Lab 8 Millikan Oil Drop Tasks

Full report (all sections) due Friday,
December 11th at 6pm

Safety/Equipment note: Adjust the high voltage slowly. Recall that you have to turn on both the AC and DC switches and you want to wait for a moment for the power supply to warm up. You will be using the DC voltage. Always turn the high voltage all the way down before turning off and make sure it is turned all the way down before turning on. Do not exceed 400V.

Take measurements on at least five different oil drops. Be sure that at least three of these have different amounts of charge on them. Make several measurements of the free fall speed of each of your droplets. Make measurements of their rise speed when the plates are polarized to push them up and several measurements of their downward speed when the plates are polarized to push them downwards.

Experimental task 1: Develop a protocol to establish that the amount of charge on each droplet is an integer multiple of a fundamental charge e.

Experimental task 2: Develop a protocol to establish the magnitude of the fundamental charge e.

Theoretical task: Recall the equation that we derived in the lab discussion section

$$a = \sqrt{\frac{9\eta v_f}{2\rho g}\left(\frac{1}{1+\frac{b}{pa}}\right)},$$

where a is the radius of the droplet, η is the viscosity of dry air, ρ is the density of the oil making up the droplets, g is the free fall acceleration due to gravity, v_f is the terminal free fall speed of the droplet, p is the atmospheric pressure, and $b = 8.2 \times 10^{-3}$ Pa m is a constant that helps to account for the small size of the droplets.

Use this equation to solve for the droplet radius a in terms of the other parameters just described. Substitute the result of your derivation into the result that we found for q in our discussion to obtain:

$$q = \frac{4\pi}{3}\left[\sqrt{\left(\frac{b}{2p}\right)^2 + \frac{9\eta v_f}{2\rho g}} - \frac{b}{2p}\right]^3 \frac{\rho g d(v_f + v_r)}{V v_f}.$$

For a detailed description of how to setup the apparatus, see the attached notes from the manufacturer. There are lots of Kim wipes in the lab. Use these to practice using the oil drop diffuser (the perfume jar) before you use it in the chamber. One of the main techniques to master in this lab is to not put too many drops into the chamber at once. This will help you in your measurements and keep the apparatus in better working order.

