Lecture 1:
Ch_1: Electrostatic Charge

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1. Introduction

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- Form of energy associated with stationary or moving electric charges.

1. Introduction

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- Electrostatics is the study of electromagnetic phenomena that occur when there are no moving charges—i.e., after a static equilibrium has been established. Charges reach their equilibrium positions rapidly because the electric force is extremely strong.

1. Introduction

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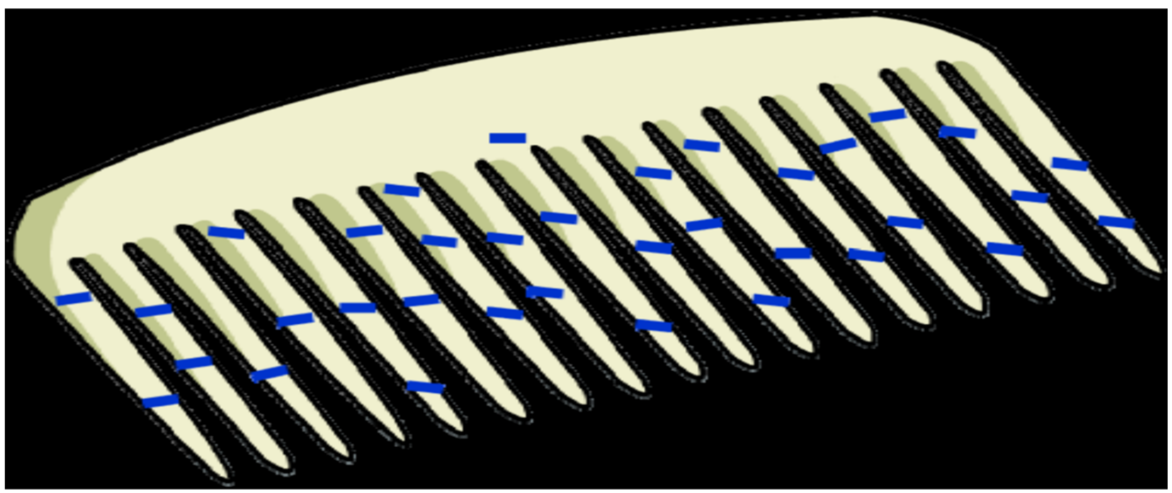
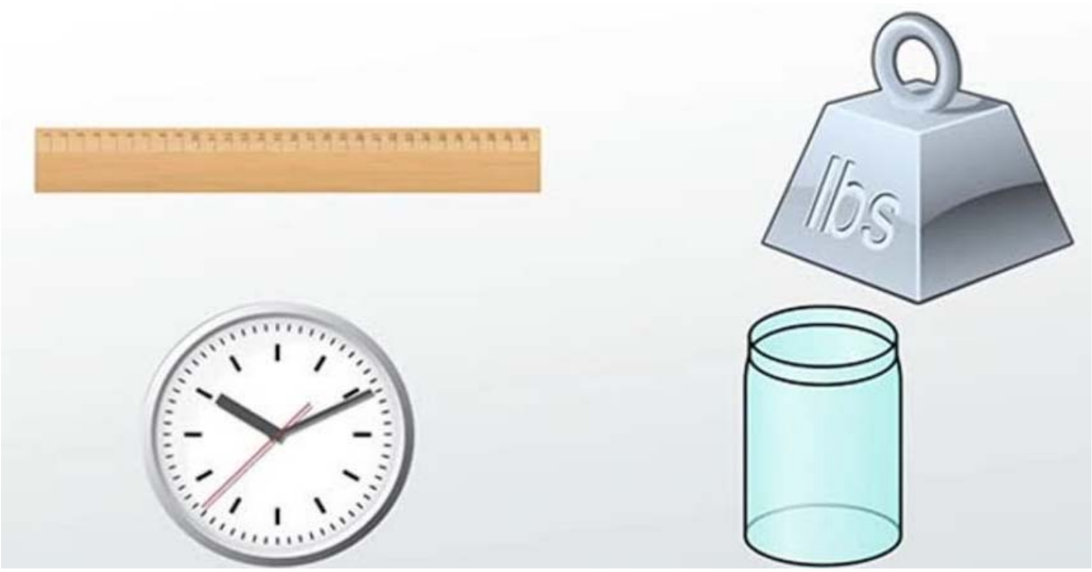
- Static electricity is due to electric charge that builds up on the surface of an insulator, such as a plastic comb.



