Chap9 Electric Forces & Electric Fields

Electric Charges

- Like charges repel each other, unlike charges attract each other.

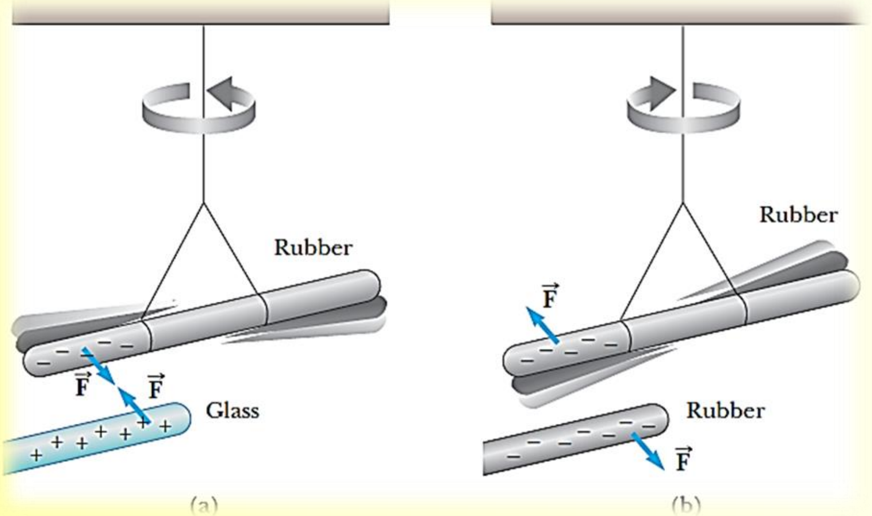
- Electric charge is always conserved:
  Net charge *can not* be created or destroyed.

- SI unit of electric charge: *coulomb* (C)

- Elementary charge: $e = 1.6 \times 10^{-19}$ C

- Charge is quantized:

$$q = ne \ \ (n = 0, \pm 1, \pm 2 \cdots)$$

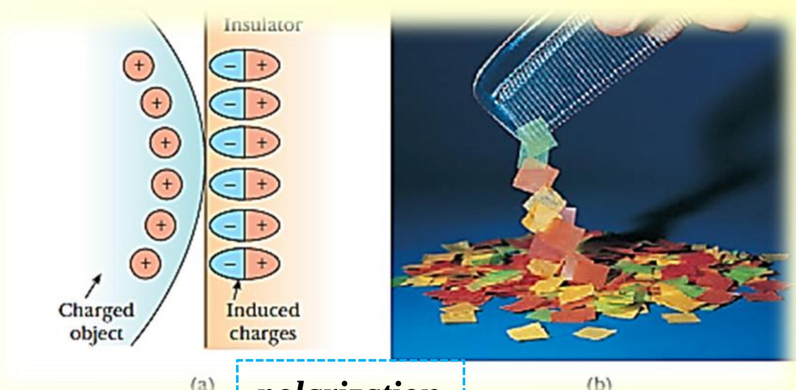


Conductors & Insulators

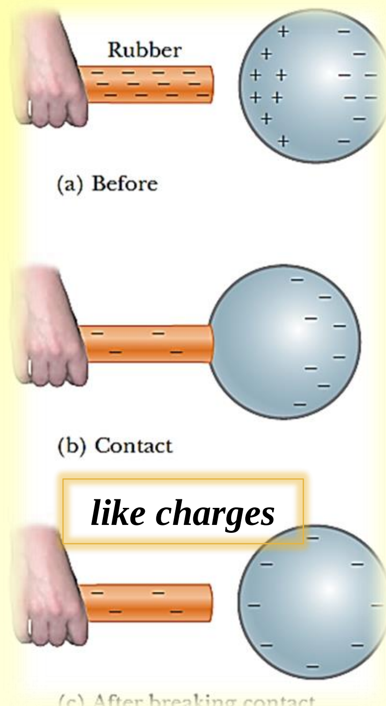
- **Conductors** are materials in which electric charges move freely in response to an electric force. All other materials are called **insulators**.
- **Semiconductors** are intermediate in their properties between good conductors and good insulators, e.g. silicon, germanium.

