Sec. 7.5 - Elementary Charge

Learning Goal: By the end of today, I will be familiar with the fundamental property called electric charge, and the value of electric charge placed on an electron.

Driving Questions

At the turn of the twentieth century, when our understanding of electric forces was beginning to increase, two fundamental questions arose regarding the nature of electric charge:

1. Does there exist,in nature,a smallest unit of electric charge of which other units are simple multiples?

2. If so,what is this elementary charge,and what is its magnitude,in coulombs?

A quantity of 1 C is equal to approximately 6.24×10^{18}, or 6.24 quintillion. In terms of SI base units, the coulomb is the equivalent of one ampere-second. Conversely, an electric current of 1 A represents 1 C of unit electric charge carriers flowing past a specific point in 1 s.

Marble Investigation (Excel or by hand)

1. In each of these bags there is a number of whole marbles. ie an integer number of them
2. Weigh each bag and record the information in a table, from least to greatest
3. Take 5 minutes and try and think of a way that you could use this data to determine the weight of ONE marble
4. Find the differences between each data entry, circle the smallest non-zero difference
5. Add a new column called Whole Difference to your table - the data for this column is achieved by taking the original weight and dividing it by the smallest non-zero difference you found
6. Round off any values in the Whole Difference column (no decimals)
7. Plot the original mass (y) vs the whole difference (x)
8. Draw a line of best fit and determine the slope

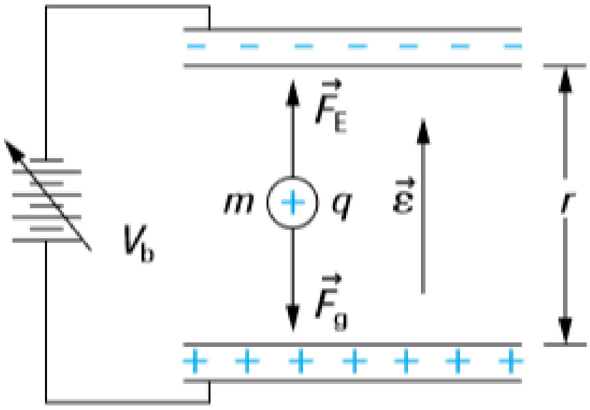
Weight	First Difference	Whole Difference

Apr 29-11:54 AM

The Millikan Experiment

Millikan hypothesized that if he were able to measure the total charge on any oil drop, it would have to be some small integral multiple of the elementary charge.

Once a mist of oil drops is sprayed through a small hole in the upper plate in a Millikan apparatus,it is possible,by carefully adjusting the potential difference between the plates, to “balance”a particular droplet that has the same sign as the charge on the lower plate. When the droplet is balanced,the gravitational force pulling it down equals the electric force pulling it up



$$\vec{F}_E = q\vec{\varepsilon}$$

where $\vec{\varepsilon}$ is the electric field between the plates.

When the droplet is in balance,

$$F_E = F_g$$ electric - Earth balance

$$q\varepsilon = mg$$

But in Section 7.4, we learned that the electric field in the region between two parallel plates is constant and has a magnitude given by

$$\varepsilon = \frac{\Delta V}{r}$$

where ΔV is the electric potential difference between the plates, and r is the separation between the plates.

Consequently, for an oil drop of mass m and charge q, balanced by a potential difference $\Delta V = \Delta V_b$,

$$q = \frac{mg}{\varepsilon}$$

$$q = \frac{mgr}{\Delta V_b}$$

Known values: g, r, and $V_{battery}$

$$q = \frac{mgr}{\Delta V}$$

After many repetitions and the gathering of lots of data, he ended up with a table similar to the following:

Table 1 Millikan's Experimental Data

Mass of Oil Drop (kg)	Electric Potential Difference (V)	Charge on Oil Drop (C)
3.2×10^{-15}	140.0	?
2.4×10^{-15}	147.0	?
1.9×10^{-15}	290.9	?
4.2×10^{-15}	214.4	?
2.8×10^{-15}	428.8	?
2.3×10^{-15}	176.1	?
3.5×10^{-15}	214.4	?
3.7×10^{-15}	566.6	?
2.1×10^{-15}	160.8	?
3.9×10^{-15}	597.2	?
4.3×10^{-15}	263.4	?
2.5×10^{-15}	382.8	?
3.1×10^{-15}	237.3	?
3.4×10^{-15}	173.5	?
2.2×10^{-15}	673.8	?

This is similar to the marble problem, could we modify our spreadsheet to perform the same operations but with Charge now, instead of mass.

Elementary Charge of an Electron

$$e = 1.602 \times 10^{-19} C$$

This allows us to move from just using "q" to represent charge, to using q = Ne , where N is the number of electrons.

SAMPLE problem 1

Calculate the charge on a small sphere with an excess of 5.0×10^{14} electrons.

Solution

$N = 5.0 \times 10^{14}$

$q = ?$

$$q = Ne$$
$$= (5.0 \times 10^{14})(1.6 \times 10^{-19}\ C)$$
$$q = 8.0 \times 10^{-5}\ C$$

The charge on the sphere is -8.0×10^{-5} C (negative because of the excess of electrons).

Example

In a Millikan-type experiment, two horizontal plates are 2.5 cm apart. A latex sphere, of mass 1.5×10^{-15} kg, remains stationary when the potential difference between the plates is 460 V with the upper plate positive.

(a) Is the sphere charged negatively or positively?

(b) Calculate the magnitude of the charge on the latex sphere.

(c) How many excess or deficit electrons does the sphere have?

Solution

$r = 2.5$ cm

$m = 1.5 \times 10^{-15}$ kg

$\Delta V = 460$ V

$q = ?$

$N = ?$

$$q = \frac{mgr}{\Delta V}$$

$q = Ne$

Apr 29-12:56 PM

Charge of a Proton

- same magnitude as an electron, but positive
- protons have a complex structure, they are built of quarks
- quarks have charge that are $\pm\frac{1}{3}q$ or $\pm\frac{2}{3}q$
- conversation for another day

SUMMARY ***The Millikan Experiment: Determining the Elementary Charge***

- There exists a smallest unit of electric charge, called the elementary charge, *e*, of which other units are simple multiples; $e = 1.602 \times 10^{-19}$ C.

Homework

Read page 360 - 364

page 362 #1, 2, 3, 4, 5

page 364 #1, 3, 5

Apr 29-1:03 PM

Attachments

MilikanCalculations.xlsx