2. Physical Quantities and Units

- Physical quantity is a feature of something which can be measured, e.g. Length, Mass or Time.
- Every physical quantity has a numerical value and a unit.



2. Physical Quantities and Units

- CGS system, where all the units were based on centimetre, gram and second.
- MKS system, where all the units are based on the metre, kilogram and second.

- As an example: The unit for Force.

➢ In CGS system dyne $= gm.\ cm/\ s^2$.

➢ In MKS system Newton (N) $= Kg.\ m/\ s^2$

Newton$=(1000\ gm).(100\ cm)\ /\ s^2 = 10^5\ gm.cm/s^2 = 10^5$ dyne.

3. Electric Charges

- Charges of the same sign repel one another and charges with opposite signs attract one another.

- The SI unit of charge is the **coulomb**.

- **Coulomb** is defined as the amount of charge that flows through a given cross-section of a wire in one second if there is a steady current of 1 ampere in the wire:

$$\mathbf{Q = i\ t}$$

3. Electric Charges

The electric charge is classified into 2 types:

Electron (with negative sign)

Proton (with positive sign)

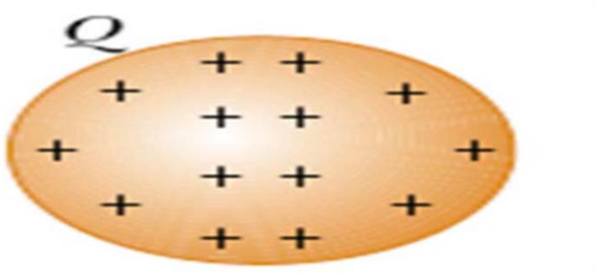
Particle	Charge (C)	Mass (kg)
Electron (e)	$-1.602\,191\,7 \times 10^{-19}$	$9.109\,5 \times 10^{-31}$
Proton (p)	$+1.602\,191\,7 \times 10^{-19}$	$1.672\,61 \times 10^{-27}$
Neutron (n)	0	$1.674\,92 \times 10^{-27}$

4. Conservation of Charge

- Electric charge is always conserved in an isolated system. That is, when one object is rubbed against another, charge is not created in the process.
- The electrified state is due to a transfer of charge from one object to the other. One object gains some amount of negative charge while the other gains an equal amount of positive charge.

5. Quantization of Charge

- The electric charge q is said to be quantized, where q is the standard symbol used for charge as a variable. That is, electric charge exists as discrete "packets," and we can write $q = \pm N e$, where N is some integer.

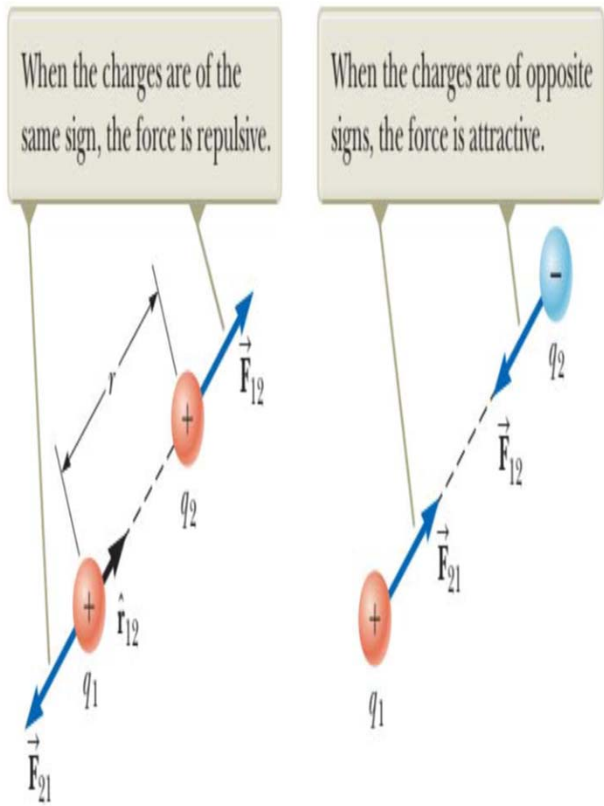


6. Conductors and Insulators

- **Conductors** are materials through which charge can move rather freely (such as metals, human body, and tap water).
- **Nonconductors**—also called **insulators**—are materials through which charge cannot move freely; examples include rubber, plastic, glass, and chemically pure water.
- **Semiconductors** are materials that are intermediate between conductors and insulators; examples include silicon and germanium.