Charging by conduction

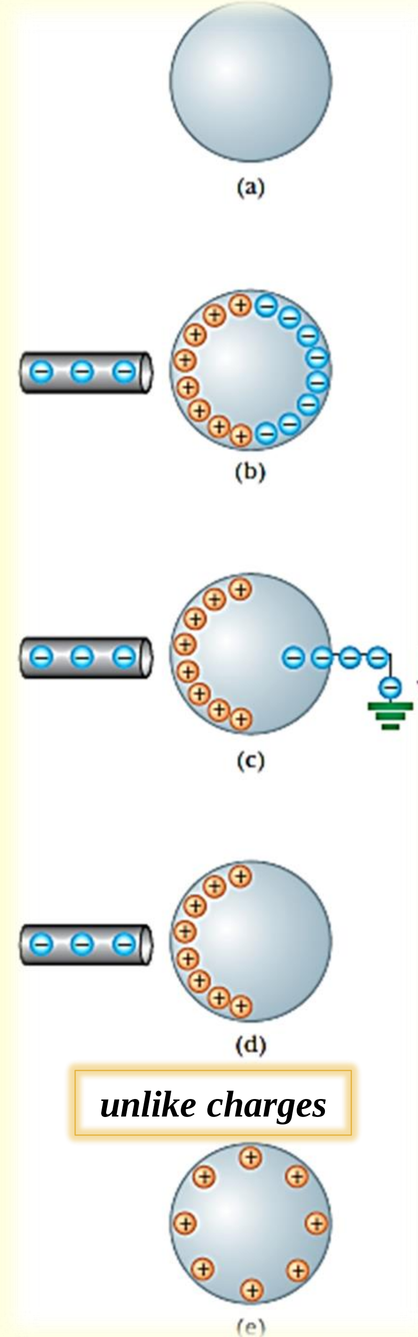
Charging by induction



polarization



like charges



unlike charges

Coulomb's Law

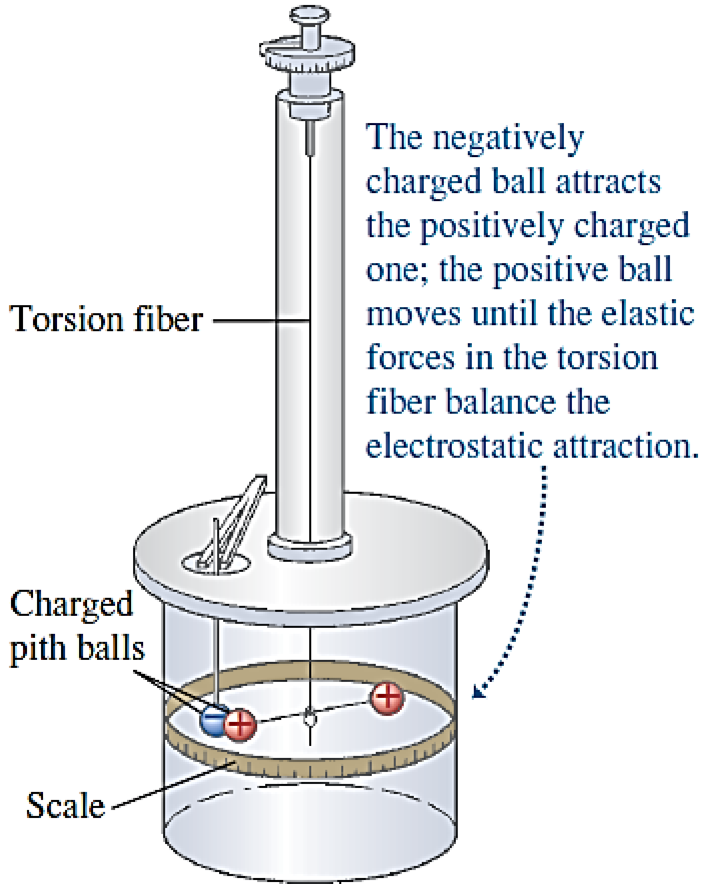
Coulomb constant

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

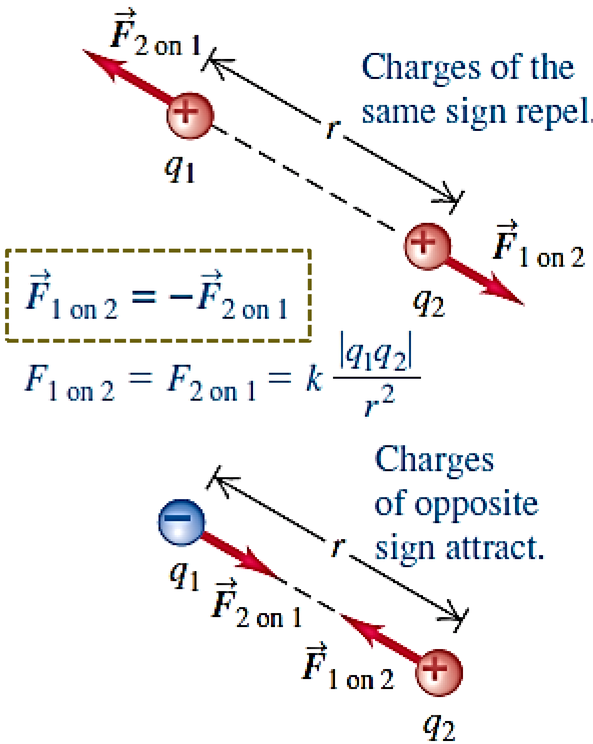
$$F = \frac{1}{4\pi\varepsilon_0}\frac{|q_1 q_2|}{r^2}$$

Permittivity of vacuum

(a) A torsion balance of the type used by Coulomb to measure the electric force



