Homework #12

(39-1) $\text{Power} = \frac{\text{energy}}{\text{sec}} = \frac{\text{energy}}{\text{photon}} \frac{\text{photons}}{\text{sec}}$

$$= \frac{hc}{\lambda}\left(\frac{\text{photons}}{\text{sec}}\right)$$

So $\text{Power} = \frac{(6.63\times10^{-34}\,\text{J}\cdot\text{sec})(3\times10^{8}\,\frac{\text{m}}{\text{sec}})}{550\times10^{-9}\,\text{m}}\left(100\,\frac{1}{\text{sec}}\right)$

$$= \boxed{3.62\times10^{-17}\ \text{watts}}$$

(39-2) From the photoelectric equation

$$hf = K_{max} + \Phi$$

with $K_{max} = 0$ for cutoff and $f = \frac{c}{\lambda}$,

$$\frac{hc}{\lambda_c} = \Phi \qquad (\lambda_c = \text{cutoff wavelength})$$

$$\lambda_c = \frac{hc}{\Phi} = \frac{1240\ \text{eV}\cdot\text{nm}}{\Phi}$$

The photoelectric effect will occur only if $\lambda < \lambda_c$.

For potassium, $\Phi = 2.25\,\text{eV}$

$$\Rightarrow \lambda_c = \frac{1240\,\text{eV}\cdot\text{nm}}{2.25\ \text{nm}} = 551\ \text{nm}$$

For cesium, $\Phi = 2.14\,\text{eV}$

$$\Rightarrow \lambda_c = \frac{1240\,\text{eV}\cdot\text{nm}}{2.14\,\text{eV}} = 579\ \text{nm}$$

a) If $\lambda = 565$ nm, the photoelectric effect will occur for $\boxed{\text{cesium}}$

b) If $\lambda = 518$ nm, the photoelectric effect will occur for $\boxed{\text{both}}$

(39-3) $K_{max} = hf - \Phi$

$$= (4.14 \times 10^{-15}\, eV\cdot sec)(3 \times 10^{15}\, \tfrac{1}{sec}) - 2.3\,eV$$

$$= \boxed{10.1\, eV}$$

(39-4) a) $hf = K_{max} + \Phi$

Set $f = \frac{c}{\lambda}$ and $K_{max} = eV_{stop}$ to get

$$\frac{hc}{\lambda} = eV_{stop} + \Phi$$

or

$$V_{stop} = \frac{hc/\lambda - \Phi}{e}$$

$$= \frac{\frac{1240\,eV\cdot nm}{400\,nm} - 1.8\,eV}{1 \text{ elementary charge}}$$

$$= \boxed{1.30\, V}$$

b) $K_{max} = \frac{1}{2} m_e V_{max}^2 = eV_{stop}$

So $V_{max} = \sqrt{\frac{2eV_{stop}}{m_e}}$

$$= \sqrt{\frac{2(1.6 \times 10^{-19} C)(1.30\,V)}{9.11 \times 10^{-31}\, kg}}$$

$$= \boxed{6.76 \times 10^{5}\, \frac{m}{sec}}$$

(39-5) a) $f = \frac{c}{\lambda} = \frac{3 \times 10^{8}\, m/sec}{35 \times 10^{-12}\, m} = \boxed{8.57 \times 10^{18}\, Hz}$

b) $E = hf = (4.14 \times 10^{-15}\, eV\cdot sec)(8.57 \times 10^{18}\, \frac{1}{sec}) = \boxed{3.55 \times 10^{4}\, eV}$

c) $p = \frac{E}{c} = \frac{(3.55 \times 10^{4}\, eV)(\frac{1.6 \times 10^{-19} J}{eV})}{3 \times 10^{8}\, m/sec}$

$$= \boxed{1.89 \times 10^{-23}\, kg\cdot m/sec}$$

(39-6) a) $\Delta\lambda = \lambda_f - \lambda_i = \frac{h}{m_e c}(1-\cos\phi) = \frac{hc}{m_e c^2}(1-\cos\phi)$

So $\Delta\lambda = \frac{1240\,eV\cdot nm}{511\times10^3\,eV}(1-\cos 30°)$

$= 2.43\times10^{-3}\,nm\,(1-\cos 30°)$

$\lambda_f - \lambda_i = 3.25\times10^{-4}\,nm = 0.325\,pm$

Thus $\lambda_f = \lambda_i + 0.325\,pm$

$= 2.4\,pm + 0.325\,pm$

$= \boxed{2.73\,pm}$

b) $\lambda_f - \lambda_i = (2.43\times10^{-3}\,nm)(1-\cos 120°)$

$= 3.65\times10^{-3}\,nm = 3.65\,pm$

So $\lambda_f = \lambda_i + 3.65\,pm$

$= 2.4\,pm + 3.65\,pm$

$= \boxed{6.05\,pm}$

(39-7) $\lambda = \frac{h}{p}$ and $K = \frac{p^2}{2m_e}$ and $K = 25\,keV$

Let's use a factor of c to make the calculation easier

$\lambda = \frac{hc}{pc}$ and $K = \frac{(pc)^2}{2m_e c^2}$ and $K = 25\,keV$

So $pc = \sqrt{2m_e c^2 K}$

and thus $\lambda = \dfrac{hc}{\sqrt{2m_e c^2 K}}$

$$\lambda = \frac{1240\ \text{eV}\cdot\text{nm}}{\sqrt{2(511\times10^3\,\text{eV})(25\times10^3\,\text{eV})}}$$

