

Physics 112

Electricity and Magnetism

- Lecturer: Tom Humanic
- Contact info:
 - Office: Physics Research Building, Rm. 2144
 - Email: humanic@mps.ohio-state.edu
 - Phone: 614 247 8950
- Office hour:
 - Tuesday 9:30 am and by appointment
- My lecture slides will be posted before my lecture on my website at
<http://www.physics.ohio-state.edu/~humanic/>

Course Overview: Electricity & Magnetism

- Electricity
 - electric force
 - electric field and potential
 - electric currents, DC circuits and circuit devices
- Magnetism
 - magnetic force
 - magnetic field
- Electricity and Magnetism combined
 - magnetic fields \longleftrightarrow electric currents
 - electromagnetic waves \rightarrow light
 - optics \rightarrow mirrors and lenses

Chapter 18

Electric Forces and Electric Fields

18.1 The Origin of Electricity

The electrical nature of matter is inherent in atomic structure.

$$m_p = 1.673 \times 10^{-27} \text{ kg}$$

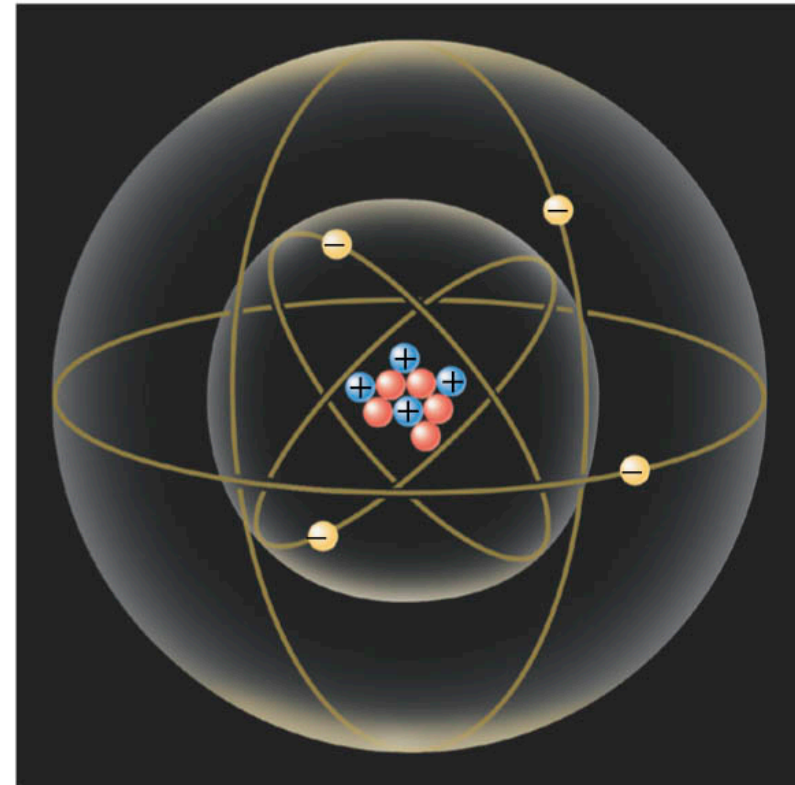
$$m_n = 1.675 \times 10^{-27} \text{ kg}$$

