HOMEWORK PROBLEMS

Basic Skills

Q4B.1 Red light emitted by a standard helium–neon laser has a wavelength of about 633 nm. What is the energy of one photon of such red light?

Q4B.2 Yellow light has a wavelength of about 590 nm. What is the energy of one photon of such light?

Q4B.3 We find that photons from a certain light source have an energy of 3.5 eV. What is the wavelength associated with this light? Is this light visible?

Q4B.4 A typical laboratory helium–neon laser produces about 1 mW (0.001 J/s) of light at a wavelength of 633 nm. How many photons per second does this laser produce?

Q4B.5 A certain argon laser produces about 5 mW of light at a wavelength of 514 nm. How many photons per second does this laser produce?

Q4B.6 Photons from a certain light source are measured to have an energy of 0.62 eV. What is the wavelength associated with this light? Is this light visible?

Q4B.7 The value of W is about 4.24 eV for zinc. What is the maximum wavelength that light falling on a zinc cathode can have if it is to be able to eject electrons?

Q4B.8 The value of W is about 2.3 eV for potassium. What is the maximum wavelength that light falling on a potassium cathode can have if it is to be able to eject electrons?

Q4B.9 Verify that the intensity of light falling on a surface 1.0 m away from a lamp radiating 40 W of visible light is 3.2 W/m^2, as claimed in exercise Q4X.1.

Q4B.10 Suppose red and green light-emitting diodes (LEDs) radiate the same amount of power in the form of light at wavelengths of 650 nm and 560 nm, respectively. Which emits more photons per second? By what factor?

Q4B.11 Suppose we do an experiment using the setup shown in figure Q4.1b where green light with a wavelength of 540 nm falls on a cesium cathode whose work function is 2.1 eV. What value will the voltmeter display?

Q4B.12 Suppose we do an experiment using the setup shown in figure Q4.1b where violet light with a wavelength of 430 nm falls on a cesium cathode whose work function is 2.1 eV. What value will the voltmeter display?

Q4B.13 About how many photons per second are broadcast by a FM radio station whose transmitter power is 10,000 W and whose frequency is 89.9 MHz?

Q4B.14 How does Einstein's photon model explain the observed result of photoelectric effect experiments indicating that the rate at which light ejects electrons from a metal surface is directly proportional to the intensity of the light?

Q4B.15 How does Einstein's photon model explain the observed result of photoelectric effect experiments that if the intensity of light falling on a metal plate is held fixed, the rate at which electrons are ejected from the metal decreases as the light's frequency increases?

Modeling

Q4M.1 When we illuminate sodium metal with monochromatic light with a wavelength of 420 nm, suppose we find that the maximum potential difference developed between the plates in the experimental setup shown in figure Q4.1b is 0.65 V; when the wavelength is 310 nm, we find this voltage to be 1.69 V. Check that these experimental results are consistent with a value of 1240 eV·nm for hc (within ±1%), and find the value of W for sodium.

Q4M.2 When we illuminate cesium meta with monochromatic light with a wavelength of 500 nm, suppose we find that the maximum potential difference developed between the plates in the experimental setup shown in figure Q4.1b is 0.57 V; when the wavelength is 420 nm, we find this voltage to be 1.04 V. Check that these experimental results are consistent with a value of 1240 eV·nm for hc (within ±1%), and find the value of W for cesium.

Q4M.3 When we illuminate iron with ultraviolet light with a wavelength of 250 nm, suppose we find the maximum potential difference developed between the plates in the experimental setup shown in figure Q4.1b to be 0.46 V. From these data and the accepted value of hc, find the potential difference between the plates if the ultraviolet light wavelength is changed to 220 nm. Also find W for iron.

Q4M.4 When we illuminate lead with ultraviolet light with a wavelength of 250 nm, suppose we find the maximum potential difference developed between the plates in the experimental setup shown in figure Q4.1b to be 0.82 V. From these data and the accepted value of hc, find the potential difference between the plates if the wavelength is 215 nm. Also find W for lead.

Q4M.5 Suppose you are standing in the dark and facing a 20-W LED bulb 100 m away. If the diameter of your pupils is about 8 mm under these conditions, about how many photons of *visible* light enter your eye every second?

Q4M.6 Imagine a model where light consists of photons but each photon carries an energy E_{ph} proportional to the wave's *intensity*, not its wavelength. How would this model contradict the expectations of a pure wave model for the photoelectric effect (or would it)? Would it be consistent with the photoelectric effect results actually observed (see section Q4.5)? Explain.