7. Coulomb Law

- If two charged particles are brought near each other, they exert an electrostatic force on each other.
- The direction of the force vectors depends on the signs of the charges. If the particles have the same sign of charge, they repel each other. That means that the force vector on each is directly away from the other particle.
- If, instead, the particles have opposite signs of charge, they attract each other. That means that the force vector on each is directly toward the other particle.



7. Coulomb Law

- Coulomb found that the electric force is proportional to $1/r^2$. That is, when the distance doubles, the force decreases to 1/4 of its initial value.
- The force also depends on the quantity of charge, q, on each body. He found that the forces that two point charges q1 and q2 a distance r apart exerts on each other is:

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

- where k is a proportionality constant called the electrostatic constant or the Coulomb constant.

7. Coulomb Law

- "The magnitude of the force of interaction between two point charges is directly proportional to the product of the charges and inversely proportional to the square of the distance between them".
- The electrostatic constant k is often written as $1/4\pi\varepsilon_o$.

$$F = \frac{1}{4\pi\varepsilon_0}\frac{|q_1 q_2|}{r^2} \qquad (1.2)$$

where $\varepsilon_0 = 8.854 \times 10^{-12}\ C^2/N.m^2$ (or $k = 8.99 \times 10^9\ N.m^2/C^2$).

8. Multiple Forces

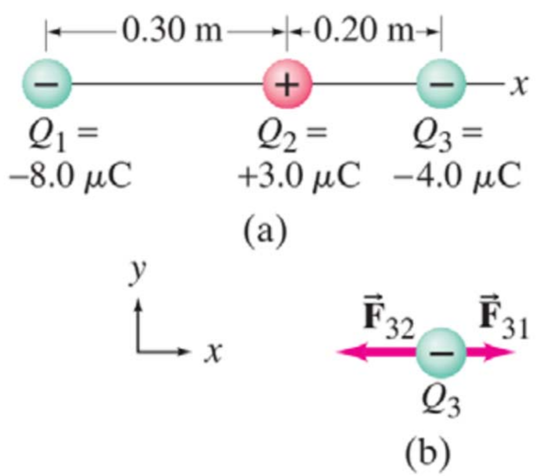
- Electrostatic force obeys the principle of superposition.

- Suppose we have "n" charged particles near a chosen particle called particle 1; then the net force on particle 1 is given by the vector sum:

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

Example 1:

Three charged particles are arranged in a line, as shown in Fig. Calculate the net electrostatic force on particle 3 (the on the right) due to the other two charges.



Solution

$$\vec{F}_3 = \vec{F}_{31} + \vec{F}_{32}$$

- The magnitude of $\vec{F}_{31}$ is:

$$F_{31} = k\frac{|q_1 q_3|}{(r_{31})^2}$$

$$= \left(8.988 \times 10^9 N.\frac{m^2}{C^2}\right)\frac{(8.00 \times 10^{-6} C)(4.00 \times 10^{-6} C)}{(0.50\ m)^2}$$

$$= 1.2\ N$$

- The magnitude of $\vec{F}_{32}$ is:

$$F_{32} = k\frac{|q_2 q_3|}{(r_{32})^2}$$

$$= \left(8.988 \times 10^9 N.\frac{m^2}{C^2}\right)\frac{(3.00 \times 10^{-6} C)(4.00 \times 10^{-6} C)}{(0.20\ m)^2}$$

