Millikan Oil Drop Experiment Lab Report

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**Abstract**

The purpose of this investigation is to recreate the oil drop experiment conducted by Robert Millikan and Harvey Fletcher to find the charge of the electron. An oil atomizer was used to spray a multitude of droplets and then allow gravity as well as electrostatic forces to raise and lower the droplet. Charges were then calculated from each of these droplets. The smallest electron charge was found to be ( C. The true charge of the electron was found to be less than or equal to C with a 95% confidence. Applying Orthogonal distance regression to the grouped charge vs number of electrons got a charge per electron of . Since the ODR model is not less than or equal to the predicted smallest charge, the number of electrons assigned to each group is suspect.

**Introduction**

The journey first begins with JJ Thompson and his discovery of the charge – mass electron relationship [1]. He utilized a cathode tube that had a high voltage to discover the existence of electrons, which was a pivotal discovery. The next step from here was to find the actual electron charge. Millikan came up with the oil drop experiment to figure out the charge of the electron and performed it in 1909 alongside Harvey fletcher at the University of Chicago [2].

It utilized the effects of gravity as well as electrostatic forces to determine the rising and falling velocities which are then used to find the charge along with a host of other parameters. The equation that is yielded from the force is used to calculate the charge of the electron. It was postulated that charge of the electron is quantized. Therefore, the charge on the droplet should be an integer multiple of the electron charge.

It will be attempted to find the charge of the electron by taking rising velocity and falling velocity data from many different particles and plugging those values, along with the other necessary variables, into the corrected charge equation found by Millikan.

**Theory**

There are two scenarios that need to be accounted for. When the droplets enter the chamber, they can either be affected only by the force of gravity or by the electrostatic attraction of the plates.

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Figure 1: Free body diagram of Oil droplet under the influence of gravity

Timeline

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Figure 2: Free body diagram of Oil droplet under influence of gravity and electrostatic forces

When the droplet is falling in the air, it will eventually reach terminal velocity. At this point, the gravitational force will equal the terminal velocity times a constant k.

When the droplet is placed under the presence of an electric field, the electrostatic attraction to the top plate will be equal to the gravitational force plus the drag force for .

K is not desired in the final equation since the buoyant force is small at a constant velocity so use the previous two equations, solve for k in each one and equate them. Then solve for q.

M makes its way into the equation and needs to be removed since we can’t determine the mass of the charge droplet, use the formula for relating the radius a to the mass.

However, a, the radius of the droplet is not known. To find this value, stokes law must be used which relates the radius of a spherical body to its velocity using a coefficient of viscosity [3].

Substitute equations 4 and 5 into equation 3 and get equation 6.

However, when the velocity is less than .1 cm/sec, the droplets velocities tend to be comparable to the mean free path of air molecules. This violates an assumption made in the stokes law derivation. A correction factor is added to yield the correct results and is shown below since the particles will mostly be in the range of .01 to .001 cm/sec [3].

Substituting equation 7 into equation 6 and rearranging terms gets the final equation

**Procedure:**

The Pasco Ap-8210 Millikan oil drop apparatus that was used is shown in figure 3.

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Thermistor chart

Light Source

Ocular Lens

Charge plate assembly

Figure 3: Pasco Ap-8210 Millikan Oil Drop Apparatus

To begin the experiment, the atomizer was primed so that it could produce a fine mist. The 500 V DC voltage supply was then set to 200 V while also acquiring pressure data from the gas pressure sensor and temperature data by converting thermistor readings from the Pasco Millikan apparatus. Then the atomizer tip was placed into the aperture on top of the charge plate assembly and one pump was administered after the light source was turned on. The phone camera that was in line with the lens was then switched to video mode to begin recording.

Oil droplets were seen as tiny white dots and were initially falling. The Pasco grid, with major and minor division of 5 mm and 1 mm respectively, was used to see how fast these droplets were rising and falling. As time went on, the control panel was used to charge the upper electric plate sending particles with negative charge upwards. A few particles were identified that were of interest in that time and so when they got to the top of the grid, the plates were then grounded allowing them to fall under the influence of gravity.

This process was repeated for 6 minutes for the first trial and then 10 minutes for the second trial. The videos were taken into logger pro and video analysis was used to determine the rise and fall velocities. With the velocities and other variables, error propagation techniques from Taylor’s book on error propagation were used to find the charge on each droplet. Further analysis followed from these results.

**Discussion**

An uninteresting but important finding was that there was an overall negative charge on the droplets. The presence of rising velocities could only be possible if electrons were attached to the oil droplet and imparted an overall negative charge.

When comparing the initial two datasets shown in figure 4, there were some observations on the relative uncertainties as well as the magnitude of the charge.

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Figure 4: Charge data from datasets 1(Left - faster velocities) and 2 (Right - slower velocities)

On average, the fractional uncertainty in dataset 1 was found to be 6.6%. The average fractional uncertainty in the second dataset was 12.1%. There was a nearly two-fold increase in uncertainty percentage from dataset 1 to dataset 2 when slower velocity particles were prioritized. This is understandable since as the estimates decrease in magnitude the uncertainties tend to have more of an effect.

In addition, lower velocities tend to produce lower charges. On average dataset 1 has a rise and fall velocity of .0005 m/s while dataset 2 has an average rise and fall velocity of .00012 m/s and .00015 m/s respectively. The average charge for dataset 1 was found to be whereas for dataset 2 the average charge was found to be C.

To find the charge on the electron, first the droplets must be investigated to see which groupings are present. The organized dataset which combined datasets 1 and 2 are shown in data table 1 and figure 5.

|  |  |
| --- | --- |
| Droplet number | (C) |
| 1 |  |
| 2 |  |
| 3 |  |
| 4 |  |
| 5 |  |
| 6 |  |
| 7 |  |
| 8 |  |
| 9 |  |
| 10 |  |
| 11 |  |
| 12 |  |
| 13 |  |
| 14 |  |

Table 1: Charges on the 14 droplets from datasets 1 and 2 organized by charge magnitude

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Figure 5: Sorted oil droplets with associated charges

There were 6 different levels in the data collected from this experiment. Droplets 1 – 6, 8-10 and 12-13 were collated together. The grouped charges were then assigned an electron number. It was necessary to average these best estimates as well as their corresponding uncertainties to produce an estimated charge for a certain number of electrons.

The resulting figure is shown in figure 6.

Chart, scatter chart

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Figure 6: Average charge vs Electron Number figure

These best estimates and uncertainties that were associated with electron number are used as inputs for Orthogonalized Distance Regression which considers uncertainties in the output variable and makes a trendline incorporating those uncertainties [4]. It was decided to use a linear model with no intercept parameter since the amount of charge would be 0 C with 0 electrons. Applying ODR on the data shown in figure 4 with linear model resulted in figure 7.

Chart

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Figure 7: ODR equation fit on data in figure 6

Printing out the parameters of the linear model yielded a charge per electron of . The smallest charge found from the dataset was . The accepted value for the charge of an electron from CODATA is [5]. Adding two standard deviations to the results found from the dataset and ODR, it can be said with 95% confidence that the charge of the electron is at or lower than and respectively. The value acquired from ODR does not agree with the value from the dataset. The smallest charge shows that the charge of the electron is one value, but the ODR is suggesting is a far larger value.

It was hypothesized from these results that the number of electrons assumed for each group was incorrect for the ODR calculation. Since the charge is quantized, the smallest charge after applying two standard deviations would most likely be closer to the correct value. To refine the analysis, more trials would be needed to gain a more accurate result for the electron charge.

**References**

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