14.1(B) ELECTRIC CHARGE AND FORCE

AP PHYSICS

April 25, 2019

Static Electricity

Learning Targets

14.1 I can describe, interpret, and solve problems involving electric charge.

Charge Object

Key Concepts

- There are two kinds of electric charge, positive and negative. Interactions of these charges explain the attraction and repulsion that you observed in the strips of tape.
- Electric charge is not created or destroyed; it is conserved. Charging is the separation, not creation, of electric charges.
- Objects can be charged by the transfer of electrons. An area with excess electrons has a net negative charge; an area with a deficit of electrons has a net positive charge.
- Charges added to one part of an insulator remain on that part. Insulators include glass, dry wood, plastics, and dry air.
- Charges added to a conductor quickly spread over the surface of the object. In general, examples of conductors include graphite, metals, and matter in the plasma state.
- Under certain conditions, charges can move through a substance that is ordinarily an insulator. Lightning moving through air is one example.

Forces on Charged Bodies

Charging a neutral body by touching it with a charged body is called charging by conduction.

Charging a single object can be charged by induction through grounding, which is the process of connecting a body to Earth to eliminate excess charge.

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Electroscope

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A single object can be charged by induction through grounding, which is the process of connecting a body to Earth to eliminate excess charge.
The SI standard unit of charge is called the **coulomb** (C).

- One coulomb is the charge of $6.24 \times 10^{18}$ electrons or protons.
- A typical lightning bolt can carry 5 C to 25 C of charge.
- The magnitude of the charge of an electron is called the **elementary charge**.

**Electron charge magnitude**, \( e = 1.60 \times 10^{-19} \text{ C} \)

The force between charges depends on......
Coulomb's Law

The force between two charges is equal to Coulomb's constant, times the product of the two charges, divided by the square of the distance between them.

\[ F = k \frac{q_1 q_2}{r^2} \]

Coulomb's law constant, \( k = \frac{1}{4\pi\epsilon_0} = 9.0 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2 \)

The rule for determining the direction of force is: like charges repel; unlike charges attract.

Comparing Electrical and Gravitational Forces

Compare and Contrast these two forces

\[ F_{\text{elec}} = \frac{kq_1 q_2}{d^2} \]
\[ F_{\text{grav}} = \frac{Gm_1 m_2}{d^2} \]

\( k = 9.0 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2 \)
\( G = 6.67 \times 10^{-11} \text{ N} \cdot \text{m}^2/\text{kg}^2 \)

Electrical Force Compared to Gravitational Force

Similarities
- Both are inverse square laws
- The mathematical form of both laws is the same

\[ F_{\text{elec}} = \frac{kq_1 q_2}{r^2} \]
\[ F_{\text{grav}} = \frac{Gm_1 m_2}{r^2} \]

Differences
- Electrical forces can be either attractive or repulsive
- Gravitational forces are always attractive
1. **Coulomb’s Law in Two Dimensions** Sphere A, with a charge of +6.0 μC, is located near another charged sphere, B. Sphere B has a charge of -3.0 μC and is located 4.0 cm to the right of A. What is the force of sphere B on sphere A?

Known: 
- \( q_A = +6.0 \mu C \)
- \( q_B = -3.0 \mu C \)
- \( r_{ab} = 4.0 \text{ cm} \)

Unknown: 
- \( F_{B \text{ on } A} \)

Find the force of sphere B on sphere A.

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F_{B \text{ on } A} = \frac{k q_A q_B}{r_{ab}^2}
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= \frac{(9.0 \times 10^9 \text{ N m}^2/\text{C}^2)(6.0 \times 10^{-6} \text{ C})(3.0 \times 10^{-6} \text{ C})}{(4.0 \times 10^{-2} \text{ m})^2}
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= 1.0 \times 10^2 \text{ N}
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2. A third sphere, \( C \), with a +1.5 μC charge, is added to the configuration. If it is located 3.0 cm directly beneath A, what is the new net force on sphere A?

**UNIT 14: In-Class Problems**

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Coulomb’s Law in Two Dimensions

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\[ F_{\text{C on A}} = \frac{kQ_1Q_2}{r^2} \]

\[ = \frac{(8.99 \times 10^9 \text{ N m}^2/\text{C}^2)(6.0 \times 10^{-6} \text{ C})(3.0 \times 10^{-6} \text{ C})}{(0.04 \text{ m})^2} \]

\[ = 9.0 \times 10^3 \text{ N} \]

A third sphere, C, with +1.5 μC charge, is added to the configuration. If it is located 3.0 cm directly beneath A, what is the new net force on sphere A?

The net force on sphere A is the vector sum of the forces due to B and C.

\[ F_{\text{net}} = F_{\text{C on A}} + F_{\text{B on C}} \]

\[ F_{\text{B on C}} = \frac{kQ_1Q_2}{r^2} \]

\[ = \frac{(8.99 \times 10^9 \text{ N m}^2/\text{C}^2)(1.5 \times 10^{-6} \text{ C})(3.0 \times 10^{-6} \text{ C})}{(0.03 \text{ m})^2} \]

\[ = 9.0 \times 10^3 \text{ N} \]

\[ \theta = \tan^{-1}\left(\frac{9.0 \times 10^3 \text{ N}}{1.0 \times 10^2 \text{ N}}\right) \approx 89.0^\circ \]

Application of Electrostatic Forces

The paint is charged as it comes out of the nozzle.
The paint is attracted to the car.
The car must be earthed or connected to a positive voltage.
Application of Electrostatic Forces

Problems (1-8)