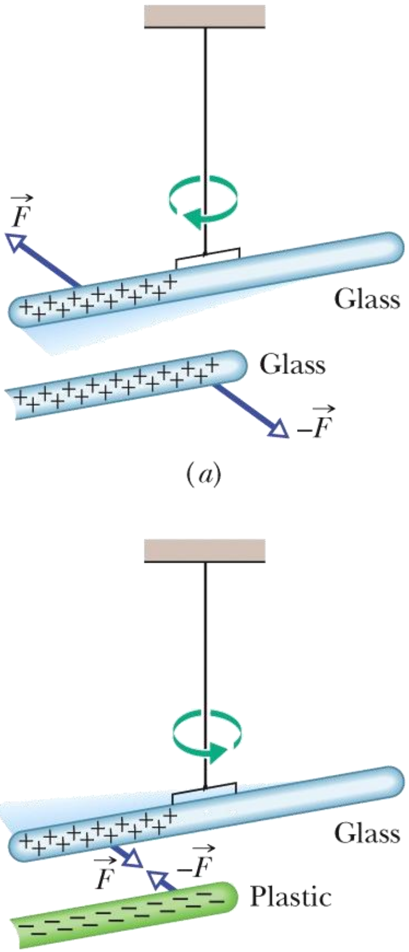
Chapter 21 Coulomb's Law

Chap. 21-1 Coulomb's Law
Chap. 21-2 Charge is quantized
Chap. 21-3 Charge is conserved

Electric Charge



(a) Two charged rods of the same sign repel each other.

(b) Two charged rods of opposite signs attract each other. Plus signs indicate a positive net charge, and minus signs indicate a negative net charge.

Particles with the same sign of electrical charge repel each other, and particles with opposite signs attract each other.

Chap. 21-1 Coulomb's Law

Materials classified based on their ability to move charge

- **Conductors** are materials in which a significant number of electrons are free to move. Examples include metals.
- The charged particles in nonconductors (**insulators**) are not free to move. Examples include rubber, plastic, glass.
- **Semiconductors** are materials that are intermediate between conductors and insulators; examples include silicon and germanium in computer chips.
- **Superconductors** are materials that are perfect conductors, allowing charge to move without any hindrance.

Chap. 21-1 Coulomb's Law

▪ Charged Particles (대전입자)

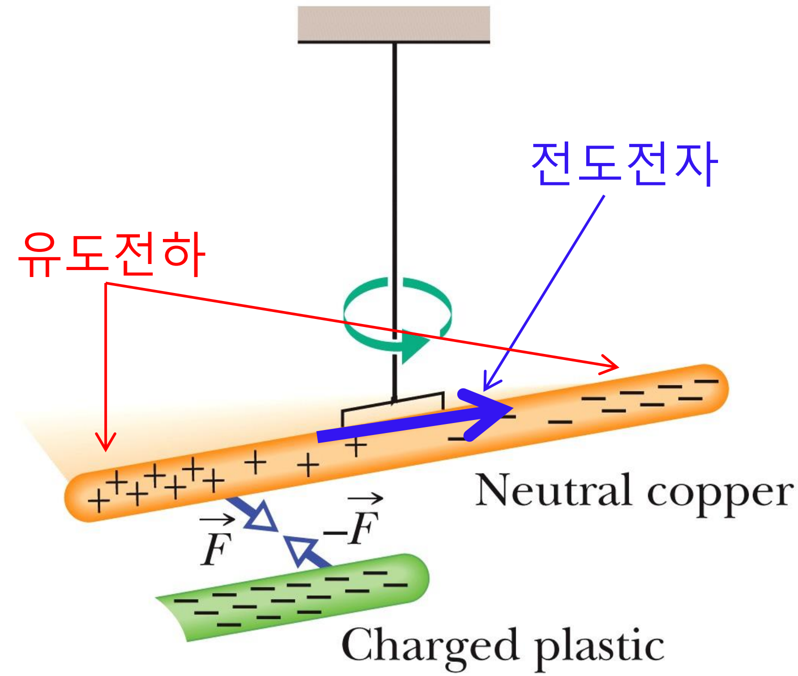
- The properties of conductors and insulators are due to the structure and electrical nature of atoms.

