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Understanding electric charges and the forces they exert on each other is fundamental in the study of electromagnetism. When two point charges are placed in proximity, they interact through Coulomb's law, which describes the electrostatic force between charged particles. This interaction depends on the magnitudes of the charges and the distance separating them. In this article, we analyze a specific scenario involving two point charges of +3.4 Coulombs and -2.0 Coulombs, positioned 5.0 centimeters apart along the x-axis. We will explore the nature of the forces involved, calculate the magnitude and direction of the electrostatic force, and discuss the implications of these interactions in practical applications.

Introduction to Coulomb's Law and Electric Forces

Coulomb's law is a fundamental principle in electrostatics that quantifies the force between two point charges. It states that the magnitude of the electrostatic force F between two charges q_1 and q_2 separated by a distance r in a vacuum or air is given by:

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

where:

- F is the magnitude of the force between the charges (in Newtons, N),
- k_e is Coulomb's constant, approximately $8.988 \times 10^9 \, \mathrm{N\,m^2/C^2}$,
- 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 direction of the force depends on the signs of the charges:

- Like charges repel each other.
- Opposite charges attract each other.

Understanding these principles is crucial to analyzing the behavior of point charges in various configurations, such as the one described in this scenario.

Scenario Description and Data

In our specific case, we have:

- Charge $q_1 = +3.4\, \mathrm{C}$,
- Charge $q_2 = -2.0\, \mathrm{C}$,
- Distance between the charges $r = 5.0\, \mathrm{cm}$.

Before proceeding with calculations, it is important to convert all measurements to SI units:

- Distance $r = 5.0\, \mathrm{cm} = 0.05\, \mathrm{m}$.

This precise setup enables us to determine the magnitude and direction of the electrostatic force exerted between these two point charges.

Calculating the Electrostatic Force

Step 1: Apply Coulomb's Law

Using Coulomb's law:

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

Substituting the known values:

$$
F = (8.988 \times 10^9) \times \frac{|3.4 \times (-2.0)|}{(0.05)^2}
$$

Note: While taking the absolute value of $q_1 q_2$ for magnitude, the signs will be considered when discussing the direction of the force.

Step 2: Calculate the Product of Charges

$$
|q_1 q_2| = |3.4 \times -2.0| = 6.8\, \mathrm{C}^2
$$

Step 3: Calculate the Force Magnitude

$$
F = 8.988 \times 10^9 \times \frac{6.8}{(0.05)^2}
$$

$$
F = 8.988 \times 10^9 \times \frac{6.8}{0.0025}
$$

$$
F = 8.988 \times 10^9 \times 2720
$$

$$
F \approx 2.445 \times 10^{13}\, \mathrm{N}
$$

This enormous force illustrates the significant impact of large charges at close distances, emphasizing the importance of understanding electrostatics in high-voltage and industrial contexts.

Direction and Nature of the Force

Given the charges:

- $q_1 = +3.4\, \mathrm{C}$,
- $q_2 = -2.0\, \mathrm{C}$,

the force between them is attractive because the charges are opposite. Since they are positioned along the x-axis, the force acts along this axis, pulling the charges toward each other.

Direction specifics:

- The positive charge q_1 experiences a force directed toward q_2,
- The negative charge q_2 experiences a force directed toward q_1.

This mutual attraction results in both charges moving closer along the x-axis, assuming they are free to move.

Calculating Electric Field at a Point

Beyond force calculations, understanding the electric field generated by these charges is crucial for analyzing their influence on other charges in the vicinity.

Electric Field Due to a Point Charge

The electric field E at a point in space due to a point charge q is given by:

$$
E = k_e \frac{|q|}{r^2}
$$

where:

- r is the distance from the charge to the point where the field is measured.

In our scenario, the electric field created by each charge at any point along the x-axis can be calculated, which helps in understanding the net field at various locations.

Superposition Principle

The net electric field at any point along the x-axis is the vector sum of the electric fields due to each individual charge. The superposition principle states that:

$$
E_{net} = E_1 + E_2
$$

where the signs of E_1 and E_2 depend on the positions and signs of the charges.

Potential Energy of the System

The potential energy U stored in the two-charge system is an important aspect in electrostatics, especially in energy considerations and electrostatic applications.

