Two Charged Particles 1.0 M Apart Exert An Attractive Electric Force On Each Other With Magnitude 104

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Introduction to Electrostatic Forces

Electrostatics is a fundamental branch of physics that deals with the study of stationary electric charges and the forces they exert on each other. The interactions between charged particles are governed by Coulomb's Law, which quantifies the magnitude and direction of the electric force between two point charges. These forces are pivotal in understanding phenomena ranging from atomic interactions to large-scale electrical systems.

Understanding Coulomb's Law

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

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

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

Given Data and Basic Calculations

In the scenario described, two particles are separated by a distance of 1.0 meter, and they exert an attractive force of magnitude 104 Newtons on each other. Let's analyze this data step-by-step.

Interpreting the Force Magnitude

- The force F is given as 104 N.
- The force is attractive, indicating that the charges are opposite in sign.
- The distance r between the particles is 1.0 m.

Determining the Product of the Charges

Using Coulomb’s Law:

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

Plugging in the known values:

$$
104 = (8.988 \times 10^9) \times \frac{|q_1 q_2|}{(1.0)^2}
$$

$$
|q_1 q_2| = \frac{104}{8.988 \times 10^9}
$$

$$
|q_1 q_2| \approx 1.157 \times 10^{-8} \, \mathrm{C^2}
$$

This value represents the product of the magnitudes of the two charges.

Analyzing Charge Magnitudes and Significance

Since the force is attractive, the charges must have opposite signs: one positive and one negative. The exact magnitudes of q_1 and q_2 cannot be determined solely from the product $|q_1 q_2|$; additional information would be necessary to find individual values. However, some important insights can be gleaned:

Potential Charge Scenarios

- If both charges have the same magnitude but opposite signs, then $q_1 = +q$ and $q_2 = -q$, and:

  $$
  |q_1 q_2| = q^2 \Rightarrow q = \sqrt{1.157 \times 10^{-8}} \approx 3.4 \times 10^{-5} \, \mathrm{C}
  $$

- Charges could also have different magnitudes, but their product will always be $\sim 1.157 \times 10^{-8} \, \mathrm{C^2}$. For example:

  - $q_1 = 5 \times 10^{-5} \, \mathrm{C}$, then $q_2 = -\frac{1.157 \times 10^{-8}}{5 \times 10^{-5}} = -2.31 \times 10^{-4} \, \mathrm{C}$.

Implications of the Force and Charges

The magnitude of the force and the charges involved reflect several important physical principles and practical considerations.

Magnitude of Charges

- The charges are relatively small, on the order of 10^{-5} to 10^{-4} coulombs.
- For comparison, a typical static charge on a small object can be in this range.

Energy Considerations

The electrostatic potential energy U between the charges can be calculated as:

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

Given the product $q_1 q_2$:

$$
U = (8.988 \times 10^9) \times \frac{\pm 1.157 \times 10^{-8}}{1.0}
$$

$$
U \approx \pm 104\, \mathrm{J}
$$

The positive or negative sign depends on whether the charges are like or opposite; here, since the force is attractive, the energy is negative, indicating a bound state.

Factors Affecting the Force

Several factors influence the magnitude and nature of the electrostatic force between particles:

Distance Between Charges

- The inverse square law: as r increases, the force diminishes rapidly.
- Halving the distance increases the force fourfold.

Magnitude of Charges

- Larger charges produce stronger forces.
- Charges of opposite signs lead to attractive forces, while like charges lead to repulsive forces.

Medium Between Charges

- Coulomb’s Law assumes a vacuum or air.
- In a medium with dielectric constant ε, the force is reduced:

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

\]

where \(\varepsilon_r \) is the relative permittivity of the medium.

Real-World Applications and Examples

Understanding the forces between charged particles has numerous practical applications:

Electrostatic Precipitators

- Used in pollution control to remove particulate matter from exhaust gases.
- Charges are applied to particles, causing them to be attracted to collection plates.

Capacitors in Electronic Devices

- Store electric energy through separated charges.
- The force between charges influences the capacitor's behavior and stability.

Atomic and Molecular Interactions

- Coulomb’s Law explains the forces within atoms and molecules, influencing chemical bonds and reactions.