Parts Diagram

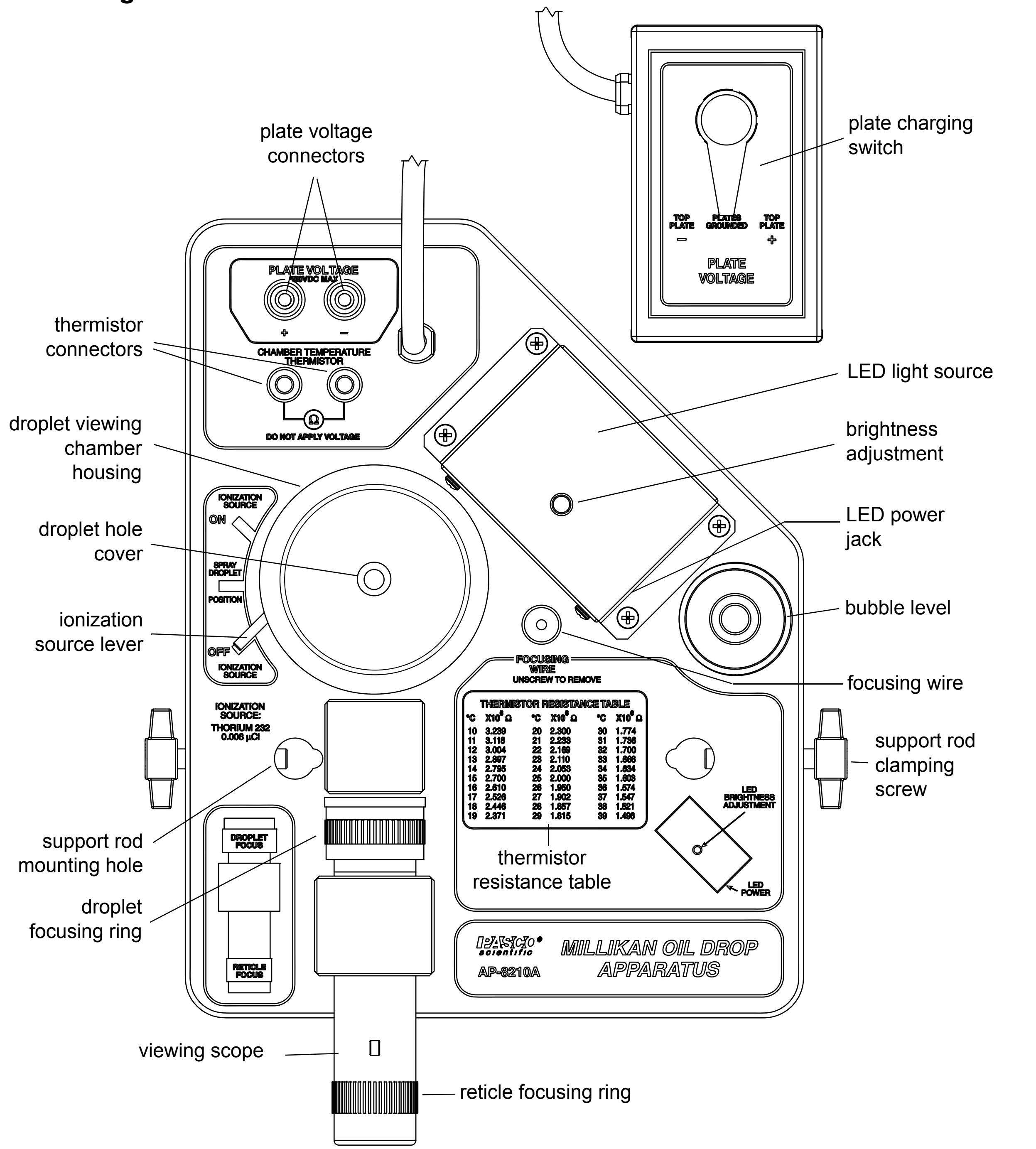

Figure 4: Apparatus platform

Components of the Platform

- droplet viewing chamber (see details in Figure 5)
- viewing scope (30X, bright-field, erect image) with reticle (line separation: 0.5 mm major divisions and 0.1 mm minor divisions), reticle focusing ring, and droplet focusing ring
- LED (light emitting diode) light source with a brightness adjustment knob
- focusing wire (for adjusting the viewing scope)
- plate voltage connectors, 4 mm diameter

- thermistor connectors, 4 mm diameter (the thermistor is mounted in the lower capacitor plate in the droplet viewing chamber)

.

> **WARNING: Do not apply voltage to the thermistor connectors!**

- thermistor resistance table (resistance versus temperature)
- ionization source lever with three positions: Ionization ON, Ionization OFF, and SPRAY DROPLET POSITION.
- bubble level
- support rod mounting holes and clamping screws to permit mounting of the platform on support rods (so the viewing scope can be raised to a comfortable eye level)
- leveling feet (3)
- plate charging switch on a one meter cord (to prevent vibration of the platform during the switching activity).

Components of the Droplet Viewing Chamber

- lid (clear plastic chamber cover)
- housing
  - *convex lens (not shown)*.
- droplet hole cover
- upper capacitor plate (brass)
- plastic spacer (approximately 7.6 mm thick)
- lower capacitor plate (brass)
  - alpha source, thorium-232, 0.00185 microcuries
  - electrical connection to the upper capacitor plate

Note: Thorium-232 is a naturally occurring, low level alpha-particle emitter with a half-life of 1.41 x 10^{10} years. It is not regulated in its use and poses no hazard to the user of the PASCO Millikan Oil Drop Apparatus.