$$m_e = 9.11 \times 10^{-31} \text{ kg}$$

$$e = 1.60 \times 10^{-19} \text{ C}$$

Charge of electron and proton, smallest non-zero charge possible

- ⊖ electron
- ⊕ proton
- neutron



Coulomb -- SI unit of charge

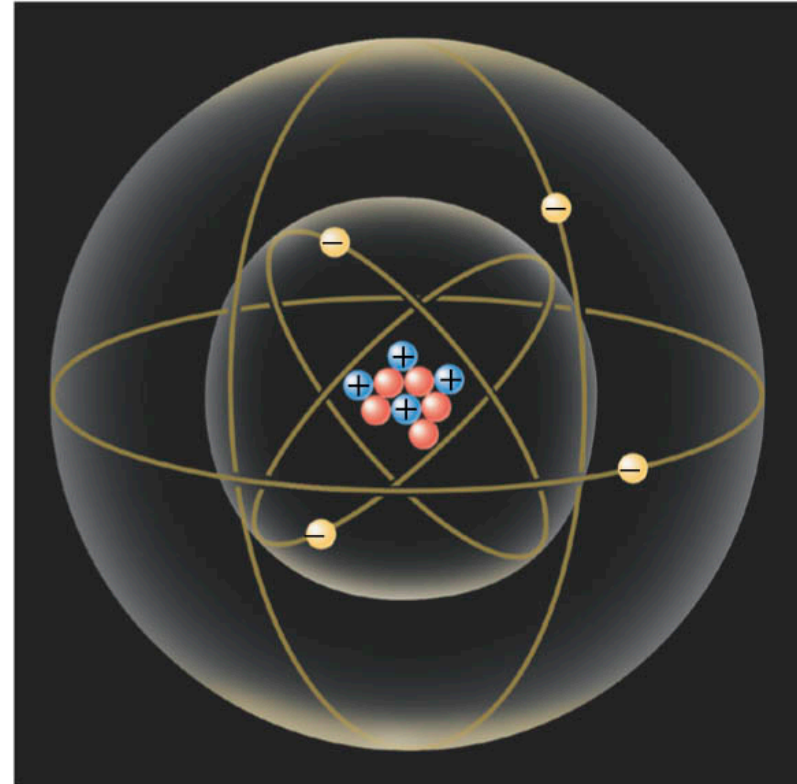
18.1 The Origin of Electricity

In nature, atoms are normally found with equal numbers of protons and electrons, so they are electrically neutral.

By adding or removing electrons from matter it will acquire a **net electric charge** with magnitude equal to e times the number of electrons added or removed, N .

$$q = Ne$$

- ⊖ electron
- ⊕ proton
- neutron



18.1 The Origin of Electricity

Example 1 A Lot of Electrons

How many electrons are there in one coulomb of negative charge?

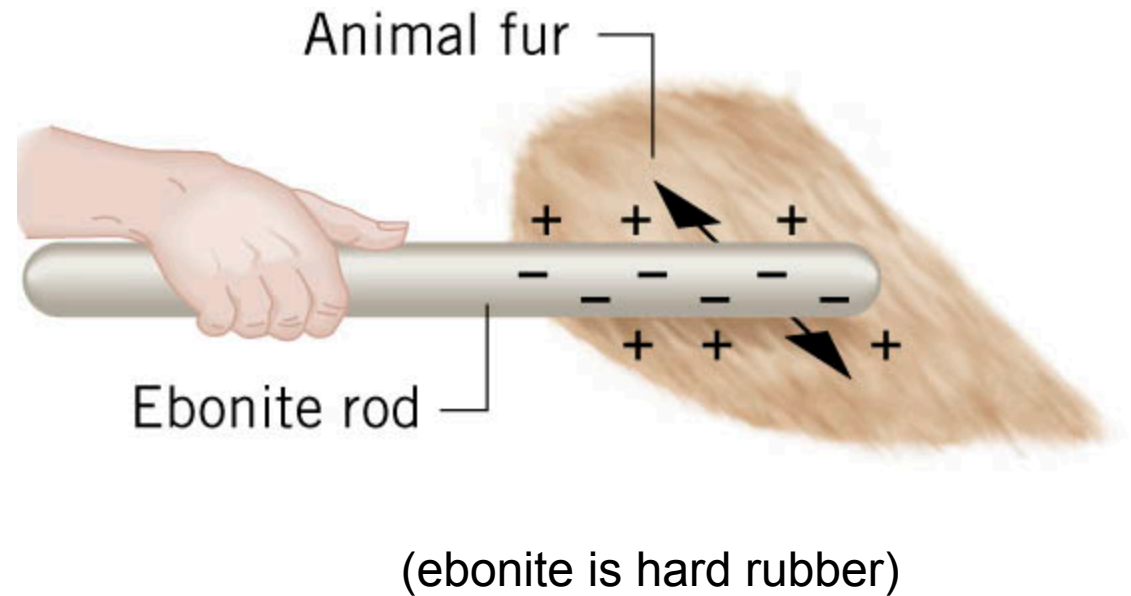
$$q = Ne$$

$$N = \frac{q}{e} = \frac{1.00 \text{ C}}{1.60 \times 10^{-19} \text{ C}} = 6.25 \times 10^{18}$$

a lot!



