A Negative Charge Of 2 C And A Positive Charge Of 3 C Are Separated By A Distance Of 40m.what Is Theforce

A Negative Charge Of 2 C And A Positive Charge Of 3 C Are Separated By A Distance Of 40m. What Is The Force?

Understanding electrostatic forces is fundamental in physics, especially when dealing with point charges and their interactions. In this article, we will explore how to calculate the electrostatic force between two charges—specifically, a negative charge of 2 coulombs and a positive charge of 3 coulombs separated by a distance of 40 meters. We will delve into Coulomb's Law, discuss the significance of the charges and separation distance, and provide step-by-step calculations to determine the magnitude of the force. This comprehensive guide aims to clarify the concepts and calculations involved in understanding electrostatic interactions.

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 1785, it states that the electrostatic force of attraction or repulsion between two charges is directly proportional to the product of the magnitudes of the charges and inversely proportional to the square of the distance between them.

Mathematical Expression of Coulomb's Law

The law is mathematically expressed as:

- $F = k \times |q_1 \times q_2| / r^2$

Where:
- F is the magnitude of the electrostatic force (in newtons, N)
- k is Coulomb's constant, approximately 8.988×10^9 N·m²/C²
- q_1 and q_2 are the magnitudes of the two point charges (in coulombs, C)
- r is the distance between the charges (in meters, m)

This equation enables us to calculate the force once the charges and their separation are known.

Given Data for the Calculation

Before proceeding to the calculation, let's clearly identify the provided data:

Details of the Charges and Distance

- Negative charge, $q_1 = -2$ C

- Positive charge, $q_2 = +3$ C
- Separation distance, $r = 40$ m

It is important to note that Coulomb's Law depends on the absolute values of the charges for calculating the force magnitude, while the sign indicates the nature of the force (attractive or repulsive).

Calculating the Electrostatic Force

Now, let's proceed step-by-step to compute the electrostatic force between these two charges.

Step 1: Use the Magnitudes of Charges

Since Coulomb's Law uses the absolute values, we take:

- $|q_1| = 2$ C
- $|q_2| = 3$ C

Step 2: Plug Values into Coulomb's Law Formula

$F = (8.988 \times 10^9\ N \cdot m^2/C^2) \times (2\ C \times 3\ C) / (40\ m)^2$

Calculating numerator:

$8.988 \times 10^9 \times 6 = 8.988 \times 10^9 \times 6$

$= (8.988 \times 6) \times 10^9$

$= 53.928 \times 10^9$

Calculating denominator:

$(40\ m)^2 = 1600\ m^2$

Now, the force:

$F = 53.928 \times 10^9 / 1600$

$F = (53.928 / 1600) \times 10^9$

$F \approx 0.033705 \times 10^9$

$F \approx 3.3705 \times 10^7$ N

Step 3: Interpret the Result

The magnitude of the electrostatic force is approximately 33.7 million newtons (N).

Since the charges are of opposite signs (negative and positive), the force is attractive, meaning the charges exert a force pulling them toward each other.

Understanding the Significance of the Force Calculation

Calculating the electrostatic force between charges helps in numerous fields, including physics, engineering, and electronics. It provides insights into how charged particles interact, which is vital in designing electronic components, understanding atomic structures, and exploring phenomena in fields like electromagnetism and electrochemistry.

Factors Influencing Electrostatic Force

- **Magnitude of Charges:** Larger charges produce stronger forces.
- **Distance Between Charges:** Increasing the separation distance decreases the force exponentially (inverse square law).
- **Medium Between Charges:** The presence of materials like insulators or conductors can influence the force's magnitude through dielectric properties.

Real-World Applications of Coulomb's Law

Understanding electrostatic forces has practical implications in various technologies and scientific research. Here are some notable applications:

1. Designing Electronic Components

Engineers use Coulomb's Law to predict forces between charged parts in circuits, ensuring stability and preventing unintended discharges.

2. Particle Physics and Atomic Models

The behavior of electrons and protons within atoms is governed by electrostatic forces, which influence atomic stability and chemical reactions.

3. Electrostatic Precipitators

These devices use electrostatic attraction to remove particles from exhaust gases in industrial processes, improving air quality.