(b) Interactions between point charges

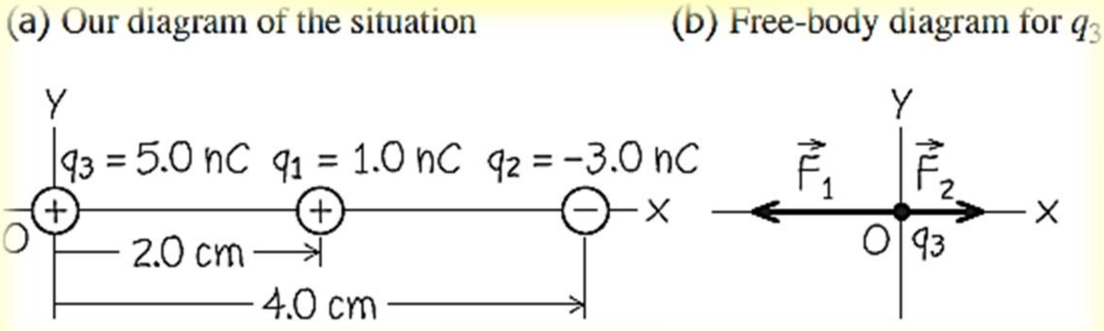


$(k = 9.0 \times 10^9 \mathrm{N \cdot m^2/C^2})$

$(\varepsilon_0 = 8.85 \times 10^{-12}\ \mathrm{C^2/N \cdot m^2})$

【Exercise】

Two point charges are located on the *x*-axis of a coordinate system: q_1 = 1.0 nC is at x = +2.0 cm, and q_2 = -3.0 nC is at x = +4.0 cm. What is the total electric force exerted by q_1 and q_2 on a charge q_3 = +5.0 nC is at x = 0?



