This report deals with the results of an experiment where Planck’s constant was measured. To measure Planck’s constant the Photoelectric effect was used. This was done by aiming a filtered Mercury lamp at a device with a slit. Behind the slit was a piece of metal. This metal would then have a potential difference across it which could be measured. The voltage was measured at various frequencies and plotted. The slope of the graph was used to determine Planck’s constant. The expected slope was $h = 4.141 \times 10^{-15}$ J·s. After taking the data and fitting it to a graph in Excel and adjusting the work function ($\phi$) to the correct value, it was determined that Planck’s constant was $5.162 \times 10^{-34}$ J·s. With a standard deviation of 0.211 V. The slope measured was 3.2087 $\pm$ 15. This gives a percent difference of 22.1%.

**INTRODUCTION**

The Photoelectric effect was discovered by Einstein in 1905. To do this Einstein “used the concept of quantization developed by Max Planck.” This concept of quantization was the idea that the energy levels of electrons are quantized. The exist only in certain energy states and no where in between. This idea allowed for light to be emitted at certain wavelengths from electrons falling to a lower energy level. This idea was used in the development of the Bohr model of the hydrogen atom. This idea can be reversed, giving us the photoelectric effect. This was the idea that atoms would absorb photons and the electrons would change energy state. This means that photons add energy to the electrons. This was summed up in the equation:

$$E = h\nu \quad (1)$$

where,
- $E$ is the energy added,
- $h$ is Planck’s Constant,
- and $\nu$ is the frequency of the light.

This equation just gave the energy added, but this can be taken a step further. Say the light was filtered so that only one frequency was being emitted and the light was then focused on a piece of metal. In metal electrons are easy to move which means that some of the electrons where the light is being shown will be ejected. This will create a positive charge on that surface and the other side of the metal will gain a negative charge. This means there will be a potential difference. The equation could then be expanded to:

$$K_{\text{max}} + \phi = E = h\nu \quad (2)$$

where,
- $K_{\text{max}}$ is the kinetic energy of the electron,
- and $\phi$ is the work function for that specific metal.

The work function is describes how much energy it takes to eject an electron. By rearranging this equation to:

$$K_{\text{max}} = h\nu - \phi \quad (3)$$

we have a function that can now be analyzed. If $h\nu \geq \phi$ then electron will be emitted. The kinetic energy that it is emitted with is $K_{\text{max}}$. By dividing each side by the charge of an electron we get a measurable quantity on the left side of the equation. This is the stopping voltage.

$$V_s = \frac{h\nu - \phi}{e} \quad (4)$$

This gives the form $y = mx + b$. This may be good but there is one more modification that needs to be made to accommodate the set up of this experiment one last thing needs to be done. The frequency needs to be converted to wave length. This can be done by replacing the $\nu$ with $\frac{c}{\lambda}$.

**EXPERIMENTAL PROCEDURE**

Performing this experiment is really simple. The setup is shown in figure 1. The first thing that must be done is it must be start by setting up the experiment tools. First start by plugging a volt meter in to the Planck’s Constant apparatus. This will measure the accelerating voltage by shining a light through the slit. Next put up the shield in front of the hall apparatus as pictured. Then place the Mercury lamp behind it. Now plug in the Mercury lamp and adjust the shield to that the light coming out of the mercury lamp shoots through the shield and into the slit. There are three things that must be kept in mind while doing this part. First, the slit cannot be too close to the Planck’s Constant Apparatus, but it should be as close as possible. The filters need to be able to be removed from the filter slit. Next, make sure the lensed end of the mercury lamp is facing the shield. Next, do not look into the Mercury lamp. It emits UV radiation.
FIG. 1: In this figure a) is the Planck’s Constant apparatus, b) is the slit, c) is the filter holder, d) is the light shield, and e) is the Mercury lamp.

which can damage your eyes. There is one last factor to take into account. There can not be any unfiltered light leakage. Turn off the lights and look at the light shining on the slit to make sure. There is one last step in the set up, and that is choosing the filters. The filters filter out all wave lengths except for the one that is marked on the filter. The wave lengths of the filters correspond to the emission wave lengths of Mercury. Pick out the best filters of wavelengths: 405 nm, 435.8 nm, 546.1 nm, and 577.7 nm.²

Now that the experiment has been set up the data can be taken now. Make sure there is no light in the room. Then, start by turning on the lamp. Then turn on the Planck’s Constant Apparatus and the voltmeter. Observe the voltage. If it starts drifting turn the devices off and wait a few minutes. This will help. Now make sure everything is in alignment. If it is drop the first filter into the the filter holder. Observe and record the new voltage. Now with out moving anything use a pair of tweezers or something to remove the filter. Then repeat this until all of the filters are used.

DATA AND ANALYSIS

Since there was so little data taken during this experiment, there is little to talk about. In this experiment there were values that needed to be looked up. These values were Planck’s constant, which is in the table, and \( \frac{\hbar}{c} \) which could be found in the Pasco interface manual. Due to the nature of the calculations there was not a way to do error analysis. To compensate the fit line was used to calculate the expected voltage at each wavelength and the difference was taken. Then the standard deviation of the differences was taken. This value was 0.211 V. The errors in this experiment seemed to be systematic suggesting equipment issues. This will be addressed further in the conclusion section. So lets get to the equations. To produce the graph in of the data \( \frac{c}{\lambda} \) vs. Voltage was graphed. Once a line was fit and slope was obtained, Planck’s constant could be calculated. This was done with the equation:

\[
m = \frac{h}{e}
\]

Planck’s constant could then be determined by multiplying the slope of the graph by the charge of an electron.

\[
3.28E-15 \times (1.6E-19 C) = 5.16167E-34 J \cdot s
\]

Now with this value the percent difference can be calculated:

\[
\% - diff = \frac{|theoretical - known|}{known} \times 100
\]
%\text{diff} = \frac{|(6.626E-34) - (5.16167E-34)|}{6.626E-34} \times 100 = 22.1\% \tag{7}

CONCLUSION

The goal of this lab was to determine the value of Planck’s constant. The data taken during this experiment was ok, but not exceptional. The percent difference was 22.1%. Normally this would mean bad data. But during this experiment there were equipment issued to deal with. The first issue and probably the biggest was with the Planck’s constant apparatus itself. There was alot of trouble with it not reading the correct voltage. The device seemed to have a great deal of voltage drift. The second issue was that there was not a given vaule for the work function of the metal in the device. There was no indication as to what the metal might be. Even the operation manual seemed to guess at the value. The third issue is light contamination. Any light contamination could add extra voltage to the device. The final problem came from the filters themselves. The Mercury lamp emits UV Radiation. The filters may not have been sufficient to deal with this issue. This would cause an increase in the voltage values. Even with all of the issues with the equipment this experiment can be reversed to make some very useful measurements. Instead of measuring Planck’s constant, the work function could have been measured. This would tell about many properties of the metal. This can be used to infer things about the atomic compostion of the metal.

REFERENCES

2 http://www.nhm.ou.edu/johnson/Education/Juniorlab/PhotoElectric/Pasco9368%252C9.pdf