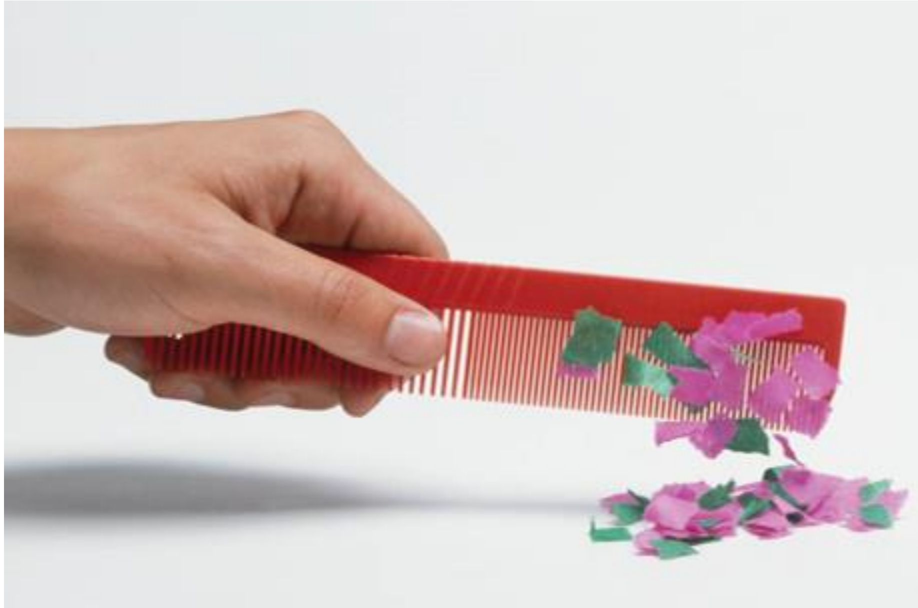
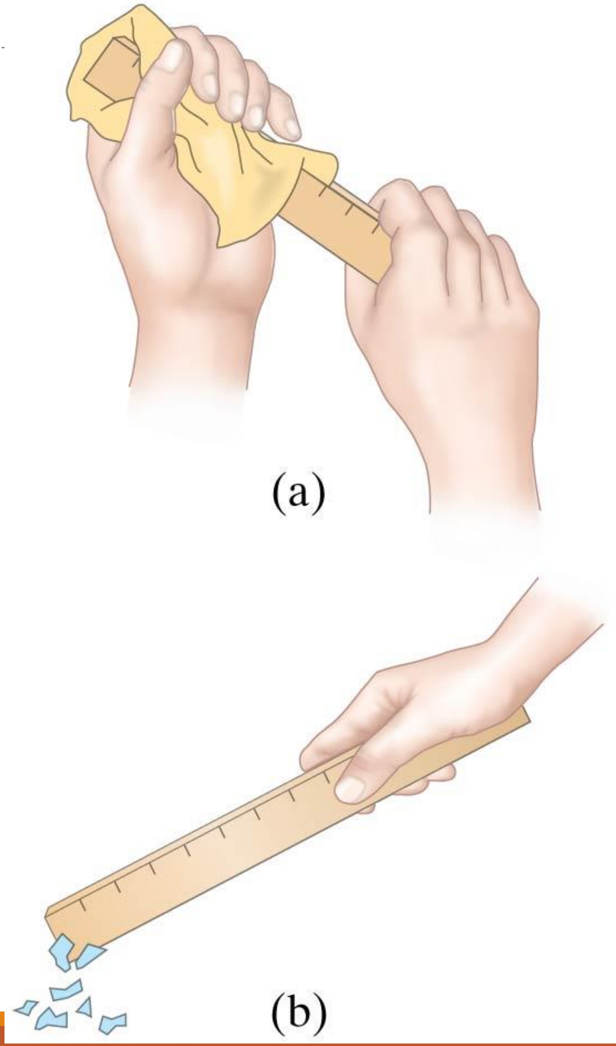
Electric Charge and Electric Field

