Problem Assignment for Lesson 9

9.1. Find the energy (eV) of a photon in light with a wavelength of \([01]\) ________ nm.

9.2. The energy of photons in a gamma ray is \([02]\) ________ MeV. Find the wavelength (m) of this radiation. Give the answer to 2 significant figures.

9.3. Consider the photoelectric effect in some metal where the work function is \([03]\) ________ eV. If we shine yellow light \((\lambda = 550 \text{ nm})\) on this metal, electrons are ejected from the surface of the metal. If we measure the kinetic energy of these ejected electrons, what maximum value (eV) will we find? Give the answer to 2 significant figures.

9.4. Do Lab 9.1. Photoelectric effect. Enter (a) the maximum kinetic energy \(K_{\text{max,1}}\) (eV) of the electrons ejected by the 578-nm light, (b) the maximum kinetic energy \(K_{\text{max,2}}\) (eV) of the electrons ejected by the 546-nm light, (c) the maximum kinetic energy \(K_{\text{max,3}}\) (eV) of the electrons ejected by the 435-nm light, (d) the maximum kinetic energy \(K_{\text{max,4}}\) (eV) of the electrons ejected by the 405-nm light, (e) the frequency \(f_{1}\) (Hz), (f) the frequency \(f_{2}\) (Hz), (g) the frequency \(f_{3}\) (Hz), (h) the frequency \(f_{4}\) (Hz), (i) the cutoff frequency \(f_c\) (Hz), (j) the cutoff wavelength \(\lambda_c\) (nm), (k) and the work function \(\phi\) (eV). Give the answers to parts (a)–(d) to the nearest 0.001 eV.

9.5. Consider the Compton effect. We direct an x-ray beam into some material. The wavelength of the x rays is \([04]\) ________ nm. (a) Find the wavelength (nm) of the x rays which are scattered back toward the source \((\theta = 180^\circ)\). Give the answer to 4 significant figures. (b) Find the kinetic energy (eV) of the electrons which these photons knock out of the material. Give the answer to 3 significant figures.

9.6. Find the kinetic energy \((J)\) of an electron which has a de Broglie wavelength equal to \([05]\) ________ nm.

9.7. Suppose we somehow knock out an electron from an atom. The energy level of the electron is \([06]\) ________ keV. Another electron in that atom makes a transition from its level at \(-1.8\) keV to that empty level and emits a photon. (a) Find the energy (keV) of the emitted photon. (b) Find the wavelength (nm) of the photon. This is how x rays are produced in commercial instruments. A beam of high-energy electrons are directed at a target where they knock electrons out of atoms. Other electrons in the atoms make transitions to these empty levels, emitting photons.
Lab 9.1: Photoelectric Effect

In this lab, we will observe the photoelectric effect and measure the cutoff frequency and work function for a certain metal. At one end of the apparatus is a mercury lamp. The housing around the lamp can be rotated, placing various filters in front of the lamp. A lens focuses the light on the emitter (E) of a photomultiplier tube. The photons in this light eject electrons from the emitter. Some of the electrons fall on the collector (C), charging it up and building a potential difference $V$ between E and C. Eventually, $V$ becomes so large that the collector repels all electrons ejected from the emitter. At this point, $V$ reaches a steady-state value $V_c$ such that $eV_c$ is equal to the maximum possible kinetic energy $K_{\text{max}}$ of the electrons ejected from the emitter. From the textbook, we find that $K_{\text{max}} = hf - \phi$, where $f$ is the frequency of the light and $\phi$ is the work function of the emitter. If we plot $K_{\text{max}}$ as a function of $f$, we ought to obtain a straight line.

Each filter allows a single wavelength of light to pass through it, as indicated below.

- filter 1: $\lambda_1 = 578$ nm
- filter 2: $\lambda_2 = 546$ nm
- filter 3: $\lambda_3 = 435$ nm
- filter 4: $\lambda_4 = 405$ nm

Watch the video, Lab 9-1 Photoelectric effect. Record the maximum kinetic energy of the electrons ejected from the emitter by each wavelength of light.

Download and print the Lab 9.1 graph.

Calculate the frequency $f_i$ for each wavelength and then plot the results on the graph on the next page. The points should fall on a straight line.

Using a ruler, draw a straight line that passes as close as possible to each of the points. Extend that straight line across the entire graph.

From the graph, determine the cutoff frequency $f_c$ (the frequency for which $K_{\text{max}} = 0$). Below this frequency, light will not eject any electrons from the emitter. Calculate the cutoff wavelength $\lambda_c$. Calculate the work function $\phi$ of the emitter.

The slope of the line on the graph should be equal to Planck’s constant $h$. Determine the slope of the line on the graph. Its value should agree with Planck’s constant to within about 10%.