LX2: The Photoelectric Effect

Austin Irvine

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Objective

The objective of this lab was to measure the voltage of different light sources on a detector through various shaded lenses and at specific nano-ampere readings. The equations used in this lab involved velocity, wavelength, kinetic energy, charge, and Plank’s constant. The equations directly dealt with how photon and electron interaction, also known as the photoelectric effect. An incandescent light, laser, mercury light, red filter, green filter, blue filter, and a photoelectric (PE) device were used in the development of this experiment.

Setup

-Basic Physics-

The theories involved in this lab heavily involved the use of Plank’s constant. The photoelectric effect was established by Albert Einstein and supported through experimentation by Robert Millikan.

To summarize, the photoelectric effect can be explained by a photon striking a sheet of metal and exciting an electron. When the electron is given enough energy, it flies from the surface of the metal. The energy needed for this much excitement is measured by the kinetic energy and voltage. The energy of the electron will not be as great as the electron or the work taken to eject an electron. KE is kinetic energy, h is plank’s constant, c is the speed of light, W is work, and λ is wavelength of the light.



Following that equation, the voltage is thrown into the equation. Voltage, V, resembles the maximum kinetic energy and energy to stop electrons from moving to a positive collector. The stands for the voltage related to work to tear the electron from the metal.



This equation is the same as the one above, just with everything reordered in terms of voltage. The, e, resembles the charge of the electron.



If the equation is solved for Plank’s constant, we get the equation below.

The instrumental error was for the most part negligible inside of this lab experiment.

-SETUP-

The setup for this experiment involved moving a different light sources close-to and away-from a PE detector.

The first experiment performed used the mercury light and a blue filter. The filter was placed over the PE detector lens. After placing filter, the machines were powered on and the detector was zeroed. After doing this, we moved the light away from the PE till the PE read 12 nano amps. We then adjusted the voltage on the detector till it reached 10 nano amps. We then recorded the voltage from a voltmeter. Subsequently, we did five more of the measurements moving down by two nano amps each time except moving down one nano amp on the last measurement of one nano amp.

The only difference in the second experiment was that a green filter was used instead of a blue filter to cover the PE detector.

The third experiment was run exactly like the first two experiments except with an incandescent light source and a red filter. The light also had to heat-up and be situated at a higher level due to being a short light.

The last experiment was the same as the three prior except that it used a laser light source. The laser was also diffused by placing a generic piece of scotch tape in front of it. For this experiment, there were no filters placed in front of the PE detector.

Sources of error from this experiment could likely come from several sources which are listed below. The sources of error ranged from poor electrical wiring, to the light sources not being as strong as they once were, to changes in height creating inaccurate results.

I believe the largest source of error was from height of the light sources. This caused the largest amount of error and inaccuracy because changing the height even the slightest amount made a significant effect on the readings. Additionally some of the lights had greater spreads of light at further distances, which at times left the light source uncentered on the detector. Moving the light further from the source at a certain height lead the light not being centered.

Sample Calculations

**-Part 0.5: Plots and Linest (Bad Graph)-**

**-Part 1: Plots and Linest-**

*Linest Calculations*

**Plot 1:** Current vs. V Mercury 436 || **Linest = 0.036** || **y-int = 0.9531**

**Plot 2:** Current vs. V Mercury 546 || **Linest = 0.021** || **y-int = 0.4889**

**Plot 3:** Current vs. V Incandescent 690 || **Linest = 0.031** || **y-int = 1.149**

**Plot 4:** Current vs. V Laser 633 || **Linest = 0.022** || **y-int = 1.0026**

**-Part 2: Stop Voltage vs. Inverse Wavelength-**

Linest = 4.79E-07

Y-Intercept = 1.342

Slope = 2.78E-07

**-Part 3: Plank’s Constant For Each Wavelength-**

**-Distance and Intensity-**

*Plank’s Constant:*

1. After finding the average values for voltage, work voltage as phi, and wavelength as lambda, plug them into the equation. The ‘e’ is the charge of an electron, 1.602 x 10^-19 coulombs, and c is the speed of light, 3x10^8 m/s. For example:
   1. = 5.34 x 10-34 m2 \* kg/s
   2. = 5.34 x 10-34 m2 \* kg/s

Partial Derivatives:

h = Plank’s Constant, V = voltage, = wavelength , e = 1.602 x 10^-19 or the charge of an electron

Error Propagation

=

= 6.72E-35 kg\*m^2/s

= 4.08E-35 kg\*m^2/s

= 1.26E-34 kg\*m^2/s

= 1.12E-34 kg\*m^2/s

Uncertainties

= = = 7.72E-35 kg\*m^2/s

= = = 4.69E-35 kg\*m^2/s

= = = 1.45E-34 kg\*m^2/s

= = = 1.29E-34 kg\*m^2/s

Plank Value

**-Part 3: Planck’s Constant From Slope-**

Equation: & Error || dk = -2.33 E -7 &

dh/dk = 34 J/s

h =

Results

Below are the results for planck constants calculated from several experiments.

**-Planck Values-**

Table 1: Planck Values In Graph Order

|  |  |  |
| --- | --- | --- |
| **Values** | **Actual (J/s)** | **Error (J/s)** |
| Planck 1 |  |  |
| Planck 2 |  |  |
| Planck 3 |  |  |
| Planck 4 |  |  |
| Planck 5 |  |  |

**- Discussion –**

The linest matched far better with the current vs. voltage measurements than the current vs. voltage squared, so we went with the first four graphs. We then created quadratic trends to predict the y-intercept.

The values for Planck’s constant that resulted in the five different calculations were not perfect by any measure, but fell into a realm of acceptable. The values were not off by a lot, but weren’t exactly what we wanted, and for the most part, the error matches with what we’d expect to get for Planck’s constant. Both methods of finding Planck’s constant did not pan out perfectly, although their values were extremely similar to one another. The results show that the mercury light gave us the most accurate results.

**- Discussion of Uncertainty -**

The error values calculated in for the experiments were impactful in the results and offered validity to our overall experiment. The errors were in the realm of possible and allowed our final answers to be closer to actually being Planck’s constant. The greatest source of error more than likely came from awkward light heights creating non-centered and biased light intensities on the photoelectric detector. This bias from light source to detector likely swayed the data. This along with smaller sources of error which may have included electrical wiring, age of the devices, and how dark the room was affected our data to some degree. If this lab were to be run in the future, I would have the light sources better focused on the detector, similar heights on all light devices, and buy brand new light source devices. I think running the experiments a few more times would help like always.

**-Concluding Statement of Results -**

In conclusion, the use of the photoelectric effect showed how photons and light at different wavelengths affect electrons on metal differently. The results of this lab relatively proved Planck’s constant with some error which came from several sources. The lab procedure was fairly easy, but lacked the feeling of accuracy in performing the experiment. In the end, the point of studying light and electrons gaining enough energy to excite from metal was delivered to the students in an efficient way.