

107 Answer Key HW #8- Chapter 13 assignment

Conceptual: 4, 8, 12, 14

Problems: 2, 8

November 3, 2005

1 Conceptual Exercises

4.) “Suppose that the photoelectric threshold frequency in a certain metal lies in the red region of the spectrum (Figure 9.7). Yellow, green, and violet light are all directed at the surface of this metal. Which, if any, of these colors will cause electrons to be ejected from the surface?”

If the frequency of incident light is larger than the threshold frequency, then electrons will be ejected (since the photons will have more than the required energy), otherwise no electrons will be ejected. We need to determine, then, whether yellow, green, and violet light have frequencies higher than the threshold: red light.

Looking at Figure 9.7, red light is listed as having the smallest frequency (largest wavelength) of all the colors. Since the frequencies of yellow, green, and violet light are all larger than the frequency of red light, all of these colors will eject electrons.

8.) “A red light beam has a variable frequency. As you increase the frequency, does the color change? Do the energies of the individual photons increase, decrease, or remain the same? Do the photons’ speeds change?”

What does it mean for a red light beam to have a variable frequency? Let’s assume they mean that as we change the frequency a little bit we see different “shades” of red. In this case, the color should not change much, since we’re still saying it’s “red”. However, as you increase the frequencies, you increase the energies of the photons, since $Energy = h * (freq.)$, where $h = 6.67 \times 10^{-34} J \cdot s$, and a higher frequency means a higher energy. Since electromagnetic radiation always travels at the same speed regardless of its fre-

quency (namely the speed of light, $c = 3 * 10^8 m/s$), all photons will travel at this speed regardless of their frequency, and the photons' speed will not change.

12.) “What is meant by a red photon? A yellow photon? Which one has greater energy? Longer wavelength?”

A red photon is a particle of light that behaves as if it had a wavelength and frequency corresponding to an electromagnetic wave that stimulates our cones to produce a signal in our brain that we interpret as red. These frequencies are $f \sim 10^{13} Hz$. Similarly, a yellow photon is a particle of light that behaves as if it had a wavelength and frequency corresponding to that of a yellow electromagnetic wave (namely $f \sim 10^{14} Hz$). Since the frequency for yellow light is larger than the frequency for red light, the yellow photon has a greater energy, using $Energy = h * (freq)$. Since red light has a smaller frequency, the red photon has a longer wavelength, using $(wavelength) = \frac{c}{(freq)}$.

14.) “Which has greater energy, a microwave photon or a visible photon?”

Looking at Figure 9.7, we see that the frequency of a microwave photon ($f \sim 10^{11} Hz$) is smaller than the frequency of any visible light (for red light, $f \sim 10^{13} Hz$). Since $Energy = h * (freq)$, the photon with the larger frequency has the larger energy; thus, a visible photon has more energy than a microwave photon.

2 Problems

2.) “In the preceding problem, find the amount of energy a photon needs to knock electrons out of this surface. Do either the orange photons or the violet photons have this much energy?”

From the preceding problem, the threshold frequency is $6.2 * 10^{14} Hz$. The threshold energy (the energy needed to knock an electron out of the surface) is the energy of a photon at the threshold frequency:

$$E_{thres} = h * 6.2 * 10^{14} Hz = 4.09 * 10^{-19} J.$$

From the preceding problem, the energy of an orange photon is: $h * f_{orange} = 3.3 * 10^{-19} J$. The energy of a violet photon is $h * f_{violet} = 4.6 * 10^{-19} J$.

We see that only the violet photon has an energy larger than the threshold energy.

8.) “Making estimates. The human eye can detect as few as 10,000 photons per second entering the pupil. About how much energy is this, per second?”

We want to find the amount of energy entering a human eye per second;

using units, the equation for this will be something like:

$$\frac{Energy}{sec} = 10,000 \frac{photons}{sec} * \frac{Energy}{photon}. \quad (1)$$

Notice that the units of photons cancel, and we are left with units of energy/sec, which is what we want. But what is the energy per photon? From the photoelectric effect, we have learned that the energy of one photon is $Energy = h * (freq)$, where $h = 6.6 * 10^{-34} J * s$. Let's assume we have green light (in the middle of the visible part of the spectrum) with a frequency of $f_{green} = 4 * 10^{14} Hz$. Then the energy per photon is $Energy/photon = h * f_{green} = 2.64 * 10^{-19} J/photon$. Putting this in the equation (1), we have:

$$\frac{Energy}{sec} = 10,000 \frac{photons}{sec} * 2.64 * 10^{-19} J/photon = \boxed{2.64 * 10^{-15} J/sec.} \quad (2)$$