

Lab: Millikan's Oil-Drop Experiment

AP Physics

Background

From 1909 to 1913, Robert Millikan performed a series of experiments designed to measure the charge of an electron. His general strategy was to place charges (electrons) on very small drops of oil, and then place those oil-drops in an electric field. By considering the Force of gravity, the electric Force, and the drag Force (air friction) acting on the drops, Millikan collected enough data that he was able to determine that the fundamental quantity of charge (the electron) is $-1.60 \times 10^{-19} \text{C}$. For his experiments, Millikan won the Nobel Prize in Physics in 1923.

Learn more about Robert Millikan in [The Millikan Experiment](#), from *The Mechanical Universe* (YouTube).

Objectives

To observe the motion of charged particles in an electric field (a modified version of Millikan's experiment), and to perform a data analysis of information "collected" in a statistical simulation of Millikan's experiment.

Equipment

Millikan oil-drop device (set up in class)

Group "data" collected in a classroom simulation

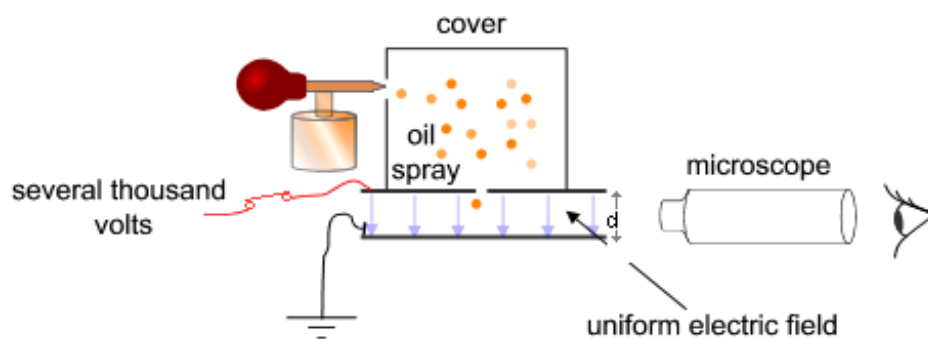
Spreadsheet software (LibreOffice *Calc*, Apple *Numbers*, Google *Sheets*, or Microsoft *Excel*)

Procedure

Part A. Millikan's Device

1. Examine the device that has been set up for this lab.

A schematic diagram of Millikan's apparatus is shown here (from wikipedia.org):



2. Read this explanation of the device's basic operation

To determine the fundamental unit of electric charge (e^-), Millikan sprayed droplets of oil in to a chamber exposed to an electric field E . The droplets, which are charged by friction in the spraying process, experience an electrostatic force F_e according to the equation $F = qE$.

The drops also experience a downward force due to gravity, F_g , and a force of air friction F_{drag} when in motion. By analyzing the motion of the drops in the absence of the E field, it is possible to determine a droplet's mass m .

With this same oil drop, if the Electric field is adjusted so that the droplet is suspended motionless, then the electrostatic force F_e will be just equal to the F_g .

$$F_e = F_g$$

$$qE = mg$$

$$q = \frac{mg}{E}$$

For a given oil-drop, there will be only one electric field that will suspend it. The strength of the field that supports a given oil drop depends on the mass of the droplet as well as the net charge of that droplet, and a given mass can have a wide variety of different charges, depending on how many electrons have been added to it (or subtracted from it) in the charging process.

How, then, did Millikan determine the magnitude of the fundamental electric charge? (Rhetorical question—we'll see how in the lab.)

3. Examine the online simulation of the oil drop experiment.

Click “Start” on the simulation at <https://www.magnus-karlsson.nu/millikan/> and see how gravity affects the oil drops as they appear in the Electric field. You can vary the strength of the Electric field by using the slider at the bottom of the simulation. Are you easily able to create a field that balances the force of gravity acting on that drop?

4. Draw a free-body diagram of the forces acting on an oil drop in static equilibrium in an Electric Field. Include E-field lines in your free-body diagram.