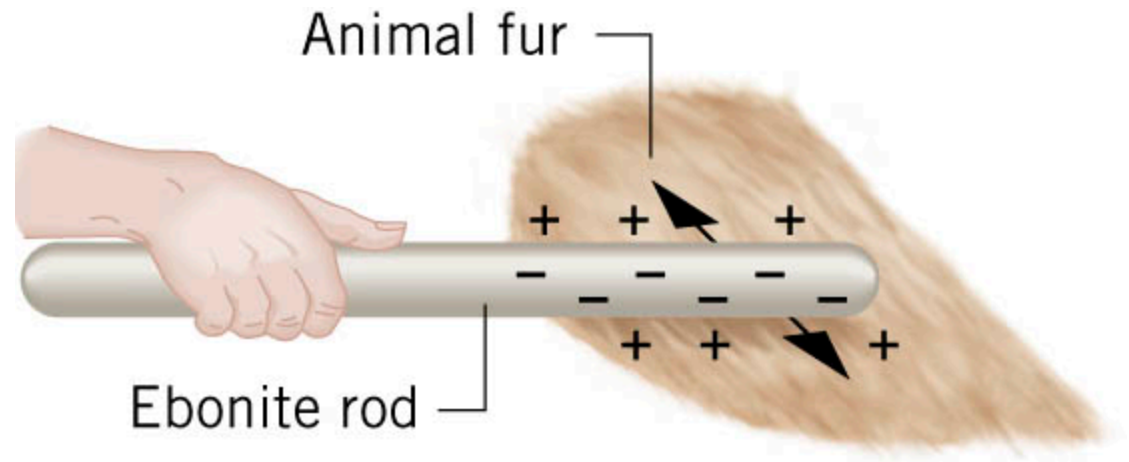
18.2 Charged Objects and the Electric Force



It is possible to transfer electric charge from one object to another by moving around **electrons**, which move easier than positive charges.

The body that **loses electrons** has an excess of **positive charge**, while the body that **gains electrons** has an excess of **negative charge**.

18.2 Charged Objects and the Electric Force

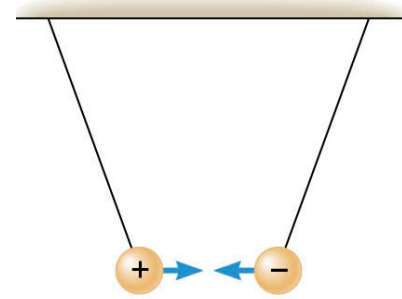


LAW OF CONSERVATION OF ELECTRIC CHARGE

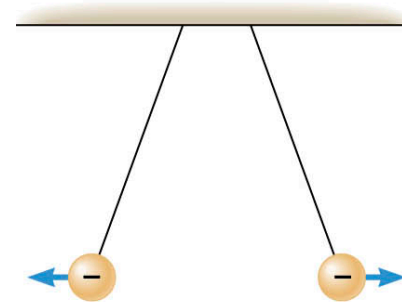
During any process, the net electric charge of an isolated system
Remains constant (is conserved).

18.2 Charged Objects and the Electric Force

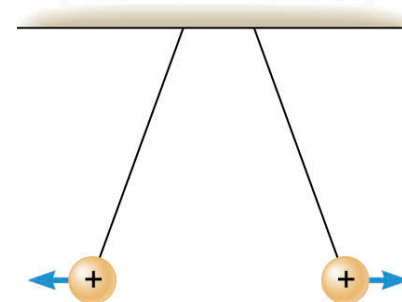
Like charges repel and unlike charges attract each other.



(a)

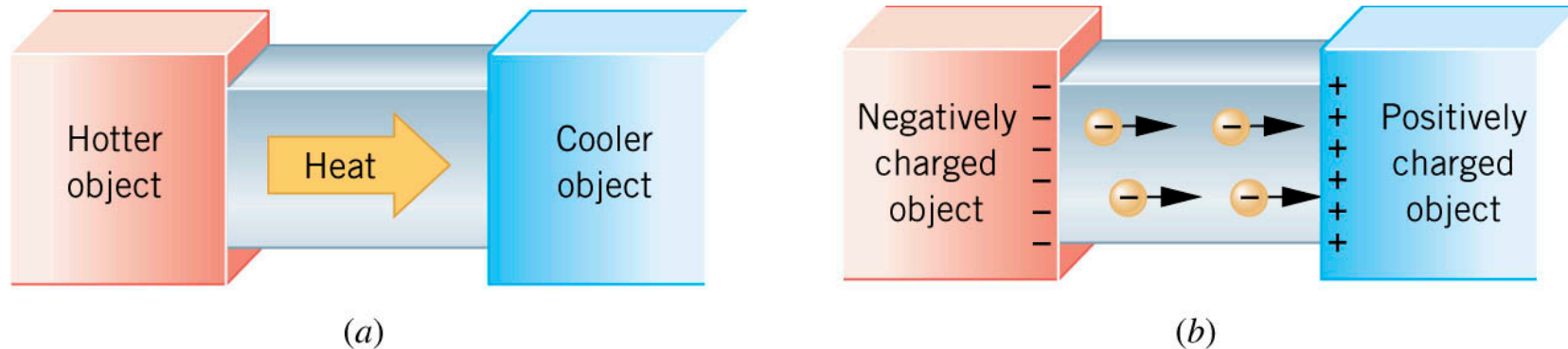


(b)



(c)

