Name: ____________________________________ **P**eriod: _____ **D**ue Date: ___________

MILLIKAN OIL DROP EXPERIMENT – WebAssign

Performing the Experiment

MILLIKAN OIL DROP EXPERIMENT – Version 1

Objective

This experiment is a highly simplified version of the Millikan Oil Drop experiment. You will use the computer simulation to determine as much as possible about the electrical charges on individual droplets. You will do this by balancing the forces on the droplet: gravity, due to the weight of the droplet, and the electric force, due to the electric field acting on the charge of the droplet.

Theory

When an electrically charged object (*with electric charge* **q**) is placed in an electric field (*of magnitude* **E**), an electrical force, $\mathbf{F_e}$, is exerted on it. This force is given by:

$$\mathbf{F_e = E\ q}$$

Since the magnitude of the electric field equals the voltage between the plates (**V**) divided by the distance between the plates (**d**), we can also write:

$$\mathbf{F_e = (V/d)\ q}$$

In this simulation, droplets are injected into an electrical field between two conducing plates. You can control the voltage between the plates, which directly controls the strength of the electric field between the plates.

Each droplet is also in the earth's gravitational field, so its mass, **m**, is subject to the gravitational force. Its weight, $\mathbf{F_g}$, (assuming **g** = 9.8 N/kg) is:

$$\mathbf{F_g = m\ g}$$

One way of studying the charge on the droplets is to adjust the voltage between the plates until the electric force acting upward on the droplet exactly balances the downward pull of the gravitational force. In that case:

$$\mathbf{F_g = F_e}$$

$$\mathbf{m\ g = (V/d)\ q}$$

$$\mathbf{q = mgd\ /\ V} \qquad (\textit{Equation 1})$$

The charge on the droplet is inversely proportional to the voltage required to balance the drop (*the balancing voltage*).

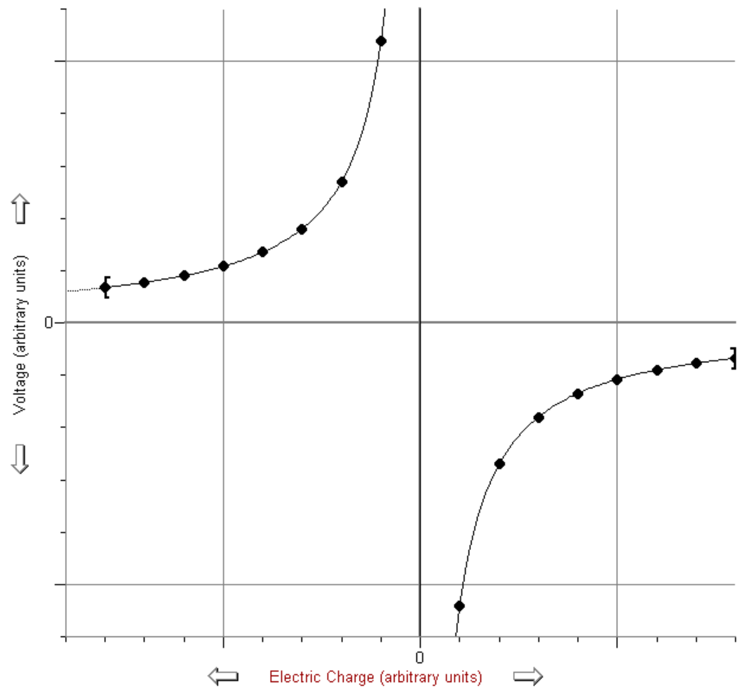
This means the droplet carrying the smallest electric charge requires the largest voltage on the plates, which creates the largest electric field, to balance the force of gravity. Here is a graphic illustration of the relationship between the charge on the droplet and the balancing voltage.

Positive voltages balance negatively charged droplets and negative voltages balance positively charged droplets. If the particle has no charge, then there is no voltage large enough to balance it against the pull of gravity.

The droplets with the smallest charges, the ones nearest to zero, require the largest voltages, either positive or negative, to balance them against the pull of gravity.

As the charge on a droplet gets larger, either positive or negative, less voltage is required to balance it against the pull of gravity.

