Measuring an Electron’s Charge: the Millikan Oil Drop Experiment

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In this experiment the Millikan Oil Drop apparatus was used to measure the charge of an electron. To find this charge five different trials of the experiment were conducted giving a total of 63 individual data points that gave 63 values for the charge of an electron. Those values were then averaged and their standard deviation of the mean was computed go give the measured value of the charge as . The accepted value of the charge of an electron is [1] and the discrepancy between our experimentally measured charge and the accepted charge is insignificant.

I. Introduction

In 1909, Robert A. Millikan re-designed an experiment that was used to measure the charge of an electron[2]. His experiment consisted of a chamber enclosed by two capacitors at the top and bottom. Oil droplets were squirted into the chamber and observed as they moved up and down between the plates. This motion led to a calculation of the droplet’s charge. One improvement Millikan made to earlier experiments was the use of oil rather than water[2]. When water was used the drops would evaporate quickly, eliminating the ability to record a significant amount of data on a single drop. In contrast, the oil would remain in its physical state, immune to evaporation, allowing for a longer trial[3]. Another difference between his and prior experiments is that he charged his capacitors to a higher potential difference[2]. In doing so he could control the motion of the oil droplets. More specifically, he retained the ability to let the drops fall under the influence of gravity or force them to rise under the influence of a powerful electric field[4].

By measuring the distance translated and the time taken by the drops as they rise and fall the velocities are calculated. With these velocities, in combination with the barometric pressure and the viscosity of the medium, Millikan was able to calculate the charge of an electron. His experiments yielded a value of in electrostatic units[3] which is not that far off from the accepted value of in electrostatic units[3].

II. Theory

The droplets of oil in this experiment fall under the influence of gravity and reach their terminal velocity. The sum of the forces is zero which gives

Where is dependent upon the friction between the drop and the air molecules, is the terminal velocity of the drop, is the mass of the droplet, and is the acceleration due to gravity. Upon charging the capacitors the drop will begin to rise at a constant velocity. In other words the force of gravity, the force of the air resistance, and the force from the electric field sum to zero.

Where is the electric field intensity, is the charge of the oil droplet, and is the rising velocity of the drop. After solving for in equation one and substituting it into equation two we are left with

The velocities can be determined by knowing the time it takes for a droplet to traverse a known distance and using

For this experiment

and varies for each rise and fall of the droplet. The value is determined by

Where is the potential difference between the capacitors and is the distance between the capacitors. For this experiment

The mass of the drop is determined using the formula for a sphere's volume where

Where is the radius of the drop and is the density of the oil, which is given as

[3]

Stokes' Law relates the velocity of travel of an object in a medium with a specific viscosity to its radius. To calculate we use Stokes' Law which gives

Where is the viscosity of the air in which the droplets are traveling. Unfortunately, Stokes' Law only holds for velocities above . We need to multiply by a correction factor to give our effective viscosity is

Where is a constant that is

And is the barometric pressure of the atmosphere. After substituting into equation 10 the radius is written as

After substituting the mass and the radius into equation three we are left with the equation for the charge of an electron. This equation can be found in Appendix one.

III. Experimental Set-Up

This particular experimental set-up calls for a PASCO Millikan Oil Drop Apparatus (*AP-8210*), a 12 volt DC transformer (for the halogen lamp), a power supply capable of producing 500 volts of potential, an atomizer and a digital multimeter for reading the potential difference across the two brass capacitors.