- Atoms consist of positively charged *protons*, negatively charged *electrons*, and electrically neutral *neutrons*. The protons and neutrons are packed tightly together in a central nucleus and do not move.

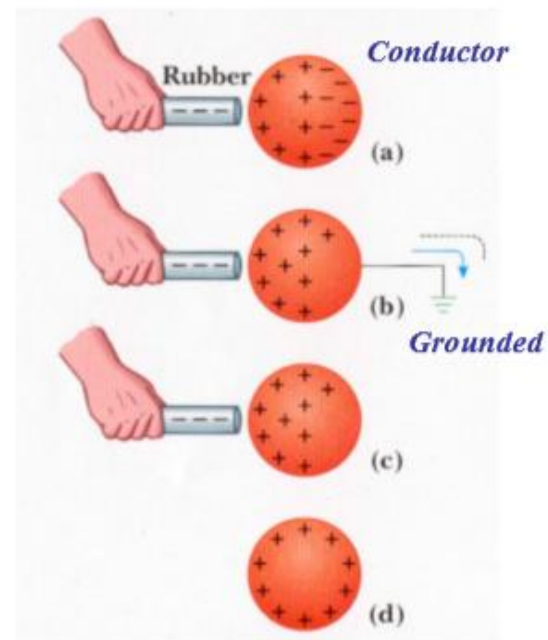
- When atoms of a conductor like copper come together to form the solid, some of their outermost—and so most loosely held—electrons become free to wander about within the solid, leaving behind positively charged atoms (positive ions). We call the mobile electrons **conduction electrons**. There are few (if any) free electrons in a nonconductor.

Chap. 21-1 Coulomb's Law

- **Induced Charge (유도전하)**

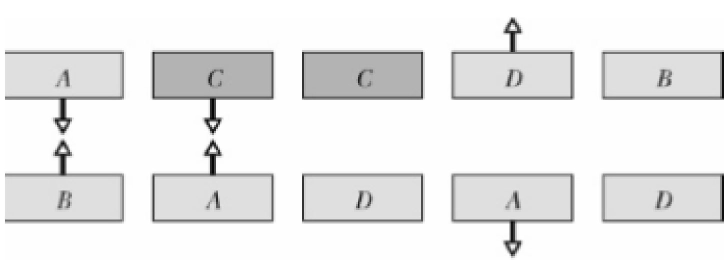


• *Charging by Induction*

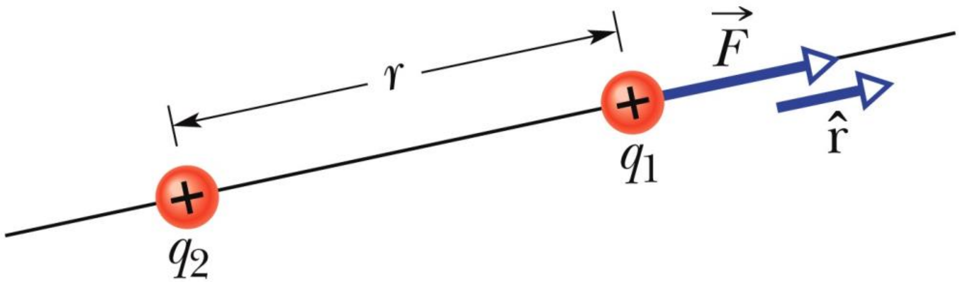


Charges are uniformly distributed at the surface of conductors.