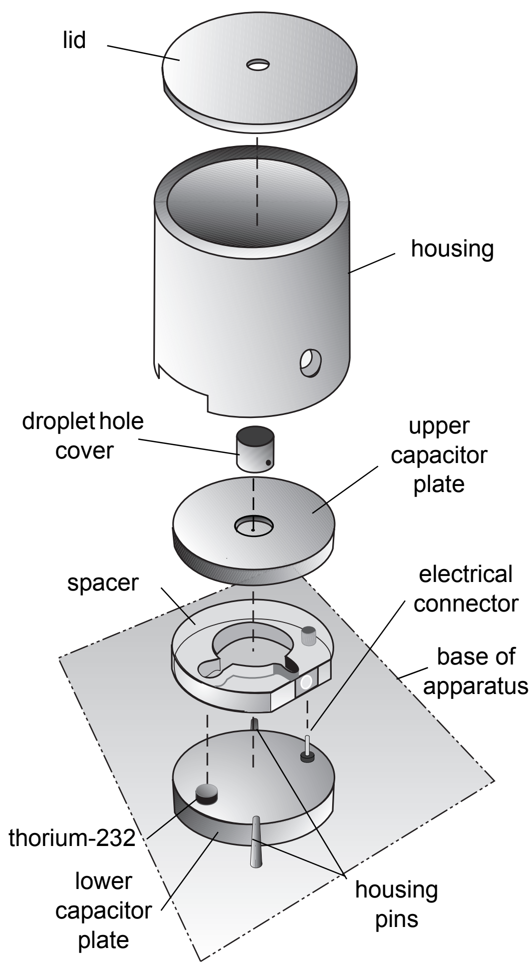

Figure 5: Droplet viewing chamber

Equipment Setup

Adjusting the environment of the experiment room

1. Make the room as dark as possible, while allowing for adequate light to read the multi meter and stopwatch and to record data.
2. Insure that the background behind the apparatus is dark.
3. Select a location that is free of drafts and vibrations.

Adjusting the height of the platform and leveling it

1. Place the apparatus on a level, solid table with the viewing scope at a height that permits the experimenter to sit erect while observing the droplets through the scope. One possible setup is to mount the apparatus on two support rods (ME-8736) on the large rod stand (ME-8735). See Figure 6.

2. Using the attached bubble level as a reference, level the apparatus with the leveling screws on the rod stand or the leveling feet on the apparatus (depending on your setup)..

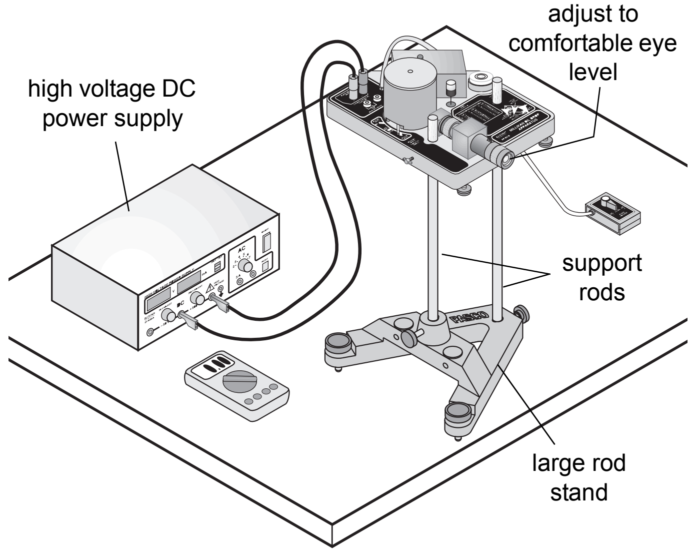

Figure 6: Equipment setup

Measuring plate separation

1. Disassemble the droplet viewing chamber by lifting the housing straight up and then removing the upper capacitor plate and the space plate. (See Figure 5.)

2. Use a micrometer to measure the thickness of the spacer plate. (The thickness is equal to the plate separation distance, *d*).

- Be sure that you are not including the raised rim of the spacer plate in your measurement. The accuracy of this measurement is important to the degree of accuracy of your experimental results.

3. Record the measurement.

.

- **NOTE**: Use care when handling the brass upper capacitor plate and the plastic spacer plate to avoid scratching them.
- **NOTE**: All surfaces involved in the measurement should be as clean as possible to prevent inaccurate readings.

Aligning the Optical System

Focusing the viewing scope

1. Reassemble the plastic spacer and the upper capacitor plate onto the lower capacitor plate. Replace the housing, aligning the holes in its base with the housing pins. (See Figure 5.)

- **NOTE**: The thorium-232 source and the electrical connection on the lower capacitor plate fit into appropriately sized holes on the plastic spacer.

2. Unscrew the focusing wire from its storage place on the platform and carefully insert it into the hole in the center of the upper capacitor plate (Figure 7.)

