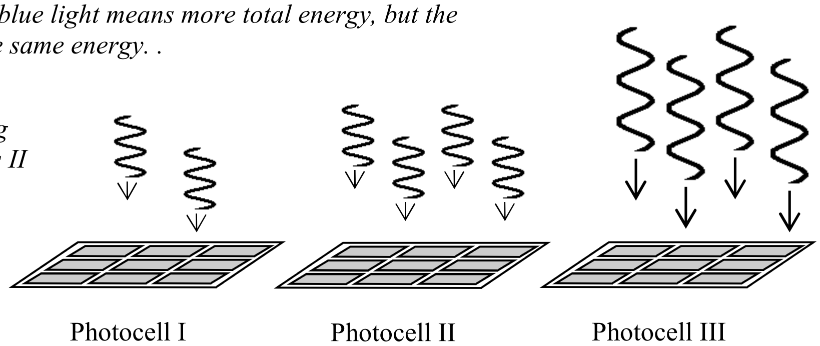
A-day: Due Mon., April 25
B-day: Due Mon., May 2

# 2011 PreAP Light and Optics 5

Photoelectric effect HW

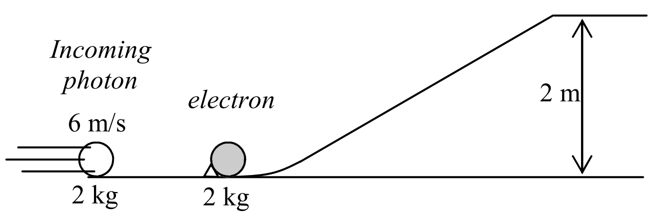
*At this point I have to assume you can calculate the energy of individual photons using E = hf. I also assume you know that shorter wavelength and higher frequencies mean more energy per photon. But what about brightness? Brightness (intensity) is about number of photons per second (power). Bright blue light means more total energy, but the same energy per photon, since every blue photon has the same energy. .*

*The diagrams at the right show photons incident (coming into) photocells (solar cells). The light coming into cells II and III is brighter than cell I (more photons per second).*




1. Which photocell at the right?
   A. More energy per photon: II or III?
   B. If the photons are blue and red, which one is red: II or III?
   C. Has more energy per photon: II or III?
   D. Has more energy per second: I or II?
   E. Has greater intensity of light: I or II?
   F. Has greater incoming power: II or III?
2. A photon has a wavelength of 600 nm. Would of the following increase or decrease the energy per photon?
   A. Increasing the wavelength.
   B. Increasing the intensity of light.
   C. Increasing the frequency.
   D. Increasing the brightness of light.

   *Understanding the work function.*
3. The diagram below shows a dark ball at the bottom of a ramp (*representing an electron in an atom*). A white ball of equal mass (*representing an incoming photon*) is shot into the dark ball from the left, striking it elastically. From conservation of momentum you should remember the first ball stops and the second one moves with the same v as the first ball, since they are of the same mass.




   A. * Calculate and label the potential energy necessary to get the dark ball up the ramp. This is the work function for this ball (φ): the minimum amount of work to get the ball up.
   B. * Calculate the energy in the white ball.
   C. Does the white ball have enough energy to get the dark ball up the ramp?

   *So the dark ball then falls back down to its initial position, just like an electron cannot get out of an atom if the incoming photon doesn't have enough energy (hf) to overcome the work function (*φ*).*

   D. If you hit the dark ball with a second identical white ball, would it get up the ramp?

   *So it doesn't matter how many white balls hit the dark ball if the white ball doesn't have enough energy. Likewise, in an atom, a brighter light (more photons) won't help electrons be ejected, since each photon doesn't have enough energy.*

   E. Now assume the white ball has 40 J of energy. Would the black ball get out?
   F. Would the black ball be moving at the top?

   *If the incoming photon's energy (hf) equals the work function (φ), an electron gets out, but has no excess KE.*

   G. Now assume the incoming white ball has 50 J of energy. Does the black ball get out?
   H. Would the black ball be moving at the top?
   I. How much excess KE does the black ball have at the top?

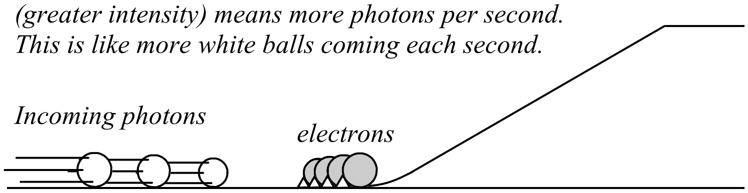
   *So, if the incoming photon's energy (hf) > than the work function (φ), the electron gets out and has extra kinetic energy (KE) at the top. So, KE = hf − φ*

   *If hf < φ, no electrons get out. If hf = φ, electrons get out, but have no excess KE.*

*Need to tell you about electron volts (eV), a unit of energy for photons. Turns out that photons have very small amounts of energy, so that joules are not convenient to use as a unit. 1 eV = 1.6×10 $^{-19}$ J or the charge of an electron (1.6×10 $^{-19}$ C) times 1 volt (J/C)). We'll do more of this later.*

4. * The work function of a metal photovoltaic cell is 2.0 eV. The energy of an incoming photon is 3.5 eV.
   A. Are electrons ejected from the photocell?
   B. If electrons are ejected, how much KE do they have?
5. * φ = 3.0 eV. The incoming photons = 2.5eV.
   A. Are electrons ejected from the photocell?
   B. If electrons are ejected, how much KE do they have?
6. The work function of a photocell is 3.3×10 $^{-19}$ J. What is the minimum frequency for incoming photons to cause electrons to be ejected?

*So, what about brighter light? Well, brighter light (greater intensity) means more photons per second. This is like more white balls coming each second.*




*You might think that the energy of the photons can add together, but this is not what we observe. An electron can only be hit by one photon at a time. Either the photons have enough energy to remove an electron or not. More photons only mean they can hit more electrons. If each photon has the work function amount of energy, then more electrons are liberated.*

7. A photovoltaic cell (*solar cell*) has green light shining onto it, but no electrons are being ejected (*coming off*).
   A. * Would electrons start to flow if you left the light on for a long time?
   B. * Would electrons be ejected if you changed to red light?
   C. Would electrons come out if you changed to blue light?
   D. Would electrons be ejected if you made the light brighter?

*Converting between eV and joules: 1 eV = 1.6×10 $^{-19}$ J   It is just another conversion.*

eV to joules: $\frac{4.5\text{eV}}{1}\left(\frac{1.6\times10^{-19}\text{ J}}{1\text{eV}}\right) = 7.2\times10^{-19}\text{ J}$

Joules to eV: $\frac{4.2\times10^{-19}\text{ J}}{1}\left(\frac{1eV}{1.6\times10^{-19}\text{ J}}\right) = 2.62eV$

8. Convert 5.2 eV to joules.
9. Convert 2.5×10$^{-19}$ J to eV.

*Putting it all together:*

10. * The incoming light has a frequency of 8×10$^{14}$ Hz. The work function for the material is 2.8eV.
    A. Calculate the energy of the photons in joules.

    B. Give the energy of the photons in eV.

    C. Are electrons ejected from the material?
    D. If electrons are ejected, how much excess KE do they have?

3A) 40 J (mgh); 3B) 36J (1/2 mv$^2$) 4A) yes, 3.5eV > 2.0eV 4B) 1.5eV 5A) no 2.5eV< 3.0eV 5B) n/a
7A) no—photon energy doesn't "add up" 7B) no, red light has less energy per photon. 10A) 5.3×10$^{-19}$ J; 10B) 3.31eV