Limitations and Assumptions in Coulomb’s Law

While Coulomb’s Law provides a fundamental understanding of electrostatic forces, it operates under several assumptions:

Point Charges

- Charges are considered to be point particles with no spatial extent.
- Real particles have finite size, which can influence interactions at very close distances.

Vacuum or Homogeneous Medium

- Assumes the space between charges is a vacuum or uniform medium unless modified by dielectric constants.

Static Charges

- Applies to stationary charges; moving charges introduce magnetic effects not covered by Coulomb’s Law alone.

Conclusion

The given scenario of two charged particles separated by 1.0 meter exerting an attractive force of 104 N offers a compelling illustration of Coulomb's Law in action. By analyzing the data, we deduce the product of the charges and explore implications for their individual magnitudes. The principles underlying this interaction form the backbone of many technological applications, from electronic components to environmental systems. Recognizing the factors that influence electrostatic forces enables scientists and engineers to manipulate and harness these interactions effectively, furthering advancements across multiple fields.

Frequently Asked Questions

What is the electric force between two charged particles placed 1.0 m apart with a magnitude of 104 N?

The electric force between the particles is 104 N, as given in the problem statement.

Which law is used to calculate the electric force between two point charges?

Coulomb's Law is used to calculate the electric force between two point charges.

What is the formula for Coulomb's Law?

Coulomb's Law is given by $F = k |q1\ q2| / r^2$, where F is the force, k is Coulomb's constant ($8.99 \times 10^9\ Nm^2/C^2$), q1 and q2 are the charges, and r is the distance between them.

Given the force and distance, how can we find the product of the charges?

Rearranging Coulomb's Law: $|q1\ q2| = F\ r^2 / k$. Substituting $F = 104$ N, $r = 1.0$ m, and $k = 8.99 \times 10^9\ Nm^2/C^2$ gives the product of the charges.

Are the charges positive or negative if the force is attractive?

The charges are opposite in sign (one positive and one negative) because the force is attractive.

Can we determine the individual charges from the given information?

No, unless additional information such as the magnitude of one charge is provided, we cannot determine the individual charges from the force and distance alone.

What is the significance of the force magnitude being 104 N in practical applications?

A force of 104 N indicates a significant electrostatic interaction, which can influence particle behavior in experiments, electronic devices, or electrostatic applications.

How does increasing the distance between charges affect the electric force?

Increasing the distance decreases the electric force, following the inverse square law: $F \propto 1/r^2$.

What safety precautions should be considered when dealing with electrostatic forces of this magnitude?

Ensure proper grounding, avoid direct contact with charged objects, and use insulating materials to prevent accidental discharges or shocks.

Additional Resources

Two Charged Particles 1.0 M Apart Exert An Attractive Electric Force On Each Other With Magnitude 104

Introduction

The fundamental interactions that govern the behavior of charged particles are central to understanding electromagnetism, a cornerstone of modern physics. In this detailed exploration, we examine a specific scenario involving two charged particles separated by a distance of 1.0 meter, which exert an attractive electric force of magnitude 104 Newtons on each other. This case provides a platform to analyze the underlying principles, mathematical formulations, and implications of Coulomb's law, as well as the nature of electrostatic interactions.

Context and Significance of the Problem

Electrostatics addresses how stationary charges influence each other through electric forces. The problem at hand—two charges separated by a meter and experiencing a force of 104 N—serves as a practical illustration of Coulomb's law, which quantitatively describes the magnitude and direction of the electrostatic force between point charges.

Understanding this scenario is not only academically intriguing but also essential for applications ranging from designing electronic components to analyzing atomic and molecular interactions. The specific magnitude of the force, combined with the separation distance, enables us to deduce critical properties of the charges involved, such as their magnitudes and signs.

Coulomb's Law: The Mathematical Foundation

The Formula

Coulomb's law states that the electrostatic force F between two point charges q_1 and q_2 separated by a distance r in a vacuum is given by:

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

where:

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

Significance of the Force Direction

- If charges have opposite signs (positive and negative), the force is attractive.
- If charges have like signs (both positive or both negative), the force is repulsive.

The problem specifies an attractive force, indicating that the charges are of opposite signs.

Analyzing the Given Data

Given:
- Separation distance, $r = 1.0\, \mathrm{m}$
- Force magnitude, $F = 104\, \mathrm{N}$

Our goal is to determine the magnitudes and signs of the charges involved.