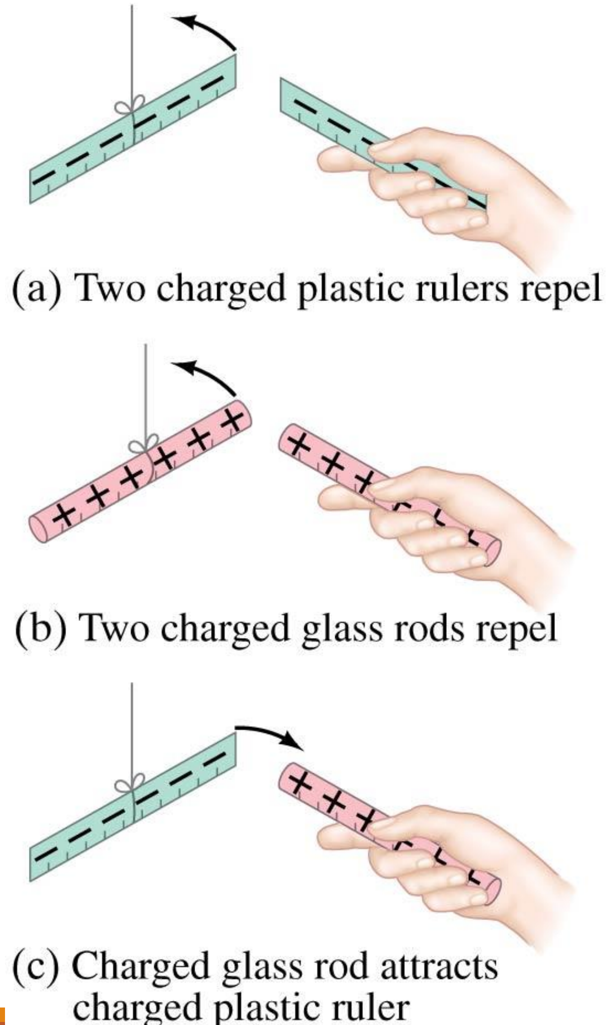


Static Electricity; Electric Charge



Objects can be charged by rubbing

Static Electricity; Electric Charge



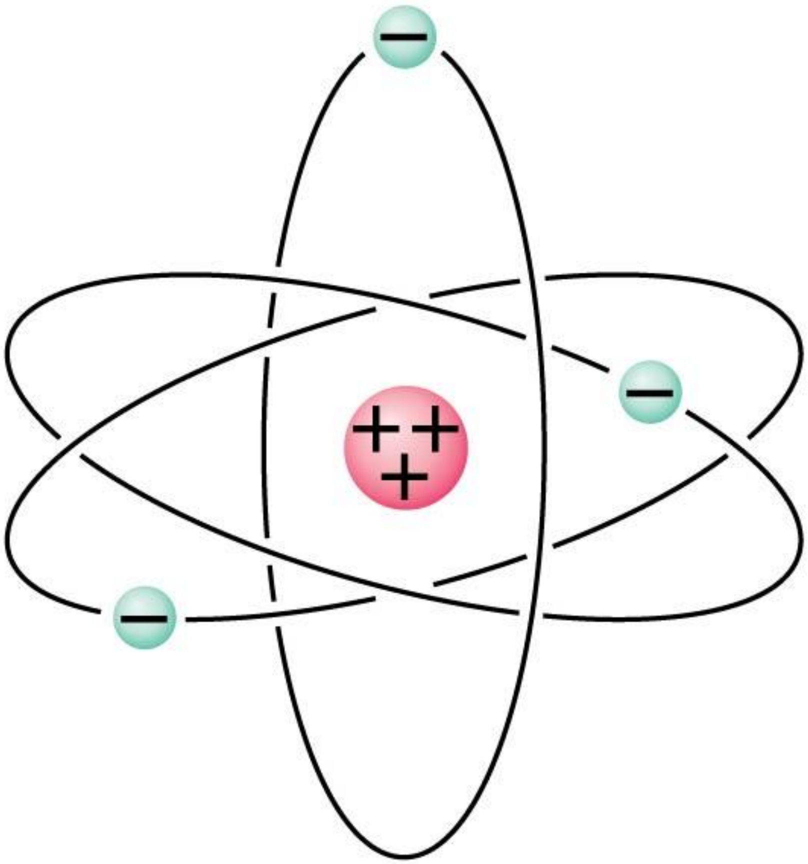
Charge comes in two types, positive and negative; like charges repel and opposite charges attract

Electric Charge in the Atom

Atom:

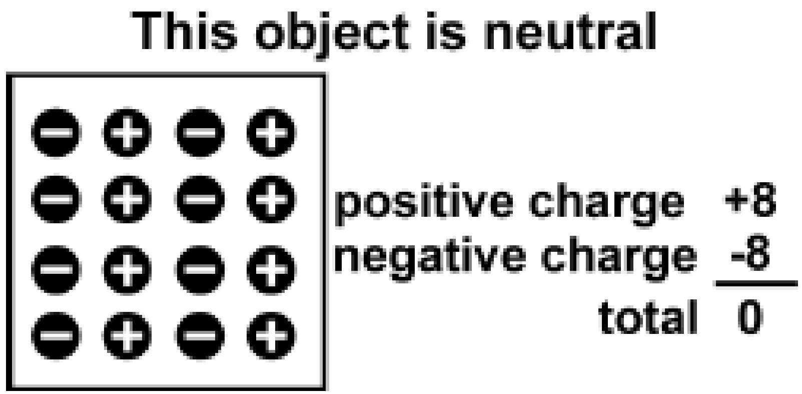
Nucleus (small, massive, positive charge)

Electron cloud (large, very low density, negative charge)



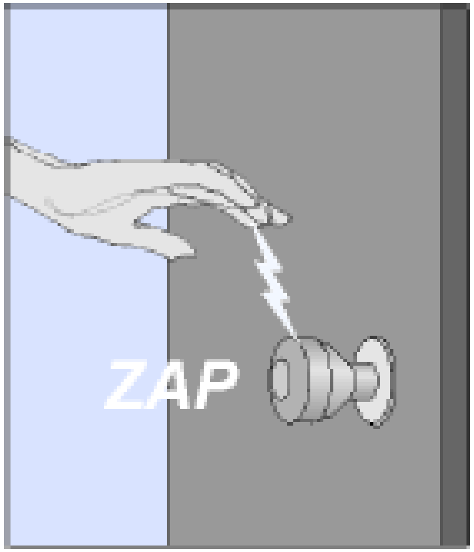
Electric Charge in the Atom

- All ordinary matter contains both positive and negative charge.
- You do not usually notice the charge because most matter contains the exact same number of positive and negative charges.
- An object is electrically neutral when it has equal amounts of both types of charge.



Electric Charge

- Objects can lose or gain electric charges.
- The net charge is also sometimes called excess charge because a charged object has an excess of either positive or negative charges.
- A tiny imbalance in either positive or negative charge on an object is the cause of static electricity.



Static electricity

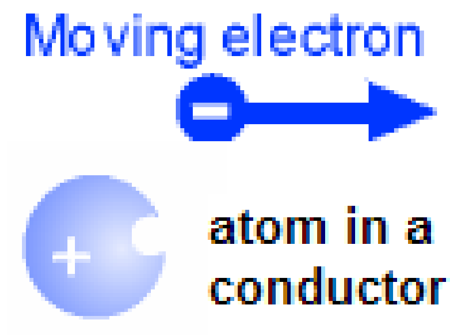
- Electric charge is a property of tiny particles in atoms.
- The unit of electric charge is the coulomb (C).
- A quantity of charge should always be identified with a positive or a negative sign.

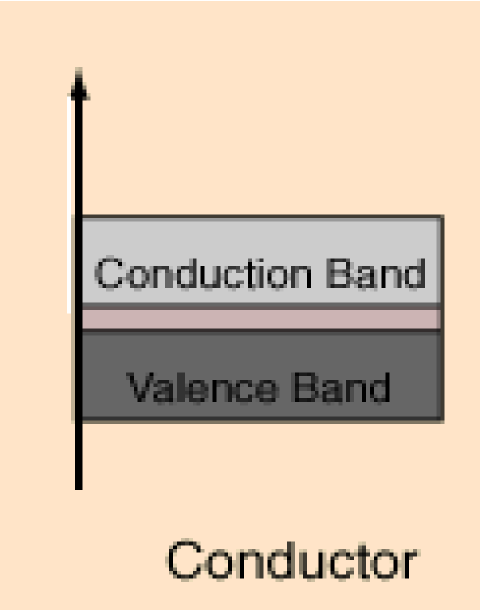
	Mass (kg)	Charge (coulombs)
Electron	9.109×10^{-31}	-1.602×10^{-19}
Proton	1.673×10^{-27}	$+1.602 \times 10^{-19}$
Neutron	1.675×10^{-27}	0

Conductors and Insulators

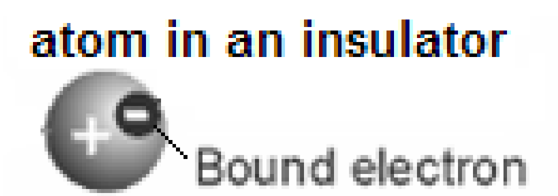
All materials contain electrons.

