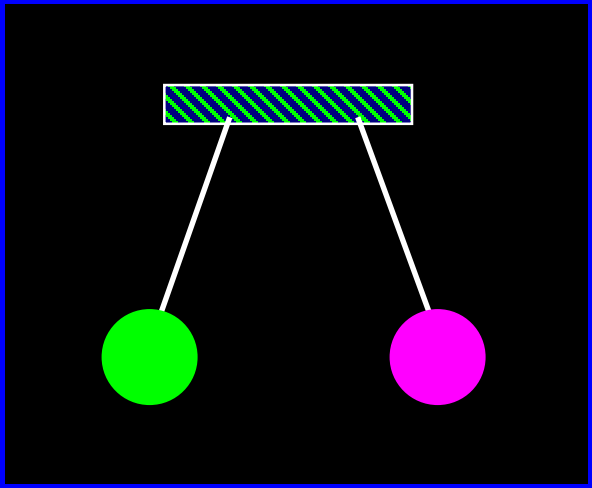
Chapter 21
Electric Charge and Electric Field

ConcepTest 21.1a Electric Charge I

Two charged balls are repelling each other as they hang from the ceiling. What can you say about their charges?

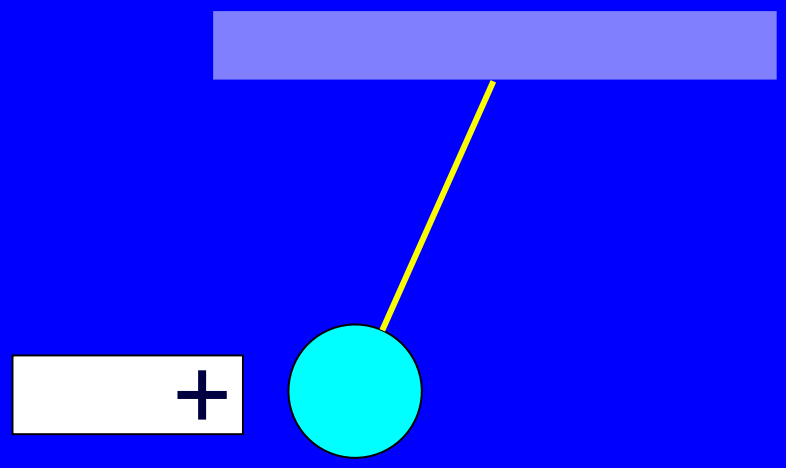
1) one is positive, the other is negative
2) both are positive
3) both are negative
4) both are positive or both are negative



ConcepTest 21.2a Conductors I

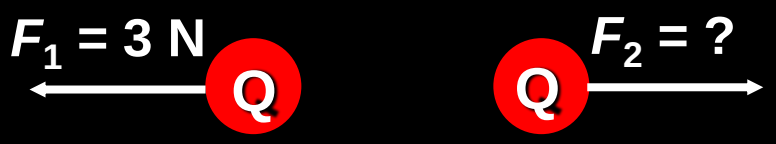
A metal ball hangs from the ceiling by an insulating thread. The ball is attracted to a positive-charged rod held near the ball. The charge of the ball must be:

1) positive
2) negative
3) neutral
4) positive or neutral
5) negative or neutral



ConcepTest 21.3a Coulomb's Law I

What is the magnitude of the force F_2?