Limitations and Considerations in Coulomb's Law

While Coulomb's Law is fundamental, it has limitations and considerations to keep in mind:

1. Point Charges Assumption

The law assumes charges are point-like and stationary. Real-world charges have size and may move, affecting interactions.

2. Medium Effects

In materials other than vacuum, the dielectric constant influences force magnitude. Coulomb's Law must be adjusted accordingly:

- $F = (1 / (4\pi\varepsilon_0\varepsilon\_r)) \times |q_1 \times q_2| / r^2$

where ε_r is the relative permittivity of the medium.

3. Quantum and Relativistic Effects

At very small scales or high velocities, classical Coulomb's Law may need modifications based on quantum mechanics or relativity.

Conclusion

Calculating the electrostatic force between a negative charge of 2 C and a positive charge of 3 C separated by 40 meters reveals a force of approximately 33.7 million newtons. This immense force underscores the strength of electrostatic interactions, especially when charges are large and close. Coulomb's Law provides a straightforward yet powerful tool to quantify these interactions, essential for understanding phenomena across physics and engineering disciplines. Whether designing electronic devices, exploring atomic structures, or developing industrial processes, grasping how charges influence each other through electrostatic forces is fundamental to advancing technology and scientific knowledge.

Frequently Asked Questions

What is the electrostatic force between a negative 2 C charge and a positive 3 C charge separated by 40 meters?

Using Coulomb's Law: $F = k |q_1 q_2| / r^2$, where $k \approx 9 \times 10^9$ Nm²/C², $q_1 = -2$ C, $q_2 = 3$ C, $r = 40$ m. $F = 9 \times 10^9 |(-2) 3| / (40)^2 = 9 \times 10^9\ 6 / 1600 = 33.75 \times 10^6$ N. The force magnitude is 33.75 million newtons, directed attractive due to opposite charges.

How does Coulomb's Law apply to calculating the force between two point charges?

Coulomb's Law states that the electrostatic force between two point charges is proportional to the product of their magnitudes and inversely proportional to the square of the distance between them: $F = k |q_1 q_2| / r^2$. It helps determine the magnitude and direction of the force.

What factors influence the magnitude of electrostatic force between two charges?

The magnitude depends on three factors: the magnitudes of the charges (larger charges produce stronger forces), the distance between them (greater distance weakens the force), and the Coulomb constant (k), which is a fixed value in vacuum.

If the distance between the charges increases, how does it affect the electrostatic force?

Increasing the distance between the charges decreases the electrostatic force, since the force is inversely proportional to the square of the distance ($F \propto 1/r^2$). So, doubling the distance reduces the force to one-quarter.

Are the charges in this scenario attracting or repelling each other?

Since one charge is negative and the other positive, they attract each other due to opposite charges, resulting in an attractive electrostatic force.

Additional Resources

A Negative Charge Of 2 C And A Positive Charge Of 3 C Are Separated By A Distance Of 40m. What Is The Force?

Understanding the forces between charged particles is fundamental in physics, revealing the invisible yet powerful interactions that govern everything from atomic structures to large-scale electrical phenomena. In this article, we delve into a specific scenario involving two point charges—one negative, one positive—and analyze the electrostatic force acting between them. Using Coulomb's Law, we'll calculate the magnitude of this force, interpret its significance, and explore related concepts in electrostatics.

Introduction to Electrostatics and Coulomb's Law

Electrostatics is the branch of physics that studies stationary electric charges and the forces they exert on each other. At the core of this discipline lies Coulomb's Law, formulated by Charles-Augustin de Coulomb in the 18th century, which quantifies the magnitude of the electrostatic force between two point charges.

Coulomb's Law Statement:

The magnitude of the electrostatic force F between two point charges q_1 and q_2 separated by a distance r is given by:

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

\]

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

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

Applying Coulomb's Law to the Given Scenario

Given Data:
- Negative charge $q_1 = -2\, \text{C}$
- Positive charge $q_2 = +3\, \text{C}$
- Separation distance $r = 40\, \text{m}$

Before proceeding with calculations, note that the sign of the charges affects the direction of the force but not its magnitude. The absolute values are used when calculating the force magnitude.

