IB PHYSICS

Name: ________________________________

Period: ________ Date: ___________________

Points: ___18_____ Score: ________________

DEVIL PHYSICS

BADDEST CLASS ON CAMPUS

PhET Photoelectric Effect

The photoelectric effect is one of the key experiments that supported early quantum theory. Light, prior to the early 20th century, was considered to be a wave phenomenon. In most ways, this idea reflects reality well — for instance, light is bendable when passed through a lens. The energy of a wave is given by amplitude of the wave squared, so a light wave of a certain frequency should be able to have any value of energy as long as there is a bright enough light source.

However, when red light was shone on a metal surface, no electrons were ejected even when the brightest red light sources were used. On the other hand, when blue light was shone on the same metal surface electrons were ejected even when the source of light was weak (and brighter blue lights ejected *more* electrons). How could this be? The energy didn't seem to depend on the amount of light hitting the metal but instead the frequency of light that hit the metal.

Planck put us on the path leading out of this thicket of confusion when he theorized that light and other forms of energy comes in "packets" or discreet "bundles". Light, in this theory, is considered to be a particle, which we now call a **photon.** The photoelectric effect was explained by Einstein when he conjectured that Planck's bundles of energy (i.e. photons) were "knocking loose" the electrons—but only if the photons had enough energy to do the job (a two year old isn't able to knock a football player off his feet, but a bull undoubtedly could). Einstein's ideas gave further support to the theory that light energy really is not continuous with infinitely small increments of change (a wave), but is in fact "chunky".

Today's lab involves a simulation of the photoelectric effect. You will be checking various metals for the point at which they begin to shed electrons, based on a specific **threshold frequency**—the exact point when the photons have enough energy to knock the electrons loose. This energy is called the **work function (ϕ)** for the metal. Different metals hold on to their electrons more strongly or weakly due to atomic structure, so the work function for various metals varies. The formula for calculating W is as follows:

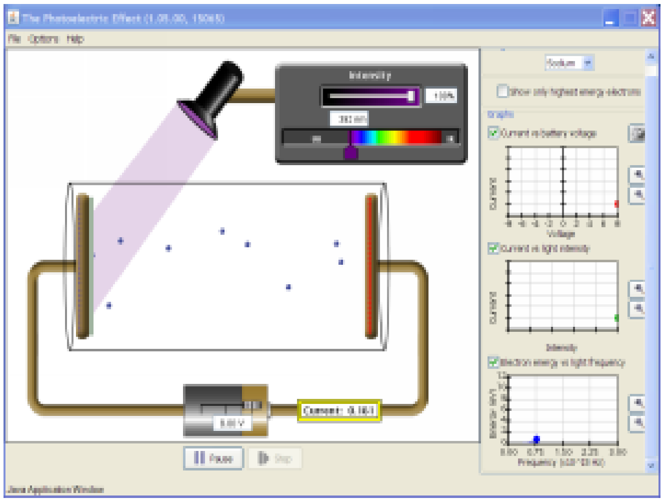
$$hf = E_k + \phi$$

Where

- h is Planck's constant (6.63×10^{-34} J·s)
- f is the frequency of the light
- E_k is the kinetic energy of the ejected electron
- ϕ is the work function

The kinetic energy of the electron refers to its actual movement once ejected. E_k can effectively be ignored if we just reach the amount of energy to loosen the electron but not get it moving (E_k in these circumstances will essentially have a value of zero). You will be trying to achieve the lowest possible speed for the electrons you eject from the virtual metal surface. W can be obtained by calculating frequency and using Planck's constant. The work function will be in joules, so in order to compare to published lists of work function values—which are in electron volts—your final value will require conversion into this unit.

The "equipment" you will be working with looks like this:



1. Bring up the internet and go to the following site: http://phet.colorado.edu/en/simulation/photoelectric
2. Click “Run Now”.
3. Keep battery voltage at 0. Turn light intensity up to 100%. You will be testing sodium first (metals are changeable in the upper right hand box).
4. (___/1) Adjust wavelength to a value which just allows electrons to leave the surface at the lowest possible speed and the lowest possible rate.

   λ = ________________.

5. Calculate ϕ (the work function) for Sodium ***in electron volts*** using the following values and formulas:

   $f = \frac{c}{\lambda}$, where c = 2.998×10^{17} nm/sec, λ is in nm and f is in s^{-1}

   h = 6.626×10^{-34} J·s

   1 electron volt = $1.60217646 \times 10^{-19}$ joules

   $hf = E_k + \phi$

   ***remember—E_k is set at zero

   (___/1) Answer: ϕ = ________________

6. (___/6, 1pt each) Calculate work function (in eV) for all other metals, including the mystery metal.

   Sodium Answer:________________________________

   Zinc Answer:__________________________________

   Copper Answer:________________________________

   Platinum Answer:______________________________

   Calcium Answer:_______________________________

   Mystery Answer:_______________________________

7. (___/1) Look up work function values on the internet and check the values obtained for the listed metals.

   Give the web address for your source: ____

   ____

8. (___/1) Identify the mystery metal: ____

Questions:

1. Choose a metal and choose a wavelength that ejects electrons at a reasonable speed. Turn the light intensity up and down. Make note of the number of electrons ejected and their speed. Now, move the slider that changes wavelength back and forth slowly. Make note of any changes you see. Explain **both issues** (results from change in intensity/change in wavelength), with reference to quantum theory.

   (___/2) Changes in Intensity:____

   (___/2) Changes in Wavelength:____

2. Choose a metal and choose a wavelength that ejects electrons at a reasonable speed. Set intensity to 100%. Change the flow of electricity from the battery (at the bottom of the screen), making note of the change in charge at both ends of the electron chamber. Speculate as to why the flow of electrons is changed.

   (___/2) Answer:____

3. Reset the battery to zero and the intensity to 100%. Turn on the electron energy vs. light frequency graph at the right of the screen. Play with light wavelength to generate data for the graph. Convert electron volts into joules, then calculate the slope of the line (be sure to use the exact values used in the graph). Explain why you obtained the value you did.

   (___/2) Answer:____

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4. Non-optional bonus physics question: kinetic energy for a particle is found by using the formula $E = 1/2mv^2$, where m = mass in kg and v = velocity in m/s (the E is the same as the E_k in the formula above). Set the equipment to sodium, 100 % intensity, 100nm, and 0.00 battery voltage. Using the above information, calculate the velocity of the ejected electrons. The mass of one electron is 9.109×10^{-31} kilograms. The value for W will have to be converted back into joules before proceeding.

   (___/2) Answer: ____

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ROOM FOR IMPROVEMENT

Comments:

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