Union College Winter 2021

Phy122: Lab 2A

The Photoelectric Effect and the Classical Expectations

In the 1880s, Heinrich Hertz discovered that when light shines on a piece of metal that was connected to a circuit, some electrons are freed from the metal and produce a current in the circuit. This is the photoelectric effect. The details of the quantitative results, however, were quite surprising and so this famous experiment played a major role in the initial realization of the quantization of nature. It is the interpretation of this experiment which earned Einstein the Nobel prize. For this week, we only approach the experiment from only the classical perspective.

When an electron is freed from the metal, it has a kinetic energy, K, given by

$$K = E - W$$

where E is the energy of the light absorbed by the electron and W is the amount energy required to remove the electron from the surface. W is called the "**work function**" for the material.

A reverse voltage can be applied which decelerates the electrons. If the "back voltage" is of the right value, you can stop the current altogether. In this case,

$$eV_{\text{stop}} = E - W.$$

The voltage which stops the current entirely, V_{stop}, is called the "**stopping potential**." This gives us the maximum kinetic energy of an electron leaving the plate:

$$K_{\text{max}} = eV_{\text{stop}}$$

Expectations in the classical view:
The understanding at the time was that light is a wave, and the energy in the light depends only on the intensity of the light. In this case, one expects the energy of the electron to depend on the intensity of the light, and be independent of the frequency of the light.

Your goal, with regards to data, is to measure the stopping potential vs. intensity of light and vs. frequency of the light.

Procedure:
A. **SETUP**:
The equipment for this lab consists of a mercury lamp, which serves as a light source, a diffraction grating spreads out the different frequencies of light, and a photoelectric cell consisting of a metal plate in an evacuated glass cell. The photoelectric cell with some electronics (which are not important to the experiment) is wired inside a box called "h/e apparatus", and the whole thing is connected to a voltmeter, which you use to measure V_{stop}.

1. The mercury lamps take a long time to warm up, so, to start, turn the lamp on and allow it to warm up. Warning: the lamps can get very hot. Do not touch the lamp when it's running. The output of the mercury lamp contains five different colors of light, with wavelengths given in the table below. While the lamp warms up, calculate and record the frequency of the light associated with each wavelength.

Emission Lines of Mercury

Color	Wavelength
Yellow	578.035 nm
Green	546.074
Blue	435.835
Violet	404.656
UV	365.483.

2. When the lamp is warmed up, position the large converging lens in front of the mercury lamp followed by the diffraction grating another 10 to 20 cm. Hold a white piece of paper after the diffraction grating -- you should be able to identify at least two sets of colored lines, corresponding to the colors listed in the table. (There is also an ultraviolet line which you cannot see, but the mask on the photoelectric cell apparatus has a special coating that will make the ultraviolet line visible.)

3. Place the detector (the "e/m apparatus") far enough back that the lines from the lamp are well separated from one another. Flip the small cylindrical light shield out of the way so that you can view inside the apparatus and locate the small rectangular piece of metal (this is the photoelectric cell). Orient the apparatus so that light from one of the lines passes through the slit, and falls onto the photoelectric cell. Be sure to flip the light shield back in place before recording data.

4. Connect the voltmeter to the red and black ports on the side of the h/e apparatus.

5. To vary the intensity of light, for each color, there is a slide consisting of five zones of different levels of transparency. This slide magneticallys mount onto the front mask of the detector the The different zones allow 100%, 80%, 60%, 40% and 20% of the intensity of the incident light to pass through.

6. You have two more slides, which contain yellow and green filters. Use these filters when getting data with these colors to block out light of other frequencies from the room.

B. GETTING DATA

You want to get data of V_{stop} vs. frequency and vs. intensity.

6. To get started, set up the equipment so that the yellow emission line shines onto the photoelectric cell. Then, taking care not to turn or move the apparatus, and remembering to close the cylindrical light shield, place the yellow filter onto the front mask of the apparatus. Then place the 5-level grey filter over the yellow filter with the yellow light passing through the 100% transmission zone. (You can use a piece of paper to help see this.)

7. Turn on the voltmeter and the apparatus (without letting it turn). Press the "PUSH TO ZERO" button on the side of the detector, let go, and watch the voltmeter. After a short time (several seconds to perhaps minutes) the voltmeter reading should settle down to a steady value. This is the "stopping potential" for yellow at 100% transmission. Obtain 3 measures of the V_{stop} by pressing the "PUSH TO ZERO" button to start the reading over again.

8. By adjusting the 5-level grey filter, measure the stopping potential for each level of transmission, obtaining 3 reading for each case.

9. Repeat the process for each of the 5 colors. (Remember to replace the yellow filter with green and use no colored filter for the blue, violet, and ultraviolet.)

Analysis

1. Calculate the frequency of each color.

2. Calculate the average Vstop of the 3 readings for each combination of color and intensity level.

3. Plot the stopping potential versus intensity of light transmitted for each color. Does the stopping potential depend on the intensity of light?

4. Plot of V_{stop} vs f. Does the stopping potential depend on the frequency of light?

Lab Report:

Following the Lab Report Guidelines on Nexus, write a first draft of a formal lab report from the classical perspective only.
(We will revise and improve the lab report during our lab meeting next week.)