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The Millikan Oil Drop Experiment
AP Physics C

Note to reader: Hi Mr. Shah. We hope everything is going well. This lab was quite the challenge, but we tried to preserve and I mean here we are. Let us know if we actually persevered.

Mr. Shah gets creative with teaching his Physics C class

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.

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.
$F = ma = mg - kv^2$
v is terminal velocity when $a = 0$
$mg = kv^2 \rightarrow m = \frac{kv^2}{g}$

2. Going off of your thoughts for Question 1: a motion detector or a force sensor would not work for a real Millikan Oil Drop experiment. What might be another possible analytical computer tool or piece of technology to determine the mass while utilizing the same steps as from Question 1?
   All that is needed is the velocity since both k and g are constants. Assuming the velocity is terminal velocity, we can use a stopwatch and measure the time between two places, allowing us to calculate the velocity and then determine mass.
3. 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?
   The field strength should be adjusted so that the force exerted by the field would be exactly equal to the gravitational force. It would mean that the net force acting on the droplets is 0. This is ideal, because then we know the charge force is equal to gravity allowing for it to be calculated.
4. 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?
   The droplets should have a positive charge because the plate closer to the ground will repel the charge and the plate higher up will attract the charge, so the electric field is pointing up. This will offset the gravitational force downwards to create a net force of 0 and keep the droplets at rest. This sign is caused by an electron deficit because changing the protons would affect the chemical composition of the droplets.

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.**

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Table 1. A table recording the velocity and voltage as measured in the lab and the calculated values.

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
-1.485	9.01E-17	93	4.75E-19	5.27E-03	2.97E+00 -> 3 e
-1.192	5.81E-17	35.5	8.02E-19	1.38E-02	5.01E+00 -> 5 e
-1.382	7.80E-17	34	1.13E-18	1.44E-02	7.03E+00 -> 7 e
-1.281	6.70E-17	205.2	1.60E-19	2.39E-03	1.00E+00 -> e

please….

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.

The relationship between mass and charge can be found by setting the gravitational force equal to the electric field force, giving us an expression for the charge in terms of mass m, g, and the electric field E.

$$mg = Eq \rightarrow q = \frac{mg}{E}$$

By substituting E as an expression of voltage and distance, we get

$$E = \frac{V}{r}$$

$$q = \frac{rmg}{V}$$

Where $r = 0.05\ m$. So, charge increases as mass increases. The values we obtained were not expected because from our expression for mass, it should be proportional to the square of the velocity, which is not always the case in our data. From observing the charge to mass ratio in terms of e, no clear trend is found as the value sometimes increases then decreases while velocity continues to decrease in magnitude, though this could be due to errors in measuring the voltage.

Sources of error are not super prevalent in this lab due to the nature of it being a simulation. Potential sources of error could come from measuring the data, specifically the voltage that results in the particle being at rest, which proved to be difficult since it was hard for the naked eye to tell if a particle was still or moving very slowly. Measurement error could be minimized by conducting more trials.

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?

A pro of having an evacuated chamber would be guaranteeing that there would be no outside interference on the experiment, as the vacuum would remove them all. However, a con would be that air resistance would be removed from the experiment, meaning the only force applied on the droplet would be gravity and the electric field. It would not be able to determine the mass of the droplets as there is no terminal velocity for them to reach, meaning the charge to mass ratio could not be determined either.

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.

   The charges of each droplet could interfere and influence the other droplets. However, as shown from the data, the charge of the droplets is insignificant compared to the charge of the plate, meaning it would not influence the data by a significant amount.