While working with this simulation program you will encounter both positively and negatively charged particles.



Since all your droplets have the same radius and density, and therefore they all have the same mass, you do not have to chase every single droplet. Nevertheless, try to chase every droplet until you find its balancing voltage. Use the **<S>** key to quickly change between positive and negative voltages. If you miss one, simply inject another, but note the missed ones in **Data Table Ia** with an X. Start each new droplet with a positive voltage on the plates in the adjustment set to COURSE, but be prepared to switch to negative voltage.

You may find as many as eight unique positive balancing voltages and eight unique negative balancing voltages. If you find all sixteen, you can stop. Otherwise, keep searching until you fill **Data Table Ia**.

Don't be surprised when you find a lot more positive voltages than negative voltages. The apparatus tends to manufacture more negatively charged droplets than positively charged ones. The x-rays that create the charges release a lot of free electrons from the metal parts. So a lot of droplets pick up extra electrons. Very few droplets tend to end up short of electrons, but there are those few. Be alert to catch those when the appear.

One interesting circumstance you will encounter is the uncharged droplet. If you cannot make a droplet move upward with either +700 V or –700 V (*use the* **<7>** *key to get 700 V and the* **<S>** *key to switch between positive and negative*), then that droplet has zero charge. Note it in **Data Table 1a** as 0 V.

If the mass of the droplet, the distance between the plates, and the voltage are known, we can calculate the actual charge on the droplet.

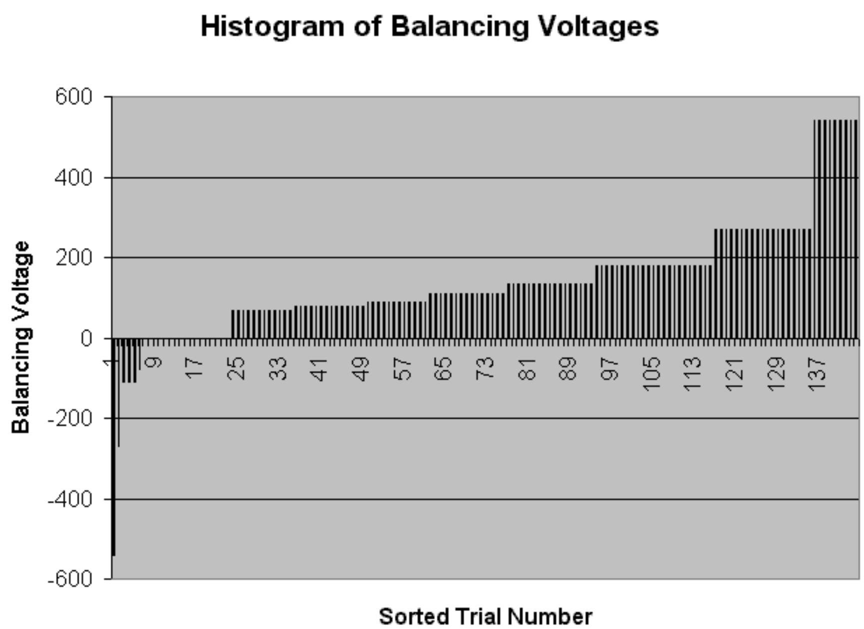
Procedure

Determine the voltage necessary to balance the droplets in 144 separate trials. Between each trial, inject a new droplet. You can do this by injecting a new droplet (*which will have a random charge*). Keep trying until you fill the table. List all the balancing voltages you measure, not just the unique ones, in **Data Table Ia**. List all the certain (0 V) and probable (X) zeroes, too. A probable zero is a droplet that you could not catch. A certain zero is a droplet that could not be forced to change directions by switching, **<S>**, between +700 V and –700 V.

Use the **<S>** key to switch between positive and negative voltages. There are fewer opportunities to use the negative voltages but be alert for the possibility. You don't want to miss those few.

If you're lucky you'll find all sixteen (*16 = 8 positive + 8 negative*) unique voltages, not counting zero. This will take as many trials as it takes; just keep going. <u>You must submit a copy of **Data Table Ia** to your instructor</u> for a statistical analysis before you start constructing your histogram. If you don't find all eight of the negative voltages before the table is filled, that will be all right. Circle the negative voltages so you can easily find them.

