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EE 178: Physics II

Electricity & Magnetism

Outline

Textbook: Halliday & Resnick

Fundamentals of Physics

9th Edition

Chapter 1: Electric charge

1.1- Introduction:

We are surrounded by devices that depend on the physics of electromagnetism, which is the combination of electric and magnetic phenomena. This physics is at the origin of computers, television, radio and telecommunications.

1.2- Electric charges:

Electric charge is an intrinsic characteristic of the fundamental particles making objects. Charged objects interact by exerting forces on one another.

1- We charge a glass rod by rubbing one end with silk and suspend from a thread to electrically isolate it from its surroundings. If we bring a second, similarly charged glass rod nearby, the two rods **repel** each other.

2- Now, if we rub a plastic rod and then bring the rod near the suspended glass rod. The two rods **attract** each other.

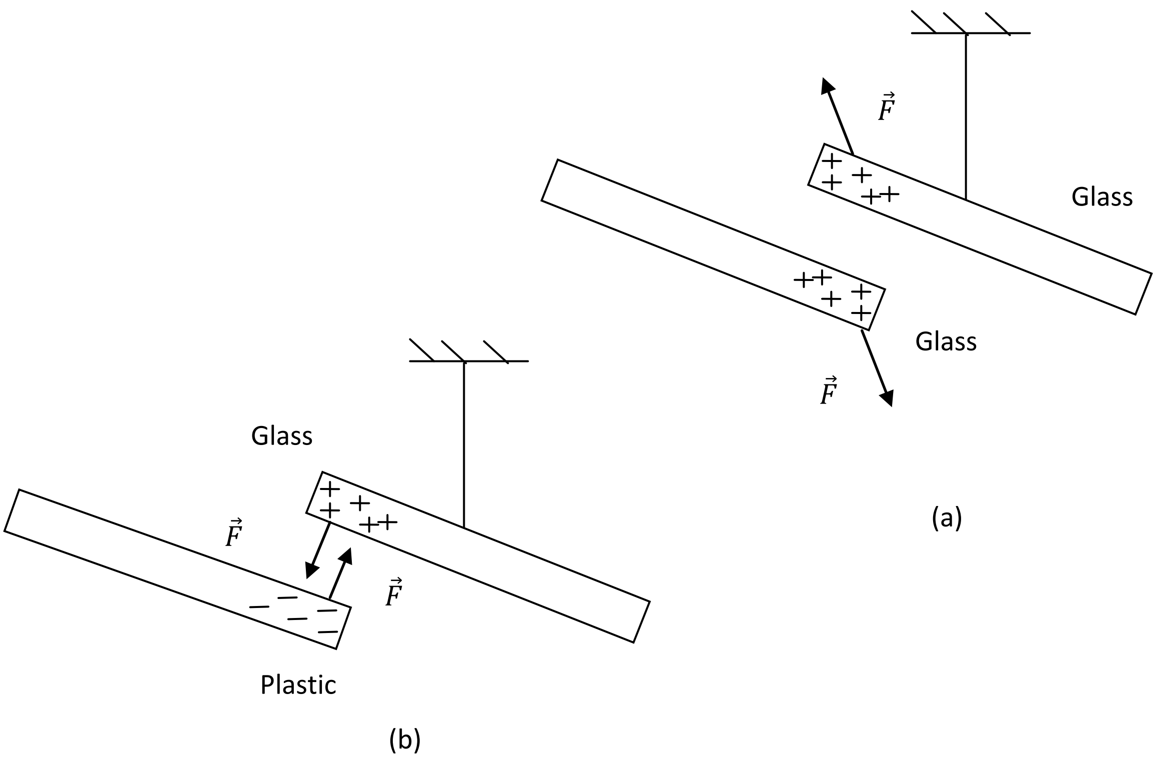

Figure 1: (a) Two charged rods of the same sign repel each other

(b) Two charged rods of opposite sign attract each other

Charges with the same sign repel each other, and charges with opposite sign attract each other

1.3 - Coulomb's Law:

Suppose that two point charges q_1 and q_2, are a distance r apart in vacuum. If q_1 and q_2 have the same sign, they repel each other. The force experienced by either charge due to the other is called a **Coulomb** or **Electric Force** and it is given by **Coulomb's Law**

$$\overrightarrow{F_{12}} = k_e \frac{q_1 \times q_2}{r^2} \overrightarrow{u_r}$$

(In vacuum)

As always in the SI, distances are measured in meters, and forces in Newtons. The SI unit for charge q is the Coulomb (C). The constant k_e has the value: $k_e = 8.988\times 10^9$ N.m^2/ C^2

which we shall usually approximate at 9.0×10^9 N.m^2/ C^2. Often, k_e is replaced by $\frac{1}{4\pi\epsilon_0}$, where $\varepsilon_0 = 8.85\times10^{-12}$ C^2/ Nm^2 is called the **permittivity of free space**. Then the Coulomb's Law becomes:

$$\overrightarrow{F_{12}} = \frac{1}{4\pi\varepsilon_0} \frac{q_1 \times q_2}{r^2} \overrightarrow{u_r}$$

(In vacuum)

When the surrounding medium is not vacuum, forces caused by induced charges in the material reduce the force between point charges. If the material has a dielectric constant κ, then ε_0 in Coulomb's Law must be replaced by $\kappa\varepsilon_0 = \varepsilon$, where ε is the **permittivity of the material**. Then:

$$\overrightarrow{F_{12}} = \frac{1}{4\pi\varepsilon} \frac{q_1 \times q_2}{r^2} \overrightarrow{u_r} = \frac{k_e}{\kappa} \frac{q_1 \times q_2}{r^2} \overrightarrow{u_r}$$

For vacuum : κ = 1; For air κ = 1.0006

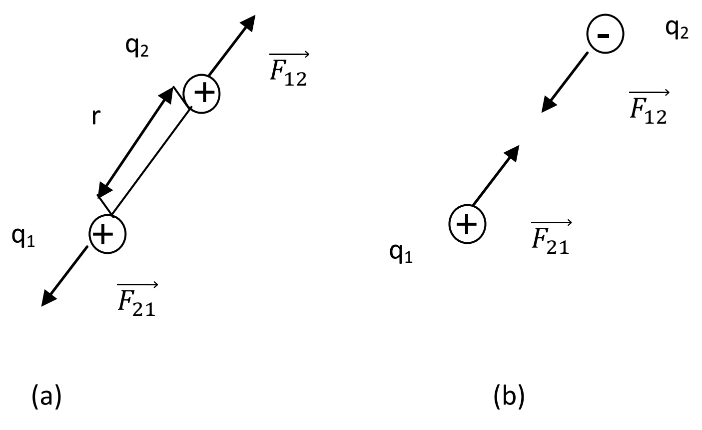

Figure 2: (a) Repulsive force; (b) Attractive force

1.4 Conductors & Insulators:

Electrical conductors are materials in which electric charges move freely, whereas electrical insulators are materials in which electric charges cannot move freely.

Glass, rubber and wood belong to the category of electrical insulators. When such materials are charged by rubbing, only the area rubbed becomes charged, and the charge is unable to move to other areas of the material.

In contract, materials such as copper, aluminum and silver are good conductors.

When such materials are charged in some small region, the charge readily distributes itself over the entire surface of the material.

Semiconductors are the third class of materials and their electrical properties are somewhere between those of insulators and those of conductors.

Silicon and Germanium are the most famous ones.

1.5 Charge is quantized:

The magnitude of the smallest charge ever measured is denoted by e (called the quantum charge), where $e = 1.60218\times10^{-19}$ C. All free charges, ones that can be isolated and measured, are integer multiple of e. The electron has a charge (-e), while the proton's charge is (+e).

1.6 Conservation of charge:

The algebraic sum of the charges in the universe is constant. When a particle with charge (+e) is created, a particle with charge (-e) is simultaneously created in the immediate vicinity.

When a particle with charge (+e) disappears, a particle with charge (+e) also disappears in the immediate vicinity. Hence the net charge of the universe remains constant.