Electric charge is quantized

In 1909, Robert Millikan (1886–1953) performed an experiment at the University of Chicago in which he observed the motion of tiny oil droplets between two parallel metal plates, as shown in **Figure 3.** The oil droplets were charged by friction in an atomizer and allowed to pass through a hole in the top plate. Initially, the droplets fell due to their weight. The top plate was given a positive charge as the droplets fell, and the droplets with a negative charge were attracted back upward toward the positively charged plate. By turning the charge on this plate on and off, Millikan was able to watch a single oil droplet for many hours as it alternately rose and fell.

Did you know?

In typical electrostatic experiments, in which an object is charged by rubbing, a net charge on the order of 10^{-6} C (= 1 μC) is obtained. This is a very small fraction of the total amount of charge within each object.

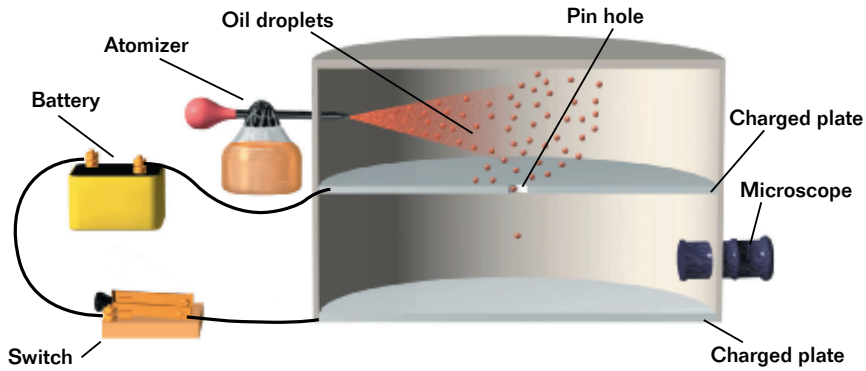

Figure 3
This is a schematic view of apparatus similar to that used by Millikan in his oil-drop experiment. In his experiment, Millikan found that there is a fundamental unit of charge.

After repeating this process for thousands of drops, Millikan found that when an object is charged, its charge is always a multiple of a fundamental unit of charge, symbolized by the letter *e*. In modern terms, charge is said to be *quantized*. This means that charge occurs as integer multiples of *e* in nature. Thus, an object may have a charge of $\pm e$, or $\pm 2e$, or $\pm 3e$, and so on.

Other experiments in Millikan's time demonstrated that the electron has a charge of $-e$ and the proton has an equal and opposite charge, $+e$. The value of *e* has since been determined to be $1.602\,176 \times 10^{-19}$ C, where the coulomb (C) is the SI unit of electric charge. For calculations, this book will use the approximate value given in **Table 2.** A total charge of −1.0 C contains 6.2×10^{18} electrons. Comparing this with the number of free electrons in 1 cm^3 of copper, which is on the order of 10^{23}, shows that 1.0 C is a substantial amount of charge.

Table 2 Charge and Mass of Atomic Particles

Particle	Charge (C)	Mass (kg)
electron	-1.60×10^{-19}	9.109×10^{-31}
proton	$+1.60 \times 10^{-19}$	1.673×10^{-27}
neutron	0	1.675×10^{-27}

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