$$= 7.76\times10^{-3}\ \text{nm} = \boxed{7.76\ \text{pm}}$$

(39-8) $\Delta p \approx \dfrac{\hbar}{\Delta X} = \dfrac{h}{2\pi\Delta X} = \dfrac{6.63\times10^{-34}\ \text{J}\cdot\text{sec}}{2\pi(50\times10^{-12}\,\text{m})}$

$$= \boxed{2.11\times10^{-24}\ \text{Kg}\cdot\text{m/sec}}$$

(40-9) $E = \dfrac{h^2}{8m_e L^2}n^2$ with $n=1$

a) So $E = \dfrac{(hc)^2}{8m_e c^2 L^2}$ for the electron

$$= \frac{(1240\ \text{eV}\cdot\text{nm})^2}{8(511\times10^3\,\text{eV})(0.1\,\text{nm})^2}$$

$$= \boxed{37.6\ \text{eV}}$$

b) $E = \dfrac{(hc)^2}{8m_p c^2 L^2}$ for the proton

$$= \frac{(1240\ \text{eV}\cdot\text{nm})^2}{8(938\times10^6\,\text{eV})(0.1\,\text{nm})^2}$$

$$= \boxed{2.05\times10^{-2}\ \text{eV}}$$

(40-10) $E = \dfrac{(hc)^2}{8m_e c^2 L^2}n^2$ with $n=1$

$$= \frac{(1240\ \text{eV}\cdot\text{nm})^2}{8(511\times10^3\,\text{eV})(1.4\times10^{-5}\,\text{nm})^2}$$

$$= 1.92\times10^9\ \text{eV} = \boxed{1.92\ \text{GeV}}$$

The atomic nucleus could not confine an electron with This much energy! There are no electrons in The nucleus.

(40-11) a) The energies of the hydrogen atom's quantum states are

$$E_n = -13.6\,eV\,\frac{1}{n^2}$$

When an atom absorbs or emits a photon, the photon's energy is

$$E_{photon} = E_{high} - E_{low}$$
$$= 13.6\,eV\left(\frac{1}{n_{low}^2} - \frac{1}{n_{high}^2}\right)$$
$$= 13.6\,eV\left(\frac{1}{1^2} - \frac{1}{3^2}\right)$$
$$= \boxed{12.1\,eV}$$

b) $$p = \frac{E}{c} = \frac{(12.1\,eV)\left(\frac{1.6\times10^{-19}J}{1\,eV}\right)}{3\times10^{8}\,m/sec}$$
$$= \boxed{6.45\times10^{-27}\,kg\cdot m/sec}$$

c) $$\lambda = \frac{hc}{E} = \frac{1240\,eV\cdot nm}{12.1\,nm} = \boxed{102\,nm}$$

(40-12) a) $$E_{absorbed} = 13.6\,eV\left(\frac{1}{n_{low}^2} - \frac{1}{n_{high}^2}\right)$$
$$= 13.6\,eV\left(\frac{1}{1^2} - \frac{1}{4^2}\right)$$
$$= \boxed{12.8\,eV}$$

b) How can the electron get from $n=4$ to $n=1$?

$4 \rightarrow 1$ one step

$4 \rightarrow 3 \rightarrow 1$ or $4 \rightarrow 2 \rightarrow 1$ two steps

$4 \rightarrow 3 \rightarrow 2 \rightarrow 1$ 3 steps

The six transitions involved are

$4 \rightarrow 3$, $4 \rightarrow 2$, $4 \rightarrow 1$, $3 \rightarrow 2$, $3 \rightarrow 1$, $2 \rightarrow 1$

The energies are:

$4 \rightarrow 3$: $E_{photon} = 13.6\,eV \left(\frac{1}{3^2} - \frac{1}{4^2}\right) = 0.661\,eV$

$4 \rightarrow 2$: $E_{photon} = 13.6\,eV \left(\frac{1}{2^2} - \frac{1}{4^2}\right) = 2.55\,eV$

$4 \rightarrow 1$: $E_{photon} = 13.6\,eV \left(\frac{1}{1^2} - \frac{1}{4^2}\right) = 12.8\,eV$

$3 \rightarrow 2$: $E_{photon} = 13.6\,eV \left(\frac{1}{2^2} - \frac{1}{3^2}\right) = 1.89\,eV$

$3 \rightarrow 1$: $E_{photon} = 13.6\,eV \left(\frac{1}{1^2} - \frac{1}{3^2}\right) = 12.1\,eV$

$2 \rightarrow 1$: $E_{photon} = 13.6\,eV \left(\frac{1}{1^2} - \frac{1}{2^2}\right) = 10.2\,eV$