확인문제 1



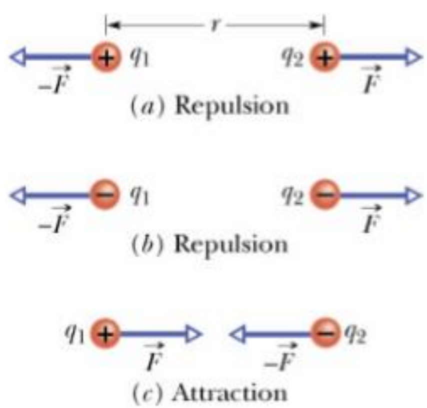
Chap. 21-1 Coulomb's Law



The electrostatic force on particle 1 can be described in terms of a unit vector ***r*** along an axis through the two particles, radially away from particle 2.

$$\boxed{F = \frac{1}{4\pi\varepsilon_0}\frac{|q_1|\,|q_2|}{r^2} \qquad \text{(Coulomb's law),}}$$

$\varepsilon_0 = 8.85 \times 10^{-12}\ C^2/N.m^2$ is the permittivity constant. The ratio $1/4\pi\varepsilon_0$ is often replaced with the electrostatic constant (or Coulomb constant) $k = 8.99 \times 10^9\ N.m^2/C^2$. Thus $k = 1/4\pi\varepsilon_0$.



같은 부호의 전하는

서로 밀어내고

$$F = \frac{1}{4\pi\varepsilon_o}\frac{q_1 q_2}{r^2} > 0$$

다른 부호의 전하는
서로 당긴다

$$F = \frac{1}{4\pi\varepsilon_o}\frac{q_1 q_2}{r^2} < 0$$

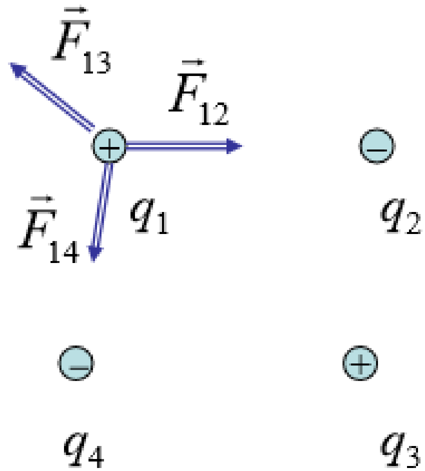
Chap. 21-1 Coulomb's Law

Multiple Forces: If multiple electrostatic forces act on a particle, the net force is the vector sum (not scalar sum) of the individual forces.

$$\vec{F}_{1,\mathrm{net}} = \vec{F}_{12} + \vec{F}_{13} + \vec{F}_{14} + \vec{F}_{15} + \cdots + \vec{F}_{1n},$$

Vector Sum

$$\vec{F}_1 = \vec{F}_{12} + \vec{F}_{13} + \vec{F}_{14} = \sum_i \vec{F}_{1i}$$



보기문제 21.01, 21.02

Chap. 21-2 Charge is quantized

- Electric charge is quantized (restricted to certain values).

- The charge of a particle can be written as ne, where *n* is a positive or negative integer and *e* is the elementary 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

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

Table 21-1 The Charges of Three Particles

Particle	Symbol	Charge
Electron	e or e^-	$-e$
Proton	p	$+e$
Neutron	n	0

Chap. 21-2 Charge is quantized

When a physical quantity such as charge can have only discrete values rather than any value, we say that the quantity is **quantized**. It is possible, for example, to find a particle that has no charge at all or a charge of $+10e$ or $-6e$, but not a particle with a charge of, say, $3.57e$.

Checkpoint 4

Initially, sphere A has a charge of $-50e$ and sphere B has a charge of $+20e$. The spheres are made of conducting material and are identical in size. If the spheres then touch, what is the resulting charge on sphere A?

