

Two Charged Objects Have A Repulsive Force Of 0.080 N. If The Distance Separating The Objects Is Tripled,

Two Charged Objects Have A Repulsive Force Of 0.080 N. If The Distance Separating The Objects Is Tripled, understanding the principles of electrostatics and Coulomb's Law is essential for exploring the behavior of electric charges and the forces they exert on each other. This article provides a comprehensive overview of electrostatic forces, Coulomb's Law, and the implications of changing the distance between charged objects, with a particular focus on how these factors influence the magnitude of the repulsive force.

Understanding Coulomb's Law

What Is Coulomb's Law?

Coulomb's Law is a fundamental principle in electrostatics that describes the force between two point charges. Formulated by Charles-Augustin de Coulomb in the 18th century, the law states that the magnitude of the electrostatic force (F) between two point charges (q_1) and (q_2) is directly proportional to the product of the magnitudes of the charges and inversely proportional to the square of the distance (r) between them:

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

where:

- (F) is the force between the charges (in newtons, N),
- (k) is Coulomb's constant $(8.988 \times 10^9 \text{ N} \cdot \text{m}^2 \cdot \text{C}^{-2})$,
- (q_1) and (q_2) are the magnitudes of the charges (in coulombs, C),
- (r) is the distance between the charges (in meters, m).

This law is analogous to Newton's law of universal gravitation but applies specifically to electric charges.

Key Characteristics of Coulomb's Law

- Inverse-square relationship: The force diminishes with the square of the distance, meaning that doubling the distance reduces the force to a quarter.
- Proportional to charge magnitude: Larger charges exert stronger forces.
- Directionality: The force acts along the line connecting the charges and is repulsive if the charges have like signs and attractive if they have opposite signs.

Initial Conditions and Calculations

Given Data

- Initial force, $(F_1 = 0.080\text{ N})$,
- The charges (q_1) and (q_2) are fixed,
- The initial distance between the charges is (r_1) ,
- The distance is then tripled to $(r_2 = 3 r_1)$.

Implication of Changing Distance

Since Coulomb's Law states that the force is inversely proportional to the square of the distance, increasing the distance affects the force significantly.

Mathematically, if the initial force is:

$$F_1 = k \frac{|q_1 q_2|}{r_1^2}$$

then, when the distance is tripled:

$$r_2 = 3 r_1$$

the new force (F_2) becomes:

$$F_2 = k \frac{|q_1 q_2|}{r_2^2} = k \frac{|q_1 q_2|}{(3 r_1)^2} = k \frac{|q_1 q_2|}{9 r_1^2} = \frac{F_1}{9}$$

Thus, the force reduces to one-ninth of its original value when the separation is tripled:

$$F_2 = \frac{0.080\text{ N}}{9} \approx 0.00889\text{ N}$$

Summary: Tripling the distance between two like-charged objects decreases the electrostatic force to approximately 0.00889 N, illustrating the inverse-square nature of Coulomb's Law.

Physical Interpretation and Real-World

Applications

Electrostatic Force Behavior

The inverse-square law indicates that the electrostatic force diminishes rapidly as charges move apart, emphasizing the importance of proximity in electrostatic interactions. This principle explains phenomena such as:

- Why electrons are bound tightly to atomic nuclei
- How electrostatic forces influence the behavior of charged particles in various materials
- Design considerations in electronic components where charge interactions are critical

Practical Applications

Understanding how distance affects electrostatic forces is crucial in numerous fields:

1. **Electronics and Microelectronics:** Precise control of charge interactions influences circuit design, especially in nano-scale devices.
2. **Electrostatic Precipitators:** Devices that remove particles from exhaust gases rely on electrostatic forces, which depend on charge separation distances.
3. **Capacitors:** The electric field and stored energy depend on charge separation, governed by Coulomb's Law.
4. **Medical Equipment:** Electrostatic principles are used in imaging and in procedures like electrotherapy.
5. **Material Science:** Charge interactions affect the properties of insulating and conducting materials.

Factors Affecting Electrostatic Forces

Magnitude of Charges

Larger charges produce stronger forces. For example, increasing either (q_1) or (q_2) results in a proportional increase in the electrostatic force.

Distance Between Charges

As discussed, increasing the separation reduces the force dramatically due to the inverse-square law.

