
PHYSICS 252 EXPERIMENT NO. 4

MEASUREMENT OF THE ELECTRON CHARGE

Introduction

The purpose of this experiment is to measure the smallest unit into which electric charge can be divided, that is, the charge of an electron e . The method is the one proposed by R.A. Millikan in 1910. A small sphere of mass m having a charge q can be suspended in air by applying an electric field of field strength E to balance the gravitational force on it. We then have

$$m g = q E .$$

We neglect here the (very) small buoyant force. The charge q will in general not be the electron charge but rather an *integral* multiple of it:

$$q = n e, \quad \text{with } n = 1, 2, 3, \dots$$

When the measurement is repeated several times, e can be found as the largest *common denominator* of the measured charges q .

In the absence of an electric field, the electrons will reach a constant terminal velocity v_T after a short time. The viscous force balances the gravitational force, so that the net force acting on the droplet is zero and we have:

$$m g = K v_T ,$$

where according to Stoke's law:

$$K = 6\pi \eta r ,$$

with η the viscosity of air ($1.83 \times 10^{-5} \text{ Nsm}^{-2}$ at 18°C), r the radius of the spheres ($\cong 0.50 \mu\text{m}$). From measuring the terminal velocity v_T of free fall, the mass of the spheres can be determined.

Measurement

Figure 1 shows a schematic sketch of the experimental set-up. A closed chamber is placed between two capacitor plates 0.4 cm apart, in which a uniform electric field E can be built up. The chamber is illuminated by a small lamp. Charged spheres (a suspension of latex in water and alcohol) can be blown into the chamber through a tube and a nozzle,

and be viewed there through a telescope with a calibrated scale (spacing of graduations 0.5 mm). Note that the telescope gives an inverted image.

1. Turn on the light and focus the telescope on the end of the nozzle which is used to blow spheres into the chamber. Then pull the nozzle back out of the field of view. Spheres can now be blown into the chamber by squeezing the rubber bulb.
2. Blow some spheres into the chamber and watch them (they will look tiny). They will quickly reach terminal velocity v_T and should all fall at the *same* rate in the absence of an electric field. Measure this velocity by timing the travel of particles over a known distance with a stop watch. Repeat several times until you get a set of consistent values. Calculate the mass from the average terminal velocity. Compare to the value you obtain by calculating the mass using a density of 1.05 g/cm^3 (error estimate!).
3. Blow more spheres into the chamber and watch them falling. Now turn up the electric field. You will see them reverse direction and reach a new terminal velocity which now depends on their charge q . Since you want to measure the smallest charges, select one that is *least* affected by the E field and adjust the voltage V to hold it *stationary*. Write down the value of V (hence E), and repeat the measurement 20 or more times trying to find spheres with slightly different charges.
4. Calculate for each measurement q , and determine from these values the charge unit e as the *largest* unit of charge consistent with your data. This is best done by guessing n for each measurement (from the groupings observed in the distribution of the measured charges q) and plotting your measured values $q(n)$ versus n . The measurements should fall on a straight line with slope e . Compare with the literature value of $1.602 \times 10^{-19} \text{ C}$, and discuss possible deviations.

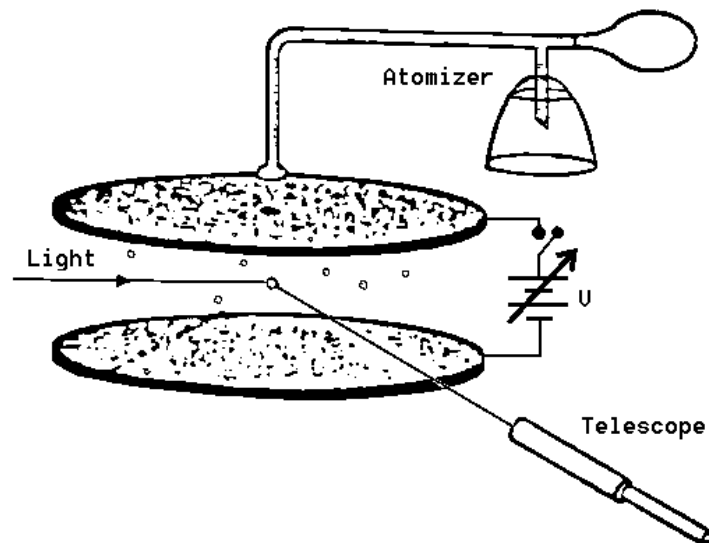


Figure 1: Schematic diagram of Millikan's oil drop apparatus