The apparatus has a housing chamber enclosed by two brass capacitors at the top and bottom, as shown in figure two. The power source charges the capacitors in order to build the electric field. The capacitors are separated by a specific distance determined by the width of a plastic spacer placed in between the plates. The housing chamber has a viewing window in its side where the microscope is secured, as shown in Appendix two. The microscope has gridlines set on its lens that are used to measure the distance the oil droplet rises or falls. In order to view the droplets, an

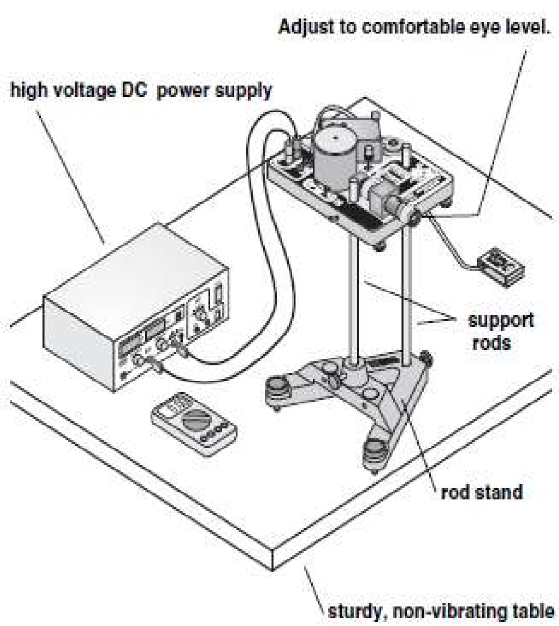

Figure 1: Experimental set-up including the power supply[3].

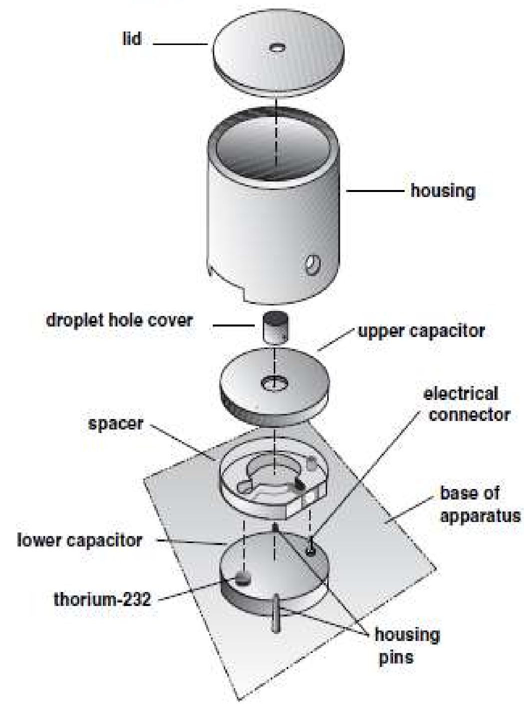

Figure 2: Schematic view of housing chamber[3].

illuminated halogen lamp is directed into the housing chamber through a convex lens. To focus the light, place the focusing wire into the top capacitor plate and adjust the microscope focus until the light is at its brightest, as shown in figure three.

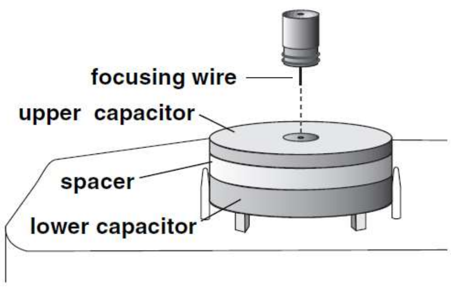

Figure 3: Focusing wire insertion[3].

Remove the focusing wire and replace it with the droplet hole cover.

IV. Experiment

First, record the temperature using the thermistor connectors and a temperature reading device. Next, record the potential difference across the plate connectors using a digital multimeter. Finally, using a barometer, record the pressure. The temperature is used to determine the viscosity of the air in which the drops were falling. See Appendix three for a graph depicting this. While looking through the microscope squirt the oil droplets from the atomizer into the housing chamber until you see a cascade of droplets falling before you. It may take some time to find a droplet that is acceptable to use. It is preferable to select one that takes roughly 15 seconds to traverse the distance between two of the darker gridlines. A drop that falls this distance in about 15 seconds will rise that same distance in this specific time if it has the corresponding charge: 15 seconds, one electron; 7 seconds, 2 electrons; 3 seconds, 3 electrons[3]. After selecting a droplet, time it as it rises and falls from one dark line to the next. To make the droplets rise use the plate charging switch to charge the capacitors. The recorded times will be used to compute the rising and falling velocities of the droplets which will be used to find the charge.