18.3 Conductors and Insulators

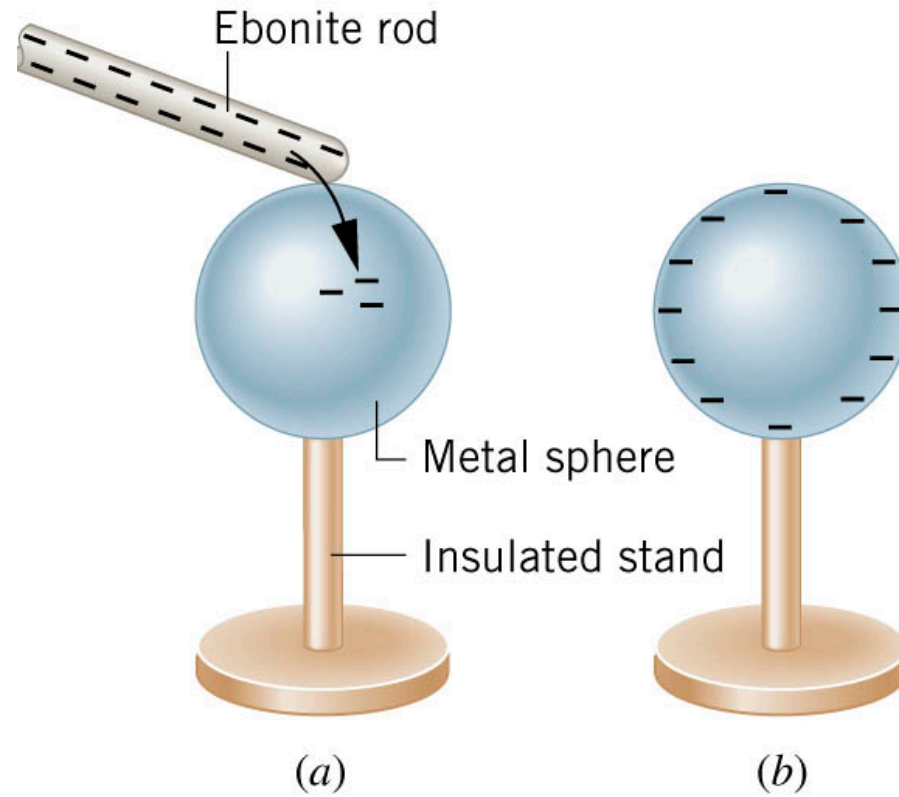


Not only can electric charge exist *on an object*, but it can also move *through an object*.

Substances that readily conduct electric charge are called **electrical conductors**.

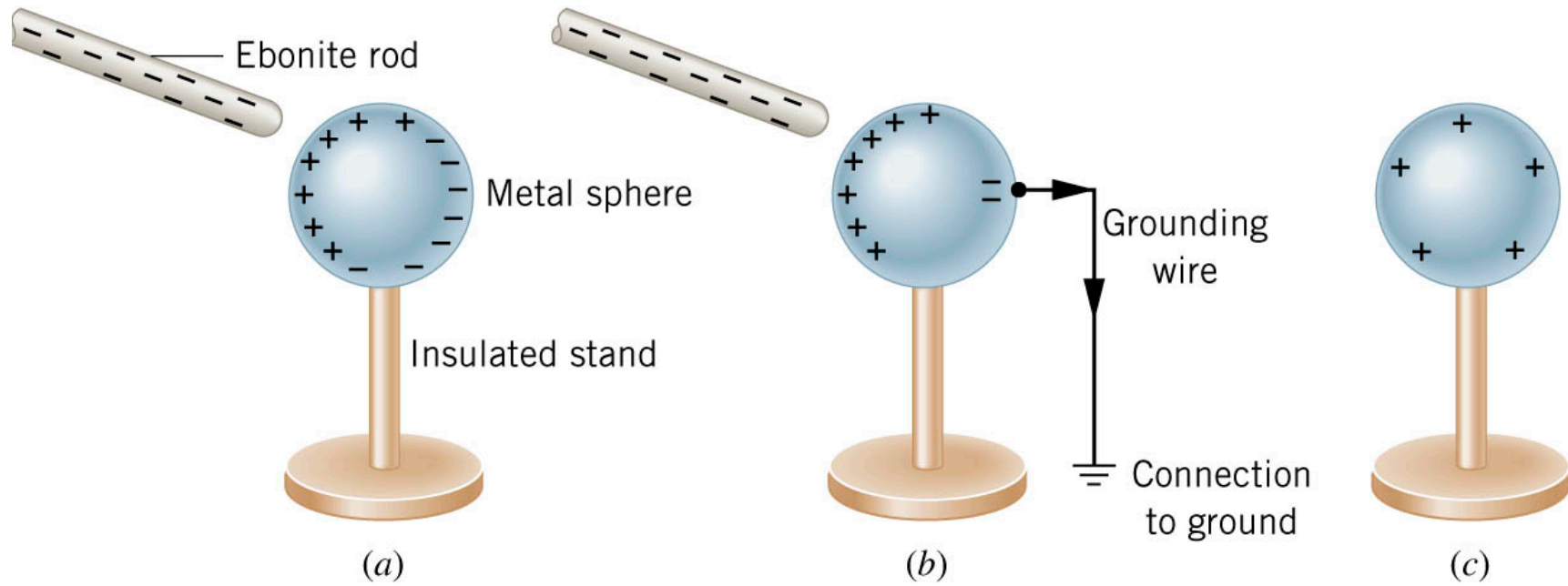
Materials that conduct electric charge poorly are called **electrical insulators**.