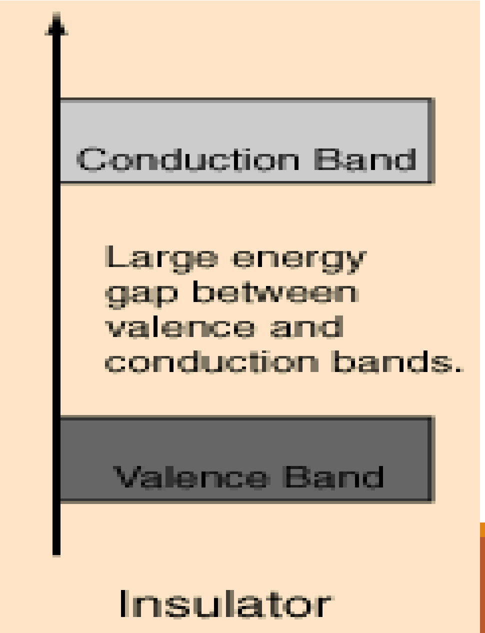
The electrons are what carry the current in a conductor.



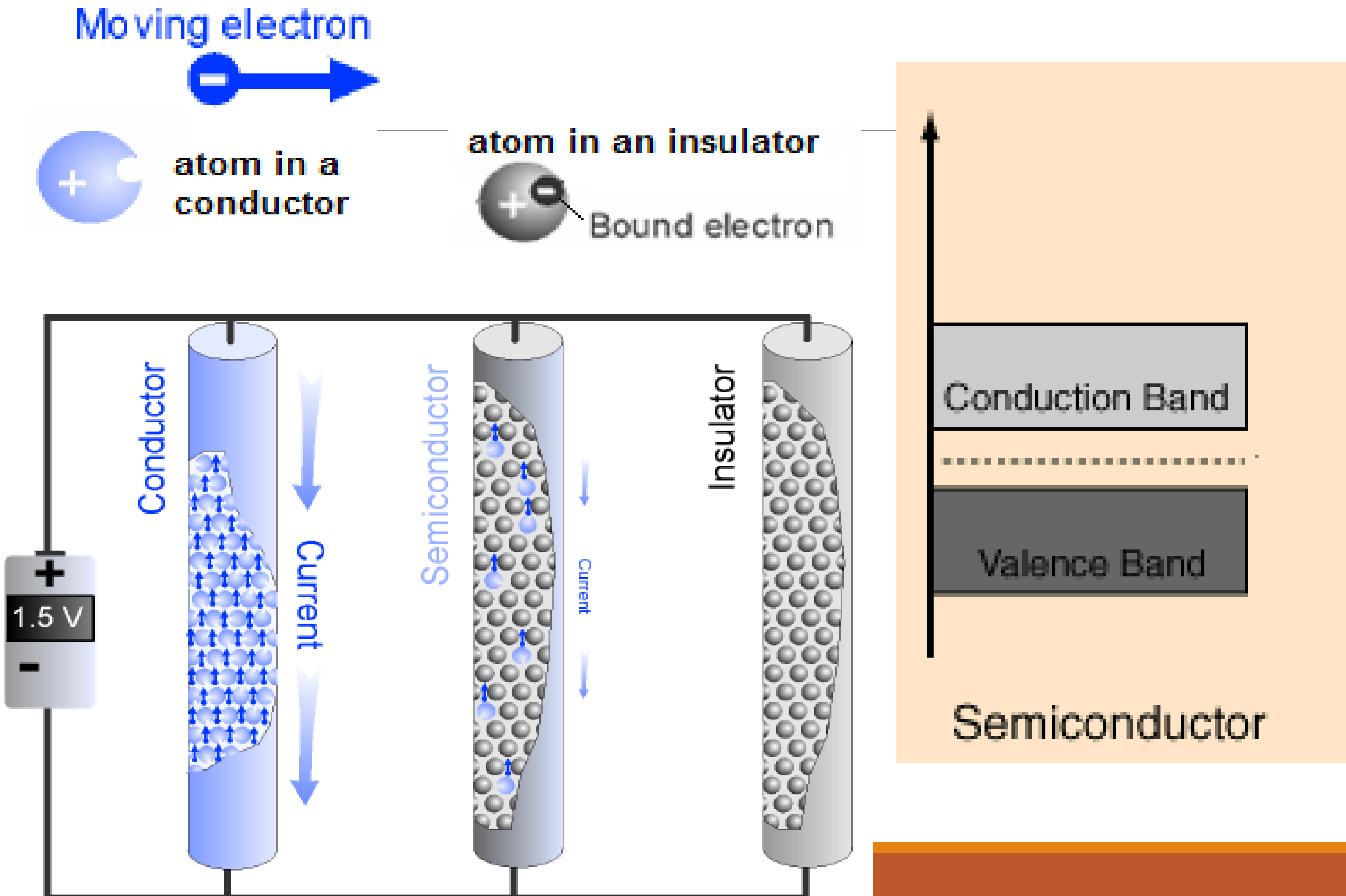


The electrons in insulators are not free to move—they are tightly bound inside atoms.



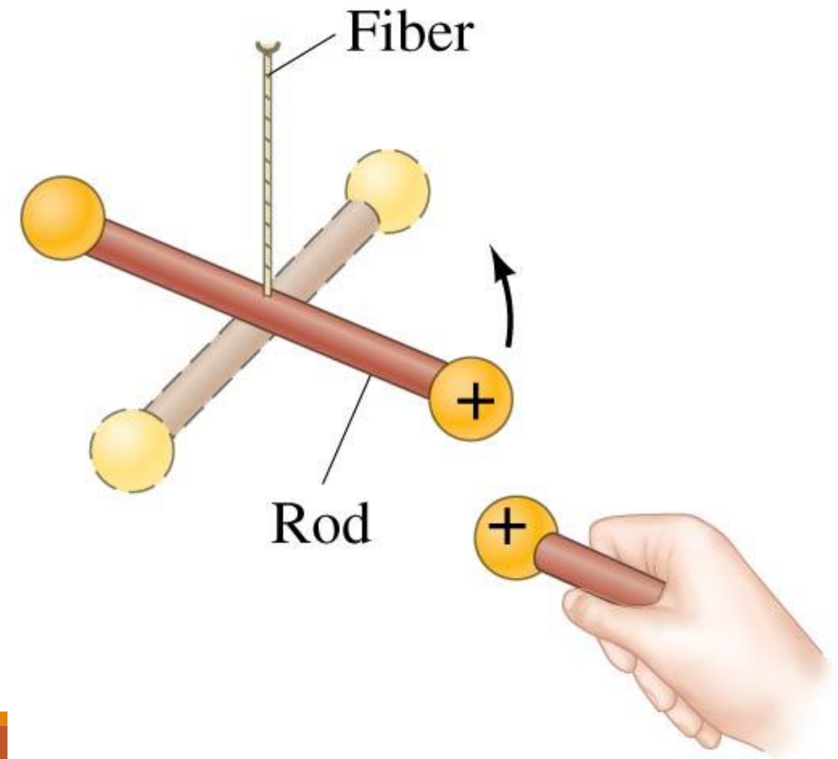


- A semiconductor has a few free electrons and atoms with bound electrons that act as insulators.



Coulomb’s Law

Experiment shows that the electric force between two charges is proportional to the product of the charges and inversely proportional to the distance between them.



Coulomb's Law

Coulomb's law relates the force between two single charges separated by a distance.

Force (F) depends on charge (q)