Determining the Magnitudes of the Charges

Assumptions

- Both particles are point charges.
- The medium is vacuum or air, approximating free space conditions.
- The forces are purely electrostatic, with no other influences.

Calculating the Product of the Charges

Rearranging Coulomb's law:

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

Plugging in the known values:

$$
|q_1 q_2| = \frac{(104\, \mathrm{N})(1.0\, \mathrm{m})^2}{8.9875 \times 10^9\, \mathrm{N\,m^2/C^2}}
$$

$$
|q_1 q_2| \approx \frac{104}{8.9875 \times 10^9}
$$

$$
|q_1 q_2| \approx 1.156 \times 10^{-8}\, \mathrm{C}^2
$$

This product indicates that the charges are of opposite signs (since the force is attractive), but their individual magnitudes cannot be uniquely determined from this product alone.

Possible Charge Magnitudes and Configurations

The calculation yields an infinite set of pairs (q_1, q_2) satisfying:

$$
|q_1| \times |q_2| = 1.156 \times 10^{-8}\, \mathrm{C}^2
$$

Some plausible examples include:

- Equal magnitude charges:

$$
|q_1| = |q_2| = \sqrt{1.156 \times 10^{-8}} \approx 3.4 \times 10^{-5}\, \mathrm{C}
$$

Both charges would be approximately $\pm 34\, \mu \mathrm{C}$, with opposite signs.

- Unequal magnitudes:

For example, if $|q_1| = 1 \times 10^{-5}\, \mathrm{C}$, then:

$$
|q_2| = \frac{1.156 \times 10^{-8}}{1 \times 10^{-5}} = 1.156 \times 10^{-3}\, \mathrm{C}
$$

Which is about $1.156\, \mathrm{mC}$.

The specific magnitudes depend on additional information about the system, such as charge sources or constraints.

Implications and Significance

Electric Field and Potential

Knowing the charges and their magnitudes allows calculation of the electric field at any point, as well as the potential energy stored in the configuration.

Force as a Function of Distance

The force magnitude varies with the inverse square of the separation distance, highlighting the importance of spatial arrangements in electrostatic systems.

Experimental and Practical Considerations

Measuring the Force

- Force sensors or torsion balances can quantify forces at this scale.
- Ensuring precision in measurements requires minimizing external influences like air currents or nearby charges.

Charge Generation and Control

- Charges can be generated via triboelectric effects, electrostatic induction, or contact with known charge sources.
- Maintaining charge stability can involve insulating materials and vacuum environments.

Broader Applications and Theoretical Insights

Atomic and Molecular Physics

- Coulomb's law underpins models of atomic structure, where electron-proton interactions are fundamental.

Engineering and Technology

- Designing capacitors, sensors, and electrostatic precipitators relies on understanding forces between charges.

Fundamental Physics

- The inverse-square nature of Coulomb's law mirrors gravitational interactions, illustrating universal inverse-square laws.

Limitations and Assumptions in the Model

While Coulomb's law provides a robust framework, it assumes point charges in a vacuum and neglects:

- Quantum effects at very small scales.
- Medium effects, such as dielectric properties of materials.
- Relativistic effects if charges move at high velocities.

In the current scenario, these assumptions are justified due to the static nature and scale of the charges involved.

Conclusion

The scenario of Two Charged Particles 1.0 M Apart Exert An Attractive Electric Force On Each Other With Magnitude 104 Newtons exemplifies core principles of electrostatics and Coulomb's law. By analyzing the force and separation, we deduce that the charges are of opposite signs and approximate magnitudes on the order of tens of microcoulombs, with their product around \(1.156 \times 10^{-8}\, \mathrm{C}^2 \).

This case underscores the elegance of Coulomb's law in describing electrostatic interactions and provides a foundation for understanding more complex phenomena, from atomic interactions to electrical engineering applications. It also highlights the importance of precise measurements and assumptions in modeling physical systems. As our understanding of charge interactions deepens, such foundational problems continue to inspire both theoretical insights and practical innovations in science and technology.

Note: Further experimental data or constraints could refine the individual charge values, but the provided analysis captures the fundamental relationships governing the system.

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