



Figure 1: The classic Millikan oil drop experiment was a measurement of the charge of an electron.

2 Electric Charge and Electric Fields

1. **Scaling problem:** (a) Some point charge produces an E-field $E_C = 2.00 \times 10^{-3} \text{ V/m}$ at a distance of 1 mm. What is the value of E_C at 5 mm produced by the same charge? (b) A $1 \mu\text{C}$ charge produces an E-field $E_C = 8.00 \times 10^{-3} \text{ V/m}$ at some distance. What is the value of E_C at the same distance if the charge is $3 \mu\text{C}$?

a.) $8.00 \times 10^{-6} \text{ V/C}$

b.) $2.40 \times 10^{-2} \text{ N/C}$

2. The classic Millikan oil drop experiment was the first to measure the electron charge. Oil drops were suspended against the gravitational force by an electric field. (See Fig. 1.) Suppose the drops have a mass of $4 \times 10^{-16} \text{ kg}$, and the E-field is oriented downward, and has a value of 6131.25 N/C . With this exact value, the drops remain suspended in air. (a) How many electrons are on the drops? (b) Suppose a cosmic ray comes along and removes an electron from a droplet. What will the acceleration of the droplet be?

a.) 4 drops suspended in the air

b.) 2.46 m/s^2

3 Potential Energy and Voltage, Capacitors

1. A mass spectrometer is a device used to accelerate ions to determine atomic masses of chemicals. Suppose two conducting plates with potential difference $\Delta V = 4 \text{ kV}$ are used to accelerate both hydrogen ions and helium ions. Hydrogens have charge $+1q_e$, and helium ions have charge $+2q_e$. (a) What is the total kinetic energy (in electron-volts) gained by the hydrogens and heliums? (b) If the plate separation is $\Delta x = 5 \text{ cm}$, what is the electric field value? *Hint: think of the E-field as the slope of voltage.*

a.) $KE_{\text{hydrogen}} = 3.99 \times 10^{13} \text{ eV}$

$KE_{\text{helium}} = 7.99 \times 10^{12} \text{ eV}$

b.) $8 \times 10^4 \text{ V/m}$

2. Suppose a parallel plate capacitor has an internal E-field of 1 kV/m , and a plate separation of 2 mm . Draw the voltage as a function of distance between the negative and the positive plates. Make sure to label the axes with proper units, and mark the x-value of each plate. What is the y-intercept of this function?

y-int 0

3. Suppose the plates in the previous problem have an area of 1 cm^2 . (a) What is the capacitance of the system? (b) How much energy (in Joules) is stored in this capacitor if the voltage is 5 V ?

a.) $4.425 \times 10^{-13} \text{ F}$

b.) $5.631 \times 10^{-12} \text{ J}$