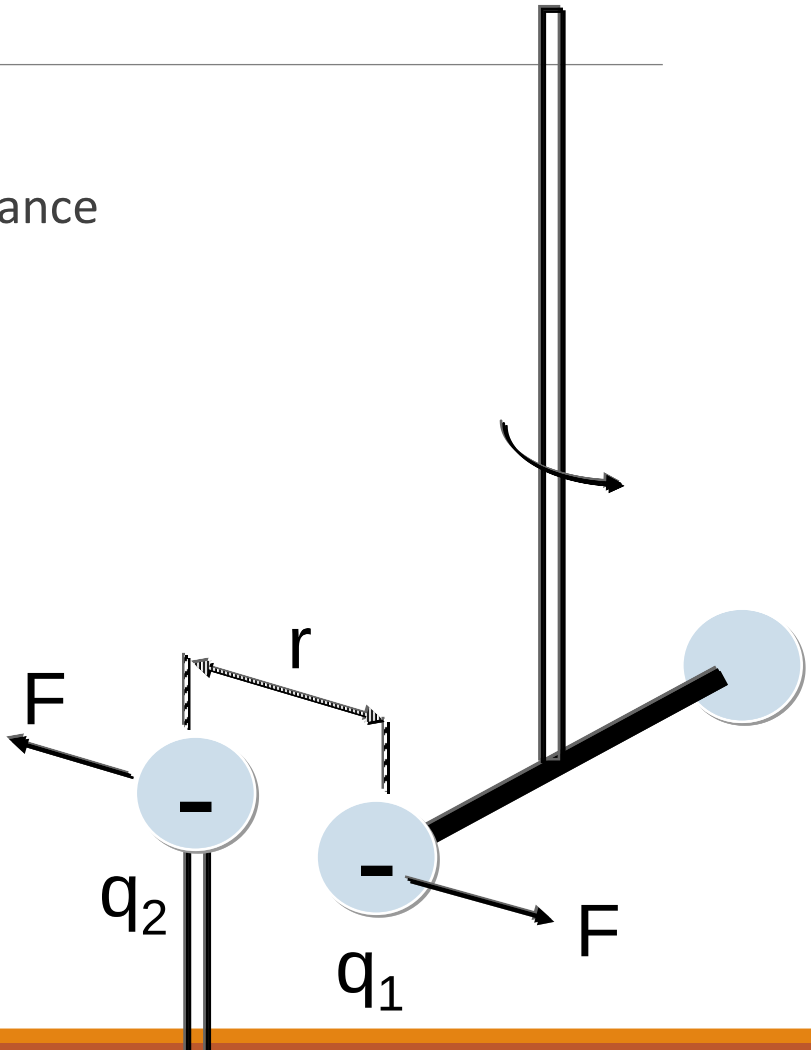
$F \propto q_1$; $F \propto q_2$

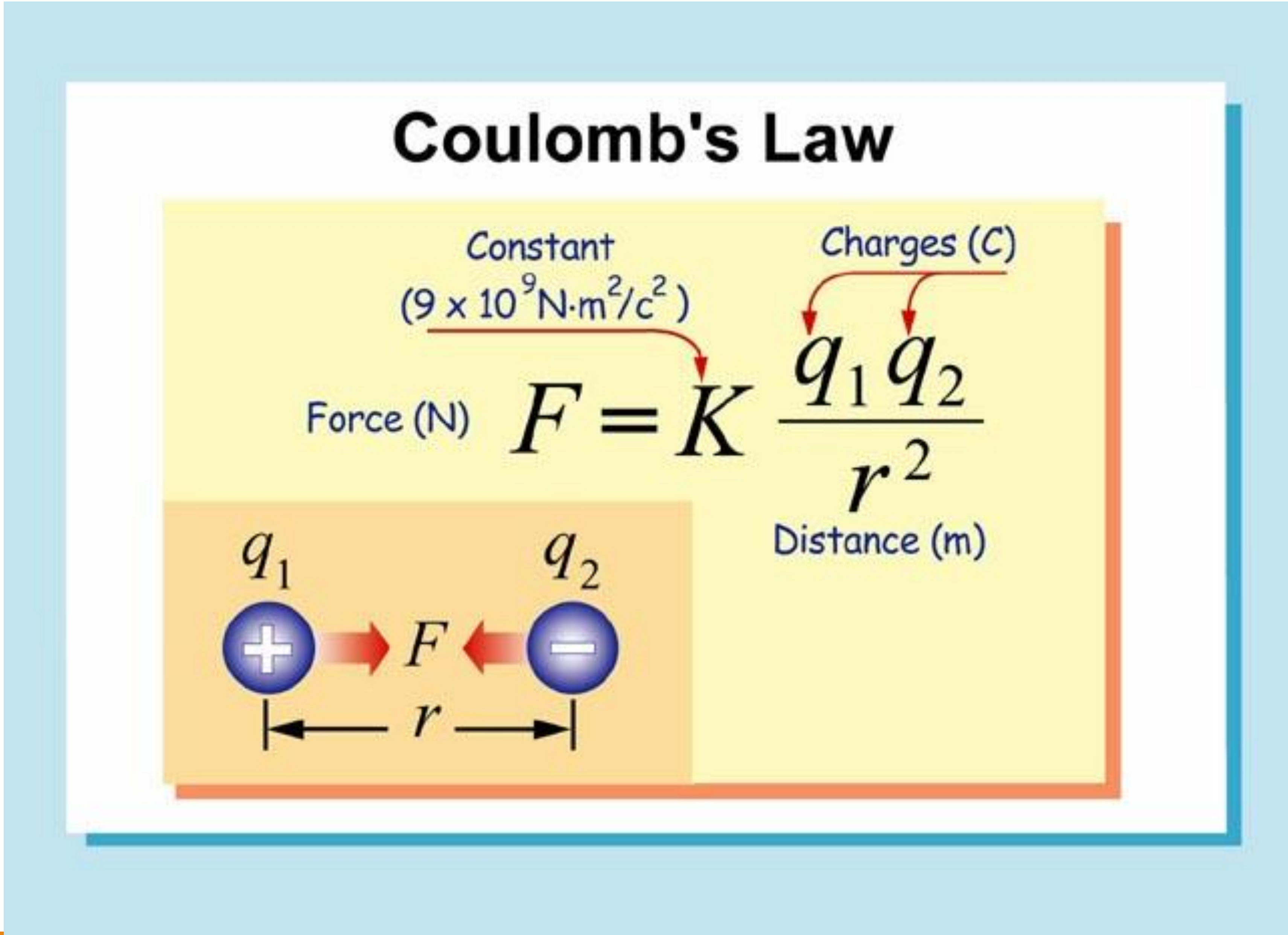
Force depends on the inverse square of the distance (r) between the charges