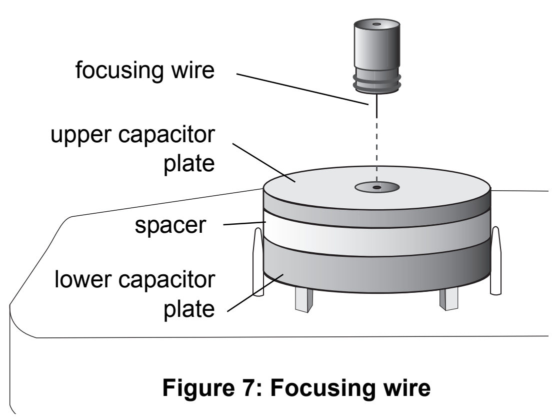

Figure 7: Focusing wire

3. Plug the included AC adapter into a receptacle (100 to 240 VAC) and connect the cable to the power jack on the side of the LED light source.

> Check to make sure that the AC adapter is the correct voltage: 100, 117, 220, or 240 V.

4. Turn the brightness adjustment knob on the LED light source to optimize the contrast between the illuminated pin and the dark background.

5. Bring the reticle into focus by turning the reticle focusing ring on the viewing scope.

6. View the focusing wire through the viewing scope and bring the wire into sharp focus by turning the droplet focusing ring.

- **NOTE**: Viewing will be easier for experimenters who wear glasses if the viewing scope is focused without using the glasses.

7. Return the focusing wire to its storage location on the platform.

Functions of Controls

Ionization source lever

1. When the lever is in the ionization **OFF** position, the ionization source is rotated away from the area of the droplets, so virtually no alpha particles enter the area. In this position, the alpha source is shielded on all sides.

2. At the **ON** position, the ionization source is rotated toward the area of the droplets and the area is exposed to the ionizing alpha particles from the thorium-232.

3. At the **SPRAY DROPLET POSITION**, the chamber is vented by a small hole that allows air to escape when oil droplets are being introduced to the chamber.

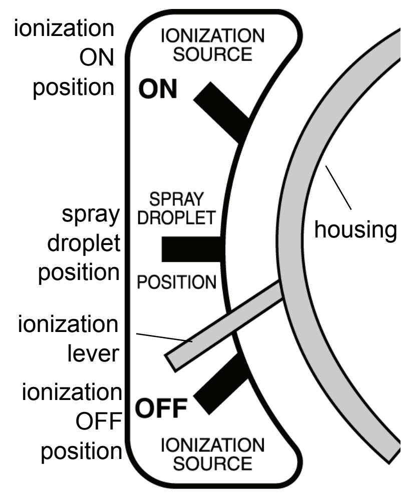

Figure 8: Ionization source lever settings

Plate charging switch

The plate charging switch has three positions:

1. TOP PLATE –: negative binding post is connected to the upper capacitor plate.

2. TOP PLATE +: negative binding post is connected to the lower capacitor plate.

3. PLATES GROUNDED: plates are disconnected from the high voltage supply and are electrically connected to each other.

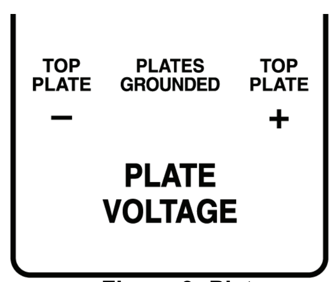

Figure 9: Plate charging switch

Adjusting and Measuring the Voltage

1. Connect the high voltage DC power supply to the plate voltage connectors using banana plug patch cords.

2. Adjust the voltage to deliver about 500 VDC. Use the digital multi meter to measure the voltage delivered to the plate voltage connectors.

.

> ⚠ **Measure the voltage at the plate voltage connectors and not across the capacitor plates. There is a ten megaohm resistor in series with each capacitor plate to prevent electric shock.**

Determining the Temperature of the Droplet Viewing Chamber

1. Connect the multi meter to the thermistor connectors on the platform in order to measure the resistance of the thermistor that is embedded in the lower capacitor plate.

2. Refer to the Thermistor Resistance Table located on the platform to find the temperature of the lower brass plate. The measured temperature corresponds to the temperature inside the droplet viewing chamber.

.