Medium Between Charges

The Coulomb's Law formula assumes a vacuum or air as the medium. In other materials, the force is affected by the dielectric constant (ϵ_r) :

$$F = \frac{1}{4\pi \epsilon_0 \epsilon_r} \frac{|q_1 q_2|}{r^2}$$

where (ϵ_0) is the permittivity of free space, and (ϵ_r) is the relative permittivity of the medium. Materials with higher dielectric constants reduce the force between charges.

Implications of the Force Reduction

Safety Considerations

In high-voltage environments, controlling charge separation distances can prevent undesired discharges or sparks. Knowing how forces diminish with distance helps engineers design safer systems.

Design Optimization

In designing capacitors or electronic components, engineers optimize charge placement to achieve desired electric field strengths without risking breakdown or discharge.

Electrostatic Shielding

Shielding involves increasing the distance or introducing conductive barriers to reduce the electrostatic influence of charges on sensitive components.

Conclusion

Understanding the relationship between charge separation and electrostatic force is fundamental in physics and engineering. When two charged objects experience a force of 0.080 N and the distance between them is tripled, the force decreases to approximately 0.00889 N, illustrating the inverse-square law's profound impact. This principle not only explains atomic-scale phenomena but also underpins numerous technological applications, from electronic circuit design to environmental control systems. Mastery of Coulomb's Law and its implications enables scientists and engineers to manipulate electric forces effectively, ensuring functionality, safety, and innovation across various domains.

Frequently Asked Questions

How does the electrostatic force change when the distance between two charged objects is tripled?

The electrostatic force becomes one-ninth of its original value because the force is inversely proportional to the square of the distance.

What is the initial force between two charged objects if the force is 0.080 N and the distance is d ?

The initial force is 0.080 N, as given in the problem statement.

If the initial force is 0.080 N and the distance is tripled, what is the new force?

The new force is approximately 0.0089 N, which is one-ninth of the original force.

Why does increasing the distance between charged objects decrease the electrostatic force?

Because Coulomb's law states that the force is inversely proportional to the square of the separation distance, so increasing distance reduces the force significantly.

What is Coulomb's law formula relevant to this problem?

$F = k |q_1 q_2| / r^2$, where F is the force, k is Coulomb's constant, q_1 and q_2 are the charges, and r is the separation distance.

How does the proportionality of force to distance help in

solving this problem?

It allows us to determine the new force after distance change by multiplying the initial force by the square of the ratio of the original to the new distance.

If the original force is 0.080 N at a certain distance, what would be the force if the distance is doubled?

The force would be one-quarter of the original, approximately 0.020 N, since $\text{force} \propto 1/r^2$.

What real-world applications depend on understanding how electrostatic force varies with distance?

Applications include designing electrostatic sensors, controlling particle interactions in physics experiments, and developing electronic components like capacitors.

Additional Resources

Two charged objects exerting a force of 0.080 N and the effect of tripling their separation distance

Introduction

Understanding the forces between charged objects lies at the heart of electrostatics, a fundamental branch of physics that explains phenomena ranging from static electricity to the behavior of atoms and molecules. When two charged objects interact, they exert forces upon each other, described quantitatively by Coulomb's Law. In this article, we delve into a specific scenario: two charged objects initially experiencing a repulsive force of 0.080 newtons, and the consequences of increasing their separation distance by a factor of three. This exploration encompasses the principles of Coulomb's Law, the relationship between force and distance, and the broader implications of such interactions in scientific and practical contexts.

Coulomb's Law: The Fundamentals of Electrostatic Force

What Is Coulomb's Law?

Coulomb's Law, formulated by Charles-Augustin de Coulomb in the 18th century, provides the mathematical foundation for calculating the electrostatic force between two point charges. It states:

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

where:

- (F) is the magnitude of the electrostatic force between the charges.
- (k_e) is Coulomb's constant, approximately $(8.9875 \times 10^9 \text{ N}\cdot\text{m}^2/\text{C}^2)$.
- (q_1) and (q_2) are the magnitudes of the two charges.
- (r) is the separation distance between the charges.

The law reveals that the force is directly proportional to the product of the magnitudes of the charges and inversely proportional to the square of the distance between them.

Nature of the Force: Attraction and Repulsion

The sign of the charges determines whether the force is attractive or repulsive:

- Like Charges (both positive or both negative): The force is repulsive; the objects push away from each other.
- Opposite Charges: The force is attractive; the objects pull toward each other.