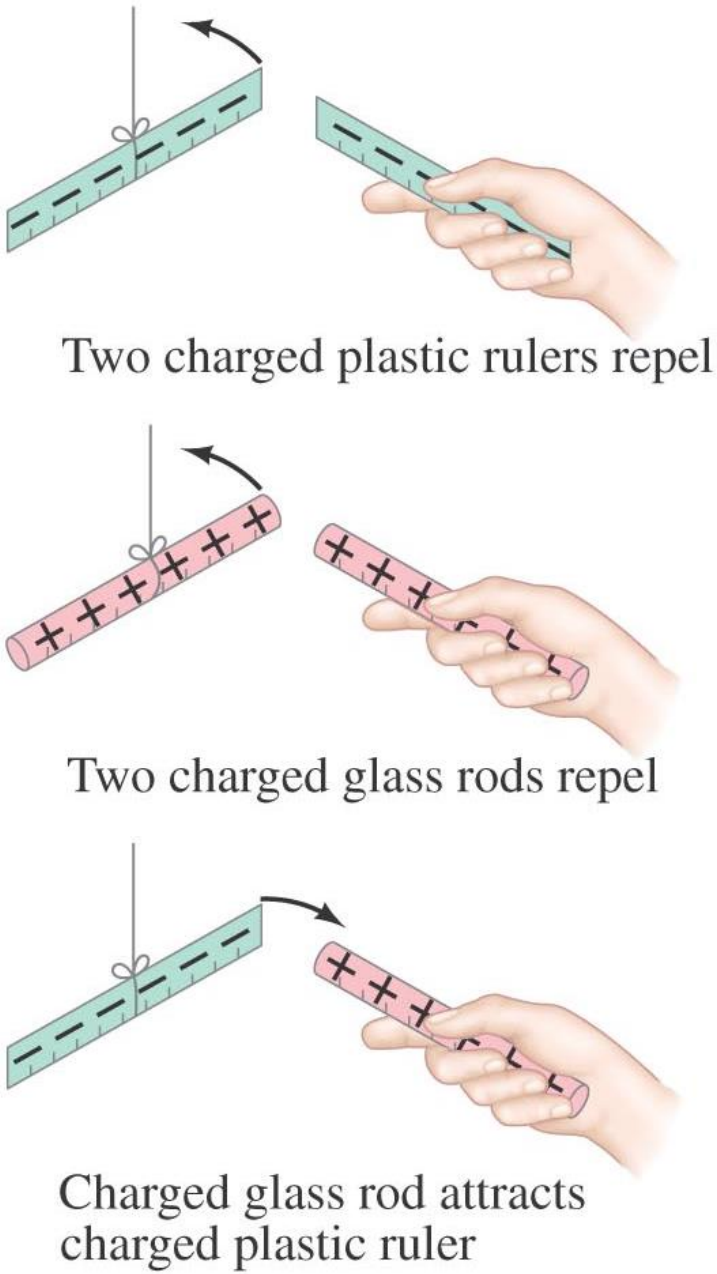


1) 1.0 N
2) 1.5 N
3) 2.0 N
4) 3.0 N
5) 6.0 N

Static Electricity; Electric Charge and Its Conservation

Objects can be charged by rubbing

Static Electricity; Electric Charge and Its Conservation



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

Static Electricity; Electric Charge and Its Conservation

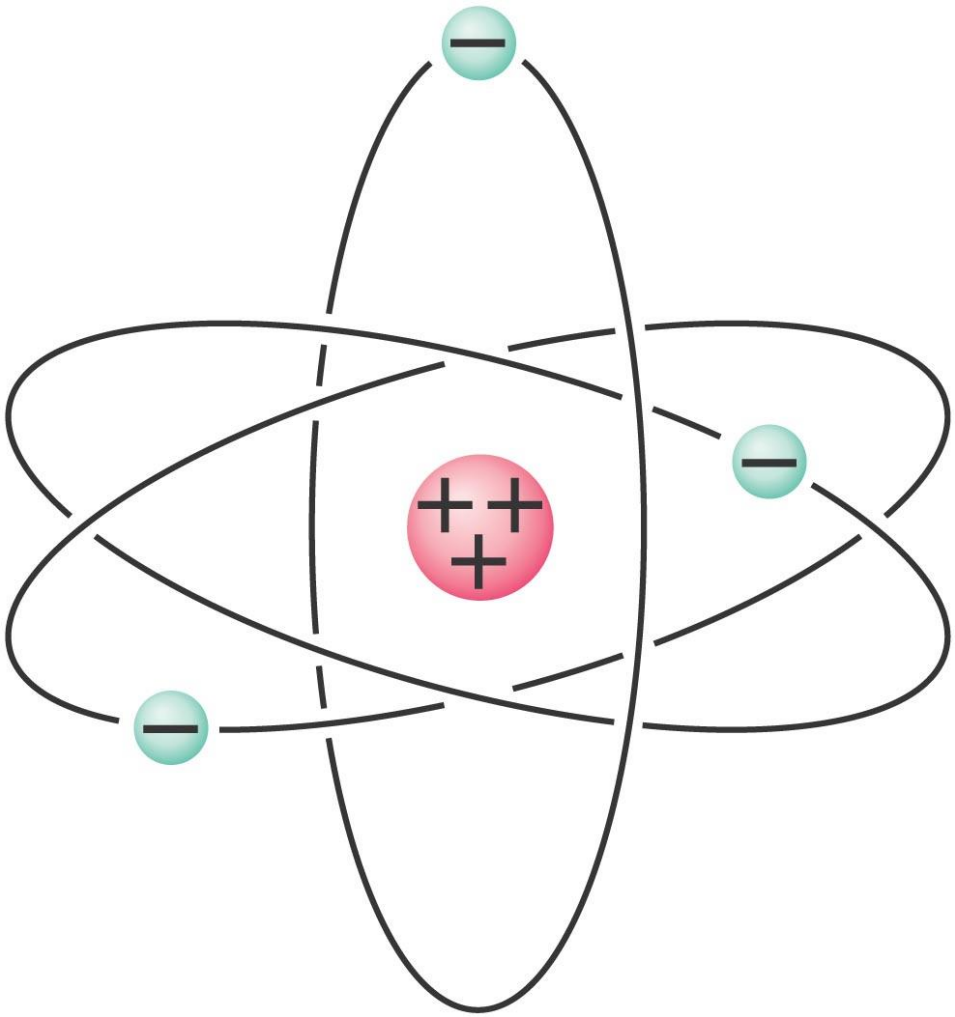
Electric charge is conserved – the arithmetic sum of the total charge cannot change in any interaction.

