The Millikan Oil Drop Experiment

AP Physics C

Objective: I can determine the motion of a charged object and calculate its charge and mass by applying the definition of electric field and calculating the net force of the object.

We talked briefly about the Millikan Oil Drop in the Fall Semester. Today, you will be conducting the experiment. Unfortunately, we do not have the materials needed to conduct this experiment in the real world regardless of the situation, so you will be using a simulation regardless of your learning model. Note that the simulation does NOT show drag force in it.

The Millikan Oil Drop consists of the following steps:

1. Determining the mass of the oil droplets given that they experience quadratic drag
2. Apply a uniform electric field between two charged plates to cause some of the droplets to accelerate upward. Note that the field strength can be determined by V=Ed, where *d* = 0.05 m (the distance between plates) and V is the adjustable voltage (don't worry about what this actually is for now).
3. Adjust the electric field strength until the droplets are at rest (or as close to rest as you can get them to be - +/- 0.04 m/s or below is fine)
4. Calculate the net charges of the oil droplets and analyze the values.

Prelab Questions

1. How can drag force be used to determine the mass of an object? For which speed would the mass be easiest to calculate if the only forces are gravitational and drag? Denote the magnitude of the drag force as $F=kv^2$, where k is a coefficient depending on the cross-sectional area, etc. and v is the speed. State how the mass can be determined and derive an equation for it in terms of v, k, and physical constants as needed.
   Measure the speed of the object, knowing the coefficient k, and g. kv^2=mg, m=(kv^2)/g
2. For the second part of the experiment, why should the electric field strength be adjusted until the droplets are at rest before calculating charge? What would this mean about the forces acting on the droplets?
   Droplets must be in equilibrium for the charge to be calculated accurately. When the droplets are at rest, the net force is zero. The electric force acting on the droplets is equal and opposite to the gravitational force acting on them. qE=mg, q=mg/E
3. What sign of charges should the droplets have if they are able to be brought to rest, noting that the plate closer to the ground is positively charged and the plate higher up is negatively charged? Justify your answer. Is this sign caused by a proton excess/deficit or an electron deficit/excess?
   Equal and opposite to the charge on the plate closer to the ground. The electric force acting on the droplets is proportional to the charge on the droplets and the electric field strength, and the electric field strength is the same for both plates.

Procedure/Data

Go to https://ophysics.com/em2.html and use your answers to the prelab to complete the exercise. The value for the "drag constant" k is given in the description below the simulation. **Note that "Create new particle" will give you a completely different particle with different mass and charge. If you mess up with collecting data, click "Reset" instead!** Fill out the table below. **Note that k takes into account g s.t. the value given is actually equal to the usual constant / g: therefore, ignore g from Prelab Question 1 when actually computing the mass. You will, however, need g for calculating the charge.**

Velocity used to measure mass (m/s)	Mass of droplet m (kg)	Voltage used (V)	Charge of the droplet q (C)	Charge to mass ratio q/m (C/kg)	Charge of the droplet in terms of *e* = 1.602*10^-19 C
1.337	7.4530683*10^-18	150	2.43466897*10^-20	0.0326666	0.15197683e
2.058	1.76588748*10^-17	252	3.4336701*10^-20	0.00194	0.21433646e
2.442	2.48635768*10^-17	324	3.76023229*10^-20	0.00151234	0.23472111e
3.022	3.80768669*10^-17	456	4.09159315*10^-20	0.00107456	0.25540531e

Results and Discussion

Analyze your data from above in this space. Talk about trends with mass and charge, why the values were or were not expected, and any observations for q/m and the last column of the data table above. Also, include possible sources of error.

As voltage used increases, velocity increases and mass of droplet increases, charge increases. Makes sense because higher voltage means higher potential and mass. Values were expected.

Postlab Questions

1. The two charged plates are usually located in a chamber in a real experiment. What would a pro of having an evacuated chamber (a vacuum between the plates) be? What might a con be? Are there any quantities you may not be able to determine in a vacuum?

   Pro: eliminates air resistance and drag, con: makes it harder to determine the mass and radius of the oil drops (no density of air). Cannot determine terminal velocity.
2. A real Millikan Oil Drop experiment would have several droplets of oil in the chamber at once. Explain how this could introduce a possible source of error into the calculation of the charges, and why, given your data, this source of error would be insignificant.

   Time and distance traveled by the drops could be wrong because some drops may be influenced by the electric field of other drops. Drops are sufficiently far apart and have similar charges so they cancel out.