Read the Photoelectric Effect introduction in your lab manual. Two labs ago the wave nature of light was observed with diffraction. This week the particle nature of light will be observed. Light has quanta called photons that have certain energy, $E=hf$, where $h$ is Planck’s constant and $f$ is frequency. In the photoelectric effect experiment, light is incident on a metal. If the light has enough energy, then an electron can be excited out of the metal. The key findings from the Photoelectric Effect are that electrons can be ejected out only if the light has enough energy to overcome the work function of the material. Increasing the intensity of light does not change whether an electron can be excited out (Recall for wave nature, the energy of the wave is proportional to the amplitude of the electric field squared.). There has to be enough energy $E=hf$ to excite the electron out. Any excess energy (beyond the work function of the metal) goes into kinetic energy of the electron, Energy of light=Work function of metal + Kinetic energy of electron.

There is a Phet simulation for the photoelectric effect. In Figure 1, ultraviolet light of 400 nm with 50% of its maximum intensity shines on a sodium metal cathode. Electrons are ejected with varying energy. The electrons ejected from the metal and collected on the anode. The electrons flow back to the cathode through a wire. In Figure 1 this current produced through the wire is 0.071 A.
Figure 1. Ultraviolet light (400 nm) shines on a sodium metal cathode. The electrons ejected from the metal flow to the anode and produce a current of 0.071 A in the wire.

If the cathode is positively charged, then the electrons are attracted to the anode and gain energy. If the anode is negatively charged, then the ejected electrons are repelled by the anode and lose energy. If the difference in potential energy of the cathode and anode becomes large enough, then electrons will not reach the anode and there will be no current flowing in the wire. The voltage needed to reduce the current in the wire to zero is called the stopping potential, and it is the maximum kinetic energy of the ejected electrons. The electrons have to be given enough energy to overcome the work function of the material to be ejected out. Any excess energy goes into the kinetic energy of the electron.

In Figure 2, a stopping potential of -0.72 V stops the current flow. Increasing the intensity to 100% of its maximum does not change the stopping potential as seen in Figure 3.
Figure 2. A stopping potential of -0.72 V stops the electrons from reaching the anode, giving a current of 0 A in the wire. The light intensity is at 50% of its maximum value.

Figure 3. A stopping potential of -0.72 V stops the electrons from reaching the anode, giving a current of 0 A in the wire. The light intensity is at 100% of its maximum value. Varying the light intensity has no effect on the stopping potential.
Blue light of 469 nm at 100% intensity changes the stopping potential to -0.18 V as seen in Figure 4. Light at 494 nm does not produce a current in the circuit as seen in Figure 5. Green light of 540 nm (energy=2.30 eV) at 100% intensity does not have enough energy to eject electrons out of the sodium metal as seen in Figure 6.

Figure 4. Light of wavelength 469 nm shines on the cathode and causes electrons to be ejected from the sodium metal. A stopping potential of -0.18 V stops the electrons from reaching the anode, giving a current of 0 A in the wire.
Figure 5. Light of wavelength 489 nm shines on the cathode and causes electrons to be ejected from the sodium metal. A stopping potential of 0 V stops the electrons from reaching the anode, giving a current of 0 A in the wire.

Figure 6. Light of wavelength 540 nm shines on the cathode and no electrons are ejected from the sodium metal.
In Figure 7 the stopping potential acquired from the simulation is plotted against the frequency of the incident light (You can see that it is not a perfect simulation.). The slope of the graph multiplied by the charge of an electron should give Planck’s constant. The y-intercept of the graph gives the work function of the sodium metal.¹

![Graph of Photoelectric Effect](image)

**Figure 7.** Plot of the stopping potential of the ejected electrons versus incident frequency of light. The y-intercept gives the work function of sodium metal.

**Questions:**

1. What is the work function of the sodium metal?
2. What does the slope of the graph in Figure 7 give you for Planck’s constant?
   Recall that $E=hf$. The plot is $E$ vs $f$, but $E$ is given in eV so has to be multiplied by the charge of the electron ($1.602 \times 10^{-19}$ C) to be converted to Joules.

**Things to remember in lab:**

1. You will use a mercury lamp to shine light onto a metal. The light will go through a diffraction grating to separate out the colors emitted by the mercury lamp. Each color will be shone onto a white area between two black marks housed inside the photoelectric head. This is the trickiest part and requires patience and adjusting the angle of the photoelectric head properly. You will have to swing the tube open, line it up, and close the tube without shaking the apparatus too much.
2. You should zero your photoelectric head without any incident light before you start (red button on the back). The multimeter should read 0 V.
3. Make sure that you turn on the photoelectric head before you start and turn it off at the end.

References:


2. https://phet.colorado.edu/en/simulation/legacy/photoelectric