18.4 Charging by Contact and by Induction



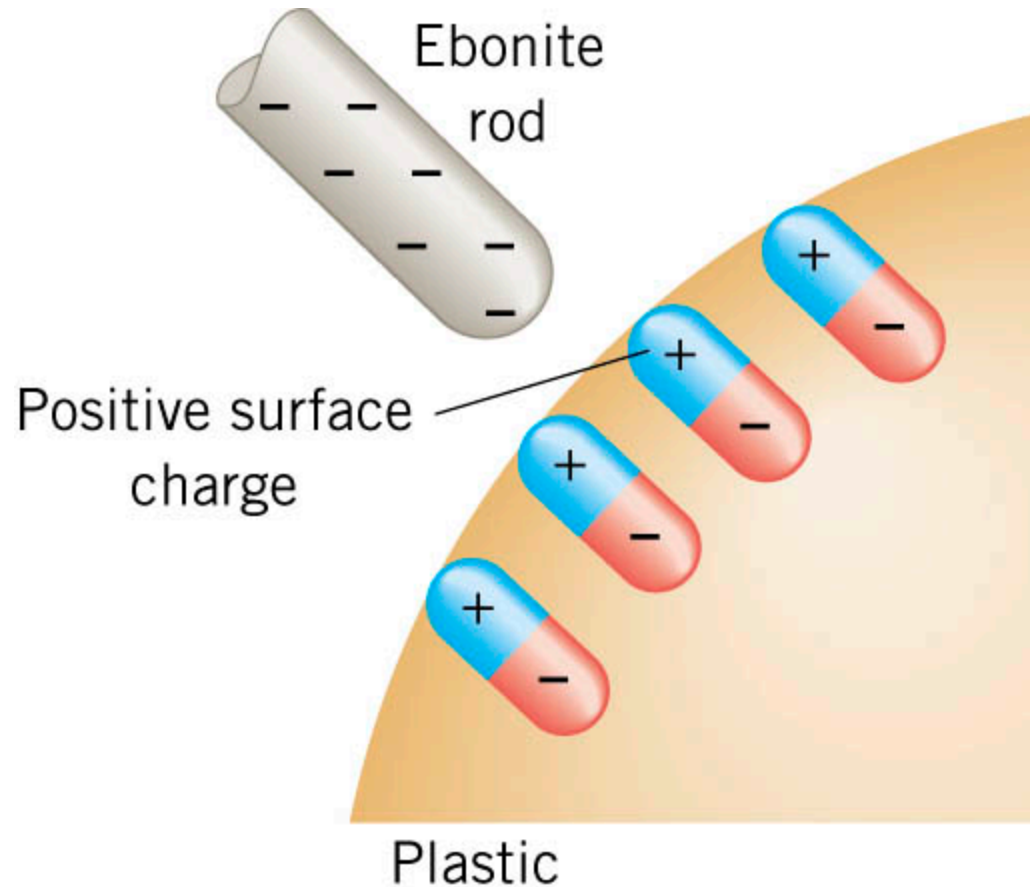
Charging by contact.

18.4 Charging by Contact and by Induction



Charging by induction.

