

Two Charged Objects Have A Repulsive Force Of 0.080 N. If The Charge Of Both Of The Objects Is Doubled

Two Charged Objects Have A Repulsive Force Of 0.080 N. If The Charge Of Both Of The Objects Is Doubled — this scenario offers a fascinating insight into the principles of electrostatics, specifically Coulomb's Law. Understanding how the forces between charged objects change when their charges are altered is fundamental in physics, with applications spanning from designing electronic components to understanding natural phenomena. In this article, we will explore the physics behind this situation, analyze the implications of doubling the charges, and delve into related concepts to deepen your understanding of electrostatic forces.

Understanding Coulomb's Law

What Is Coulomb's Law?

Coulomb's Law describes the electrostatic force between two point charges. It states that the magnitude of the force (F) between two 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. Mathematically, it is expressed as:

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

where:

- (F) is the magnitude of the electrostatic force,
- (k) is Coulomb's constant $(8.988 \times 10^9 \text{ Nm}^2/\text{C}^2)$,
- (q_1) and (q_2) are the magnitudes of the point charges,
- (r) is the distance between the charges.

This law underpins our understanding of how charges interact and allows us to predict the force once we know the charges and the separation distance.

Key Factors Affecting Electrostatic Force

The magnitude of the electrostatic force depends on:

- Magnitude of charges: Larger charges produce stronger forces.
- Distance between charges: Increasing separation decreases the force quadratically.
- Nature of charges: Like charges repel; unlike charges attract.

In this scenario, the initial force is known, and the charges are to be doubled, which will affect the force according to Coulomb's Law.

Analyzing the Given Situation

Initial Data

Given:

- Initial electrostatic force, $F_i = 0.080 \text{ N}$
- Charges of both objects, q_1 and q_2 , are initially at some values (unknown but related)
- The charges are doubled, i.e., new charges $q_1' = 2q_1$ and $q_2' = 2q_2$

Effect of Doubling Charges

Since Coulomb's Law states that force is proportional to the product of charges, when both charges are doubled:

$$F' = k \frac{|q_1' q_2'|}{r^2} = k \frac{|(2q_1)(2q_2)|}{r^2} = 4 \times k \frac{|q_1 q_2|}{r^2} = 4F_i$$

This indicates that the new force F' will be four times the original force.

Calculating the New Force

Step-by-Step Calculation

Given the initial force:

$$F_i = 0.080 \text{ N}$$

When charges are doubled:

$$F' = 4 \times 0.080 \text{ N} = 0.32 \text{ N}$$

Therefore, the repulsive force between the objects becomes 0.32 N after doubling their charges.

Implications of the Calculation

This straightforward multiplication demonstrates a key principle: electrostatic force scales quadratically with charge. Doubling charges increases the force by a factor of four, which can have significant effects in practical applications, such as in designing electrostatic devices or understanding charge interactions in natural systems.

Real-World Applications of Coulomb's Law and Charge Manipulation

Electrostatic Devices and Technologies

Understanding how forces change with charge adjustments helps engineers design:

- Electrostatic precipitators for pollution control
- Capacitors in electronic circuits
- Electrostatic spray painting systems

By manipulating charges, these devices optimize performance and efficiency.

Natural Phenomena and Biological Systems

Electrostatic forces influence:

- The behavior of dust particles in the atmosphere
- The functioning of nerve cells, which rely on charge distributions
- The formation of lightning, where charges build up and discharge

Understanding charge interactions allows scientists to model and predict such phenomena accurately.

Additional Considerations in Electrostatics

Role of Distance in Force Calculation

While doubling charges amplifies the force, the distance between objects remains crucial. If the distance (r) changes, the force adjusts accordingly:

- Increasing (r) decreases the force quadratically.
- Decreasing (r) increases the force quadratically.

Limitations and Assumptions

Coulomb's Law assumes point charges and neglects:

- Charge distribution effects
- Medium effects (like dielectric materials)
- Other forces such as magnetic interactions

In real-world scenarios, factors like the presence of a medium or non-point charges can modify the force.

Summary and Key Takeaways

- Coulomb's Law provides a fundamental understanding of electrostatic forces.
- The force between two charges is proportional to the product of their magnitudes and inversely proportional to the square of their separation.
- Doubling both charges increases the force by a factor of four.
- Practical applications of this principle include designing electronic components, pollution control devices, and understanding natural phenomena.
- The relationship between charge, distance, and force is critical for manipulating and predicting electrostatic interactions.

