Chapter 22 Electrostatics

What is the electrical effects in our everyday life?

•A comb brushed through hair can pick up pieces of papers.

•You see flashes when a blanket is peeled off a sheet.

•You feel a shock on touching a doorknob.

Virtually all the physical phenomena we experience, such as light, chemical reactions, the properties of materials, and the transmission of signals along nerve fibers, are electrical in nature.

Charge is a property of matter that causes it to produce and experience electrical and magnetic effects.

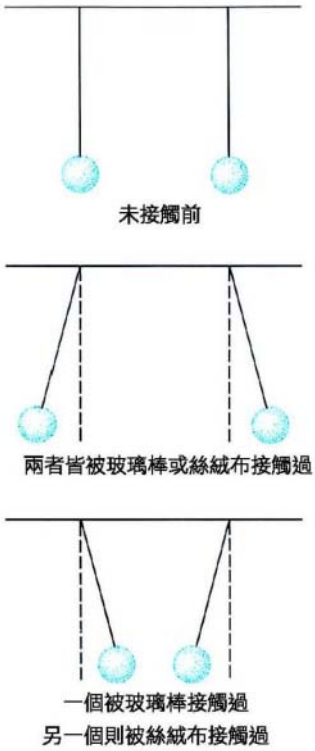
22.1 Charge

Experience: When a glass rod is rubbed with a silk cloth, both become charged.

Clearly observation*: like charges repel, and unlike charges attract.*

Right figures provide a clear demonstration.

Modern view: a neutral object possesses an equal number of positive and negative charges. Why?



22.1 Charge (II)

How the materials exchange charges in the rubbing process?

Electrons or ions are transferred from one body to the other. However, the signs of the charges depends on the electrical properties of the two materials and the condition of their surfaces.

In some case, a charge from gentle rubbing to hard rubbing can change the signs of the charges acquired by the two bodies.
What reason causes such unpredictability to happen? Dust.

The SI unit of charge is the coulomb (C). It is defined in terms of electrical current, which is the rate of flow of charge. *Can we measure the charges directly? Yes, but…*

22.1 Charge: Quantization of Charge

What is the basic unit of charge? Chemical evidence led to the suggestion that molecular dissociate into ions, each of which carries a fixed charge that is the multiple of some basic unit of charge.

In 1909, Millikan first directly measured the charge and found that the charge is quantized. The quantum of charge is:
$e=1.602\text{x}10^{-19}$ C

Recent theories postulate that the ***quarks*** as the building blocks for a dozens of elementary particles. However, no one has yet detected an isolated quark.

It seems that *e* is still the smallest isolated charge in nature.

22.1 Charge: Conservation of Charge

Is the total charge conserved in an isolated system? Yes.

Can we derive this law from our daily experience? Maybe.

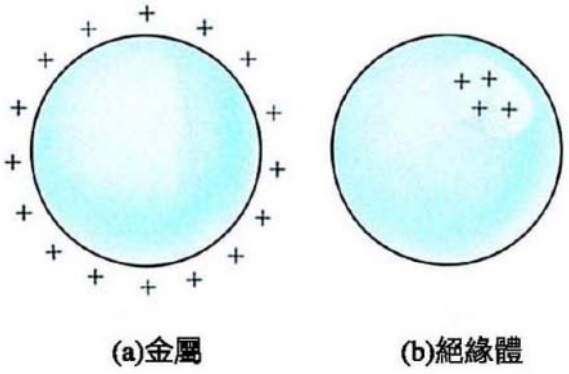
Charge is neither created nor destroyed; it is transferred from one body to the other. Conservation of charge:

In an isolated system, the total charge stays constant.

22.2 Conductors and Insulators

How to distinguish conductors, insulators, and semiconductors? The boundaries are not very clear.

The charge distribution of a conductor and insulator.



22.3 Charging by Induction

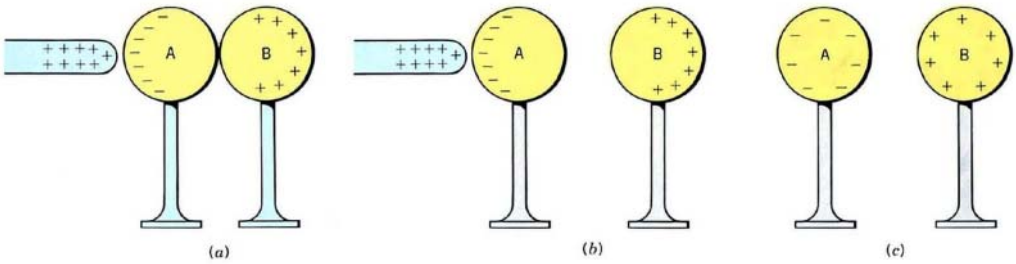


圖 22.5

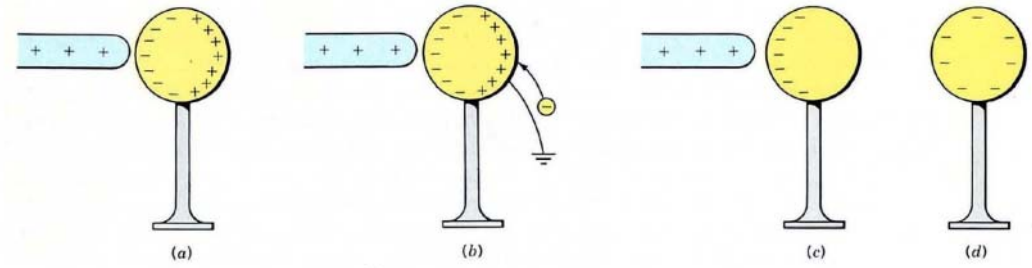
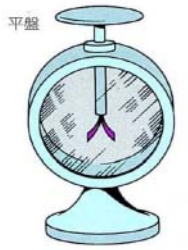