Electric Charge in the Atom

Atom:

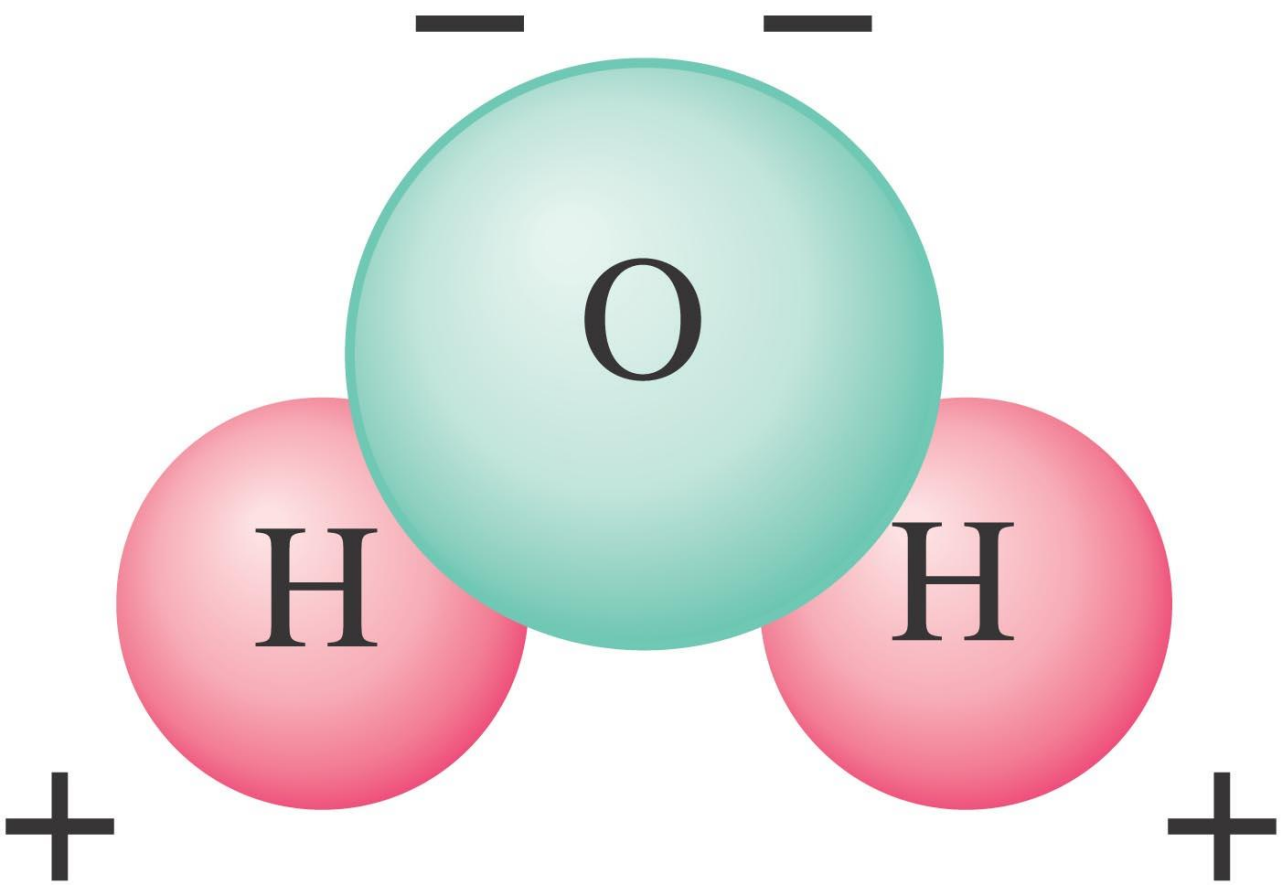
Nucleus (small, massive, positive charge)

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



Electric Charge in the Atom

Polar molecule: neutral overall, but charge not evenly distributed



Insulators and Conductors

Conductor:

Charge flows freely

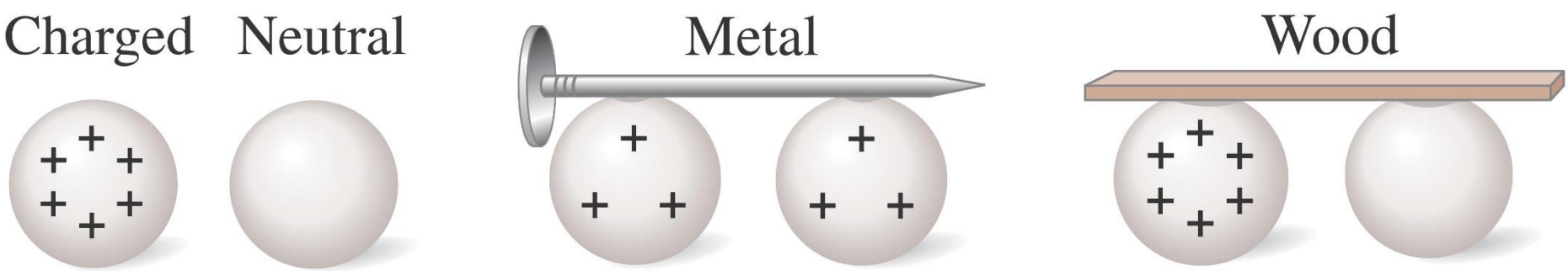
Metals

Insulator:

Almost no charge flows

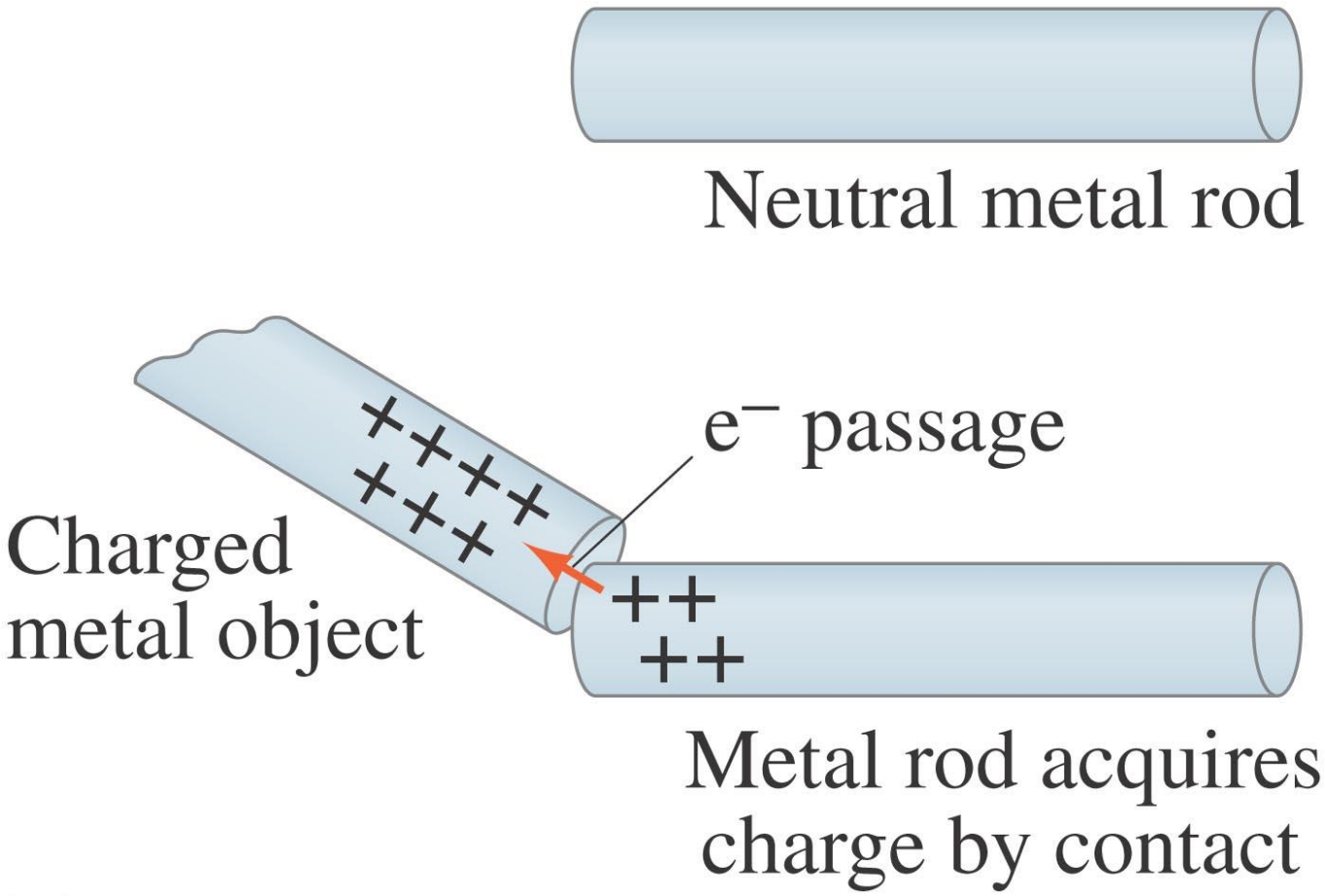
Most other materials

Some materials are semiconductors.