V. Experimental Results

After averaging the 63 values obtained from performing the Millikan Oil Drop experiment our best guess for the charge of an electron is

Only ten of our 63 values fall within one and only 14 of those 63 values fall within two One reason for this abnormally low amount is that the time for the rise and fall of each drop was recorded with hand-held stop watches. This results in a large amount of random errors in the measured time due to our reaction times. This caused the range of values to expand; however, an elimination of this particular error would in fact make our measured charges more precise. A greater precision would lead to more values falling within one and two standard deviations.

VI. Conclusion

Obviously the low amount of precise data points is very undesirable, but nonetheless our calculated charges are extremely accurate. This accuracy allows us to accept the value that has been calculated from our recorded data. These particular experimental trials are acceptable in measuring the charge of an electron using Millikan's Oil Drop experiment.

VII. Appendices

Appendix 1: Equation for the charge of an electron.

Appendix 2: Figures for experimental set-up.

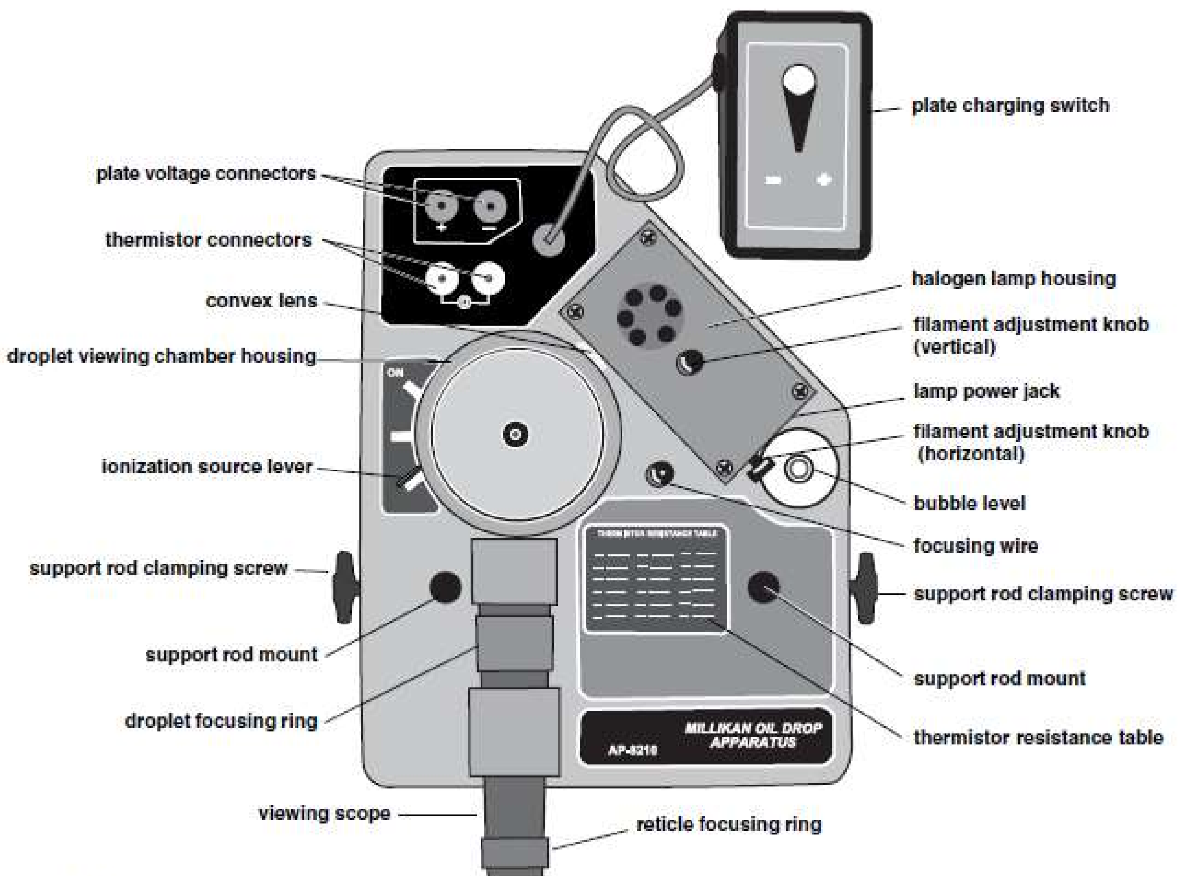

Figure 4: Bird's-eye view of experimental apparatus[3].

Appendix 3: Graph of Temperature vs. Viscosity.

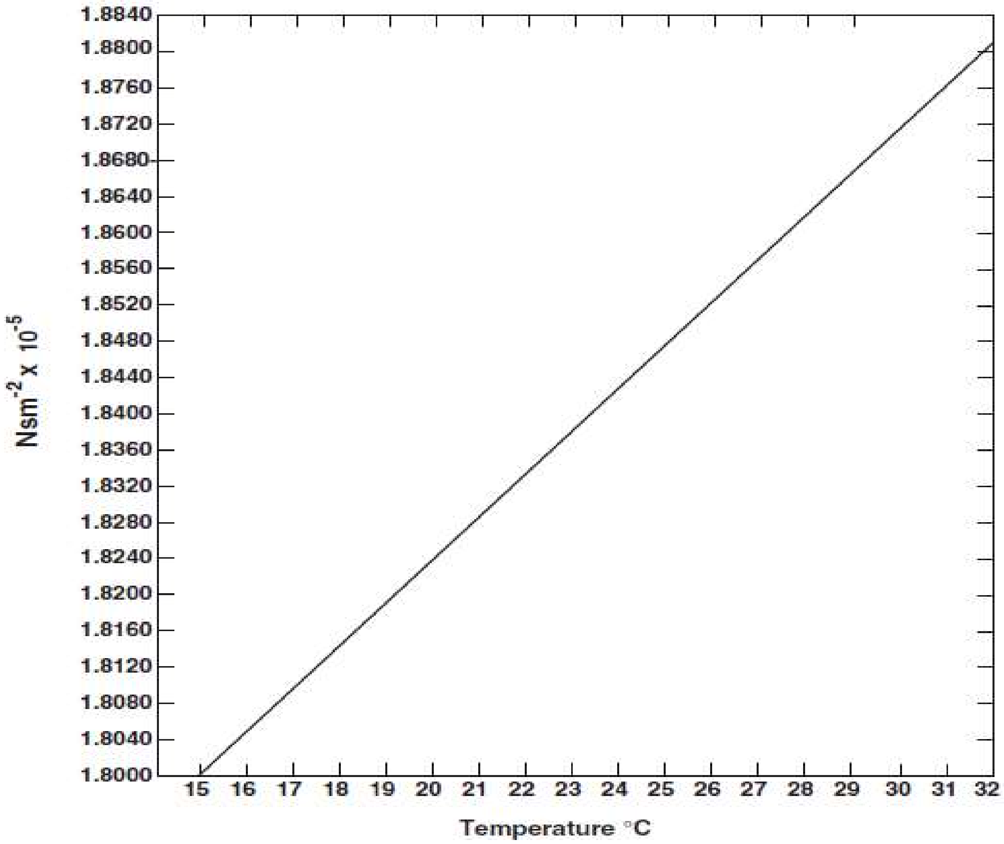

Figure 5: Graph of Temperature vs. Viscosity; used for determining viscosity[3].

VIII. Acknowledgements

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IX. References

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