Recitation Problems (Week 8)

All problems taken from *University Physics,* Young and Freedman, 12th Ed.

38.7. **IDENTIFY and SET UP:** Eq.(38.3): $\frac{1}{2}mv_{max}^2 = hf - \phi = \frac{hc}{\lambda} - \phi$. Take the work function ϕ from Table 38.1. Solve for v_{max}. Note that we wrote f as c/λ.

EXECUTE: $\frac{1}{2}mv_{max}^2 = \frac{(6.626\times10^{-34}\ \text{J}\cdot\text{s})(2.998\times10^{8}\ \text{m/s})}{235\times10^{-9}\ \text{m}} - (5.1\ \text{eV})(1.602\times10^{-19}\ \text{J/1 eV})$

$\frac{1}{2}mv_{max}^2 = 8.453\times10^{-19}\ \text{J} - 8.170\times10^{-19}\ \text{J} = 2.83\times10^{-20}\ \text{J}$

$v_{max} = \sqrt{\frac{2(2.83\times10^{-20}\ \text{J})}{9.109\times10^{-31}\ \text{kg}}} = 2.49\times10^{5}\ \text{m/s}$

EVALUATE: The work function in eV was converted to joules for use in Eq.(38.3). A photon with $\lambda = 235$ nm has energy greater then the work function for the surface.

38.9. **IDENTIFY and SET UP:** $c = f\lambda$. The source emits $(0.05)(75\ \text{J}) = 3.75$ J of energy as visible light each second. $E = hf$, with $h = 6.63\times10^{-34}\ \text{J}\cdot\text{s}$.

EXECUTE: **(a)** $f = \frac{c}{\lambda} = \frac{3.00\times10^{8}\ \text{m/s}}{600\times10^{-9}\ \text{m}} = 5.00\times10^{14}\ \text{Hz}$

(b) $E = hf = (6.63\times10^{-34}\ \text{J}\cdot\text{s})(5.00\times10^{14}\ \text{Hz}) = 3.32\times10^{-19}\ \text{J}$. The number of photons emitted per second is

$\frac{3.75\ \text{J}}{3.32\times10^{-19}\ \text{J/photon}} = 1.13\times10^{19}$ photons.

(c) No. The frequency of the light depends on the energy of each photon. The number of photons emitted per second is proportional to the power output of the source.

38.15. **IDENTIFY and SET UP:** Balmer's formula is $\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{n^2}\right)$. For the H_γ spectral line $n = 5$. Once we have λ, calculate f from $f = c/\lambda$ and E from Eq.(38.2).

EXECUTE: **(a)** $\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{5^2}\right) = R\left(\frac{25-4}{100}\right) = R\left(\frac{21}{100}\right)$.

Thus $\lambda = \frac{100}{21R} = \frac{100}{21(1.097\times10^{7})}\ \text{m} = 4.341\times10^{-7}\ \text{m} = 434.1\ \text{nm}$.

(b) $f = \frac{c}{\lambda} = \frac{2.998\times10^{8}\ \text{m/s}}{4.341\times10^{-7}\ \text{m}} = 6.906\times10^{14}\ \text{Hz}$

(c) $E = hf = (6.626\times10^{-34}\ \text{J}\cdot\text{s})(6.906\times10^{14}\ \text{Hz}) = 4.576\times10^{-19}\ \text{J} = 2.856\ \text{eV}$

EVALUATE: Section 38.3 shows that the longest wavelength in the Balmer series (H_α) is 656 nm and the shortest is 365 nm. Our result for H_γ falls within this range. The photon energies for hydrogen atom transitions are in the eV range, and our result is of this order.

38.24. **IDENTIFY and SET UP:** For a hydrogen atom $E_n = -\frac{13.6 \text{ eV}}{n^2}$. $\Delta E = \frac{hc}{\lambda}$, where ΔE is the magnitude of the energy change for the atom and λ is the wavelength of the photon that is absorbed or emitted.