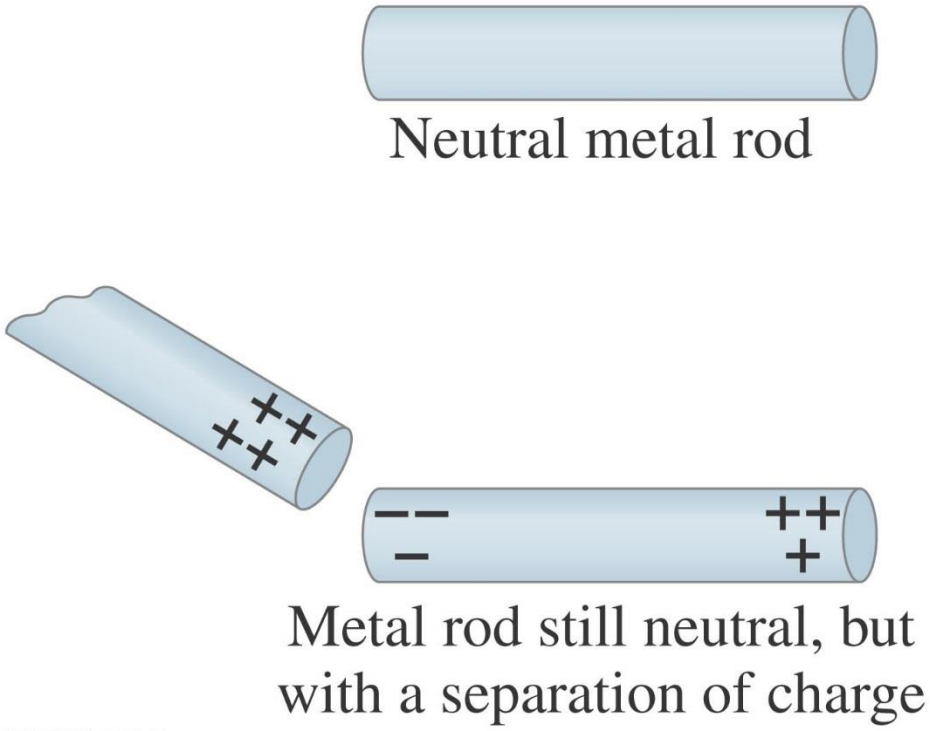
Induced Charge

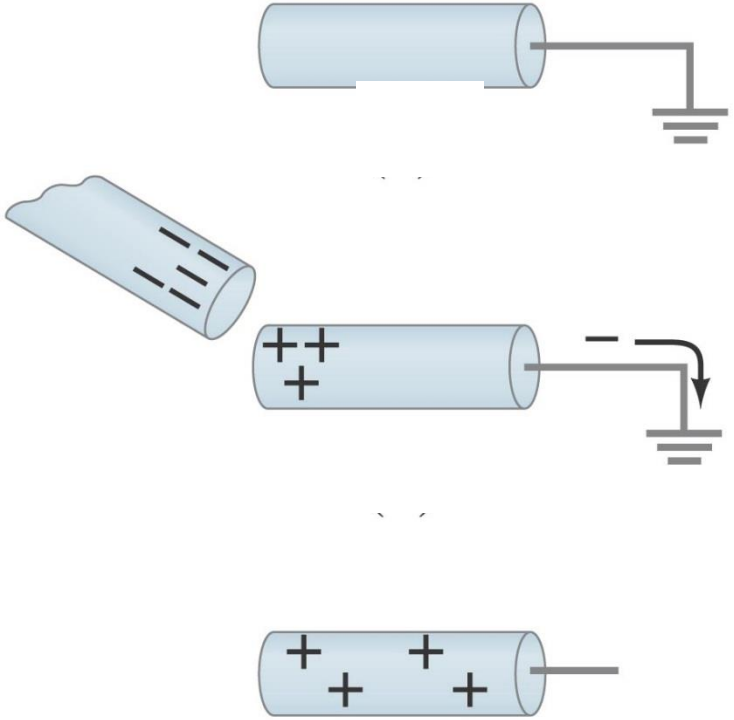
Metal objects can be charged by <u>conduction</u>:



Induced Charge

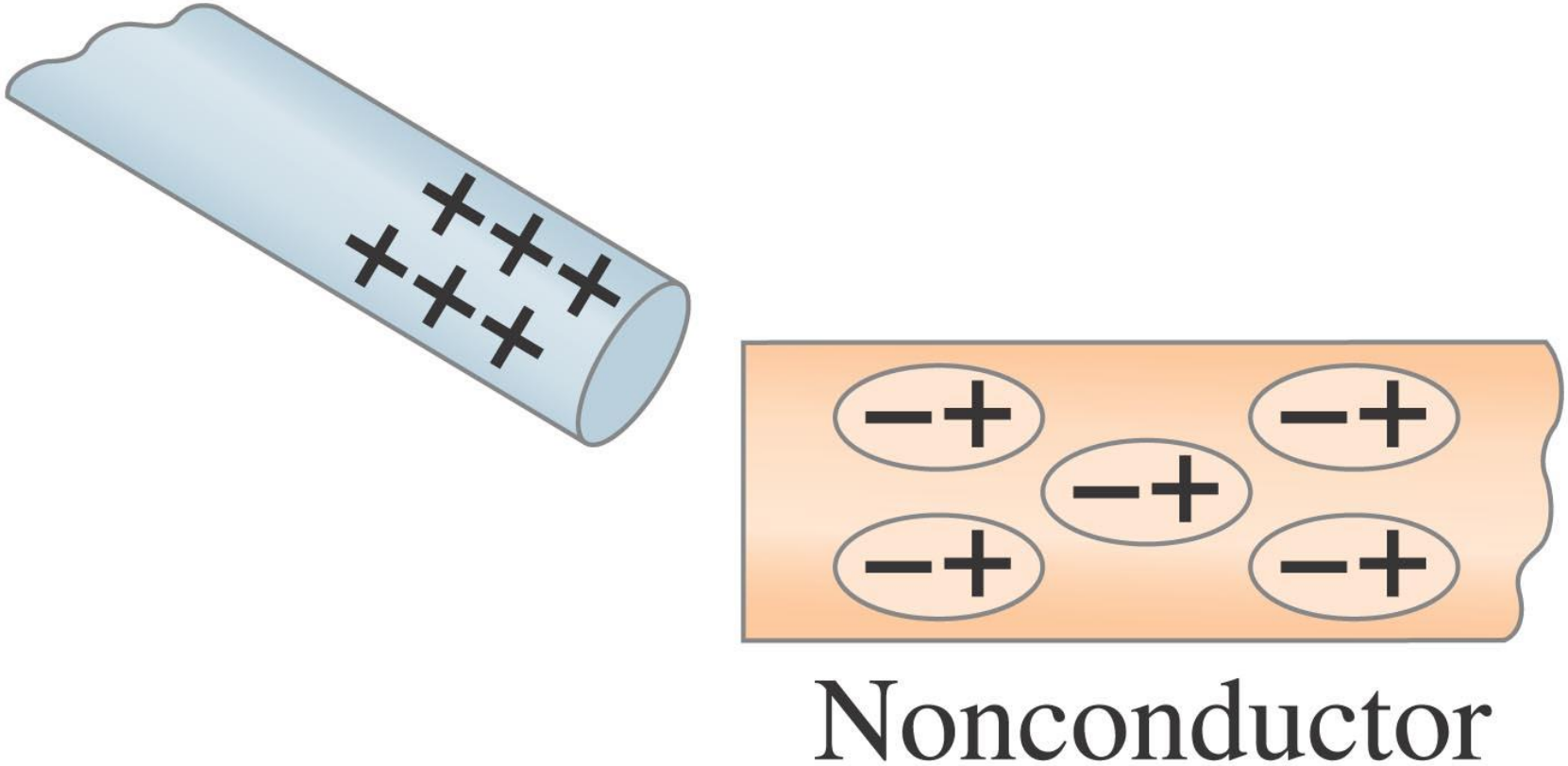
They can also be charged by <u>induction</u>, either while connected to ground or not:





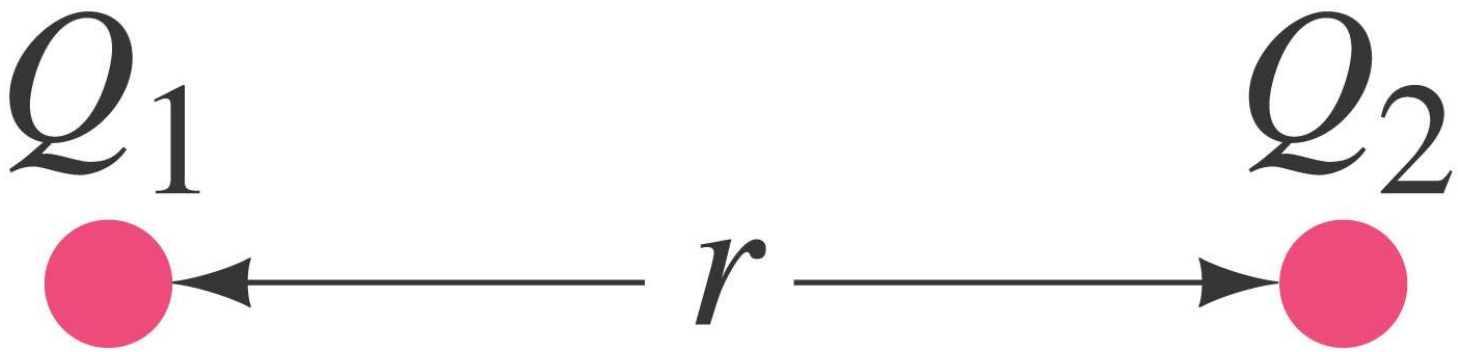
Induced Charge

Nonconductors won't become charged by conduction or induction, but will experience <u>charge separation</u>:



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

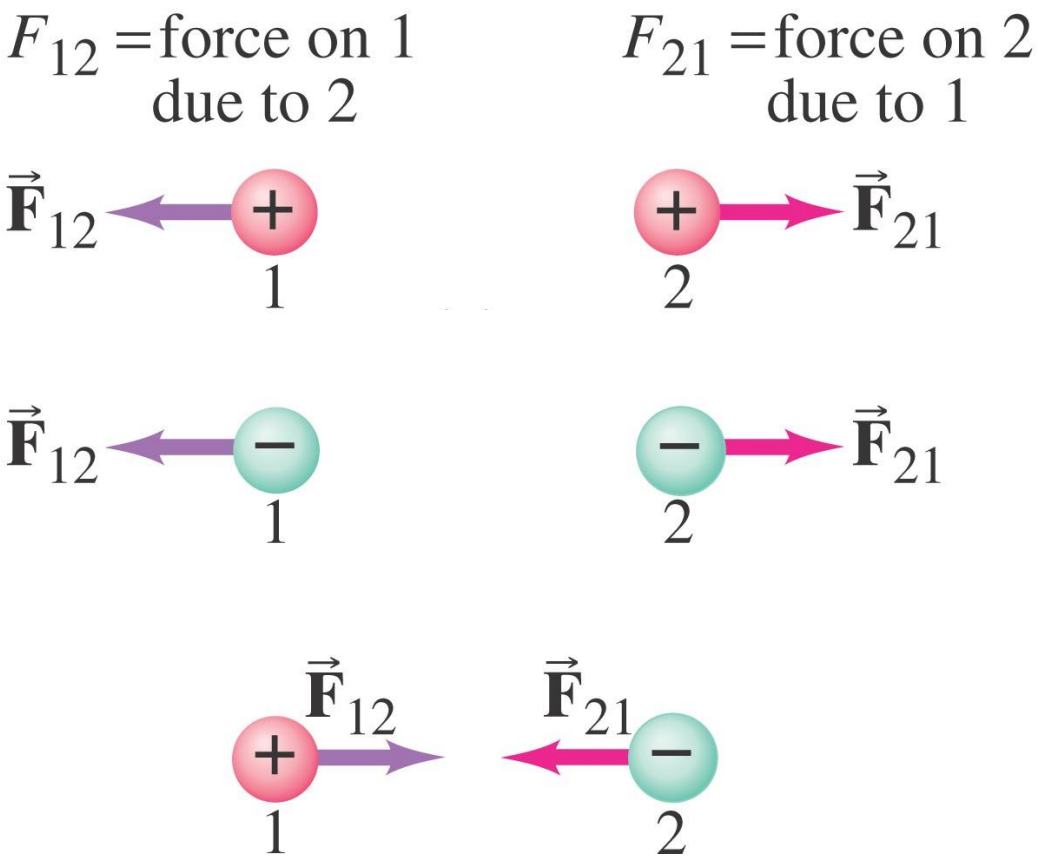
Coulomb's law:

$$F = k\frac{Q_1 Q_2}{r^2}$$

This equation gives the <u>magnitude</u> of the force between two charges.

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:

$$\vec{F}_{12} = k\frac{Q_1 Q_2}{r_{12}^2}\hat{r}_{12}$$

$\hat{r}_{12}$ is a unit vector in the pointing in the direction from charge $Q_1$to charge Q_2.

Coulomb's Law

<u>Unit of charge</u>: coulomb, C.

The proportionality constant in Coulomb's law is then:

$$k = 8.99 \text{ x } 10^9 \text{ N}\cdot\text{m}^2/\text{C}^2.$$

Charges produced by rubbing are typically around a microcoulomb:

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

Coulomb's Law

Charge on the electron:

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

Electric charge is quantized in units of the electron charge.

Coulomb's Law

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

$$F = \frac{1}{4\pi\epsilon_0}\frac{Q_1 Q_2}{r^2},$$

where

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

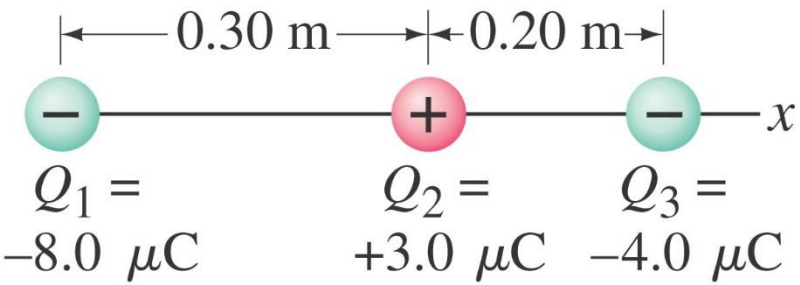
Coulomb's Law

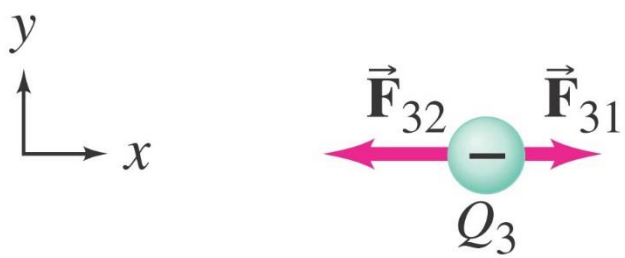
Which charge exerts the greater force?

