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 $-1.60 \times 10^{-19} C$. For his experiments, Millikan won the Nobel Prize in Physics in 1923.

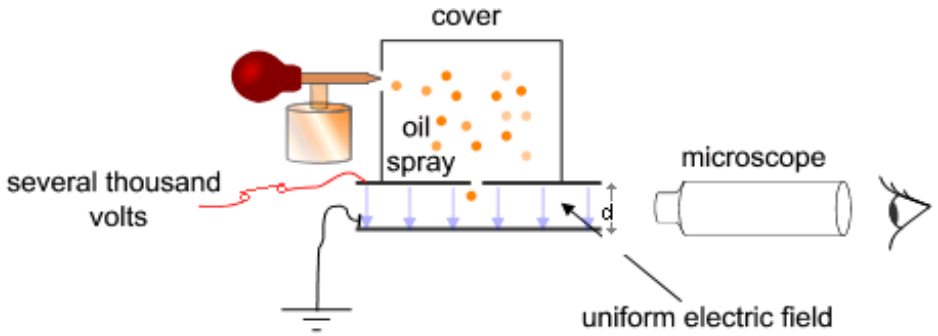
Objectives
To observe the motion of charged particles in an electric field (a modified version of Millikan's experiment), and to perform a data analysis of information "collected" in a statistical simulation of Millikan's experiment.

Equipment
Millikan oil-drop device (set up in class)
Group "data" collected in a classroom simulation
Excel or similar spreadsheet software

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 $\mathbf{F}_e$ according to the equation $F = qE$.

   The drops also experience a downward force due to gravity, $\mathbf{F}_g$, and a force of air friction $\mathbf{F}_{drag}$ when in motion. By analyzing the motion of the drops both 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 $\mathbf{F}_e$ will be just equal to the $\mathbf{F}_g$.

$$F_e = F_g$$
$$qE = mg$$
$$q = \frac{mg}{E}$$

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For a given oil-drop, there will be only one electric field that will suspend it. The strength of the field 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 Java applet that simulates the oil drop experiment.**
   If you have trouble getting Java to run on your computer, use one of the computers in class.
   https://www.crashwhite.com/apphysics/materials/assignments/lab/millikan/index.html

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

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 charge on a given droplet, floating motionless in a given electric field?
   - **b.** Create a bar graph showing the charges of the different droplets. Are there any patterns immediately evident?
   - **c.** Copy the column of charges that you've calculated, and paste just the values into a new column, then sort them. What does a bar graph of the charges look like now? Are there are any patterns evident?
   - **d.** Discuss with the instructor additional ways to pull meaningful data from your results.

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