After **Data Table Ia** is approved by your instructor, use Excel to make a sorted histogram of the voltages. Sort them from most negative at the top of the list, to most positive at the bottom of the list. The histogram constructed from the sorted data should look something like the figure below. This histogram is from a run of 144 trials in which one droplet could not be identified. It was listed as 0 V for purposes of making the histogram.



You should use Excel to sort your data and make your own histogram. <u>Submit the printed histogram to your instructor</u> before you begin work on **Data Table I**. Be sure to save your spreadsheet. If your instructor says you need more trials, then analyzing the new trials along with the older trials will be a lot easier if you do not have to construct a new spreadsheet from scratch.

Once your histogram is approved by the instructor, fill-in all the data at the top of the **Data Table I** and calculate the mass of the droplets. All droplets are identical in size, density, and mass. The density of the plastic droplets is 128 kg/m^3. The radius, **r**, is given in the lower left-hand corner of the main screen. Here is the equation for calculating the mass of one droplet.

$$\boldsymbol{m} = \rho \times \text{volume} = \rho \times \left(\tfrac{4}{3}\right)\pi r^3 = \frac{128 \times 4}{3}\pi r^3$$

The distance between the plates, which you need to list at the top of **Data Table I**, is given in the lower left-hand corner of the main screen. Call the distance between the plates **d**. Do not confuse **d** and **r**.

Then you may enter the unique voltages (except for 0 V) into **Data Table I**. You should have multiple instances of most of all the positive voltages. If they vary by plus or minus one volt, then average all instances in the same step together. When you enter the average voltages in the **Data Table 1**, enter them in order with the largest (*most positive*) voltage on the left and the smallest (*most negative*) voltage on the right. There should be eight positive balancing voltages, between +60 V and +600 V and as many as eight more negative balancing voltages between –60 V and –600 V.

Complete the calculations to fill out the rest of **Data Table I**. Calculate the Electric field for each voltage (**V/d**), and then calculate the charge balanced by each unique voltage (*Equation 1*). Finally, calculate the absolute difference between successive charges. This will correspond to the smallest increment of charge, i.e., the quantum of electric charge.

On the following page, there are 15 questions for you to answer. These should not be attempted until after you have completed **Data Table I**. The first 5 questions can be answered in the space provided. The remaining questions must be typed on a separate sheet (*or sheets*) of paper and attached to the lab report just ahead of the histogram. Read each question carefully. Make sure you answer the question that is asked.

Make sure that the histogram is the last page of the completed lab write-up.

Questions for Version 1

1. If you found all the voltages in the recommended voltage range, then all the charge <u>differences</u> should be about the same. Are they? _________

2. What is the average charge difference, $|\Delta q|$? ______________________ C

3. What is the accepted value for the magnitude of the charge on an electron? _____________________ C

4. What is the percent difference between your result and the correct value? _____________ %

5. How many extra electrons were on the droplets captured at each voltage? (*List the voltage in order from the highest voltage at the top to the smallest voltage at the bottom of the table below.*)

Voltage	_____	_____	____	____	____	____	____	____	____	____	____	____	____	____	____	____
# e's	_____	_____	____	____	____	____	____	____	____	____	____	____	____	____	____	____

More Questions for Version 1 – These must be typed on a separate sheet (*or sheets*) of paper.

6. Why are some of the droplets unaffected by the presence of an electric field?

7. Why do some of the droplets require a positive voltage, while others require a negative voltage for balance?

8. Why are the balancing voltages clumped into discrete groups rather than spread out more or less evenly over a range of voltages? What does this tell us about the charges on the droplets and ultimately about the nature of electric charge itself?

9. As you look at the histogram of balancing voltages, the "steps" are not all the same size. Explain why this is so.

10. Why are the steps between charges the same when the steps between voltages are not the same?

11. a) If a particular droplet had 280 extra electrons, what capture voltage would you expect to measure? b)If you captured a droplet at 30 Volts, how many excess charges would there be on that drop?