Conclusion

The scenario where two charged objects experience a repulsive force of 0.080 N, and their charges are doubled, exemplifies the powerful and predictable nature of electrostatic forces. By understanding Coulomb's Law and the quadratic relationship between charge and force, scientists and engineers can design systems that leverage these principles effectively. Whether in technological innovations or natural sciences, mastering the fundamentals of electrostatics enables advancements across numerous fields, illustrating the importance of this fundamental physical law.

Understanding the nuances of how charge manipulations influence forces not only deepens our grasp of physics but also empowers us to harness these forces for practical benefits.

Frequently Asked Questions

What happens to the electrostatic force if the charges of both objects are doubled?

The electrostatic force will increase by a factor of four because force is proportional to the product of the charges.

If the initial repulsive force between two charged objects is

0.080 N, what will be the new force after doubling both charges?

The new force will be 0.320 N, since doubling both charges quadruples the force ($0.080 \text{ N} \times 4$).

Why does doubling both charges increase the repulsive force between the objects?

Because Coulomb's law states that the electrostatic force is directly proportional to the product of the charges, so doubling both charges increases the force by a factor of four.

What is Coulomb's law formula for the electrostatic force?

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

If the initial charges are q , what are the new charges after doubling?

The new charges are $2q$ for each object.

Does increasing the distance between the objects affect the force? How?

Yes, increasing the distance decreases the force because force is inversely proportional to the square of the distance (r^2).

What assumptions are made in calculating the change in force when charges are doubled?

It is assumed that the distance between the objects remains constant and Coulomb's law applies without other influencing factors.

How does the force change if only one object's charge is doubled instead of both?

The force will double because the force is proportional to the product of the charges; doubling one charge doubles the product.

Can doubling the charges ever cause the force to be negative?

No, the electrostatic force is a scalar magnitude and always positive; the sign indicates attraction or repulsion, but the magnitude remains positive.

Additional Resources

Understanding the Effect of Doubling Charges on the Repulsive Force Between Two Charged Objects

When analyzing electrostatic interactions, one of the fundamental principles is Coulomb's Law, which quantifies the force between two point charges. In this detailed exploration, we will examine a scenario where two charged objects initially exert a repulsive force of 0.080 N, and then explore what happens when the charges of both objects are doubled. This analysis will delve into the physics underlying Coulomb's Law, the mathematical implications of changing charges, and the broader significance of such changes in electrostatics.

Fundamentals of Coulomb's Law

What Is Coulomb's Law?

Coulomb's Law states that the magnitude of the electrostatic force (F) between two point charges is directly proportional to the product of the magnitudes of the charges (q_1 and q_2) and inversely proportional to the square of the distance (r) between their centers. Mathematically, it is expressed as:

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

Where:

- F = magnitude of the electrostatic force (in Newtons, N)
- k = Coulomb's constant ($8.988 \times 10^9 \text{ Nm}^2/\text{C}^2$)
- q_1, q_2 = magnitudes of the charges (in Coulombs, C)
- r = distance between charges (in meters, m)

This law applies to point charges and assumes a vacuum or air as the medium, where the permittivity is approximately ϵ_0 .

Nature of the Force: Repulsive or Attractive

- Like charges (both positive or both negative) repel each other.
- Opposite charges attract each other.
- The sign of the charges influences the direction, but the magnitude of the force depends on the absolute values of the charges.

In our scenario, the initial force of 0.080 N is a repulsive force, indicating both objects carry charges of the same sign.

Initial Conditions and Parameters

Given Data

- Initial Force, $(F_1 = 0.080\text{ N})$
- Charges: (q_1) and (q_2) (unknown individual magnitudes)
- Distance between charges: (r) (unknown)

Assumptions to Simplify the Problem

- The objects are point charges or sufficiently small relative to their separation.
- The medium is vacuum or air, so Coulomb's Law applies directly.
- The charges are both positive or both negative, maintaining a repulsive force.

Effect of Doubling the Charges

What Changes When Charges Are Doubled?

- New charges: $(q_1' = 2q_1)$, $(q_2' = 2q_2)$
- The new force, (F_2) , can be calculated using Coulomb's Law with doubled charges.

