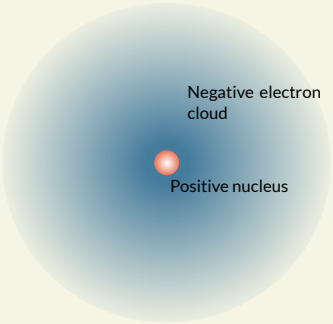
1 Charge and Coulomb's Law

What is charge?

Charge is a property of electrons, which have negative charge, and protons, which have positive charge.

- All charged objects have either an excess of electrons or an excess of protons. Neutral objects have equal numbers of each.
- Charges exert long-range forces between them: attractive for opposite charges, repulsive for like charges.



- Charge is quantized – it always comes in amounts of e, called the elementary charge: $e = 1.60 \times 10^{-19}$ C.
- Charge is always conserved.

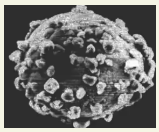
Proton
Mass: 1.67×10^{-27} kg
Charge: $+e = +1.60 \times 10^{-19}$ C

Electron
Mass: 9.11×10^{-31} kg
Charge: $-e = -1.60 \times 10^{-19}$ C

MODEL: Point Charges

Many objects that have excess positive or negative charge can be modelled as point particles – their size and shape can be neglected, and we can think of all excess charge as being concentrated at a specific point.

Good examples of point charges are electrons and protons, atomic or molecular ions, and even much larger objects such as photocopier toner beads.



Coulomb's Law

Two point charges q_1 and q_2, a distance r apart, exert forces on each other of magnitude

$$F_{1 \text{ on } 2} = F_{2 \text{ on } 1} = \frac{1}{4\pi\epsilon_0}\frac{|q_1||q_2|}{r^2}.$$

The forces are directed along a line joining the two point charges, either repulsive for like charges or attractive for opposite charges.

Constants
Permittivity constant: $\epsilon_0 = 8.85 \times 10^{-12}$ C^2/Nm^2.
Electrostatic constant: $K = \frac{1}{4\pi\epsilon_0} = 8.99 \times 10^9$ Nm^2/C^2.

Conductors and Insulators

Insulators: All electrons are tightly bound to their atoms. Charges are fixed in place.
Conductors: Valence electrons form a "sea of electrons." Charges can move easily. Any excess charge in an isolated conductor is located on the surface.

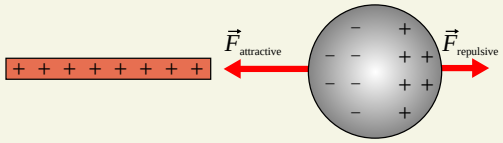
Both insulators and conductors can be *charged*.

Polarization

Charge separation can easily occur in conductors, leading to *polarization*: a slight separation of the positive and negative charges in a neutral object.

Polarization can also occur in insulators since each atom can become polarized, with a net overall polarization throughout the object.

Polarization can lead to an attractive polarization force between a charged object and a neutral object.



Applying Coulomb's Law

When multiple point charges are present, use the *principle of superposition* to find the net force on point charge 1:

$$\vec{F}_{1,\text{net}} = \vec{F}_{2 \text{ on } 1} + \vec{F}_{3 \text{ on } 1} + \vec{F}_{4 \text{ on } 1} + \cdots$$

For example, if there are three point charges arranged as shown below, you would add the forces due to charges q_2 and q_3 as vectors to find the net force on q_1.