Step 1: Identify the magnitude of the charges.

$$
|q_1| = 2\, \text{C}
$$
$$
|q_2| = 3\, \text{C}
$$

Step 2: Plug the values into Coulomb's Law formula.

$$
F = 8.988 \times 10^9 \times \frac{(2)(3)}{(40)^2}
$$

Calculating numerator:

$$
(2)(3) = 6\, \text{C}^2
$$

Calculating denominator:

$$
(40)^2 = 1600\, \text{m}^2
$$

Step 3: Compute the force.

$$
F = 8.988 \times 10^9 \times \frac{6}{1600}
$$

Simplify the fraction:

$$
\frac{6}{1600} = 0.00375
$$

Now multiply:

$$
F = 8.988 \times 10^9 \times 0.00375
$$

$$
F \approx 33,705,000\, \text{N}
$$

Expressed in scientific notation:

$$
F \approx 3.37 \times 10^7\, \text{N}
$$

Interpreting the Result: Magnitude and Direction

The calculated force magnitude is approximately 33.7 million Newtons—an enormous force indicating a very strong electrostatic interaction. To put this into perspective:

- The force is enormously larger than typical everyday forces, reflecting the high magnitude of the charges involved.
- Such large quantities are generally theoretical or applied in specialized scientific contexts, as real-world charges of this magnitude are rare and usually confined within controlled environments.

Direction of the Force:

- Since the charges are opposite in sign—negative and positive—the electrostatic force is attractive, pulling the two charges toward each other.
- Conversely, if both charges had the same sign, the force would be repulsive, pushing them apart.

Implications and Real-World Contexts

While the calculated force is illustrative, real-world applications seldom involve charges of several Coulombs separated by such distances due to the impracticality and safety concerns. However, understanding these principles is vital in various fields:

- Electronics and Circuit Design: Small charges and voltages, but the principles of Coulomb's Law underpin electromagnetic interactions.
- Particle Physics: Studying interactions between subatomic particles involves similar calculations at quantum scales.
- Electrostatic Engineering: Designing electrostatic precipitators, photocopiers, and other devices relies on understanding charge interactions.

Moreover, the magnitude of forces at microscopic scales can be vastly different, and Coulomb's Law remains valid across scales, provided charges are point-like and static.

Additional Factors and Considerations

While the calculation here is straightforward, several factors influence electrostatic interactions in practical scenarios:

- Medium Between Charges: Coulomb's Law assumes a vacuum or air. When charges are separated by a dielectric material, the force is reduced by the material's relative permittivity (ε_r). The modified law becomes:

$$
F = \frac{1}{4\pi \varepsilon_0 \varepsilon_r} \frac{|q_1 q_2|}{r^2}
$$

where ε_0 is the vacuum permittivity ($8.854 \times 10^{-12} \, \text{F/m}$).

- Charge Distribution: Real charges often distribute over surfaces or volumes, complicating force calculations.

- Dynamic Charges: Moving charges generate magnetic fields and additional forces, requiring electromagnetic analysis beyond Coulomb's Law.

- Limitations of Point Charges: Coulomb's Law applies to ideal point charges; extended charges or complex geometries require more advanced methods such as finite element analysis.

Conclusion: The Power of Coulomb's Law in Understanding Electric Forces

The scenario of a negative 2 C charge and a positive 3 C charge separated by 40 meters vividly illustrates the application of Coulomb's Law and the magnitude of electrostatic forces. Despite the hypothetical nature of such large charges, the calculation demonstrates how fundamental physics principles quantify the interactions that shape our universe.

From designing electronic components to understanding atomic interactions, Coulomb's Law offers a window into the invisible forces that govern matter. Recognizing the enormous magnitude of forces at play, even across seemingly vast distances, underscores the importance of electrostatics in both theoretical physics and practical engineering.

By mastering these concepts, scientists and engineers can better predict, harness, and manipulate electric forces, advancing technology and expanding our understanding of the natural world.

Summary:
- The electrostatic force between the charges is approximately 3.37×10^7 N.
- The force is attractive because the charges are opposite.
- Coulomb's Law provides a reliable means to compute such forces, assuming point charges and ideal conditions.
- Real-world applications and complexities require consideration of medium, charge distribution, and other factors.

Understanding the magnitude and nature of electrostatic forces allows us to appreciate the intricate interactions that underpin both everyday devices and the fabric of the universe itself.

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