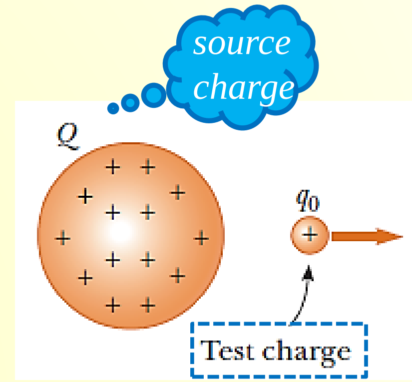
$$F_1 = k\frac{|q_1 q_3|}{r_{13}^2} = (9.0\times10^9)\frac{(1.0\times10^{-9})(5.0\times10^{-9})}{(0.02)^2}\,\text{N} = 112\mu\text{N}$$

$$F_2 = k\frac{|q_2 q_3|}{r_{23}^2} = (9.0\times10^9)\frac{(3.0\times10^{-9})(5.0\times10^{-9})}{(0.04)^2}\,\text{N} = 84\mu\text{N}$$

$$F_{net} = F_2 - F_1 = 84\mu\text{N} - 112\mu\text{N} = -28\mu\text{N}$$

Electric Field

- An **electric field** exists in the region of space around a charged object.
- The **electric field** exerts an electric force on any other charged object within the field.

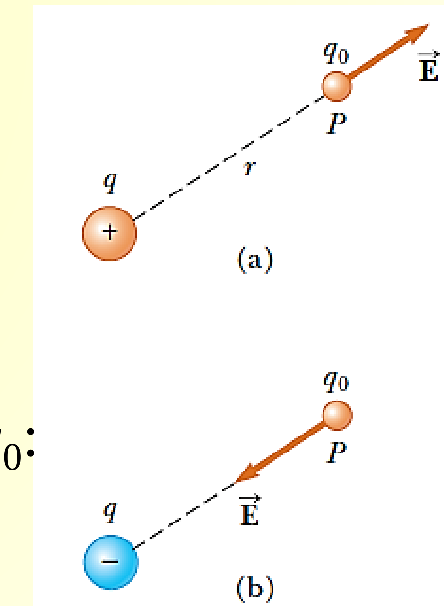


➢ **Electric field:** vector

- Magnitude:

$$\vec{E} = \frac{\vec{F}_0}{q_0}$$

- Direction: the same direction as the electric force on a *positive test charge* at the point.



- Electric field of a source charge q at the position of q_0:

$$E = \frac{F_0}{q_0} = k\frac{q}{r^2}$$

source charge

【Quick Quiz】

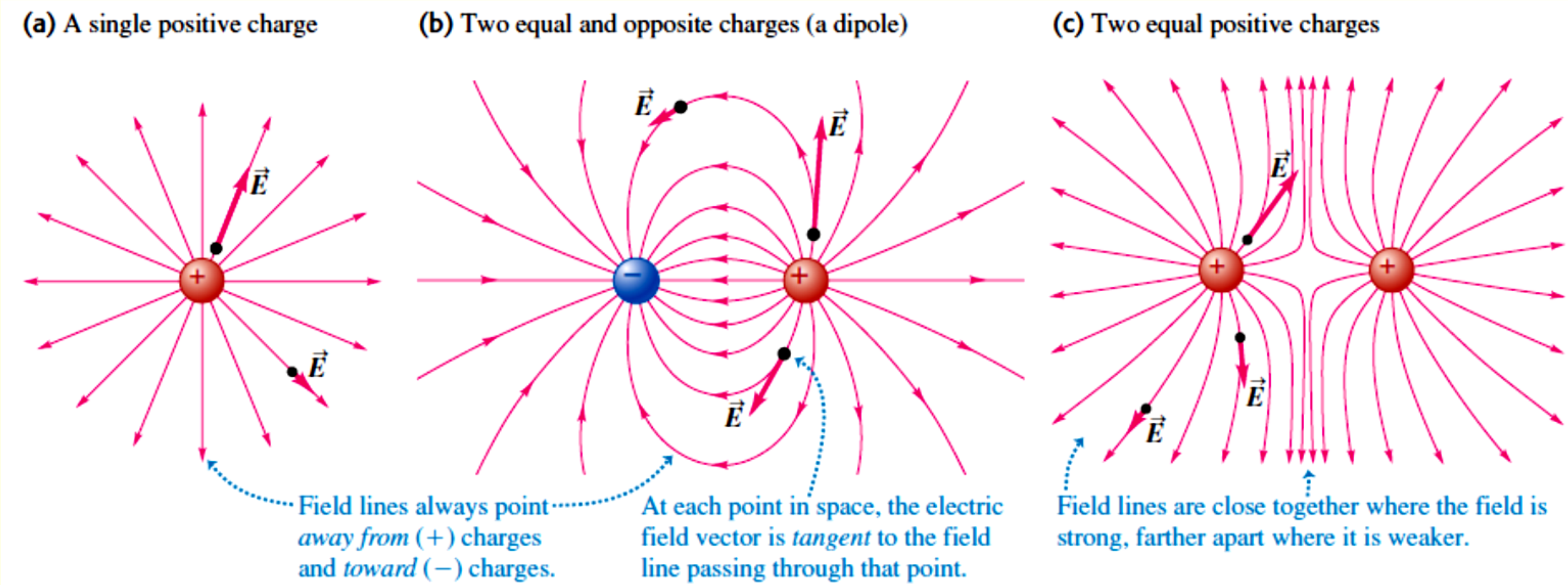
1. A test charge of +3 μC is at a point P where the electric field due to other charges is directed to the right and has a magnitude of 4×10^6 N/C. If the test charge is replaced with a charge of - 3 μC, the electric field at P (a) has the same magnitude as before, but changes direction, (b) increases in magnitude and changes direction, (c) remain the same, or (d) decreases in magnitude and changes direction.

2. A circular ring of charge of radius b has a total charge q uniformly distributed around it. The magnitude of the electric field at the center of the ring is
(a) 0 (b) kq/b^2 (c) kq^2/b^2 (d) kq^2/b

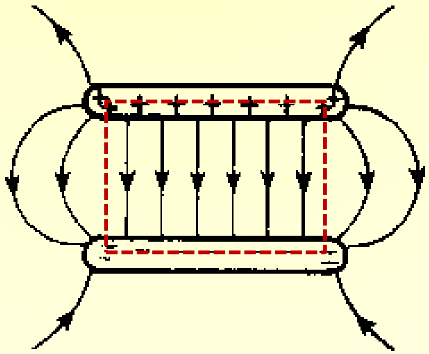
3. A "free" electron and a "free" proton are placed in an identical electric field. Which of the following statements are true?
(a) Each particle is acted upon by the same electric force and has the same acceleration.
(b) The electric force on the proton is greater in magnitude than the force on the electron, but in the opposite direction.
(c) The electric force on the proton is equal in magnitude to the force on the electron, but in the opposite direction.
(d) The magnitude of the acceleration of the electron is greater than that of the proton.
(e) Both particles have the same acceleration.

Electric Field Lines

- Non-uniform electric field

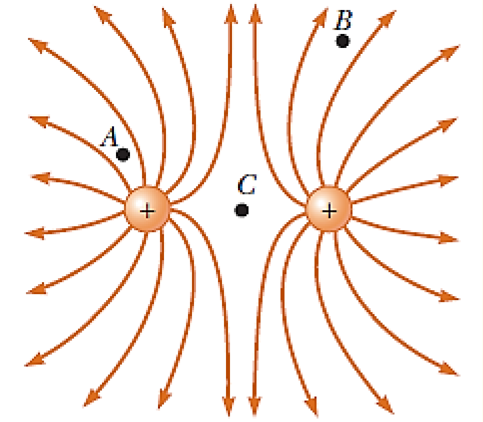


- Uniform electric field



【Quick Quiz】

Rank the magnitudes of the electric field at point *A*, *B*, and *C* in the Figure below, with the largest magnitude first.



(a) *A*, *B*, *C*

(b) *A*, *C*, *B*

(c) *C*, *A*, *B*

(d) Can’t be determined by visual inspection