> ⚠ **The temperature inside the droplet viewing chamber should be determined periodically (about every fifteen minutes).**

Experimental Procedure

1. Complete the reassembly of the droplet viewing chamber by placing the droplet hole cover on the upper capacitor plate and then placing the lid on the housing. (See Figure 5.)

- **NOTE**: The droplet hole cover has a hole in one side and a hole in the bottom. The hole in the bottom lines up with the small hole in the center of the upper capacitor plate.
- **NOTE**: The droplet hole cover prevents additional droplets from entering the chamber once the experiment has started.

2. Measure and record the plate voltage and the thermistor resistance (temperature).

Introducing the droplets into the chamber

1. Put non-volatile oil of known density into the atomizer, such as the included Squibb #5587 Mineral Oil, density of 886 kg/m^3.

2. Insure that the tip of the atomizer is pointed down (90° to the shaft; see Figure 10). Prepare the atomizer by rapidly squeezing the bulb until oil is spraying out.

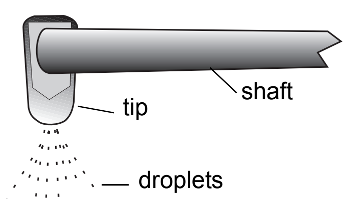

Figure 10: Atomizer tip

3. Move the ionization source lever to the "SPRAY DROPLET POSITION" to allow air to escape from the chamber during the introduction of droplets into the chamber.

4. Place the tip of the atomizer into the hole on the lid of the droplet viewing chamber.

5. While observing through the viewing scope, squeeze the atomizer bulb with one quick squeeze. Then squeeze it slowly to force the droplets through the hole in the droplet hole cover, through the droplet entry hole in the upper capacitor plate, and into the viewing area space between the two capacitor plates.

6. When you see a shower of drops through the viewing scope, move the ionization source lever to the 'OFF' position.

.

> ⚠ **If repeated "squirts" of the atomizer fail to produce any droplets in the viewing area but produce a rather cloudy brightening of the field of view, the hole in the upper capacitor plate or in the droplet hole cover may be clogged. Refer to the Maintenance section for cleaning instructions.**

- **NOTE**: The exact technique of introducing droplets will need to be developed by the experimenter. The object is to get a small number of drops, not a large, bright cloud from which a single drop can be chosen.
- **NOTE**: Remember that the droplets are being forced into the viewing area by the pressure of the atomizer. Excessive pumping of the atomizer can cause too many droplets to be forced into the viewing area and, more importantly, into the area between the chamber wall and the focal point of the viewing scope. Drops in this area prevent observations of drops at the focal point of the scope.
- **NOTE**: If the entire viewing area becomes filled with droplets so that no one drop can be selected, either wait three or four minutes until the droplets settle out of view, or turn off the DC power supply and disassemble the droplet viewing chamber, thus removing the droplets.
- **NOTE**: When the amount of oil on the parts in the droplet viewing chamber becomes excessive, clean the parts as detailed in the Maintenance section. Remember that the less oil that is sprayed into the chamber, the few times the chamber must be cleaned.

Selection of the Droplet

1. From the drops in view, select a droplet that both falls slowly (about 0.02 to 0.05 mm/s) when the plate charging switch is in the "Plates Grounded" position, and can also be driven up and down by turning the plate charging switch to "TOP PLATE –" or "TOP PLATE +".

- **HINT**: A droplet that requires about 15 seconds to fall the distance between the major reticle lines (0.5 mm) of the viewing scope will rise the same distance, under the influence of an electric field (1000 V/cm) in the following times with the following charges:

Table 1.1:

Time	Excess electron
15 s	1
7 s	2
3 s	3

- **NOTE**: If too many droplets are in view, you can clear out many of them by turning the plate charging switch to "TOP PLATE –" (connecting power to the capacitor plates) for several seconds.
- **NOTE**: If too few droplets have net charges to permit the selection of an appropriately sized and charged drop, move the ionization source lever to the ON position for about five seconds.

2. When you find an appropriately sized and charged oil droplet, fine tune the focus of the viewing scope.

- **NOTE**: The oil droplet is in best focus for accurate data collection when it appears as a pinpoint of bright light.

3. Turn the brightness adjustment knob on the light to optimize the contrast between the illuminated drop and the dark background.