EXECUTE: $\Delta E = E_4 - E_1 = -(13.6 \text{ eV})\left(\frac{1}{4^2} - \frac{1}{1^2}\right) = +12.75 \text{ eV}$.

$\lambda = \frac{hc}{\Delta E} = \frac{(4.136\times10^{-15} \text{ eV}\cdot\text{s})(3.00\times10^8 \text{ m/s})}{12.75 \text{ eV}} = 97.3 \text{ nm}$. $f = \frac{c}{\lambda} = 3.08\times10^{15} \text{ Hz}$.

38.29. **IDENTIFY and SET UP:** The number of photons emitted each second is the total energy emitted divided by the energy of one photon. The energy of one photon is given by Eq.(38.2). $E = Pt$ gives the energy emitted by the laser in time t.

EXECUTE: In 1.00 s the energy emitted by the laser is $(7.50\times10^{-3} \text{ W})(1.00 \text{ s}) = 7.50\times10^{-3} \text{ J}$.

The energy of each photon is $E = \frac{hc}{\lambda} = \frac{(6.626\times10^{-34} \text{ J}\cdot\text{s})(2.998\times10^8 \text{ m/s})}{10.6\times10^{-6} \text{ m}} = 1.874\times10^{-20} \text{ J}$.

Therefore $\frac{7.50\times10^{-3} \text{ J/s}}{1.874\times10^{-20} \text{ J/photon}} = 4.00\times10^{17}$ photons/s

EVALUATE: The number of photons emitted per second is extremely large.

38.36. **IDENTIFY and SET UP:** The wavelength of the x rays produced by the tube is give by $\frac{hc}{\lambda} = eV$.

$\lambda' = \lambda + \frac{h}{mc}(1-\cos\phi)$. $\frac{h}{mc} = 2.426\times10^{-12}$ m. The energy of the scattered x ray is $\frac{hc}{\lambda'}$.

EXECUTE: **(a)** $\lambda = \frac{hc}{eV} = \frac{(6.63\times10^{-34} \text{ J}\cdot\text{s})(3.00\times10^8 \text{ m/s})}{(1.60\times10^{-19} \text{ C})(18.0\times10^3 \text{ V})} = 6.91\times10^{-11} \text{ m} = 0.0691 \text{ nm}$

(b) $\lambda' = \lambda + \frac{h}{mc}(1-\cos\phi) = 6.91\times10^{-11} \text{ m} + (2.426\times10^{-12} \text{ m})(1-\cos 45.0^\circ)$.

$\lambda' = 6.98\times10^{-11} \text{ m} = 0.0698 \text{ nm}$.

(c) $E = \frac{hc}{\lambda'} = \frac{(4.136\times10^{-15} \text{ eV}\cdot\text{s})(3.00\times10^8 \text{ m/s})}{6.98\times10^{-11} \text{ m}} = 17.8 \text{ keV}$

EVALUATE: The incident x ray has energy 18.0 keV. In the scattering event, the photon loses energy and its wavelength increases.

38.50. **(a)** Wien's law: $\lambda_m = \frac{k}{T}$. $\lambda_m = \frac{2.90\times10^{-3} \text{ K}\cdot\text{m}}{30{,}000 \text{ K}} = 9.7\times10^{-8}\text{m} = 97 \text{ nm}$

This peak is in the ultraviolet region, which is *not* visible. The star is blue because the largest part of the visible light radiated is in the blue/violet part of the visible spectrum

(b) $P = \sigma A T^4$ (Stefan-Boltzmann law)

$$(100{,}000)(3.86\times10^{26} \text{ W}) = \left(5.67\times10^{-8}\frac{\text{W}}{\text{m}^2\text{K}^4}\right)(4\pi R^2)(30{,}000 \text{ K})^4$$

$$R = 8.2\times10^9 \text{ m}$$

$$R_{star}/R_{sun} = \frac{8.2\times10^9 \text{ m}}{6.96\times10^8 \text{ m}} = 12$$

(c) The visual luminosity is proportional to the power radiated at visible wavelengths. Much of the power is radiated nonvisible wavelengths, which does not contribute to the visible luminosity.