Homework #3. Problems: 2, 4, 11, 15, 18, 20, 21 in chapter 3

3-2 Assume that your skin can be considered a blackbody. One can then use Wien's displacement law, $\lambda_{\text{max}} T = 0.289\,8 \times 10^{-2}\ \text{m} \cdot \text{K}$ with $T = 35\ ^0\text{C} = 308\ \text{K}$ to find

$$\lambda_{\text{max}} = \frac{0.289\,8 \times 10^{-2}\ \text{m} \cdot \text{K}}{308\ \text{K}} = 9.41 \times 10^{-6}\ \text{m} = 9\,410\ \text{nm}\ .$$

3-4 (a) From Stefan's law, one has $\frac{P}{A} = \sigma T^4$. Therefore,

$$\frac{P}{A} = \left(5.7 \times 10^{-8}\ \text{W/m}^2 K^4\right)(3000\ \text{K})^4 = 4.62 \times 10^6\ \text{W/m}^2\ .$$

(b) $$A = \frac{P}{4.62 \times 10^6\ \text{W/m}^2} = \frac{75\ \text{W}}{4.62 \times 10^6\ \text{W/m}^2} = 16.2\ \text{mm}^2\ .$$

3-11 Following the same reasoning as in Problem 3-9, one obtains

$$\frac{n}{t} = \frac{P}{hf} = \frac{P\lambda}{hc} = \left(3.74 \times 10^{26}\ \text{J s}\right) \frac{500 \times 10^{-9}\ \text{s}^{-1}}{6.63 \times 10^{-34}\ \text{J s}} \left(3 \times 10^8\ \text{s}^{-1}\right) = 9.45 \times 10^{44}\ \text{photons/s}\ .$$

3-15 (a) At the cut-off wavelength, $K = 0$ so $\frac{hc}{\lambda} - \phi = 0$, or $\lambda_{\text{cut-off}} = \frac{hc}{\phi} = \frac{1\,240\ \text{eV nm}}{4.2\ \text{eV}} = 300\ \text{nm}$.

The threshold frequency, f_0 is given by

$$f_0 = \frac{c}{\lambda_{\text{cut-off}}} = \frac{3.0 \times 10^8\ \text{m/s}}{3.0 \times 10^2 \times 10^{-9}\ \text{m}} = 1.0 \times 10^{15}\ \text{Hz}\ .$$

(b) $$eV_s = K = hf - \phi = \frac{hc}{\lambda} - \phi$$

$$V_s = \frac{hc}{\lambda e} - \frac{\phi}{e} = \frac{1\,240\ \text{eV nm}}{200\ \text{nm e}} = -4.2\ \text{eV/e} = 2.0\ \text{V}$$

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

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

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

3-20 $K_{\text{max}} = hf - \phi = \frac{hc}{\lambda} - \phi \Rightarrow \phi = \frac{hc}{\lambda} - K_{\text{max}}$;

First Source: $\phi = \frac{hc}{\lambda} - 1.00\ \text{eV}$.

Second Source: $\phi = \frac{hc}{\frac{\lambda}{2}} - 4.00\ \text{eV} = \frac{2hc}{\lambda} - 4.00\ \text{eV}$.

As the work function is the same for both sources (a property of the metal),

$$\frac{hc}{\lambda} - 100\text{ eV} = \frac{2hc}{\lambda} - 4.00\text{ eV} \Rightarrow \frac{hc}{\lambda} = 3.00\text{ eV} \text{ and } \phi = \frac{hc}{\lambda} - 1.00\text{ eV} = 3.00\text{ eV} - 1.00\text{ eV} = 2.00\text{ eV}.$$

3-21 $V_s = \left(\frac{h}{e}\right)\frac{f - \phi}{e}$. Choosing two points on the graph, one has $\left(\frac{h}{e}\right)\left(4\times10^{14}\text{ Hz}\right) - \frac{\phi}{e} = 0$ and $\left(\frac{h}{e}\right)\left(8\times10^{14}\text{ Hz}\right) - 1.7\text{ eV}$. Combining these two expressions one obtains:

(a) $\phi = 1.6\text{ eV}$

(b) $\frac{h}{e} = 4.0\times10^{-15}\text{ Vs}$

(c) For cut-off wavelength, $\lambda_c = \frac{hc}{\phi} = \frac{1\,240\text{ eV nm}}{1.6\text{eV}} = 775\text{ nm}$.

(d) Accepted $\frac{h}{e} = 4.14\times10^{-15}\text{ Vs}$, about a 3% difference.