Calculating Electric Potential Energy

The potential energy between two point charges:

$$
U = k_e \frac{q_1 q_2}{r}
$$

Substituting known values:

$$
U = 8.988 \times 10^9 \times \frac{3.4 \times -2.0}{0.05}
$$

$$
U = 8.988 \times 10^9 \times \frac{-6.8}{0.05}
$$

$$
U = 8.988 \times 10^9 \times -136
$$

$$
U \approx -1.222 \times 10^{12}\, \mathrm{J}
$$

The negative sign indicates that the system is in a bound state due to attractive interaction, and energy would need to be supplied to separate the charges.

Practical Applications of Point Charge Interactions

Understanding the interactions between point charges has numerous real-world applications:

- Electrostatic Precipitators: Used in pollution control to remove particles from exhaust gases using electrostatic forces.
- Capacitors: Devices that store electrical energy through separated charges, relying on electrostatic principles.
- Particle Accelerators: Utilize electric fields to accelerate charged particles to high energies.
- Electrostatic Painting: Uses static electricity to evenly coat surfaces.
- Design of Microelectromechanical Systems (MEMS): Small-scale devices that depend on electrostatic forces for actuation.

Summary and Conclusions

In this comprehensive analysis, we explored the interaction between two point charges of +3.4 C and -2.0 C separated by 5.0 cm along the x-axis. Utilizing

Coulomb's law, we calculated that the magnitude of the electrostatic force between them is approximately 2.445×10^{13} Newtons, indicating an extremely strong attractive force due to the large magnitudes of the charges at close proximity. The force acts along the line connecting the charges, pulling them toward each other.

Additionally, we discussed the electric field generated by each charge, the principle of superposition, and the potential energy stored within the system. The negative potential energy signifies a stable, bound system due to the attractive interaction.

Understanding these electrostatic principles is vital for various technological applications, from designing capacitors and sensors to understanding natural phenomena like lightning and static electricity buildup. Recognizing the magnitude of forces involved with large charges over small distances highlights the importance of safety and proper engineering practices in high-voltage environments.

By mastering the concepts discussed in this article, students and professionals can better analyze electrostatic systems, predict their behavior, and innovate in fields that rely on electrostatics' fundamental principles.

Frequently Asked Questions

What is the electric force between two point charges of 3.4 C and -2.0 C placed 5.0 cm apart on the x-axis?

Using Coulomb's Law: $F = k |q1\ q2| / r^2$, with $k \approx 8.99 \times 10^9$ Nm²/C², $q1 = 3.4$ C, $q2 = -2.0$ C, $r = 0.05$ m, the force magnitude is $F \approx (8.99 \times 10^9)\ (3.4\ 2.0) / (0.05)^2 \approx 2.44 \times 10^{12}$ N. The force is attractive because the charges are opposite in sign.

What is the direction of the force experienced by each charge in this setup?

The positive charge (3.4 C) experiences a force directed toward the negative charge (-2.0 C), i.e., toward the negative charge. Conversely, the negative charge experiences a force toward the positive charge, meaning both are attracted toward each other along the x-axis.

How does the magnitude of the electric force change if the charges are increased to 6.8 C and -4.0 C?

Since force is proportional to the product of the charges, doubling both charges to 6.8 C and -4.0 C will double the force magnitude. The new force will be approximately 4.88×10^{12} N.

What is the potential energy of the system of these two charges?

Using $U = k q_1 q_2 / r$, $U \approx (8.99 \times 10^9) (3.4) (-2.0) / 0.05 \approx -1.22 \times 10^{12}$ Joules. The negative sign indicates a bound, attractive potential energy.

If the negative charge is moved 2 cm closer to the positive charge, what is the new separation and how does that affect the force?

The new separation is 3.0 cm (5.0 cm - 2.0 cm). Since force varies as $1/r^2$, decreasing the distance increases the force. Specifically, the force becomes $F_{new} \approx 8.99 \times 10^9 (3.4\ 2.0) / (0.03)^2 \approx 8.99 \times 10^9\ 6.8 / 0.0009 \approx 6.81 \times 10^{13}$ N, significantly stronger.

What is the electric field at a point midway between the charges?