$$= 2.7\ N$$

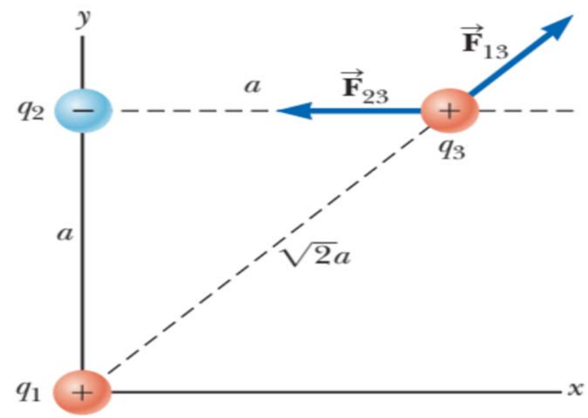
$$F_3 = -F_{32} + F_{31}$$

$$= -2.7\ N + 1.2\ N = -1.5\ N$$

The magnitude of the net force is 1.5 N, and it points to the left.

Example 2:

Consider three point charges located at the corners of a right triangle as shown in Fig., where q1 = q3 = 5.00 μC, q2 = -2.00 μC, and a = 0.100 m. Find the resultant force exerted on q3.



Solution

- The magnitude of $\vec{F}_{32}$ is:

$$F_{32} = k\frac{|q_2 q_3|}{a^2}$$

$$= \left(8.988 \times 10^9 N.\frac{m^2}{C^2}\right)\frac{(2.00 \times 10^{-6}C)(5.00 \times 10^{-6}C)}{(0.100\ m)^2}$$

$$= 8.99\ N$$

- The magnitude of $\vec{F}_{31}$ is:

$$F_{31} = k\frac{|q_1 q_3|}{(\sqrt{2}a)^2}$$

$$= \left(8.988 \times 10^9 N.\frac{m^2}{C^2}\right)\frac{(5.00 \times 10^{-6}C)(5.00 \times 10^{-6}C)}{2(0.100\ m)^2}$$

$$= 11.2\ N$$

- The x and y components of the force $\vec{F}_{31}$:

$$F_{31x} = (11.2\ N) \cos 45.0° = 7.94\ N$$

$$F_{31y} = (11.2\ N) \sin 45.0° = 7.94\ N$$

- The net force acting on q_3 is:

$$F_{3x} = F_{31x} + F_{32x} = 7.94\ N + (-8.99\ N) = -1.04\ N$$

$$F_{3y} = F_{31y} + F_{32y} = 7.94\ N + 0 = 7.94\ N$$

- Net force on q3 in unit-vector form:

$$\vec{F}_3 = (-1.04\ \hat{\imath} + 7.94\ \hat{\jmath})\ N$$

Problems

1. Two point charges attract each other with an electric force of magnitude F. If the charge on one of the particles is reduced to one-third its original value and the distance between the particles is doubled, what is the resulting magnitude of the electric force between them?

(a) $\frac{1}{12}$ F (b) $\frac{1}{3}$ F (c) $\frac{1}{6}$ F (d) $\frac{3}{4}$ F (e) $\frac{3}{2}$ F

2. The magnitude of the electric force between two protons is 2.30×10^{-26} N. How far apart are they?

(a) 0.1 m (b) 0.022 m (c) 3.1 m (d) 0.0057 m (e) 0.48 m

3. Three point charges lie along the x axis as shown in Fig. (1.7). The positive charge $q_1 = 15.0$ μC is at $x = 2.00$ m, the positive charge $q_2 = 6.00$ μC is at the origin, and the net force acting on q_3 is zero. What is the x coordinate of q_3?

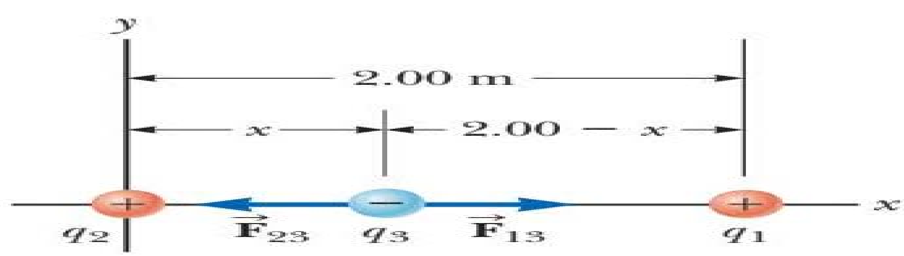


Figure (1.7): Problem 3