text{ m} + 0.325\times10^{-12}\text{ m} = 4.465\times10^{-12}\text{ m, and}$$
$$E' = \frac{hc}{\lambda'} \Rightarrow E' = \frac{(4.14\times10^{-15}\text{ eV s})(3\times10^{8}\text{ m/s})}{4.465\times10^{-12}\text{ m}} = 2.78\times10^{5}\text{ eV}.$$

(c) $\frac{hc}{\lambda_0} = \frac{hc}{\lambda'} + K_e$, (conservation of energy)

$$K_e = hc\left(\frac{1}{\lambda_0} - \frac{1}{\lambda'}\right) = \frac{(4.14\times10^{-15}\text{ eV s})(3\times10^{8}\text{ m/s})}{\frac{1}{4.14\times10^{-12}} - \frac{1}{4.465\times10^{-12}}} = 22\text{ keV}$$

3-35 (a) The energy vs wavelength relation for a photon is $E = \frac{hc}{\lambda}$. For a photon of wavelength given by $\lambda_0 = 0.0711\ \text{nm}$ the photon's energy is

$$E = \frac{(6.626\times10^{-34}\ \text{J}\cdot\text{s})(3\times10^{8}\ \text{m/s})}{(0.0711\times10^{-9}\ \text{m})(1.602\times10^{-19}\ \text{J/eV})} = 17.4\ \text{keV}$$

(b) For the case of back scattering, $\theta = \pi$ the Compton scattering relation becomes $\lambda' - \lambda_0 = \left(\frac{2hc}{m_e c^2}\right)$. Setting $\lambda_0 = 0.0711\ \text{nm}$ we obtain

$$\lambda' = 0.711\ \text{nm} + \frac{2hc}{m_e c^2} = 7.60\times10^{-11}$$

or 0.076 0 nm.

(c) $$E' = \frac{hc}{\lambda'} = \frac{(6.626\times10^{-34}\ \text{J}\cdot\text{s})(3\times10^{8}\ \text{m/s})}{(7.60\times10^{-11}\ \text{m})(1.602\times10^{-19}\ \text{J/eV})} = 16.3\ \text{keV}.$$

(d) $\Delta E = 17.45\ \text{keV} - 16.33\ \text{keV} = 1.12\ \text{keV} \sim 1.1\ \text{keV}$.

3-42 (a) $eV_S = \frac{hc}{\lambda} - \phi \Rightarrow \phi = \left(\frac{1\,240\ \text{eV}\cdot\text{nm}}{546.1\ \text{nm}}\right) - 1.70\ \text{eV} = 0.571\ \text{eV}$

(b) $eV_S = \left(\frac{1\,240\ \text{eV}\cdot\text{nm}}{587.5\ \text{nm}}\right) - 0.571\ \text{eV} \Rightarrow V_S = 1.54\ \text{V}$

3-45 From a plot of V_s versus f one finds $h = 6.7\times10^{-34}\ \text{J}\cdot\text{s}$, $f_0 = 7.1\times10^{14}\ \text{Hz}$, and $\phi = 2.29\ \text{eV}$.

3-46 Using Compton shift formula

$$\lambda' = \lambda_0 + \lambda_c(1-\cos\theta) = 0.5\ \text{nm} + 0.002\,43\ \text{nm}(1-\cos 134°) = 0.504\ \text{nm}.$$

conservation of p_x: $p_{0x} = p'_x + p_{ex}$, $\frac{h}{\lambda_0} = \frac{h}{\lambda'\cos\theta} + \gamma m_e v_e \cos\phi$, $\gamma m_e v_e \cos\phi = \frac{h}{\lambda_0} - \frac{h}{\lambda'\cos\theta}$.

Conservation of p_y: $p_{0y} = p'_y + p_{ey}$, $\Delta\lambda_0 = \frac{h\sin\theta}{\lambda'} - \gamma m_e v_e \sin\phi$, $\gamma m_e v_e \sin\phi = \frac{h\sin\theta}{\lambda'}$, and so

$$\frac{\gamma m_e v_e \sin\phi}{\gamma m_e v_e \cos\phi} = \frac{\frac{h}{\lambda'}\sin\theta}{\frac{h}{\lambda_0} - \frac{h}{\lambda'}\cos\theta}$$

$$\tan\phi = \frac{\lambda_0 \sin\theta}{\lambda' - \lambda_0\cos\theta}$$

$$\tan\phi = \frac{0.5\ \text{nm}\ \sin 134°}{0.504\ \text{nm} - (0.5\ \text{nm})\cos 134°} = 0.424,\ \phi = 22.9°$$