At the midpoint (2.5 cm from each charge), the electric field contributions from each charge sum vectorially. The magnitudes are $E_1 = k |q_1| / r^2$ and E_2 = same with q_2. Calculating: $E_1 \approx 8.99 \times 10^9\ 3.4 / (0.025)^2 \approx 4.88 \times 10^{12}$ N/C; $E_2 \approx 8.99 \times 10^9\ 2.0 / (0.025)^2 \approx 2.87 \times 10^{12}$ N/C. Since the charges are opposite, the fields add in the direction toward the negative charge, resulting in a net electric field of approximately 7.75×10^{12} N/C directed toward the negative charge.

What are the implications of having charges of different magnitudes on the forces experienced by each charge?

The larger charge experiences a force proportional to the magnitude of the other charge, so it experiences a bigger force if the charges are unequal. Also, the forces on both charges are equal in magnitude and opposite in direction, consistent with Newton's Third Law, but the acceleration each charge experiences depends on its mass and force.

How would the electric potential energy change if the charges were both positive and placed farther apart?

If both charges are positive and placed farther apart, the potential energy becomes less negative (approaching zero), indicating weaker attraction. The magnitude of U decreases, following the inverse relationship with separation distance, U = k q1 q2 / r.

What safety considerations should be taken into account when working with charges of this magnitude?

Charges of several coulombs produce extremely strong electric fields and forces, which can cause electrical shocks or damage electronic components. Proper insulation, grounding, and safety protocols are essential to prevent accidental discharge or injury when handling large charges.

Additional Resources

Two Point Charges, 3.4 C And -2.0 C, Are Placed 5.0 Cm Apart On The X Axis. Assume That The Negative charges create an interesting scenario for analyzing electrostatic forces, electric fields, and potential energy. This setup serves as a fundamental example in electrostatics, illustrating how Coulomb's law governs interactions between point charges. Understanding this configuration provides critical insights into the principles that underpin numerous phenomena in physics and engineering, from atomic interactions to electrical circuit design. In this comprehensive review, we will dissect various aspects of this charge configuration, including the calculation of forces, electric fields, potential energy, and the implications of the negative charge.

Understanding Coulomb’s Law

Coulomb's law is the cornerstone of electrostatics, describing the force between two point charges. It states that the magnitude of the electrostatic force F between two charges q_1 and q_2 separated by a distance r is given by:

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

where:
- k_e is Coulomb’s constant, approximately $8.9875 \times 10^9 \, \text{Nm}^2/\text{C}^2$,
- q_1 and q_2 are the magnitudes of the charges,
- r is the separation distance.

In this scenario:
- $q_1 = 3.4\, C$,
- $q_2 = -2.0\, C$,
- $r = 5.0\, \text{cm} = 0.05\, \text{m}$.

Applying Coulomb’s law allows us to quantify the magnitude and nature of the forces involved.

Calculating the Electrostatic Force

Step-by-Step Calculation

Plugging in the known values:

$$
F = 8.9875 \times 10^9 \times \frac{|3.4 \times (-2.0)|}{(0.05)^2}
$$

Since the force depends on the absolute value of the product of charges:

$$
F = 8.9875 \times 10^9 \times \frac{6.8}{0.0025}
$$

Calculating the denominator:

$$
0.0025\, \text{m}^2
$$

And the numerator:

$$
6.8
$$

Thus:

$$
F = 8.9875 \times 10^9 \times \frac{6.8}{0.0025} = 8.9875 \times 10^9 \times 2720
$$

Finally:

$$
F \approx 8.9875 \times 10^9 \times 2720 \approx 2.448 \times 10^{13}\, \text{N}
$$

Features and Implications:
- The force magnitude is extremely large, reflecting the high charges and small separation.

- The force is attractive because the charges are opposite in sign.

Direction of the Force and Electric Field

Force Direction

Since one charge is positive (+3.4 C) and the other negative (-2.0 C), the electrostatic force between them is attractive. The positive charge experiences a force directed toward the negative charge, and vice versa. On the x-axis:
- The positive charge at $x=0$ (assuming it to be at the origin) experiences a force toward the negative charge located at $x=0.05\, \text{m}$.
- The negative charge at $x=0.05\, \text{m}$ experiences a force toward the positive charge at $x=0$.

Electric Field at a Point

Electric field generated by a point charge is given by:

$$
E = k_e \frac{|q|}{r^2}
$$

The electric field direction points away from positive charges and toward negative charges.

