C Team - Electric Field

Ray Liu

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1 Introduction

We have already discussed the implications of gravitational force near the surface of the Earth and away from Earth. Another fundamental force in nature is called the Electromagnetic Force, which acts on charged objects. A simple form of it, without a time variation of charge, is called the Electrostatic Force.

2 What is Charge?

Charge is an electric property of electrons and protons, where an electron has a negative charge, and a proton has a positive charge. The magnitude of the charge of an electron and proton is 1.6×10^{-19} coulombs, where coulombs are the SI unit of charge.

An important difference between charges and masses is that while masses can only attract each other, charges can act as either an attractive and or a repulsive force. Like charges repel, while unlike charges attract. We will see the mathematical implications of this fact later.

2.1 Charged Objects

If an object has an equal number of protons and electrons, the charges will cancel, creating a neutral object. On the other hand, if an object has an imbalance of protons and electrons, it has a net charge. For atoms, these are called ions. For example, if you take away 1 electron from a neutral sodium atom, you get a Na^+ ion.

2.2 Conservation of Charge

Charge, like matter, is a conserved quantity. Charges can travel from one object to another object, but the net charge of a system does not change.

3 Conductors and Insulators

In conductors, there are electrons that flow freely because some electrons are held loosely. For example, metals are conductors, and they are used to make wires that facilitate electron flow.

Insulators are the opposite of conductors because the atoms/molecules hold all electrons tightly to themselves. Plastics are one example of a good insulator.

4 Charging

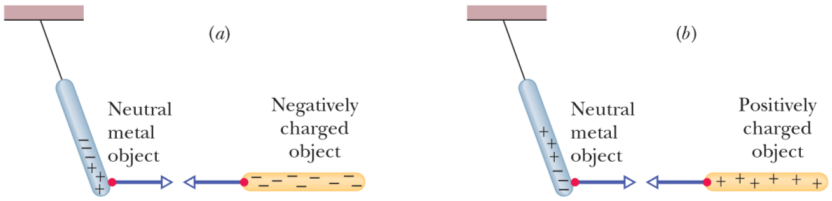
There are two major methods of charging: conduction and induction.

4.1 Conduction

Conduction involves the physical touching of two objects. For example, excess charges can flow between two conductors if they are touched together.

4.2 Induction

Induction is a method of charging that happens without physical touching of two objects. This usually involves a charged object and an uncharged object. As shown in the diagram below, charges on an uncharged object may separate, or polarize.



5 Coulomb's Law

Quantitatively, electrostatic force can be described by Coulomb's Law:

$$F_{elec} = k\frac{|q_1||q_2|}{r^2}, \tag{1}$$

where k is a constant equal to $8.99 \times 10^9 \mathrm{N{\cdot}m^2/C^2}$.

Notice how the absolute value signs are present because electrostatic force can be either repulsive or attractive. Another form of this equation is:

$$F_{elec} = \frac{1}{4\pi\epsilon_0}\frac{|q_1||q_2|}{r^2}, \tag{2}$$

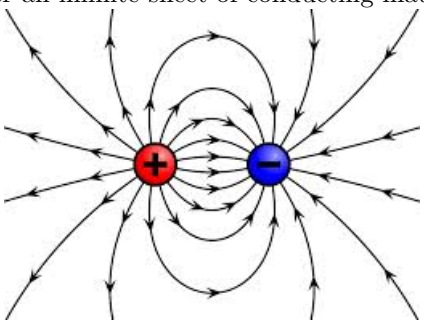
where ϵ_0 is the permittivity of free space, equal to $8.85 \times 10^{-12} \mathrm{C}^2/\mathrm{N}\cdot\mathrm{m}^2$. Unlike charges have a negative F_{elec} denotes attraction; like charges have a positive F_{elec} denotes repulsion.

6 Electric Field

Electric field is the force a unit (positive) charge receives, just like gravity field is the force received by a unit mass:

	Electricity	Gravity
Uniform field	$F_e = qE$	$F_G = mg$
Field of a point	$E_e = kq/r^2$	$g = Gm/r^2$

Shown here is the electric field lines emanating from a point positive electric charge suspended over an infinite sheet of conducting material.



7 Problems

1. Adding extra electrons to a previously neutron atom results in
(A) a new element (B) a positive ion (C) a negative ion (D) a positive isotope (E) a negative isotope

2. Two particles with charge Q and $2Q$ repel one another. How does the electric force acting on the particle with charge Q compare with the force acting on the particle with charge $2Q$?
(A) The force on charge Q is 1/4th of the force acting on charge $2Q$
(B) The force on charge Q is 1/2 of the force acting on charge $2Q$
(C) The force on charge Q is the same as the force acting on charge $2Q$
(D) The force on charge Q is twice as large as the force on charge $2Q$
(E) The force on charge Q is four times larger than the force on charge $2Q$

3. An object has a charge of 3.0 coulombs and a mass of 2.0 kilograms. Determine the magnitude of the electric field that would create 12 newtons of force on this object.

(A) 0.25 N/C (B) 0.50 N/C (C) 2.0 N/C (D) 4.0 N/C (E) 8.0 N/C

4. The electric field of a charged sphere has a magnitude of E at a distance, r, from the center of the sphere. How does the magnitude of the electric field at a point that is $\frac{1}{2}r$ from the center of the sphere compare?
(A) It is $\frac{1}{4}E$. (B) It is $\frac{1}{2}E$. (C) It is E. (D) It is $2E$. (E) It is $4E$.

5. What is the strength and direction of the electric field 3.74 cm on the left hand side of a 9.1 μC negative charge?

All problems are from the Barron's SAT Physics Subject Test book.