Two positive point charges, Q_1 = 50 μC and Q_2 = 1 μC, are separated by a distance ℓ. Which is larger in magnitude:
a) the force that Q_1 exerts on Q_2 or
b) the force that Q_2 exerts on Q_1?
c) More information is needed.

Coulomb's Law

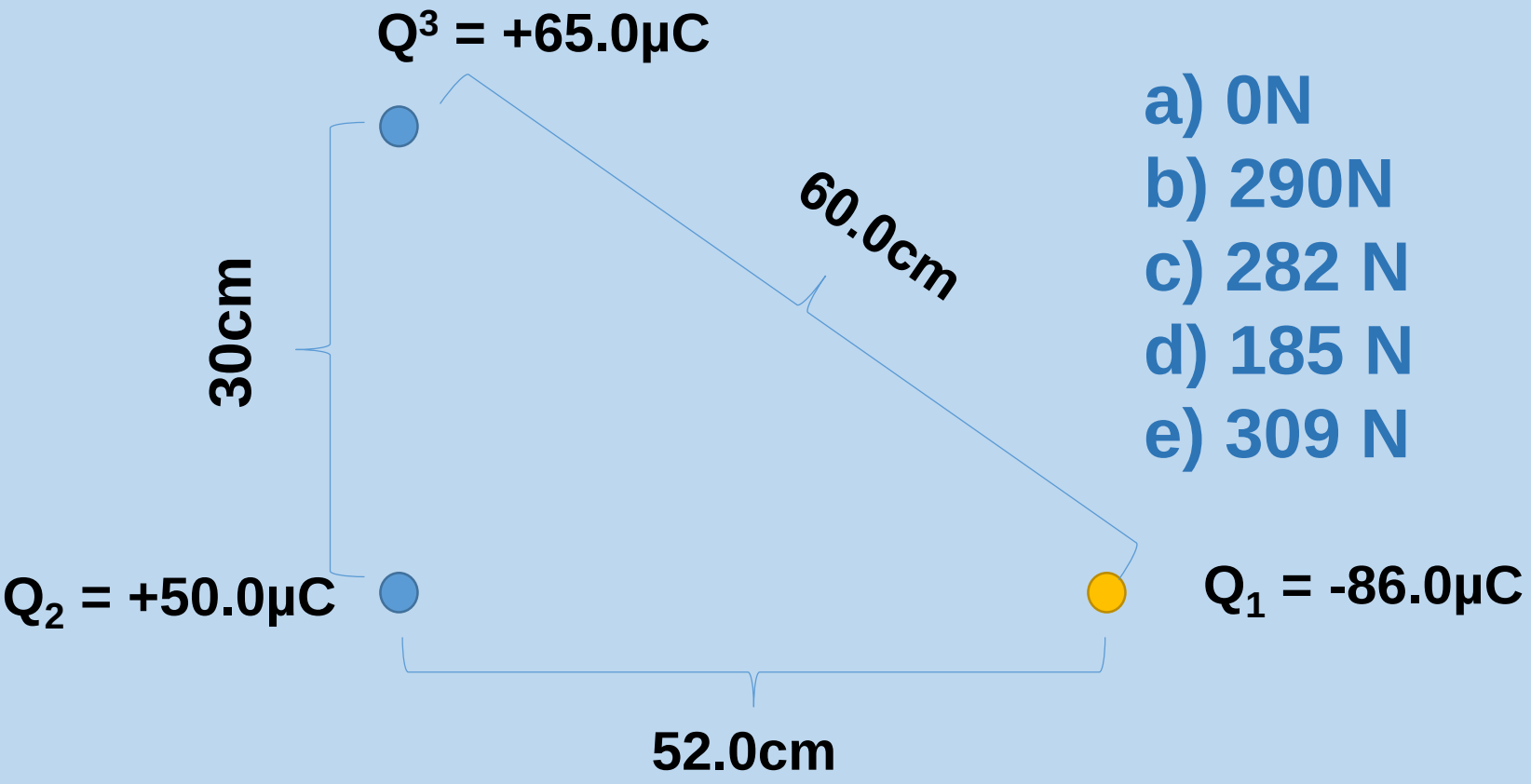
Three charged particles are arranged in a line, as shown. Calculate the net electrostatic force on particle 3 (the -4.0 μC on the right) due to the other two charges.





Coulomb's Law

Calculate the net electrostatic force on charge Q_3 shown in the figure due to the charges Q_1 and Q_2.



a) 0N
b) 290N
c) 282 N
d) 185 N
e) 309 N