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
**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
What is the magnitude of the force $F_2$?

$F_1 = 3 \text{ N}$

- 1) 1.0 N
- 2) 1.5 N
- 3) 2.0 N
- 4) 3.0 N
- 5) 6.0 N
Objects can be charged by rubbing.
Charge comes in two types, positive and negative; like charges repel and opposite charges attract.

Static Electricity; Electric Charge and Its Conservation

Two charged plastic rulers repel

Two charged glass rods repel

Charged glass rod attracts charged plastic ruler
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.
Metal objects can be charged by conduction:
Induced Charge

They can also be charged by **induction**, either while connected to ground or not:

Neutral metal rod

Metal rod still neutral, but with a separation of charge
Nonconductors won’t become charged by conduction or induction, but will experience charge separation:

Induced Charge
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 magnitude 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.

\[ F_{12} = \text{force on } 1 \text{ due to } 2 \]

\[ F_{21} = \text{force on } 2 \text{ due to } 1 \]
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 direction from charge \( Q_1 \) to charge \( Q_2 \).
Coulomb’s Law

Unit of charge: coulomb, C.

The proportionality constant in Coulomb’s law is then:

\[ k = 8.99 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2. \]

Charges produced by rubbing are typically around a microcoulomb:

\[ 1 \mu\text{C} = 10^{-6} \text{ C}. \]
Coulomb’s Law

Charge on the electron:

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

Electric charge is quantized in units of the electron charge.
Coulomb’s Law

The proportionality constant $k$ can also be written in terms of $\varepsilon_0$, the permittivity of free space:

$$F = \frac{1}{4\pi\varepsilon_0} \frac{Q_1 Q_2}{r^2},$$

where

$$\varepsilon_0 = \frac{1}{4\pi k} = 8.85 \times 10^{-12} \text{ C}^2/\text{N} \cdot \text{m}^2.$$
Which charge exerts the greater force?

Two positive point charges, \( Q_1 = 50 \, \mu C \) and \( Q_2 = 1 \, \mu C \), are separated by a distance \( \ell \). 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.
Three charged particles are arranged in a line, as shown. Calculate the net electrostatic force on particle 3 (the $-4.0 \, \mu C$ on the right) due to the other two charges.

Coulomb’s Law

\[ Q_1 = -8.0 \, \mu C \]
\[ Q_2 = +3.0 \, \mu C \]
\[ Q_3 = -4.0 \, \mu C \]
Coulomb’s Law

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

$Q^3 = +65.0 \mu C$

$Q_2 = +50.0 \mu C$

$Q_1 = -86.0 \mu C$

$30 \text{ cm}$

$60.0 \text{ cm}$

$52.0 \text{ cm}$

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