Mathematical Derivation

Applying Coulomb's Law:

$$F_2 = k \frac{|q_1' q_2'|}{r^2}$$

Substituting $(q_1' = 2q_1)$, $(q_2' = 2q_2)$:

$$F_2 = k \frac{|(2q_1)(2q_2)|}{r^2} = k \frac{4|q_1 q_2|}{r^2}$$

Recalling the initial force:

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

Comparing the two:

$$F_2 = 4 \times F_1$$

Thus, the force becomes four times larger when both charges are doubled.

Calculating the New Force

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

$$F_2 = 4 \times 0.080 \text{ N} = 0.320 \text{ N}$$

Result: The new repulsive force after doubling the charges will be 0.320 N.

Implications and Broader Understanding

The Proportionality of Force to Charge Products

- Coulomb's Law emphasizes that force is proportional to the product of the charges.
- Doubling both charges leads to quadrupling the force, a quadratic relationship.
- If only one charge is doubled, the force doubles; if both are doubled, force increases by a factor of four.

Real-World Applications of Charge Manipulation

Understanding how forces change with charge variations is vital in multiple fields:

- Electronics and Circuit Design: Managing electrostatic forces influences the placement and insulation of components.
- Particle Physics: Manipulating charge magnitudes affects particle interactions.
- Electrostatic Precipitators: Increasing charges on particles enhances collection efficiency.

- Capacitors: Adjusting charges impacts stored energy and electric fields.

Limitations and Assumptions

- Coulomb's Law applies strictly to point charges; real objects may have distributions of charge.
- The law assumes a vacuum; in mediums with dielectric properties, the force is modified by the relative permittivity (ϵ_r):

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

- The effect of other forces (gravity, magnetic forces) is neglected in this idealized model.

Impact of Distance

- The force is inversely proportional to the square of the distance.
- If the distance between the objects changes, the force adjusts accordingly.

For example, if the distance is halved:

$$F \propto \frac{1}{(r/2)^2} = \frac{4}{r^2}$$

Increasing force by a factor of 4.

Practical Example and Numerical Illustration

Suppose the charges are such that:

$$F_1 = k \frac{|q_1 q_2|}{r^2} = 0.080 \, \text{N}$$

If, for instance, the charges are $1 \, \mu\text{C}$ each, and the separation is $0.1 \, \text{m}$:

$$q_1 = q_2 = 1 \times 10^{-6} \, \text{C}$$

Calculate r :

$$r = \sqrt{k \frac{|q_1 q_2|}{F_1}} = \sqrt{8.988 \times 10^9 \times \frac{(1 \times 10^{-6})^2}{0.080}}$$

$$r = \sqrt{8.988 \times 10^9 \times 1 \times 10^{-12} / 0.080} = \sqrt{\frac{8.988 \times 10^{-3}}{0.080}} \approx \sqrt{0.11235} \approx 0.335, \text{m}$$

When charges are doubled:

$$q_1' = q_2' = 2 \times 10^{-6} \text{C}$$

The new force:

$$F_2 = 4 \times 0.080 \text{N} = 0.320 \text{N}$$

And the force calculation confirms the proportional increase, assuming the separation remains unchanged.

Summary and Key Takeaways

- Coulomb's Law provides a quantitative description of the electrostatic force between two point charges.
- The force is directly proportional to the product of the charges and inversely proportional to the square of the distance.
- When both charges are doubled, the force increases by a factor of four, leading to a new force magnitude of 0.320 N.
- This quadratic relationship emphasizes the sensitivity of electrostatic forces to charge magnitudes.
- Understanding these principles is crucial across physics, engineering, and various technological applications.

Closing Remarks

The scenario of increasing charges and observing the resultant force change illustrates a core principle of electrostatics: the nonlinear yet predictable relationship between charge magnitude and force. This understanding enables scientists and engineers to manipulate electrostatic forces

effectively, whether in designing electronic components, controlling particle interactions, or understanding natural phenomena. Recognizing that doubling both charges results in quadrupling the force underscores the importance of precise charge management in practical applications, ensuring safety, efficiency, and accuracy.

In essence, the simple act of doubling charges results in a significant, predictable increase in electrostatic force, reaffirming Coulomb's Law as a foundational principle in understanding electrical interactions.

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