$F \propto 1/r^2$

$F \propto (q_1\, q_2)/r^2$

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

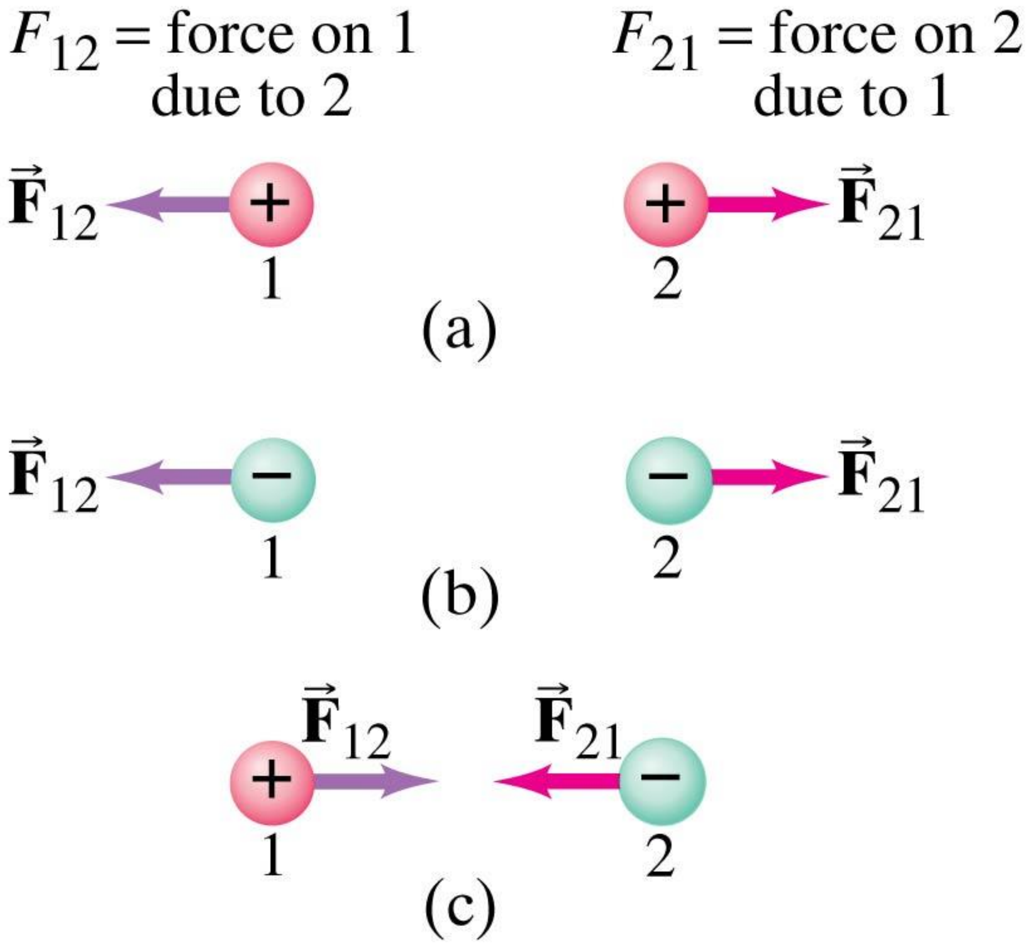




Coulomb's Law
Constant
(9×10^{9} N·m²/c²)
Charges (C)
Force (N)
$F = K \frac{q_1 q_2}{r^2}$
Distance (m)
q_1
q_2
F
r

Coulomb’s Law

The force is along the line connecting the charges, and is attractive if the charges are opposite, and repulsive if they are the same.



Coulomb’s Law

Unit of charge: coulomb, C

The proportionality constant in Coulomb’s law is then:

$$k = 8.988 \times 10^{9}\ \mathrm{N{\cdot}m^2/C^2}$$

Charges produced by rubbing are typically around a microcoulomb:

$$1\ \mu\mathrm{C} = 10^{-6}\ \mathrm{C}$$

Coulomb's Law

The proportionality constant *k* can also be written in terms of ε_0, the permittivity of free space:

$$F = \frac{1}{4\pi\epsilon_0}\frac{Q_1 Q_2}{r^2}, \quad (16\text{-}2)$$

$$\epsilon_0 = \frac{1}{4\pi k} = 8.85 \times 10^{-12}\,\mathrm{C^2/N\cdot m^2}.$$

Conservation of Charge

Electric charge is conserved—the arithmetic sum of the total charge cannot change in any interaction.

Nuclear reactions $\gamma^0 = e^+ + e^-$

Radioactive decay ${}^{238}U_{92} = {}^{234}Th_{90} + {}^{4}He_2$

High energy particle reactions $e^- + p^+ = e^- + \pi^+ + n^0$

Quantization of charge

Any positive or negative charge q that can be detected can be written as

$$q = ne, \qquad n = \pm 1, \pm 2, \pm 3, \ldots,$$

in which e, the **elementary charge,** has the approximate value

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

Calculate the Force

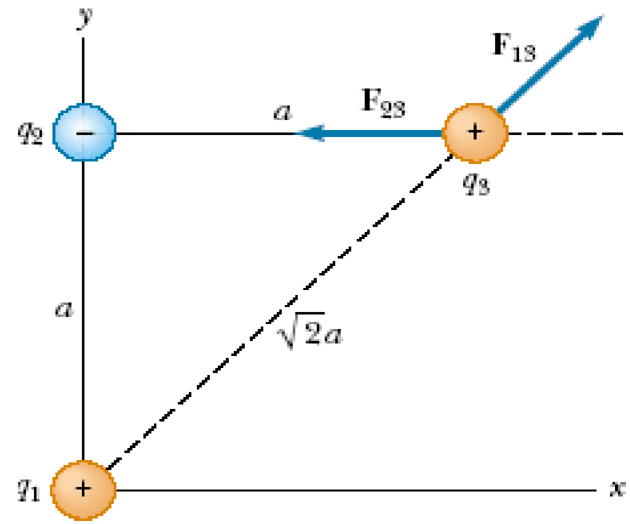
Consider three point charges located at the corners of a right triangle as shown in Figure. Find the resultant force exerted on *q3* .

$q_1 = q_3 = 5.0\ \mu C$, $q_2 = -2.0\ \mu C$, and $a = 0.10$ m.

$$F_{3x} = F_{13x} + F_{23} = 7.9\ N - 9.0\ N = -1.1\ N$$

$$F_{3y} = F_{13y} = 7.9\ N$$

$$\mathbf{F}_3 = (-1.1\mathbf{i} + 7.9\mathbf{j})\ N$$



Find the magnitude and direction of the resultant force $\mathbf{F}_3$.

8.0 N at an angle of 98° with the x axis.