18.4 Charging by Contact and by Induction

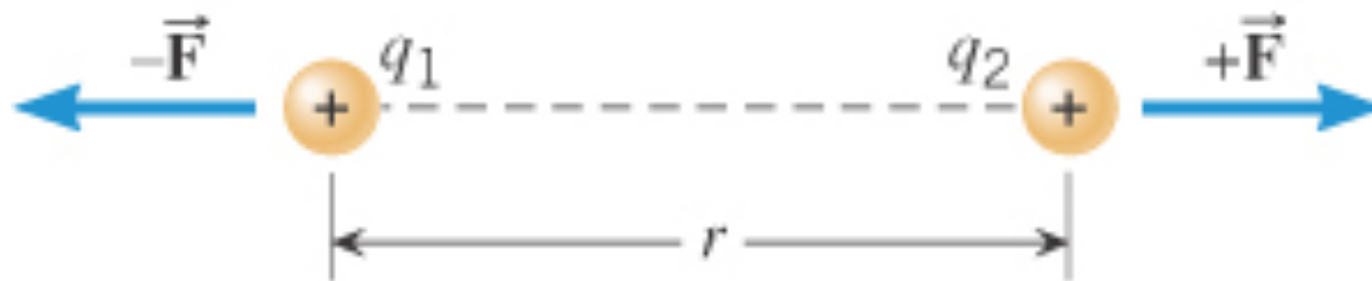


The negatively charged rod **induces** a slight positive surface charge on the plastic by polarizing the plastic molecules.

18.5 Coulomb's Law

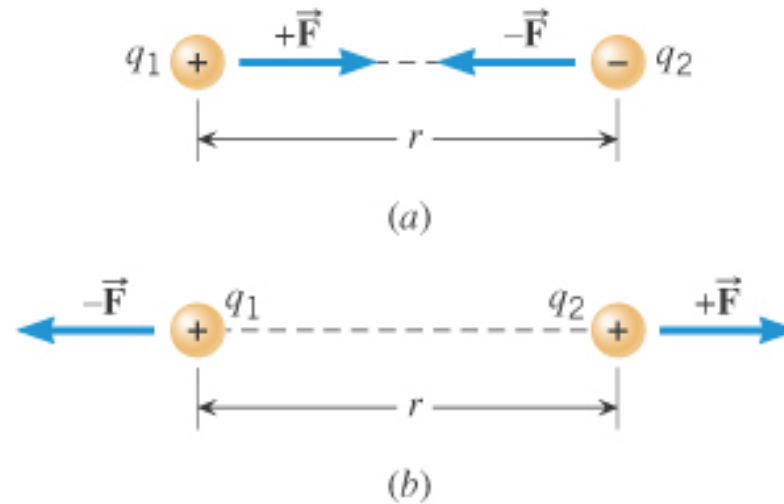


(a)



(b)

18.5 Coulomb's Law



COULOMB'S LAW

The magnitude of the electrostatic force exerted by one point charge on another point charge is directly proportional to the magnitude of the charges and inversely proportional to the square of the distance between them.

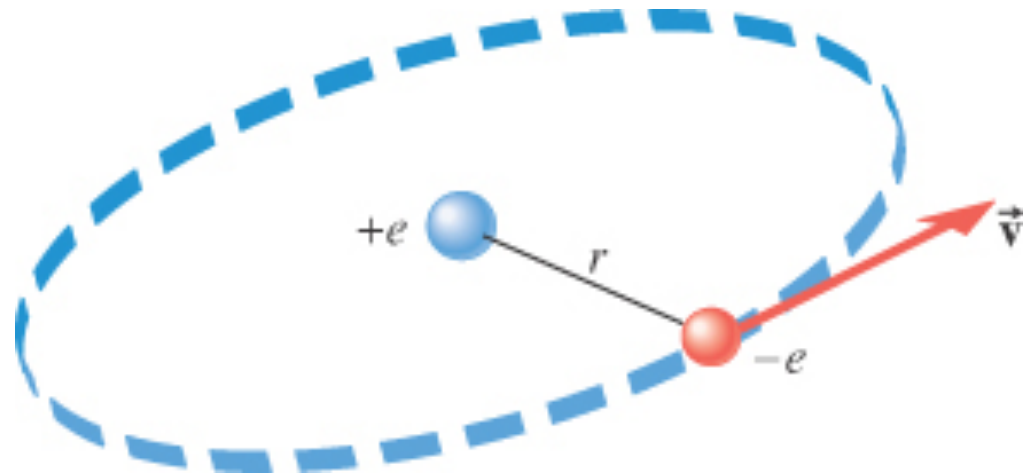
$$F = k \frac{|q_1||q_2|}{r^2}$$

analogous to
Newton's law of
Gravitation!