12. If a proton traveling horizontally at 2.3 E5 m/s enters a uniform electric field pointing vertically upward. How far (meters from its original path) and in which direction (up or down) will the proton be deflected by the field, assuming it stays in an electric field of 2300 N/C for 7.76 microseconds. Draw the picture and label it carefully.

13. If an electron is fired at the same speed into the same electric field for the same amount of time, how far will it be deflected and in which direction. Again, draw and label the diagram.

14. Why don't we have to look for droplets that need more than 600 volts to stabilize then in the electric field of this apparatus? (Hint: what would the charge on a droplet have to be if you could stabilize it with, for example, 1000 Volts?)

15. How would your measured voltages change if the plates were twice as far apart? Half as far apart? Explain both of your answers. (*Millikan was originally limited to using 90 V batteries with his apparatus. His principle variable was therefore the distance between the plates. Your setup is much easier to use since you can easily change the voltage and keep the plate separation constant.*)

Data Table Ia – **Balancing Voltages** – **X** marks droplets that escaped without being balanced; probably uncharged droplets.

V = __________ __________ __________ __________ __________ __________ __________ __________ V

V = __________ __________ __________ __________ __________ __________ __________ __________ V

V = __________ __________ __________ __________ __________ __________ __________ __________ V

V = __________ __________ __________ __________ __________ __________ __________ __________ V

V = __________ __________ __________ __________ __________ __________ __________ __________ V

V = __________ __________ __________ __________ __________ __________ __________ __________ V

V = __________ __________ __________ __________ __________ __________ __________ __________ V

V = __________ __________ __________ __________ __________ __________ __________ __________ V

V = __________ __________ __________ __________ __________ __________ __________ __________ V

V = __________ __________ __________ __________ __________ __________ __________ __________ V

V = __________ __________ __________ __________ __________ __________ __________ __________ V

V = __________ __________ __________ __________ __________ __________ __________ __________ V

V = __________ __________ __________ __________ __________ __________ __________ __________ V

V = __________ __________ __________ __________ __________ __________ __________ __________ V

V = __________ __________ __________ __________ __________ __________ __________ __________ V

V = __________ __________ __________ __________ __________ __________ __________ __________ V

V = __________ __________ __________ __________ __________ __________ __________ __________ V

V = __________ __________ __________ __________ __________ __________ __________ __________ V

Data Table I

Distance between plates = **d** = ____________________ mm (screen)   Radius of droplet = **r** = ______________________ μm (screen)

Distance between plates = **d** = ____________________ m (calc)   Radius of droplet = **r** = ______________________ m (calc)

Volume of droplets = ____________________ m^3 (calc)   Density of droplet (kg/m^3) = ρ = ______________________ kg/m^3 (given)

[*Recall, **mass** = **density** × **volume**; calculate the mass of the droplet*]----------→ Mass of droplet = **m** = ______________________ kg (calc)

Table of balancing voltages: (*There are sixteen different balancing Voltages. Keep trying until you get them all.*) Write them in order.

V = ______ ______ ______ ______ ______ ______ ______ ______ | ______ ______ ______ ______ ______ ______ ______ ______ V

Most positive **V**   Most negative **V**

Calculate the magnitude of the electric field, using **E = V / d**, at each voltage.

E = ______ ______ ______ ______ ______ ______ ______ ______ | ______ ______ ______ ______ ______ ______ ______ ______ N/C

Now calculate the electric charge on the droplet for each of the balancing voltages using the balanced force-field equation: **q = mg / E**

q = ______ ______ ______ ______ ______ ______ ______ ______ | ______ ______ ______ ______ ______ ______ ______ ______ C

Now, find the magnitude of the ***difference*** between each consecutive pair of charges:

|Δq| = ______ ______ ______ ______ ______ ______ ______ | ______ ______ ______ ______ ______ ______ ______ C

The charge of one electron should equal the smallest of these differences (*Any larger charges should be integer multiples of this smallest charge.*):

Your best estimate of the fundamental unit of charge is; ***e*** = __________________________ C (*Averaging the smallest ones should work best. Any larger charge differences must be integer multiples of the smallest charge.*)