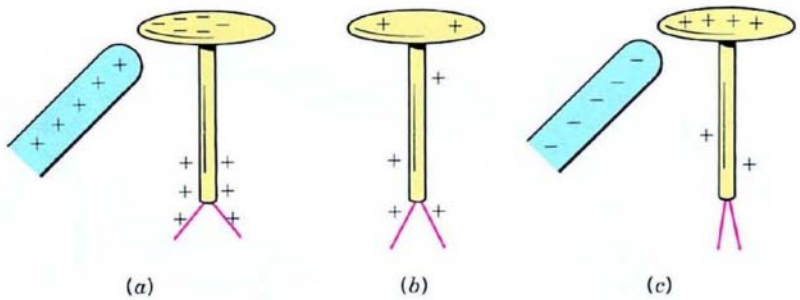
圖 22.6

22.4 Gold Leaf Electroscope

An electroscope is a device that detects charge.



How to use electroscope to indicate the sign of a charged object?



22.5 Coulomb's Law

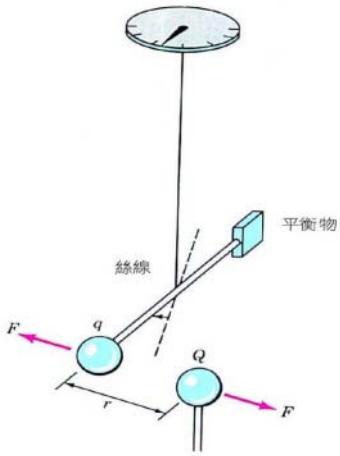
Coulomb's law quantitatively describe the interaction of charges.

Coulomb determined the force law for electrostatic charges directly by experiment.

$$F = \frac{kqQ}{r^2}$$

where k is a constant that depends on the system of units. In the SI units its approximate value is

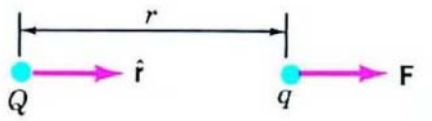
$k = 9.0 \times 10^9 \ N \cdot m^2 / C^2$



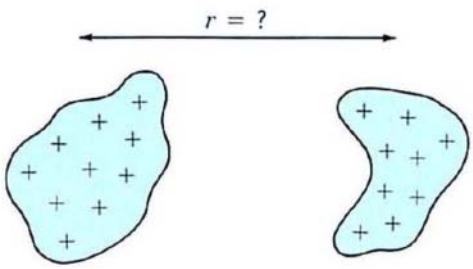
Vector Form of Coulomb's Law

The electrostatic force is central (it is directed along the line joining the particles) and spherical symmetric (it is function only of r).

$$\mathbf{F} = \frac{kqQ}{r^2}\hat{\mathbf{r}}$$



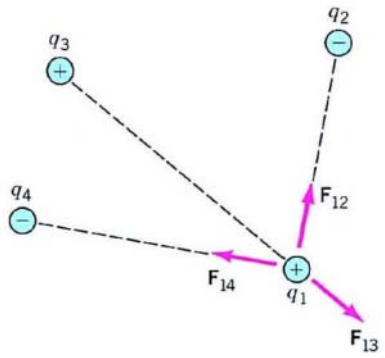
How do we handle the charge bodies of arbitrary shape?
Integration.



Principle of Superposition

Electrostatic forces obey the **principle of linear superposition**. Why?

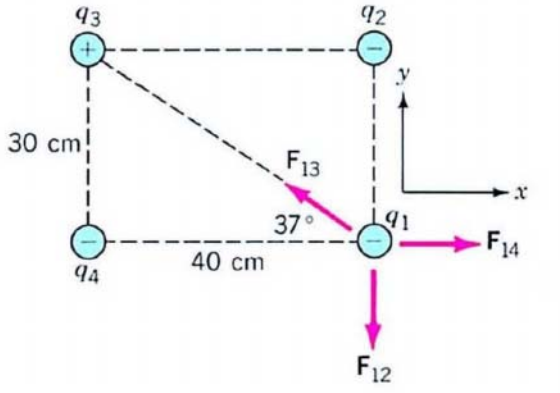
$$\mathbf{F}_1 = \mathbf{F}_{12} + \mathbf{F}_{13} \cdots + \mathbf{F}_{1N}$$



Example 22.1

Find the force on charge q1 due to the three other charges in Fig.22.14. Take q1=-5 uC, q2=-8 uC, q3=15 uC, and q4=-16 uC.

Solution:



The net force on q_1 is $\mathbf{F}_1 = 2.3\mathbf{i} - 2.4\mathbf{j}$ N.

Exercises and Problems

Ch.22:

Ex. 14

Prob. 2, 8, 10