$\epsilon_o = 8.85 \times 10^{-12} \text{ C}^2/(\text{N} \cdot \text{m}^2)$
permittivity of free space

$$k = 1/(4\pi\epsilon_o) = 8.99 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2$$

18.5 Coulomb's Law

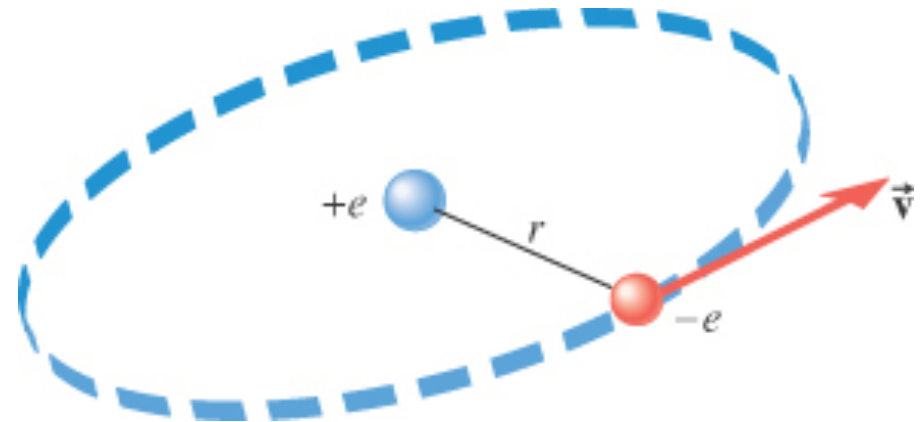


Example 3 A Model of the Hydrogen Atom

In the Bohr model of the hydrogen atom, the electron is in orbit about the nuclear proton at a radius of $5.29 \times 10^{-11} \text{m}$. **Determine the speed of the electron**, assuming the orbit to be circular.

$$F = k \frac{|q_1| |q_2|}{r^2}$$

18.5 Coulomb's Law



$$F = k \frac{|q_1||q_2|}{r^2} = \frac{(8.99 \times 10^9 \text{ N} \cdot \text{m}^2 / \text{C}^2) (1.60 \times 10^{-19} \text{ C})^2}{(5.29 \times 10^{-11} \text{ m})^2} = 8.22 \times 10^{-8} \text{ N}$$

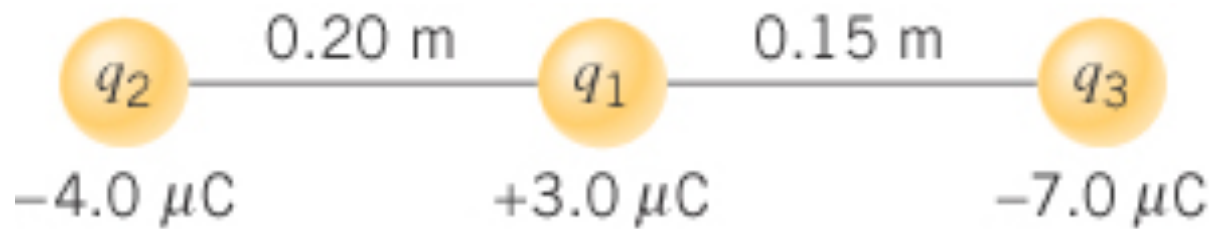
$$F = ma_c = mv^2/r$$

$$\longrightarrow v = \sqrt{Fr/m} = \sqrt{\frac{(8.22 \times 10^{-8} \text{ N})(5.29 \times 10^{-11} \text{ m})}{9.11 \times 10^{-31} \text{ kg}}} = 2.18 \times 10^6 \text{ m/s}$$

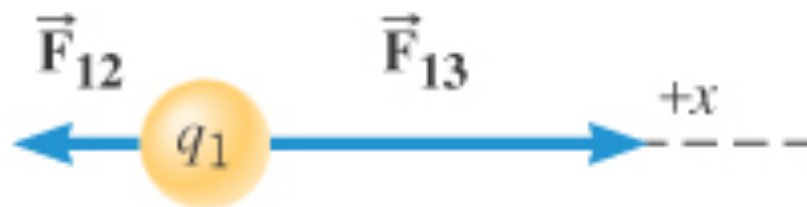
18.5 Coulomb's Law

Example 4 Three Charges on a Line

Determine the magnitude and direction of the net force on q_1 .

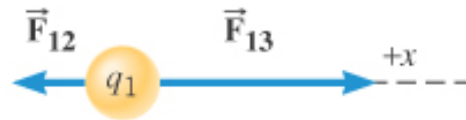
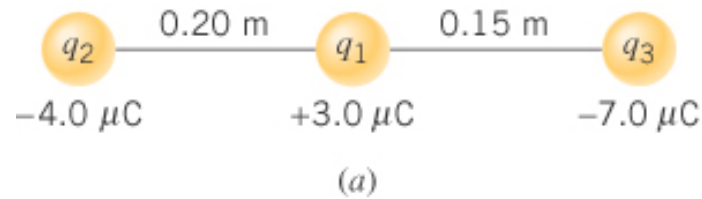


(a)