Answer: $-15e$

Chap. 21-2 Charge is quantized

전기력 　　　　 중력

$$F_C = \frac{1}{4\pi\varepsilon_o}\frac{q_1 q_2}{r^2} \Longleftrightarrow F_G = -G\frac{m_1 m_2}{r^2}$$

거리의 제곱에 반비례 + (반발력), – (인력) 껍질정리 항상 성립	항상 – (인력)

보기문제 21.04

Chap. 21-3 Charge is conserved

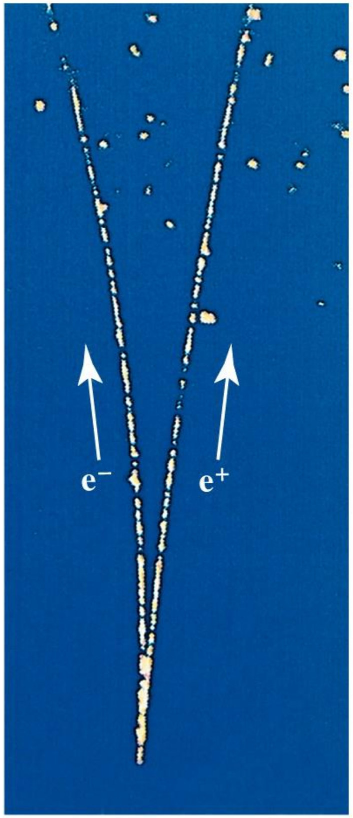
The net electric charge of any isolated system is always conserved.

If two charged particles undergo an **annihilation process**, they have equal and opposite signs of charge.

$$e^- + e^+ \rightarrow \gamma + \gamma \qquad \text{(소멸과정)}$$

If two charged particles appear as a result of a **pair production process**, they have equal and opposite signs of charge.

$$\gamma \rightarrow e^- + e^+ \qquad \text{(쌍생성)}$$



Courtesy Lawrence Berkeley Laboratory

A photograph of trails of bubbles left in a bubble chamber by an electron and a positron. The pair of particles was produced by a gamma ray that entered the chamber directly from the bottom. Being electrically neutral, the gamma ray did not generate a telltale trail of bubbles along its path, as the electron and positron did.

Summary

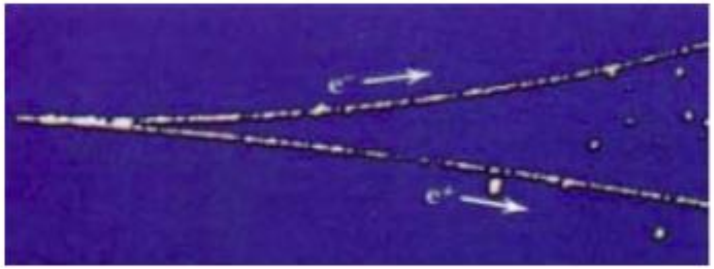
- 전하 (charges) : 두 종류가 있으며, (+) 전하와 (-) 전하로 나타난다.

•양자화: 전하량은 최소단위가 있다 (양자화 되어 있다).

$$q = ne, \quad n = \pm 1, \pm 2, \pm 3, \cdots$$
$$e = 1.602 \times 10^{-19}\, C \text{ (Coulomb)}$$

•보존 : 총 전하량은 언제나 같다 (보존된다).
(전하가 생길 때 부호가 반대인 전하도 동시에 똑같은 양이 생긴다; 사라질 때도 같다.)

$$e^{-} + e^{+} \rightarrow \gamma + \gamma \quad \text{(소멸과정)}$$
$$\gamma \rightarrow e^{-} + e^{+} \quad \text{(쌍 생성)}$$



Summary

Electric Charge

- The strength of a particle's electrical interaction with objects around it depends on its electric charge, which can be either positive or negative.

Conductors and Insulators

- Conductors are materials in which a significant number of electrons are free to move. The charged particles in nonconductors (insulators) are not free to move.

Conservation of Charge

- The net electric charge of any isolated system is always conserved.

Coulomb's Law

- The magnitude of the electrical force between two charged particles is proportional to the product of their charges and inversely proportional to the square of their separation distance.
- .

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

Eq. 21-4

The Elementary Charge

- Electric charge is quantized (restricted to certain values).
- *e* is the elementary charge

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

Eq. 21-12