5. How did Millikan know what the Electric Field strength was? How could he vary it? In the graphic above and in the simulation you performed, you can see that the electric field is maintained between two conducting plates (one positive, one negative) with a potential difference between them. If a 500.0 Volt potential difference exists between the two plates, and there is a 1.50 centimeter distance between them, calculate the strength of the electric field between the plates.

Part B. Data Analysis

1. Get a data set of Electric field strengths and charge mass.

Download the Common Separated Values (CSV) data at

<https://www.crashwhite.com/apphysics/materials/assignments/lab/millikan/data.csv>

2. Analyze a subset of that data to determine the fundamental quantity of charge, i.e. the charge of an electron.

- a. How will you calculate the electric field that each droplet has been exposed to, given the potential and gap distance specified in the data?

- b. How will you calculate the charge on a given droplet, floating motionless in the electric field?

- c. Use a spreadsheet to record a subset of the data values you downloaded, and use the spreadsheet's cell-calculation capabilities to identify the charge on each droplet.

- d. Create a bar graph showing the charges of the different droplets. Are there any patterns immediately evident?

- e. To help identify any patterns in your data, copy the column of charges that you've calculated and paste just the values (not the formulas) into a new column, then sort them. What does a bar graph of the charges look like now? Are there any patterns evident? Can you identify the elementary charge unit from this? If so, do it!

- f. Discuss with the instructor additional ways to pull meaningful data from your results.

DATA NOTES:

If you copy the double-entry list of mass/voltage data provided by Mr. White into a spread sheet, you are going to have to split the entry into two columns and do some other manipulations. Below is a brief outline of how to do that for a Google Sheet. The approach is similar for an Excel spread sheet.

- 1.) Pick a subset (maybe half) of the double-entry data provided by Mr. White at <https://www.crashwhite.com/apphysics/materials/assignments/lab/millikan/data.csv>
- 2.) Paste double-entry data into Google Sheet, then go to Data and select "split text to columns." (I would put the first entry into the second row so you can use the first row later to label the columns).
- 3.) With all the data highlighted, go to format, then Number and select "Scientific Notation."
- 4.) Create a column in which you determine "q" (put the equation into the top cell, then when the program has done the calculation, put the cursor over the bottom right-hand area of the cell and a tiny downward triangle will show up—click on the triangle and pull it downward—this will make each included cell do the same calculation).
- 5.) With the calculated-q column highlighted, go to Format, then Number and select "Scientific Notation" (if the data isn't already in Scientific notation)
- 6.) As this column has calculated values in it, we have to detach the numbers from the equation that generated them (which is to say, we need to make those numbers into "values only" information). To do this, highlight the column (or, at least, the numbers in the column), copy, then in a different column control-click (this is right-click) and select the "paste values only" option for the pasting.
- 7.) If needed, highlighted the column, go to Format, then Number and select "Scientific Notation."
- 8.) To see what your charge data looks like, select the "values only" column, go to Insert and select Chart (use the Column graph option). You should see a random arrangement of charge values graphed.
- 9.) To make sense of the randomness, highlight the charge (q) column, go to Data and select Sort Range. The window should identify the column you have highlighted. You want to order the data "from A to Z" (this should sort the data from the lowest to highest—if it doesn't try using "Z to A").
- 10.) Make another Column chart with this newly ordered data. You should see very definite steps (if the chart is to spread out, select the first twenty entries in your sorted column and do a Column chart with that data—that should get rid of the higher order values, which you don't really need in any case.)
- 11.) You should now have four or five groupings on your chart. You have no idea how many charges are on the oil drops that are in the first grouping, but you know there is one elementary-charge-unit difference between that group and the next. So count the number of oil drops there are in the first group (actually count them off the graph) and in a new column, determine the average charge for the group. You can do this by writing " $=\text{average}()$ ", putting the column/row identifier for each of the charges you want summed in the parenthesis. Use this process to find the average "q" for the first four groups.
- 12.) Create a column in which the difference between each successive average is taken. You should find that the values are very close to 1.6×10^{-19} , the elementary charge unit.