(b) Free-body diagram for q_1

18.5 Coulomb's Law

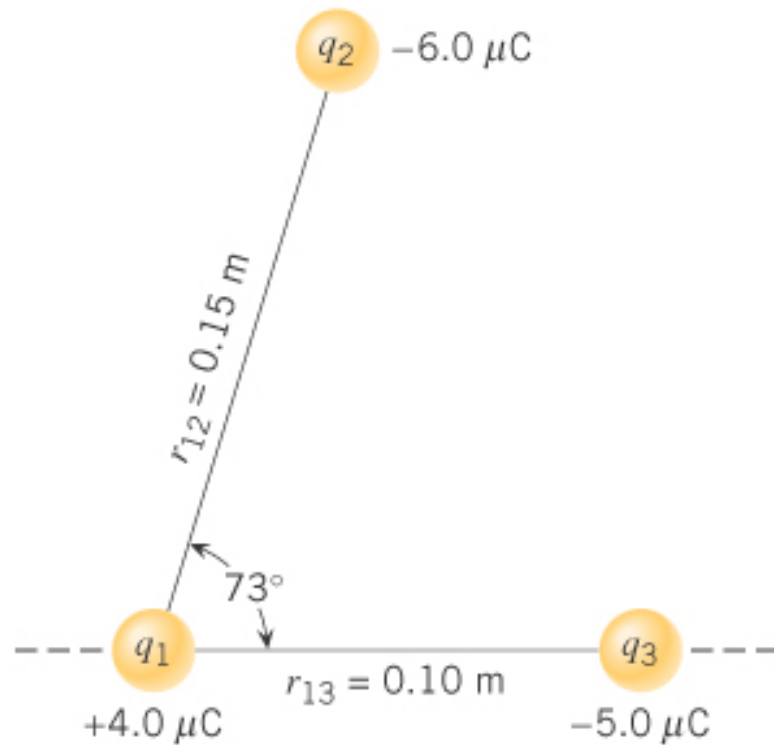


$$F_{12} = k \frac{|q_1||q_2|}{r^2} = \frac{(8.99 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2) (3.0 \times 10^{-6} \text{ C}) (4.0 \times 10^{-6} \text{ C})}{(0.20 \text{ m})^2} = 2.7 \text{ N}$$

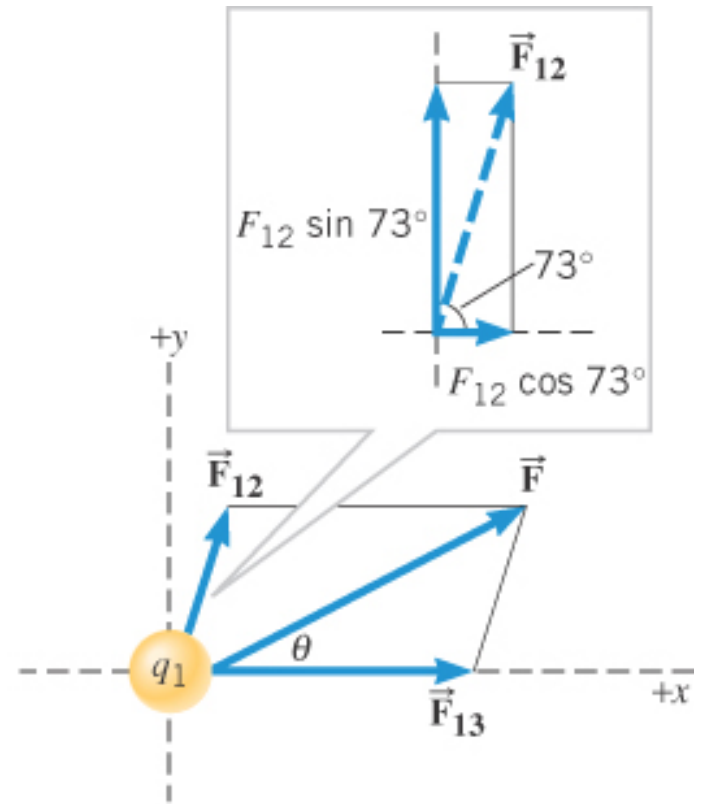
$$F_{13} = k \frac{|q_1||q_3|}{r^2} = \frac{(8.99 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2) (3.0 \times 10^{-6} \text{ C}) (7.0 \times 10^{-6} \text{ C})}{(0.15 \text{ m})^2} = 8.4 \text{ N}$$

$$\vec{F} = \vec{F}_{12} + \vec{F}_{13} = -2.7 \text{ N} + 8.4 \text{ N} = +5.7 \text{ N}$$

18.5 Coulomb's Law



(a)



(b) Free-body diagram for q_1

Find the net electrostatic force exerted on q_1