Millikan Oil Drop Experiment

Introduction

This experiment involves the determination of the charge of the electron \((e)\). But remember, the objective of this class is to test models: what model is being tested here? You will see that the end result, the electronic charge, is the result of a calculation involving a large number of measured parameters, each of which carries with it an uncertainty. It is important that you keep track of each parameter that you actually measure so that at the end you can propagate errors through your calculation to determine an aggregate uncertainty in your final answer.

You will be using a commercial apparatus manufactured by PASCO Scientific to do this experiment. The PASCO manual gives a detailed description of both how to take the measurements and how to analyze your results. It also comes in two versions: one dated 4/98, included in the “historical lab manuals” (available in the teaching lab), and a newer one in .pdf format [1]. NOTE: These versions may have some typing mistakes. Hence verify the formulas are correct. An alternative approach to manipulating the data is given by Melissinos [2].

Experimental Setup

Required Equipment

PASCO AP-8210 Millikan Oil Drop Apparatus
Power cord for Apparatus lamp
Voltage source for plate voltage (Kepco)
Plate Voltage switch
DMM to measure plate voltage (Keithley 169 DMM)
DMM to measure thermistor resistance (Keithley 169 DMM)
Mineral oil
Volumetric flask and balance
Pressure gage to measure atmospheric pressure; vacuum pump for reference
Oil sprayer

Figure 1 shows the experimental setup of the Millikan oil drop experiment. The Kepco voltage supply provides the voltage between the plates that generate the required electric field. It should be set to 500 V; the experiment should not be run at any voltage greater than 500 V. The PASCO manual explains where to connect this voltage. Is the polarity important? Explain. The plate voltage switch allows you to switch among a negative, positive, and zero voltage.
While this switch is attached to the apparatus, it must be grounded. One of the Keithley 169 DMMs measures this voltage. The other Keithley 169 DMM measures the resistance of a thermistor from which the temperature of the air in the apparatus, and hence its viscosity, can be calculated. The PASCO manual also clearly states where this should be connected. The oil sprayer is used to introduce oil droplets into the plate chamber. Indeed, the PASCO AP-8210 manual gives a detailed explanation of the apparatus, some tips on technique, and other valuable information on data analysis, as discussed above. Consult the manual as necessary.

![Fig 1](image)

**Figure 1.** Experimental setup of the Millikan oil drop experiment.

**Experimental Procedure**

NOTE: Nearly all of this procedure is taken from the PASCO manual, pages 1-10.

In this experiment, you will be able determine that electrons are indeed unique particles all having the same charge.

1) Decide which method you will use to measure the charge on the electron. Derive the equations necessary to process the data you take in this experiment; fill in the steps missing in the explanation in the manual or the Melissinos approach.

2) Using a 100 ml volumetric flask and the balance in South Physics (SP) room 306, determine the density of the mineral oil you will be atomizing.

3) Determine the barometric pressure using the gauge in SP 307 H.
4) Record the plate voltage and the oil density.
5) Determine the temperature of the chamber from the resistance of the thermistor using the table in the back of the PASCO manual.
6) Calculate the viscosity of air at the temperature of the droplet viewing chamber (consult Appendix A of the PASCO manual). You may develop an equation from the linear approximation and insert it into your calculations.
7) Monitor the barometric pressure for each set of velocity measurements.
8) Level the apparatus. Why is this important?
9) Connect the power cord to the lamp. This is an on/off connection. Plugged in = On. Not Plugged In = Off. Alternatively, supplement with a fiber-optic illuminator.
10) Introduce some oil droplets into the plate chamber. This is most easily done by using a few quick, small squirts with the sprayer bulb mostly depressed. After there are some droplets inside the large outside chamber, squeezing the bulb slowly puts more air than oil into the large chamber, encouraging the oil droplets already present to fall between the plates. If there are too many droplets, they will form a bright cloud and you will not be able to distinguish between particles. The ionization source lever should be in the “Spray droplet” position.
11) Focus the reticle and focus in on a droplet. This can be done before introducing the oil using the focusing wire that is attached to the oil drop apparatus. This will give you some insight into the size of these droplets. Consult the PASCO manual (pg. 8) for details on selecting a good droplet.

**NOTE:** To see the “right” drops it is very critical to adjust the filament of the halogen lamp by adjusting the horizontal and vertical knobs until the light is brightest on the wire in the area of the reticle. The PASCO manual (pg. 6) suggests that “the light is best focused when the right edge of the wire is brightest (in highest contrast compared to the center of the wire)”. If this suggestion doesn’t work, also try to obtain the brightest light right behind the wire.

12) What data do you actually measure and record to perform this experiment? What quantities should you calculate while taking data? What data will you repeat and average in order to reduce your uncertainty? How will you determine the number of electrons on any one droplet?

As noted earlier, there are at least two ways to calculate the charge of the electron (e) from your data. One is given in Melissinos, the other in the PASCO manual.

1. The Melissinos method is mathematically simpler, but if you use it, it is recommended that you re-derive the equations for the measured times for your oil drops to rise, fall with electrical assist, and fall without field. Use vector notation to keep track of the directions of the various forces. If you use the Melissinos method directly you must explain why your use of negative values for some of the times and numbers of electrons is legitimate. If you study his method long enough to figure out what each term is for, it’s a lot easier to start from scratch than to try to figure out his sign convention, especially the ± sign at the beginning of the first equation.

2. The big problem with the Melissinos method is that he totally finesses how to figure out how many electrons are on each drop for which you measure rise and fall times. Doing this is not
trivial. You can almost do it from the Melissinos approach, but modification is required since he never addresses this issue.

3. In the PASCO manual they do their calculations in esu, which involves statvolts, which haven’t been used in the last 100 years. If you decide to use this approach, re-derive the equations from first principles to culminate with parameters you actually measure, and convert the final unit to a most commonly used one. You still have the issue of determining the number of electrons on each droplet for each opening of the radioactive cell. How will you do this?

4. It is recommended that you formulate a procedure for determining the number of electrons on each droplet before starting the experiment, then do your calculations in data analysis software as data are taken. Hopefully this will allow you to determine that you have taken adequate data so that you actually can determine the number of electrons on each droplet.

5. Determine the value of $e$, the charge on an electron. Propagate your measurement uncertainties through your calculations to estimate the uncertainty in your final measurement of the charge on the electron.

6. Since it is quite easy and gives you a “useful” number, calculate the size of each drop you use.

References