In this scenario, the force is specified as repulsive, indicating that both objects carry like charges.

Initial Force and Charge Magnitudes

Given Data

- Initial force $(F_1 = 0.080 \text{ N})$
- Initial separation (r_1)

Determining the Charges

While the problem doesn't specify the individual charges, we can infer their relationship based on Coulomb's Law:

$$F_1 = k_e \frac{q_1 q_2}{r_1^2}$$

Assuming the charges are equal in magnitude $(q_1 = q_2 = q)$, the formula simplifies to:

$$F_1 = k_e \frac{q^2}{r_1^2}$$

Rearranged to find (q) :

$$q = \sqrt{\frac{F_1 r_1^2}{k_e}}$$

\]

Without explicit values for (r_1) , we focus on the proportional relationships rather than exact charges.

Effect of Tripling the Separation Distance

The Core Question

What happens to the electrostatic force if the distance separating the objects is tripled?

This question is fundamental in understanding the inverse-square nature of Coulomb's Law.

Applying Coulomb's Law

Let:

$$r_2 = 3 r_1$$

Then, the new force (F_2) is:

$$F_2 = k_e \frac{q_1 q_2}{r_2^2} = k_e \frac{q_1 q_2}{(3 r_1)^2} = k_e \frac{q_1 q_2}{9 r_1^2}$$

Comparing (F_2) to the initial force (F_1) :

$$F_2 = \frac{F_1}{9}$$

Thus, the force decreases by a factor of nine when the separation is tripled.

Quantitative Result

Given $(F_1 = 0.080 \, \text{N})$:

$$F_2 = \frac{0.080 \, \text{N}}{9} \approx 0.00889 \, \text{N}$$

This significant reduction illustrates the sensitivity of electrostatic forces to distance changes, emphasizing the inverse-square law's importance.

Broader Implications and Applications

Electrostatics in Daily Life

The principles discussed are not merely theoretical—they underpin numerous practical applications:

- Electronics and Microelectronics: Design of integrated circuits, where electrostatic forces influence component behavior.
- Electrostatic Precipitators: Devices that remove particles from exhaust gases by charging and collecting particles using electrostatic forces.
- Touchscreens: Capacitive screens rely on changes in electric fields, which depend on electrostatic principles.

Scientific and Technological Significance

Understanding how forces change with distance helps in:

- Designing Insulation and Shielding: To prevent undesired electrostatic effects.
- Developing Sensors: Sensitive to charge variations and electric field changes.
- Studying Atomic and Molecular Interactions: Where Coulomb's Law explains the forces binding electrons to nuclei.

Limitations and Real-World Considerations

While Coulomb's Law provides a clear mathematical framework, real-world scenarios involve complexities:

- Non-point Charges: Many objects are not point charges, and their charge distributions affect forces.
- Medium Effects: Dielectric materials between charges influence force magnitudes.
- Quantum Effects: At atomic scales, quantum mechanics governs interactions, sometimes deviating from classical Coulomb predictions.

Analytical Insights and Summary

Summary of Key Findings

- The electrostatic force between two charges is governed by Coulomb's Law, which states that force is proportional to the product of charges and inversely proportional to the square of distance.
- When the separation distance between two charges is increased by a factor of three, the force diminishes by a factor of nine.
- For an initial force of 0.080 N, tripling the distance results in a force of approximately 0.00889 N.

Analytical Significance

This scenario underscores a fundamental principle: small changes in distance can lead to significant variations in electrostatic forces. Such sensitivity is crucial in designing electronic components, understanding molecular interactions, and controlling electrostatic

phenomena in various industries.

Future Directions in Research

Advancements in nanotechnology and materials science continue to leverage electrostatic principles:

- Nanostructured Materials: Exploit electrostatic interactions for novel functionalities.
- Electrostatic Manipulation: Precise control of charges for applications like targeted drug delivery.
- Quantum Computing: Understanding charge interactions at quantum levels.

Conclusion

The interplay of charge magnitude, separation distance, and the resulting electrostatic force is a cornerstone of physics that influences numerous technological and scientific fields. The specific case of two charges experiencing a 0.080 N force and the subsequent reduction when their separation increases threefold exemplifies the profound impact of Coulomb's Law. Recognizing these relationships enables scientists and engineers to predict, manipulate, and harness electrostatic forces in innovative ways, shaping the future of technology and our understanding of the physical universe.

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