For the positive charge:

$$
E_{+} = 8.9875 \times 10^9 \times \frac{3.4}{r^2}
$$

For the negative charge:

$$
E_{-} = 8.9875 \times 10^9 \times \frac{2.0}{r^2}
$$

If we consider a point midway between the charges:

$$
r_{mid} = 2.5\, \text{cm} = 0.025\, \text{m}
$$

At this midpoint:
- The electric field due to the positive charge points away from it, toward the negative charge.
- The electric field due to the negative charge points toward itself, i.e., away from the positive charge.

Calculations at the midpoint:

$$
E_{+} = 8.9875 \times 10^9 \times \frac{3.4}{(0.025)^2} = 8.9875 \times 10^9 \times \frac{3.4}{0.000625} \approx 8.9875 \times 10^9 \times 5440 \approx 4.898 \times 10^{13}\, \text{N/C}
$$

Similarly,

$$
E_{-} = 8.9875 \times 10^9 \times \frac{2.0}{0.000625} \approx 2.877 \times 10^{13}\, \text{N/C}
$$

Since both fields point toward the negative charge, their magnitudes add, resulting in a strong electric field at the midpoint.

Features:
- The net electric field magnitude at the midpoint is approximately $7.775 \times 10^{13}\, \text{N/C}$, directed toward the negative charge.
- The electric field intensity drops off with the square of the distance from each charge, highlighting the importance of proximity in electrostatics.

Potential Energy of the System

The electrostatic potential energy U of two point charges is given by:

$$
U = k_e \frac{q_1 q_2}{r}
$$

Plugging in the values:

$$
U = 8.9875 \times 10^9 \times \frac{3.4 \times (-2.0)}{0.05}
$$

$$
U = 8.9875 \times 10^9 \times \frac{-6.8}{0.05} = 8.9875 \times 10^9 \times -136
$$

$$
U \approx -1.222 \times 10^{12}\, \text{J}
$$

The negative sign indicates that the system's configuration is energetically favorable — energy must be supplied to separate the charges to infinity.

Features:
- The high magnitude reflects the large charges and close proximity, making the system highly energetic.
- The negative potential energy indicates an attractive bound state.

Impact of the Negative Charge and System Stability

The negative charge influences the behavior of the entire system significantly:
- The attractive force ensures the charges tend to move toward each other, potentially leading to collision if unconstrained.
- The high potential energy suggests a stable bound system, but also a highly reactive one in the context of electrostatic interactions.

Pros/Cons:

Pros	Cons
Demonstrates fundamental electrostatic principles	Extremely high force and energy may be unrealistic physically without stabilization
Clarifies the role of charge sign in force direction	Potentially dangerous in practical applications due to high voltages and forces
Useful for educational visualization	Not representative of typical charge magnitudes in real-world scenarios

Features in Summary:
- Clear illustration of Coulomb's law and electric field concepts.
- Highlights the importance of charge sign and magnitude.
- Demonstrates how small changes in distance or charge value dramatically affect forces and energies.

Applications and Broader Implications

Understanding this charge configuration extends beyond theoretical physics:
- Electrostatic Force Engineering: Designing systems where precise control of forces at microscopic scales is required.
- Atomic and Molecular Physics: Modeling interactions between charged particles, such as ions and electrons.

- Capacitor Design: Recognizing how charge separation influences energy storage.
- Electrostatic Shielding: Utilizing the principles of electric fields to protect sensitive equipment.

Limitations:
- Real-world charges are rarely as large as several coulombs at such small distances due to breakdown of insulation.
- Practical systems involve complex distributions rather than ideal point charges.

Conclusion

The scenario involving two point charges, 3.4 C and -2.0 C, separated by just 5.0 cm, offers a rich landscape for exploring fundamental electrostatic principles. Calculations reveal an immensely strong attractive force, intense electric fields, and significant potential energy, underscoring the importance of charge magnitude and proximity in electrostatics. The negative charge notably influences the force direction and system stability, illustrating fundamental concepts such as Coulomb's law, electric field behavior, and potential energy. While idealized, this setup facilitates a deeper understanding of electrostatic interactions, which serve as foundational knowledge for advanced applications across physics, chemistry, and electrical engineering. Recognizing the strengths and limitations of such models enables scientists and engineers

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